SACE ONE

NUTRITION

WORKBOOK
SECOND EDITION

CHRISTOPHER CAREY

Essentials education

ADELAIDE TUITION CENTRE

THE AUTHOR

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Preface

This workbook has been written for educators and students undertaking SACE Stage 1 Nutrition in 2024 and beyond. The main changes to the Second Edition include:

- a new topic, Topic 9: Sports nutrition,
- updated chapter review questions and suggested solutions,
- updated Topic Review Tests and suggested solutions,
- updated SHE examples and suggested solutions,
- new SHE questions spread throughout the chapter review questions and Topic Review Tests with suggested solutions, and
- new 'Helpful online resources' for each topic.

The author and publisher hope that you find this resource helpful, and that it demonstrates the significant role Nutrition plays in the many aspects of our lives. Some information to help navigate the SACE Stage 1 Nutrition course and this workbook are outlined below:

10-credit subject and 20-credit subject

The SACE requirements for a 10-credit subject (one semester) is to study two or three Nutrition Understandings, (preferably from different concepts). However, for a 20-credit subject (full year), students' study five Nutrition Understandings across the three concepts. These understandings may be selected or developed by the teacher, but they must relate to one of the three concepts.

Stage 1 Nutrition Concepts and Nutrition Understandings

The workbook consists of nine topics that are aligned with the three concepts for Stage 1 Nutrition outlined in the SACE Subject Outline. The concept that each topic relates to is highlighted on the title page for each topic. The nine topics include the five Nutrition Understandings listed on page 12 of the SACE Subject Outline. The Nutrition Understanding 'Fundamentals of Nutrition' has been split into two topics due to the amount of theory covered. Three new teacher developed Nutrition Understandings have also been included at Topics 3, 6 and 9. Please note that Topic 6 covers two concepts, giving teachers greater flexibility when planning their course outline.

Resources

This workbook provides educators with some additional resources aligned with the SACE Nutrition course: Science as a Human Endeavour (SHE), Science Inquiry Skills (SIS), Case Study and Excursion ideas. These can be used as formative tasks or adjusted to create Summative Investigations Folio (IF) task sheets or questions for Skills and Applications Tasks (SATs). Please refer to the contents list for information on these additional resources and their page numbers. Please note that the Science Inquiry Skills (SIS) tasks are now found in the online version only.

There are also many 'Helpful online resources' and 'Did you know?' facts spread throughout each topic that summarise the main concepts in a visual way and help to provide some light on common misconceptions.

The author and publisher wish you all the best for your studies in Stage 1 Nutrition.

Christopher Carey

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Topic 1 Fundamentals of nutrition



Concept: Principles of nutrition, physiology and health

1.1 Macronutrients
1.2 Carbohydrates
1.3 Proteins
1.4 Lipids
1.5 Micronutrients
1.6 Vitamins
1.7 Minerals
1.8 Increasing bioavailability of nutrients
1.9 Nutrient and energy density
1.10 Water
Topic 1 Review Test

1.1 Macronutrients

Nutrition Understanding

Macronutrients are a category of nutrients that are needed in large amounts daily and provide us with energy. They are measured in grams (g). There are three types of macronutrients: carbohydrates, proteins and lipids (fats). Each macronutrient provides us with a different amount of energy and has a differing role within cells and the body. Carbohydrates and proteins provide us with 16.7 kJ/g, whereas lipids are more energy dense containing 37.7 kJ/g.

Alcohol is another molecule that provides us with energy but it is considered a toxin because it causes harm to the body's cells. Alcohol is more energy dense than carbohydrates and proteins, providing 29.3 kJ/g.

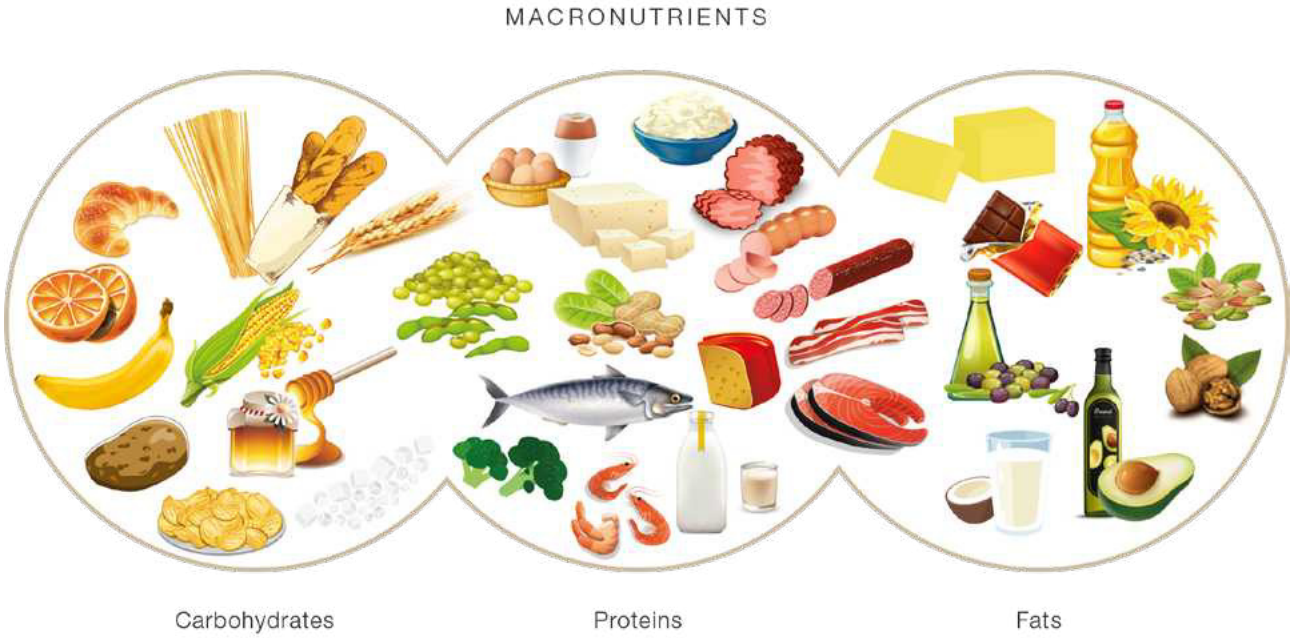


Figure 1.1.1: A variety of macronutrients.

Did you know?

Every day our body is constantly replacing cells and growing new ones. Our red blood cells have a life cycle of 120 days and approximately two million are replaced every second. Furthermore, the lining of our intestines is replaced every three to five days. Our body needs nourishment to replace these cells and the food we eat provides us with the energy and nutrients we need to replace them. However, it is not true that all of our body's cells are replaced every seven years. This is a misconception and there are some cells that are never replaced, such as particular types of brain cells. For more information, including how nuclear testing has allowed us to determine how frequently cells are replaced, please watch the following video:

Helpful online resources

SciShow: Do You Really Have a New Body Every 7 Years?

https://www.youtube.com/watch?v=ZCiuMomjVx0

Helpful online resources

FuseSchool - Global Education: Balanced Diet

https://www.youtube.com/watch?v=NqV1Ig4_nfI

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1.2 Carbohydrates

Nutrition Understanding

Carbohydrates are very important molecules that help fuel our daily activities. Our brains cannot function without a carbohydrate known as glucose and require approximately 130 grams per day to function effectively. Every second, our brain is making roughly ten trillion calculations and requires glucose to fuel this activity. Our brain cannot store glucose and obtains it from our blood supply. It is therefore essential that we consume sufficient carbohydrates throughout each day to provide our brain with enough glucose so that we can function normally and learn efficiently.

Carbohydrates are made up of three elements of the Periodic Table: **C**arbon, **H**ydrogen and **O**xygen. For this reason, carbohydrates are generally abbreviated as **CHO**. There are many different types of carbohydrates and they are split into two categories: **simple carbohydrates** and **complex carbohydrates**.

Did you know?

Potatoes are a common food source that provides us with a rich source of starch (complex carbohydrates) and are easily accessible. The potato crop has an interesting past and is often credited with supporting population growth throughout history. Potatoes were also widely utilised by the Allies during World War II. Watch the video below to find out more about the role of the potato in modern history.

Helpful online resources

TED-Ed: History through the eyes of the potato–Leo Bear-McGuinness

https://www.youtube.com/watch?v=xROmDsULcLE

Simple carbohydrates

Simple carbohydrates consist of one or two units of sugar (saccharide). There are six important simple carbohydrates. Three of these are **monosaccharides** that consist of one unit of sugar ('mono' means one). The remaining three are **disaccharides** that consist of two units of sugar ('di' means two). Food items are rarely made up of one single monosaccharide or disaccharide and generally contain varying combinations of them. Simple carbohydrates are easily absorbed by the body and can cause increased spikes in blood sugar levels. Simple carbohydrates have less nutritional value to the body than complex carbohydrates and excess intake has been linked to many diseases, including obesity, diabetes, cardiovascular disease, brain degenerative diseases, and many more.

Monosaccharides

The three monosaccharides consist of the same number and type of atoms (six carbon atoms, 12 hydrogen atoms and six oxygen atoms), but they are arranged slightly differently. The difference in their arrangement contributes to the difference in their sweetness; for example, fructose is the sweetest of the simple sugars. The three monosaccharides are **glucose**, **fructose**, and **galactose**.

Glucose is generally sourced from the conversion of more complex carbohydrates but small amounts can be naturally found in some fruits, vegetables and honey. It can also be found as an additive in processed food items. **Fructose** is naturally found in fruits, vegetables and honey. It can also be sourced through the breakdown of the disaccharide sucrose. **Galactose** is sourced from milk through the digestion of the disaccharide lactose.

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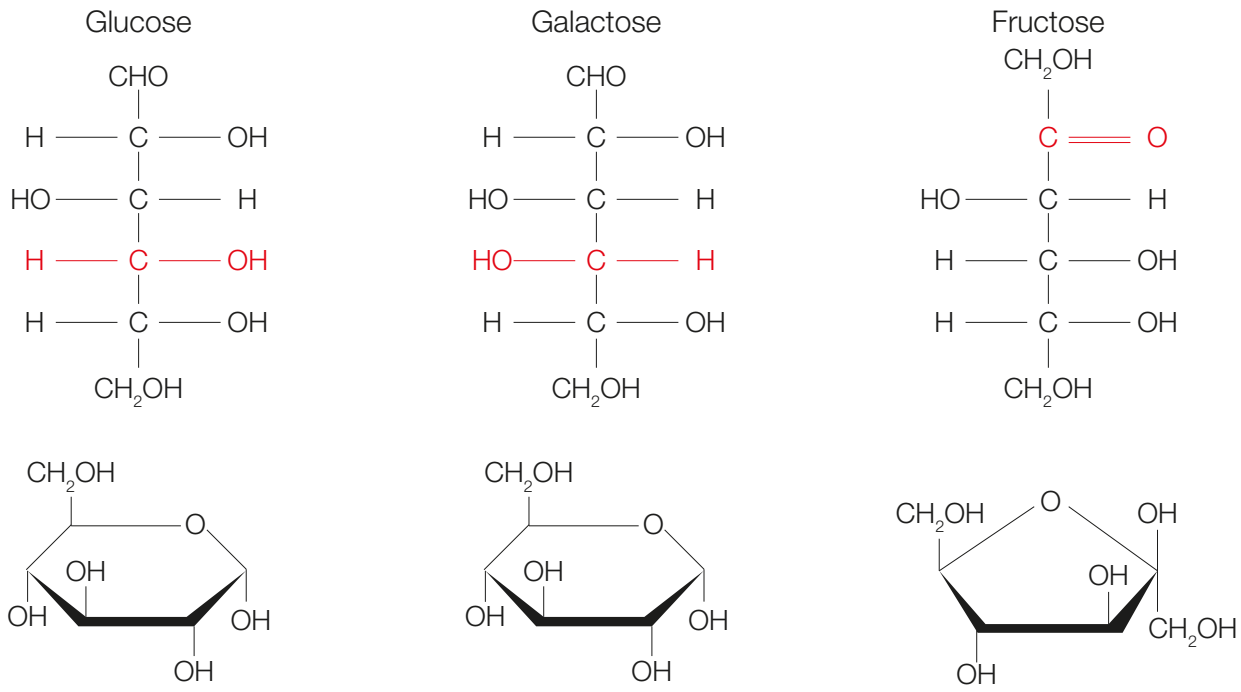


Figure 1.2.1: The molecular structures of the monosaccharides glucose, galactose and fructose.

Disaccharides

Disaccharides are made up of **two** of the monosaccharides mentioned above. See diagram below:

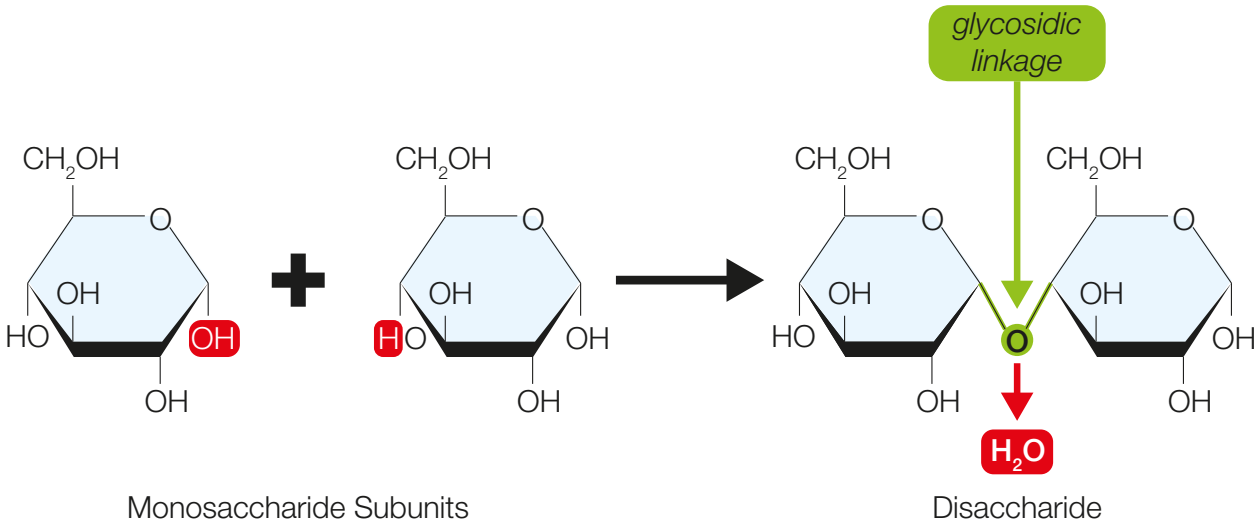


Figure 1.2.2: The formation of a disaccharide from two monosaccharides.

There are three important disaccharides: **sucrose**, **lactose** and **maltose**. Disaccharides cannot be absorbed in the small intestine (they are too big) and require processing in the intestines. Only monosaccharides can be absorbed across the small intestine into the blood. Each of the three disaccharides are broken down into their monosaccharides by a specific enzyme (protein). However, some people can't produce enough of the required enzyme and this can result in complications. An example of this is individuals who are **lactose intolerant**. These individuals cannot produce enough of the enzyme lactase so they cannot break the lactose in milk down into its two monosaccharides.

The combination of monosaccharides that make up disaccharides, enzymes to digest them and sources of disaccharides are highlighted in Table 1.2.1 on the next page:

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Table 1.2.1: The monosaccharides that make up the three disaccharides and their sources.

Disaccharide	Combination of monosaccharides	Enzyme required to digest into monosaccharides	Sources of disaccharide
Sucrose	Glucose + Fructose	Sucrase	Naturally found in different types of sugar such as cane sugar and brown sugar. This is the most common disaccharide and is commonly known as 'table sugar'.
Lactose	Glucose + Galactose	Lactase	Naturally found in milk and dairy products.
Maltose	Glucose + Glucose	Maltase	The main source of maltose is breakfast cereals, but it is also found in seeds and beer.

Complex carbohydrates

Complex carbohydrates consist of three or more monosaccharide subunits bound together to form chains (see Figure 1.2.3). There are two types of complex carbohydrates:

- **oligosaccharides** that contain three to 10 monosaccharide units ('oligo' means few); and
- **polysaccharides** that contain greater than 10 monosaccharide units, with some containing thousands ('poly' means many).

Oligosaccharides are found in legumes and prebiotics (such as kombucha and kimchi). Oligosaccharides help absorb some minerals and are fermented by bacteria in the intestines, producing short chain fatty acids that nourish our intestines (protecting it from inflammation). This will be explored further in Topic 3: Digestion, malabsorption and the microbiome.

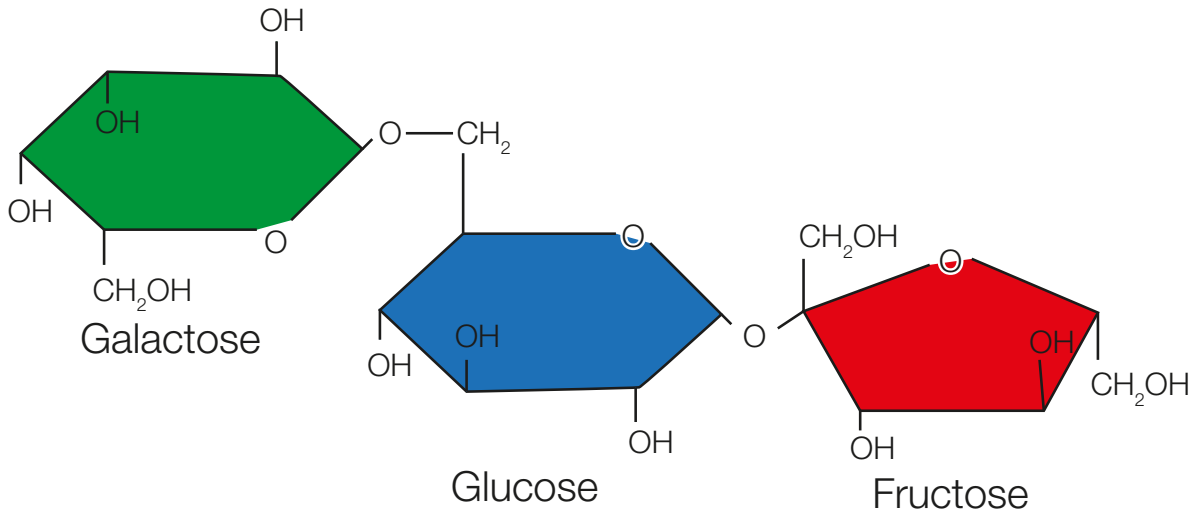


Figure 1.2.3: The structure of an Oligosaccharide: Raffinose, consisting of three singular sugar units.

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There are three major types of polysaccharides: **glycogen**, **starch** and **fibre**.

Glycogen is an **energy** storage molecule in **animals**. The majority of glycogen is stored in the **liver**, with smaller amounts stored in **skeletal muscles**. Glycogen in the skeletal muscles can be broken down to provide muscles with glucose for respiration (to produce energy). The glycogen in the liver can be broken down to release glucose into the blood, providing other types of cells (and muscles when needed) with glucose. Glycogen is a highly branched molecule, which makes it easier for enzymes to break down.

Starch is the **energy** storage molecule in **plants**. Starch is also a highly branched polysaccharide, which means it is easier for the body to digest. However, starch consists of different types of branches to glycogen. Starch is found in plant sources such as grains, vegetables, seeds, etc.

Cellulose is an important **structural** polysaccharide in **plant** cells. It is also known as insoluble **fibre**. Cellulose makes up the cell wall of plant cells and aids in maintaining cell shape and protects the cell. When we eat plant-based foods, we also consume cellulose. Humans cannot digest cellulose because we do not have the enzymes required to break the bonds between monosaccharides. This is because cellulose has a different arrangement of glucose molecules to glycogen and starch.

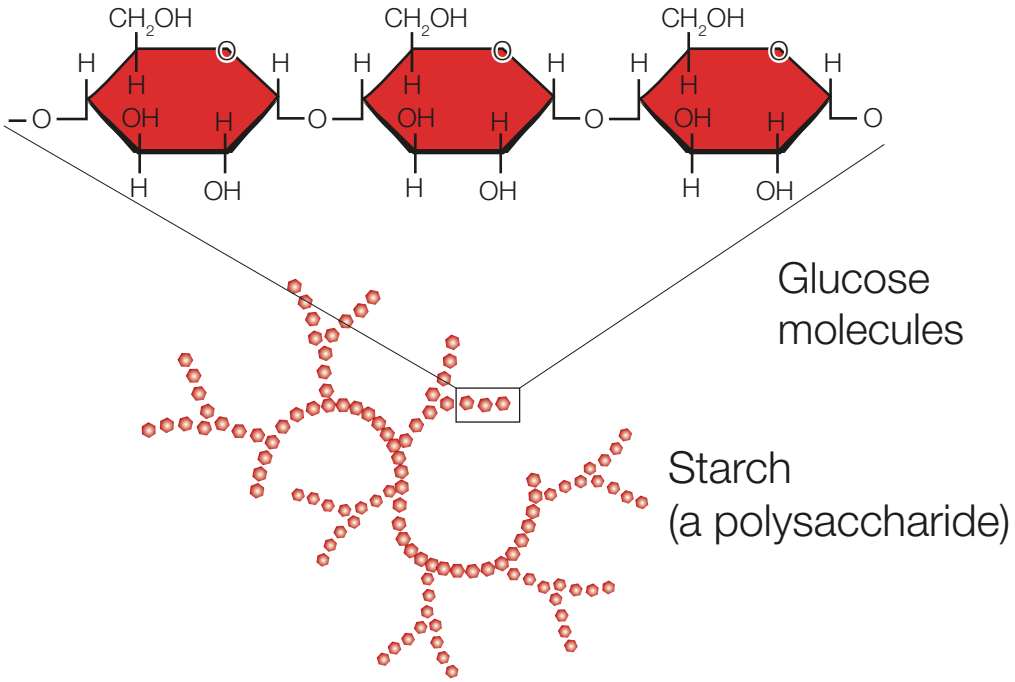


Figure 1.2.4: The structure a Polysaccharide, Starch consisting of many singular sugar units.

Each of the hexagons in the molecules in Figure 1.2.4 represent a glucose molecule. The bonds between these glucose molecules in starch and glycogen can be broken down to isolate glucose molecules so they can be released into the blood for other cells to access when the body requires energy.

Helpful online resources

Free Animated Education: What are Carbohydrates? What are its different Types?

https://www.youtube.com/watch?v=lJUwdlups9o

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Did you know?

Cruciferous vegetables, such as broccoli, contain compounds called glucosinolates and in a different area of the cell there is an enzyme called myrosinase. Chopping, blending or chewing cruciferous vegetables breaks the plants cell walls and allows myrosinase and glucosinolate to react and produce isothiocyanates (ITCs). Some studies have demonstrated that ITCs could possibly remove cancer inducing chemicals from the body. Scientists in China have discovered the ideal way to cook broccoli to release the most ITCs. Their study revealed that it is best to chop broccoli up as small as possible (they chopped it into 2mm cubes) and leave it for 90 minutes before lightly cooking (stir fry). This method produced the highest amount of sulforaphane (an ITC) because there was more time for the chemical reaction to occur. In reality, we often don't have the time to pre-chop broccoli into tiny pieces and leave it for 90 minutes prior to cooking. However, we can easily implement greater chewing of cruciferous vegetables to increase the release of ITCs from our food.

The study has also resulted in a couple of new fads. Firstly, it resulted in increased sales of powdered 'broccoli' pills. Sales increased due to advertising claims that they have anti-cancer benefits (this might be true, but this can be achieved by regularly including cruciferous vegetables in the diet). Due to this research, broccoli lattes have also started to become an option at cafes. Broccoli stems are processed into powder and mixed into people's lattes to consume some greens with their morning coffee with the added benefit of extra phytonutrients such as ITCs.

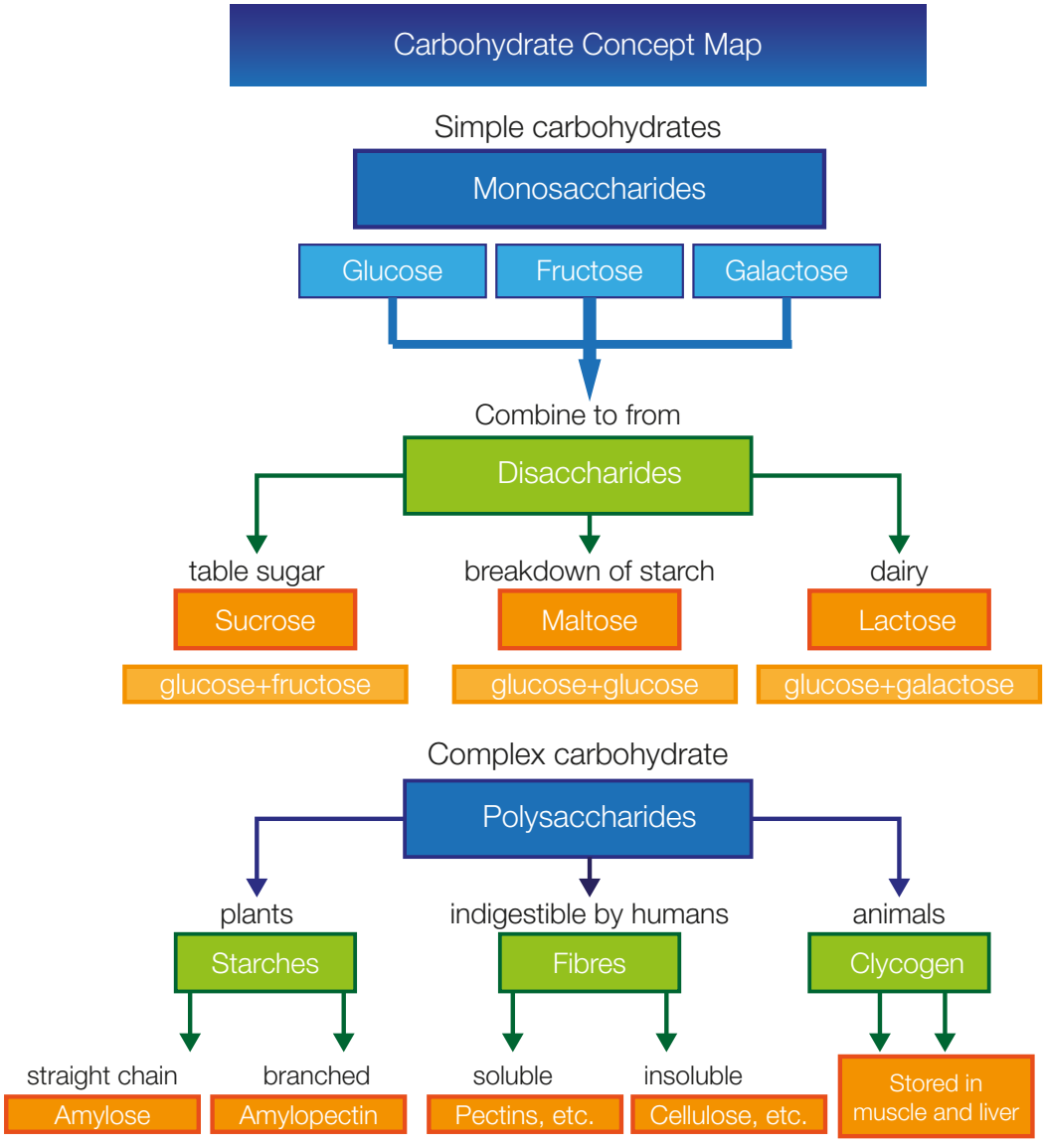


Figure 1.2.5: A summary concept map of the simple and complex carbohydrates.

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Dietary fibre

Dietary fibre is found in **plant-based products** such as fruit, vegetables, legumes, and whole grains. Fibre is **not** found in animal products such as meat and cheese. Dietary fibre is found in the structural parts of plant such as their cell walls, stems, seeds and skins. Fibres are complex carbohydrates that consist of many repeating monosaccharide units bound together. Unlike glycogen and starch, the human body does not contain the necessary enzymes to break the bonds between the repeating monosaccharides of fibre. This means that they progress through the intestines without being digested and releasing energy. Dietary fibre is generally broken down into two categories: **soluble** and **insoluble** fibre. Most plant-based foods contain a mixture of both types of fibre, but they generally contain more of one type than the other.

Soluble fibre

Soluble fibre dissolves in water easily forming a **gel-like substance**. A good way to think about this is thinking about what happens when you make porridge. The oats absorb the water and form a more gel-like, mushy porridge. This is because oats are high in soluble fibre. As the soluble fibre dissolves in water, it also results in the gel-like substance expanding. This is because it is retaining water as well. Foods that contain a lot of soluble fibre expand in the stomach, taking up more space, which makes us **feel fuller**. Therefore, eating foods high in soluble fibre can prevent us from overeating and **reduce the risk of weight gain**. Because our bodies do not contain the enzymes to break down soluble fibre, the gel-like soluble fibre also **slows digestion**. This means that the absorption of nutrients in the intestines is also slowed down. In particular, it takes longer for the sugar in our meal to be absorbed and this prevents large spikes in blood sugar and **lowers the risk of developing type 2 diabetes**. Soluble fibre also **reduces the risk of cardiovascular disease** because it binds with cholesterol in the intestines, which means the cholesterol cannot be absorbed and is removed from the body with the soluble fibre in the stool. This can lower blood cholesterol levels.

Soluble fibre cannot be digested by humans, but the good bacteria in our intestines can easily ferment it, obtaining nutrition for themselves and releasing short chain free-fatty acids that provide us with small amounts of energy. It is estimated that soluble fibre provides our body with approximately 8 kJ of energy per gram.

As mentioned above, soluble fibre is commonly found in **oats**; however, it is also found in **legumes**, **psyllium**, **barley** and **fruits containing pectin such as berries, apples and citrus fruits**. To increase soluble fibre in one's diet, it is easy to add a legume such as lentils to your everyday meals (e.g. pasta).

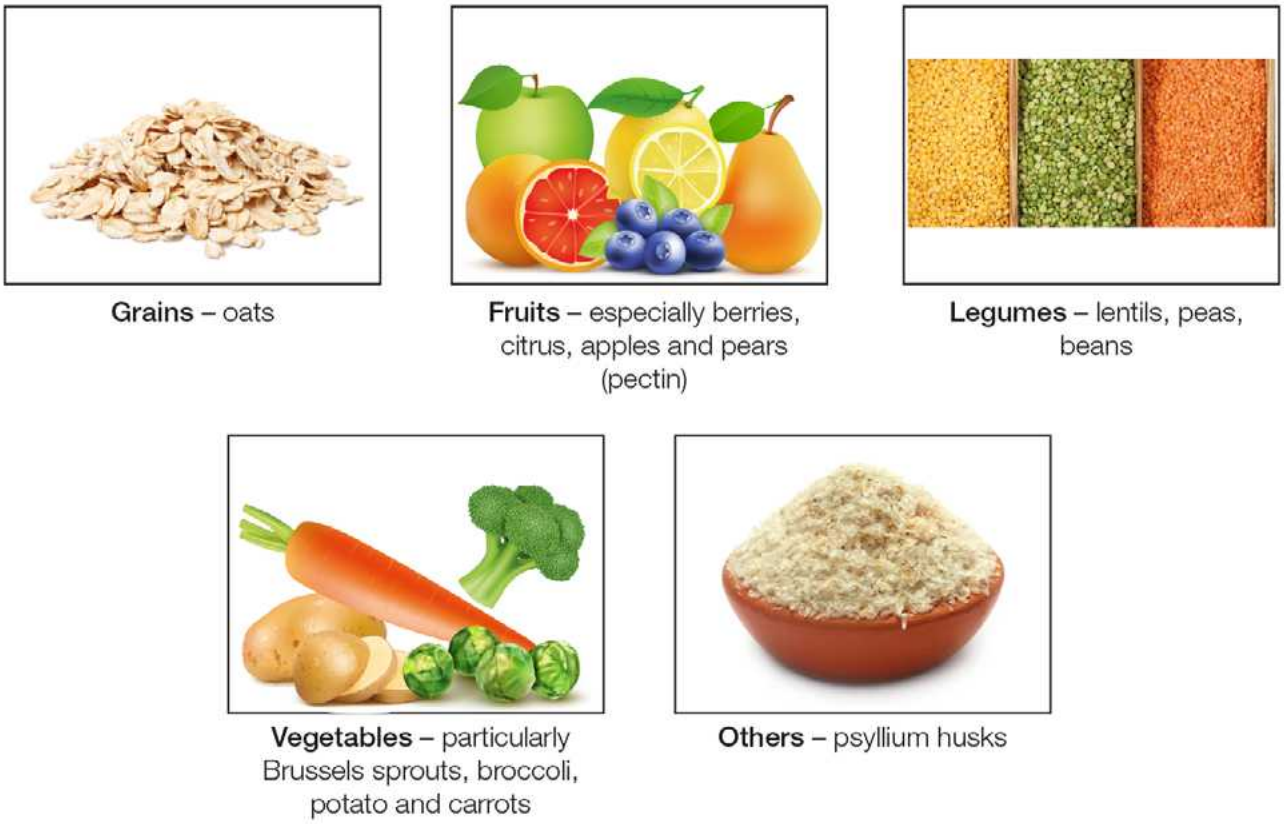


Figure 1.2.6: Some examples of foods that are rich in soluble fibre.

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Insoluble fibre

Insoluble fibre does not dissolve in water and therefore does not form a gel-like substance. In contrast to the porridge example for soluble fibre, placing a food high in insoluble fibre, such as pure wheat or celery, in water will not result in a gel-like substance. Insoluble fibre is also less readily fermented by bacteria in the large intestine and very little (if any) energy is extracted from insoluble fibre for human use.

Because insoluble fibre is indigestible, it **provides bulk** and sits in the intestines and binds to other waste products that need to be excreted. This facilitates the processing of waste and increases the gastrointestinal tract movement **preventing constipation**. In doing so, this also reduces the risk of inflammation of the intestinal lining and blockages of the intestines. Insoluble fibre can promote intestinal health by reducing the risk of small pouches forming at weak points in the intestines resulting in **diverticular disease** and could also reduce the risk of intestinal cancer. As it is indigestible it also takes up space in the stomach and intestines, making us feel fuller and preventing overeating, whilst providing the body with no energy.

Insoluble fibre is commonly found in **grains** such as **wheat**, bran, **nuts**, seeds, brown rice and **vegetables such as celery**. Insoluble fibre such as **cellulose** is found in high amounts in the skin of fruits and vegetables. Cellulose makes up the cells walls of plant cells (animal cells do not contain cell walls and therefore do not provide cellulose when eaten). An easy way to increase insoluble fibre is to make sure that you don't peel your fruits/vegetables and instead eat them whole (where appropriate). This is also one reason why it is better to consume fruits instead of fruit juice because fruit juice has lost the majority of its beneficial fibre. You can also include 30g of nuts to your diet daily to increase insoluble fibre.



Grains - mixed grain or wholemeal bread, whole wheat pasta, brown rice, corn



Outer skins - vegetables and fruits



Legumes - kidney beans, chickpeas



Nuts & seeds

Figure 1.2.7: Some examples of foods that are rich in insoluble fibre.

Helpful online resources

WebMD: What's the Difference Between Soluble and Insoluble Fiber?

https://www.youtube.com/watch?v=zFoD3F-nlec

Free Animated Education: Dietary Fibre: The Most Important Nutrient? Best Fiber Foods?

https://www.youtube.com/watch?v=_qo5Bllt1_M

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Functions of fibre in the body

A summary of the main functions of fibre are listed below:

- Because fibre is very tough it can increase chewing, stimulating greater saliva release, promoting healthier gums and teeth.
- Both types of fibre (but especially soluble fibre) slow down the emptying of the stomach into the intestines. This makes us feel fuller for longer and reduces the likelihood of us overeating (whilst providing very little energy because we cannot break it down).
- Because digestion is slowed down, this also results in a slower absorption of nutrients and reduces the likelihood of blood glucose spikes and, in turn, the risk of developing type 2 diabetes.
- Soluble fibre helps reduce blood cholesterol levels by binding to cholesterol, preventing its absorption and facilitating its excretion from the body.
- Insoluble fibre also results in the softening of stools (preventing constipation), which also reduces the likeliness of straining when emptying the bowels. This reduces the risk of developing diverticular disease and cancer.

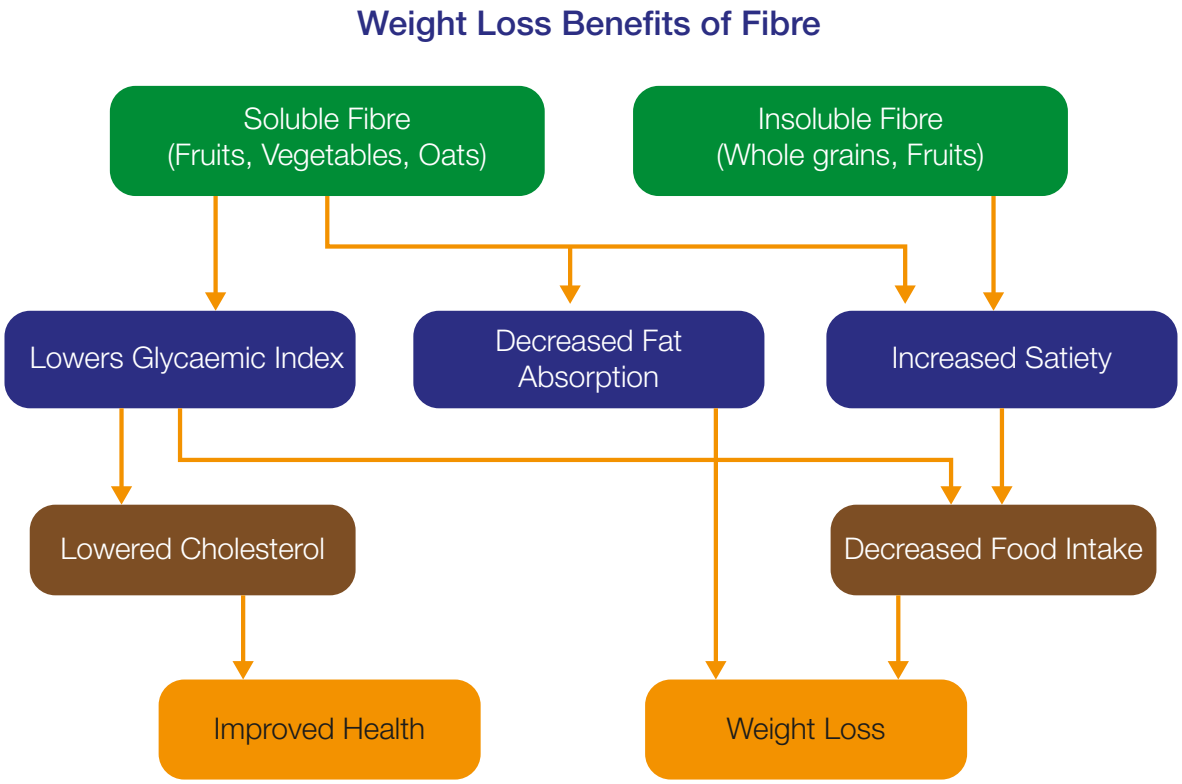


Figure 1.2.8: A flow diagram summarising how both forms of fibre can contribute to increased weight loss and health outcomes.

Functions of carbohydrates

Energy provision

The **primary function** of carbohydrates is to provide **energy**. Carbohydrates provide us with **16.7kJ/g**. This means that for every gram of carbohydrate we consume, it provides us with 16.7kJ of energy. The average recommended amount of energy an adult should consume per day is 8700kJ, but the energy requirements of each individual differs. This energy **fuels our activities** throughout the day, such as movement, repairing wounds, growing, thinking, etc. As glucose is the **primary source of energy for our brains**, consuming carbohydrates also **prevents us from getting headaches and feeling tired and irritable**.

When we eat simple and complex carbohydrates, they are digested by enzymes in the digestive system into their simplest form: monosaccharides. These monosaccharides are absorbed into the blood and directed to the liver. The liver is an important organ in the metabolism of carbohydrates.

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Figure 1.2.9: Glucose is absorbed through the small intestine and carried by blood to the liver.

Depending on the body's needs at a given time, three different outcomes can occur after glucose is absorbed into the blood:

1. **The glucose is used:** if the body's cells require glucose, then the glucose is released back into the bloodstream so that cells can access it and use it for immediate energy. Under normal circumstances, approximately 70% of glucose is redirected back into the blood for other cells to use and muscle cells to store.
2. **The glucose is converted to glycogen:** if the body has excess glucose, then the liver converts the glucose to glycogen (long chains of glucose) and stores it for when it is needed in the future. The liver stores approximately 4,200kJ of glycogen which equates to approximately four hours' worth of glucose supply for the average human. The liver stores approximately a quarter of the body's total glycogen. The skeletal muscles store the rest.

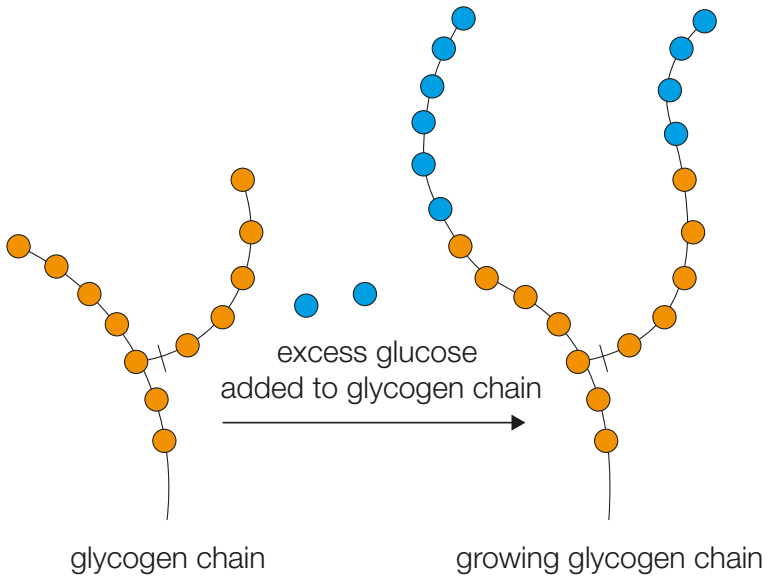


Figure 1.2.10: Excess glucose molecules being stored as glycogen in the liver. Each circle represents a glucose molecule (monosaccharide). When there is an excess of monosaccharides, they are bound together to be stored as the polysaccharide glycogen in the liver.

3. **The glucose is converted to fats:** if the glycogen stores in the liver and muscles are full, then the glucose is converted to fats and stored in adipose tissue (fat tissue).

Did you know?

Sugary drinks such as juices and soft drinks are a large contributor to gaining weight. When a sugary drink is consumed, the 'liquid sugar' is generally not registered by the brain and doesn't make us feel full. Because the kilojoules are not registered, it is likely that extra kilojoules are consumed through extra food. This can lead to an excess carbohydrate intake and result in the sugar being converted to fats.

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Cellular communication

Carbohydrates also play important roles in **cellular communication and recognition**. The cell membrane contains short chains of carbohydrates that are bound to a protein (glycoprotein) or the phospholipid membrane (glycolipid). These receptor molecules recognise other cells and recognise **hormones** that are sent from another area of the body to communicate a specific message to a particular cell (e.g. when the hormone insulin communicates with skeletal muscle cells to take up excess glucose in the blood).

Protects protein from being used for energy

For an average person consuming 8,700kJ per day, between 3,915 to 5,655kJ is required from carbohydrate intake (or 230 to 333g of carbohydrates). It is important to remember that we need to consume carbohydrates daily to fuel our activities, especially the activity of our brain that relies on glucose. If we do not consume enough carbohydrates, our body activates different processes to obtain it. One example of this is muscle degradation. This means that our **muscles break down so that the protein can be converted to glucose to fuel our brain**. In doing so, this lowers our basal metabolic rate. This is discussed further in Topic 9.1.

Summary of carbohydrate functions

Carbohydrates:

- are an immediate energy source providing 16.7 kJ/g;
- are the primary fuel for the brain and nervous system;
- can be stored as glycogen for times when the body is carbohydrate deficient;
- supply dietary fibre to regulate bowel movements and slow digestion;
- make up structural components of cell membranes (carbohydrate receptors) and allow communication;
- protect protein from being used as a primary energy source;
- prevent headaches and fatigue; and
- allow a person to participate in activities requiring energy.

Carbohydrate recommended dietary intake

The Acceptable Macronutrient Distribution Range for carbohydrates (AMDR), recommends that **45% to 65%** of daily kilojoules (energy) come from **carbohydrates**. However, as highlighted throughout this topic not all carbohydrates are created equal. It is recommended that these carbohydrates are obtained from sources that they occur naturally in, such as fruits, vegetables, grains, milk etc. It is also recommended that only **10% to 15%** of the daily carbohydrate intake should come from **simple sugars**. Simple sugars do occur naturally, but they are often added to processed foods. The amount of added sugars in processed foods might surprise you. Some jars of pasta sauce contain more sugar than a 50g packet of M&Ms. Our diet should also include fibre. It is recommended that **women consume 25g and males consume 30g of dietary fibre per day.**

Deficiency of carbohydrates

When people have **deficient carbohydrate consumption** their glycogen reserves are used up first. However, once the glycogen reserves are low, the body needs to ensure it has an ongoing supply of glucose to supply to the brain and nervous tissues. The protein that makes up our muscles can be broken down and converted into glucose molecules. This results in reduced muscle mass. This is why athletes eat before and after workouts. Athletes want to provide their body with carbohydrate fuel and reduce the risk of their muscles being broken down to fuel their body (see Topic 9: Sports nutrition for more information). There is also another emergency energy backup supply for the brain. When the brain's energy needs cannot be met by carbohydrates alone, the liver can convert fats into **ketone bodies**. The brain can also use these ketone bodies for energy, but it prefers glucose as its energy source. This is the theory behind the **ketogenic diet.** Reduce the intake of carbohydrates so the body uses fat (ketone bodies) to fuel the brain instead of carbohydrate. However, this diet can result in reduced cognitive function and other side effects that will be explored in Topic 5: Food trends.

Generally, if someone is **carbohydrate deficient,** they experience **symptoms** such as **headaches, weakness, irritability, inability to exercise** and **even fainting**. Carbohydrates are a major energy source for the body and a lack of them results in people feeling lethargic. The brain primarily uses glucose for its daily processes and without energy it makes sense that there are side effects such as headaches and irritability.

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Excess of carbohydrates

When **carbohydrates** are consumed in **excessive amounts**, the excess can be stored as fat and could result in **obesity**. This can also contribute to other health implications such as **type 2 diabetes**, hypertension and cardiovascular disease. Furthermore, excessive consumption of carbohydrates also increases the risk of developing **dental caries** (tooth decay). This is because bacteria in the mouth ferment the sugar in the mouth producing acid as a bi-product. This acid can erode tooth enamel leading to dental caries.



Figure 1.2.11: The comparison of a healthy tooth compared with progressive tooth decay and a cavity.



Figure 1.2.12: An image of dental caries.

Helpful online resources

TedEd: How do carbohydrates impact your health–Richard J. Wood

https://www.youtube.com/watch?v=wxzc_2c6GMg

Osmosis: Carbohydrates & sugars–biochemistry

https://www.youtube.com/watch?v=jQi84Tnstl4

FreeMedEducation: What causes tooth decay?

https://www.youtube.com/watch?v=BE_h4bTdcdQ

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How to make informed decisions about carbohydrate content in foods and beverages

Food labels can be very confusing and tricky to understand. Often, we don't have the time to spend trying to work out what they mean and how to use them. When it comes to carbohydrates it can be particularly confusing.

Firstly, you need to look at the **servings per package and serving size** on the Nutrition Information Panel (NIP) (refer to **(1)** on Figure 1.2.13). If there is only one serve, then what you read in the **'Per Serve' column (2)** is what you would consume if you ate all of the food in the packaging. However, if it says that there are two serves per package then you would have to double everything in that column to determine the nutritional value if you were to eat all of the contents. The **'Per 100g' column (3)** is very useful when trying to **compare different items** because generally items have different serving sizes and the number in this column informs consumers of the percentage composition of each nutrient as it is "per 100.".

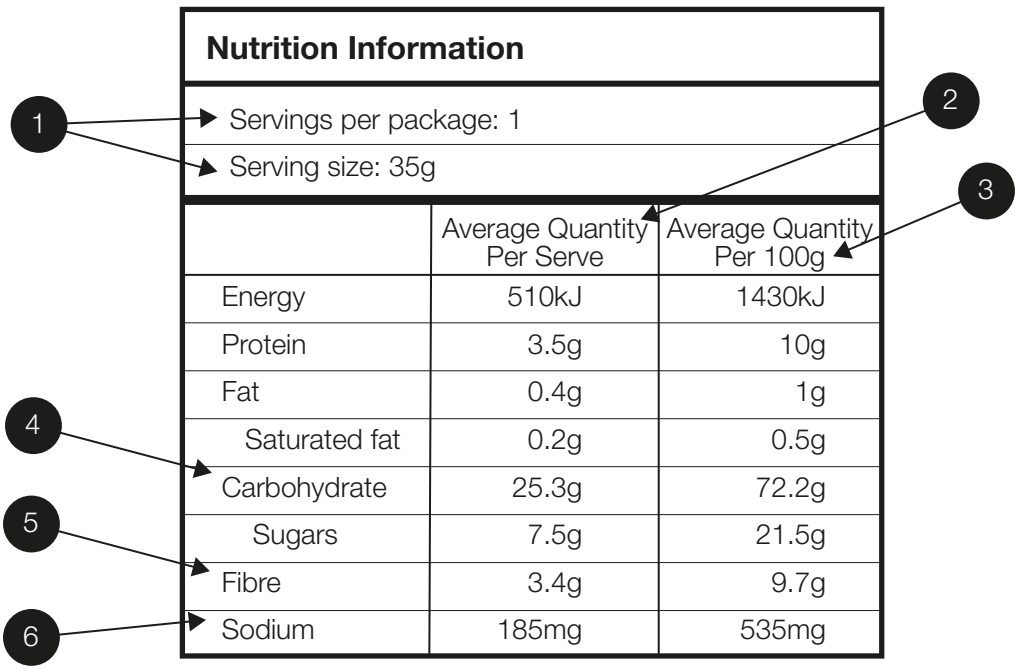
In the left-hand column on the NIP in Figure 1.2.13, you will see the word **'Carbohydrate' (4)**. The numbers in this row represent the total number of carbohydrates per serve and per 100g. It is compulsory for the manufacturers to display the amount of **sugar (5)** in the NIP, but not all labels will include fibre on the NIP (this is because not all products contain fibre, e.g. milk). Recall that sugar and fibre are both forms of carbohydrates. On Australian food labels, the dietary fibre is separated from the 'Carbohydrates'; however, sugar is grouped under 'Carbohydrates' (this is indicated by the indent highlighted at (5) in Figure 1.2.13). This means that the sugar is included in the number represented by the total number of carbohydrates. **Therefore, to work out the amount of energy providing complex carbohydrates (e.g. starch), you need to subtract the sugar (5) from the total number of carbohydrates (4)**.

Example calculation

In the NIP in Figure 1.2.7, there is 17.8g of complex carbohydrate per serve. The calculation for this is 25.3 (carbohydrate) – 7.5 (sugar) = 17.8g.

If you were travelling to Europe you would find that the carbohydrates section of the nutrition labels are the set up the same way; however, in the USA and Canada fibre is included in the Carbohydrates and is not represented as its own entity.

When choosing a food item, it is best to pick items that have **15g of sugar per 100g or less**. It is also best to choose the product that has the highest amount of fibre **(or at least 7.5g per 100g)**. It also a good habit to choose breads and cereals with 3g of fibre or more per serve.



Nutrition Information

Servings per package: 1

Serving size: 35g

	Average Quantity Per Serve	Average Quantity Per 100g
Energy	510kJ	1430kJ
Protein	3.5g	10g
Fat	0.4g	1g
Saturated fat	0.2g	0.5g
Carbohydrate	25.3g	72.2g
Sugars	7.5g	21.5g
Fibre	3.4g	9.7g
Sodium	185mg	535mg

Figure 1.2.13: A nutrition information panel.

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1.2 Review questions

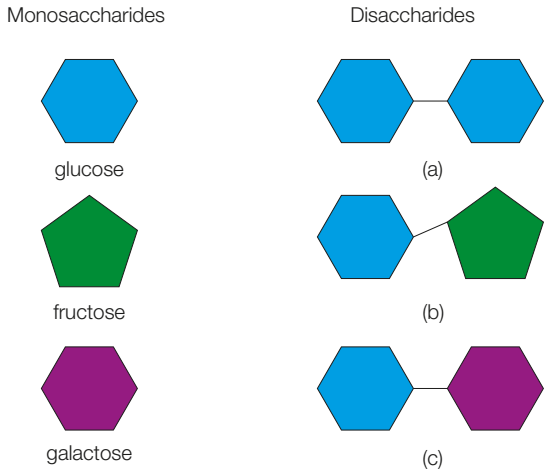
1. State the three elements that carbohydrates consist of.

(1 mark)

2. Name a common source of galactose? Describe why galactose can be obtained from this source.

(2 marks)

3. Refer to the following picture:



Using the legend in the picture above, identify the three disaccharides:

(a)

(b)

(c)

(3 marks)

4. Name the simple sugar that is commonly known as 'table sugar' **and** state the two monosaccharides that it consists of.

(2 marks)

5. Describe how simple sugars differ structurally to complex carbohydrates.

(2 marks)

6. Describe how glycogen and starch differ in structure and function to cellulose.

(3 marks)

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7. Refer to the following two Nutrition Information Panels and Figure 1.2.7 to answer questions 7 (a) to (c):

Nutrition Information		
Servings per can: 2		
Serving size: 210g		
	Average Quantity Per Serve	Average Quantity Per 100g
Energy	895kJ	425kJ
Protein	10.8g	5.1g
Fat	1.2g	0.6g
Saturated fat	0.2g	0.1g
Carbohydrate	33.7g	16.1g
Sugars	15.5g	7.4g
Fibre	11.9g	5.7g
Sodium	1300mg	620mg

(1)

Nutrition Information		
Servings per package: 3		
Serving size: 150g		
	Average Quantity Per Serve	Average Quantity Per 100g
Energy	608kJ	405kJ
Protein	4.2g	2.8g
Fat	7.4g	4.9g
Saturated fat	4.5g	3.0g
Carbohydrate	18.6g	12.4g
Sugars	18.6g	12.4g
Fibre	0g	0g
Sodium	90mg	60mg

(2)

(a) State how many servings there are per can for food item number 1.

(1 mark)

(b) Calculate the amount of energy provided by complex carbohydrates per serve for both food items.

(2 marks)

(c) Identify which of the two food items would raise blood sugar levels the quickest and use data to justify your answer.

(3 marks)

8. Explain why the dietary fibre cellulose is not found in ham.

(2 marks)

9. Describe **two** reasons why soluble fibre is beneficial for the body.

(4 marks)

10. State whether oats contains both soluble and insoluble fibre or just soluble fibre. Justify your answer.

(2 marks)

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11. Name a food that is rich in insoluble fibre **and** describe a function of insoluble fibre in the human body.

(2 marks)

12. Describe **two** functions of carbohydrates.

(4 marks)

13. Explain why individuals feel tired when they are carbohydrate deficient.

(3 marks)

14. Describe one consequence that could result from an individual exceeding the recommended sugar intake (which is 10-15% of the total daily energy intake), over an extended period of time.

(2 marks)

E Extension question

Discuss why carbohydrates are the primary energy source for the human body.

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1.3 Proteins

Nutrition Understanding

There are many misconceptions about proteins and their importance for the body. Many people associate protein with meat and eat steak to increase strength and muscle mass. However, this is only part of the picture. Protein is a vital component of all cells in our body, not just muscle cells. In fact, it has recently been discovered that on average, **each of our cells have approximately 42 million proteins**. This highlights the **importance of protein** in our diet for cellular function.

When we eat protein, it is generally accompanied by other vital nutrients. By overconsuming protein, individuals could reduce their intake and absorption of other important nutrients that are needed to maintain good health. Furthermore, there are different types of protein and proteins can be found in plant-based products as well as animal-based products.

Protein structure and classification

Proteins are large compounds made up of **carbon**, **hydrogen**, **oxygen** and **nitrogen** atoms and are essential to cellular function. In contrast to carbohydrates that contain carbon, hydrogen and oxygen, **nitrogen** is also present in **proteins** and this can help us differentiate between the two macronutrients. Proteins are made up of **amino acids**, which are the structural unit of proteins. Each amino acid consists of a central carbon atom that is bonded to a hydrogen atom, an amino group (NH_2), a carboxylic acid/carboxyl (COOH) group and a unique side chain (R group) (see Figure 1.3.1 and 1.3.2).

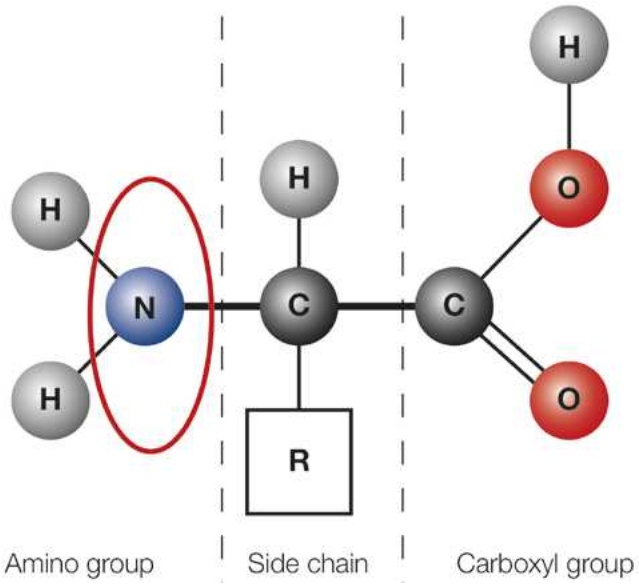


Figure 1.3.1: The general structure of an amino acid. The red oval highlights the element nitrogen of the amino group that is not present in carbohydrates.

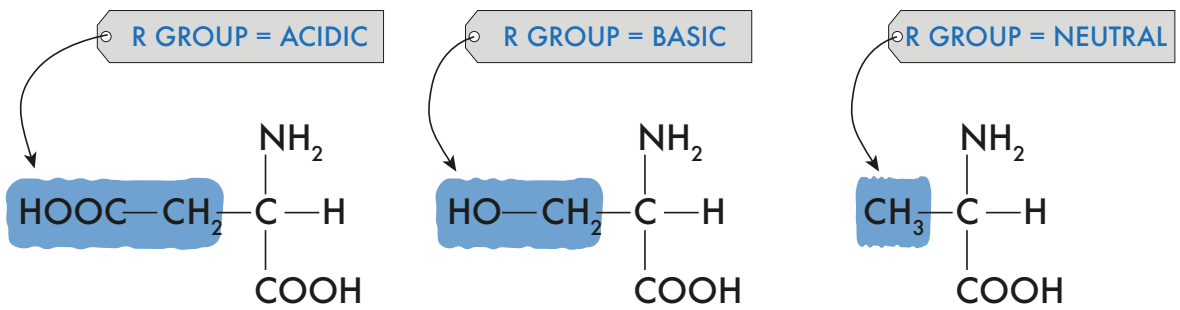


Figure 1.3.2: The unique side chains (R group) of three of the 20 amino acids.

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There are **20 different amino acids** that make up proteins and each protein has a **unique** sequence of amino acids. There is an extensive amount of possible combinations of amino acids, which gives rise to the significant amount of different proteins not just inside humans but all living things.

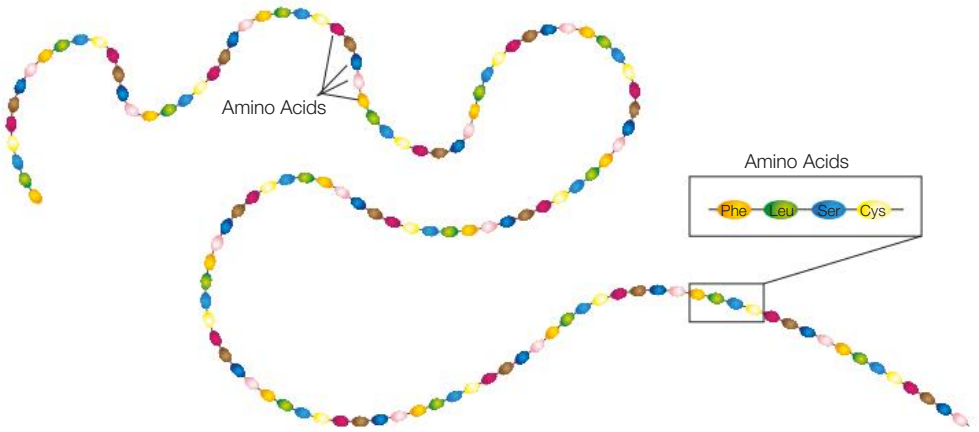


Figure 1.3.3: A section of a single protein, which is made up of a specific order of amino acids.

Essential amino acids

Of the 20 amino acids, nine of them are referred to as **essential amino acids (EAAs)**. These amino acids cannot be synthesised (made) by the human body and **must be consumed** through the diet. The remaining 11 amino acids are termed **non-essential amino acids** because they can be synthesised by the body (see Figure 1.3.4).

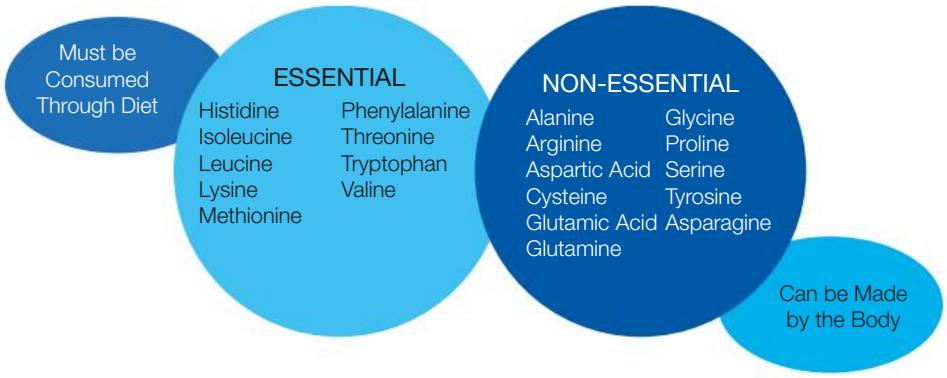


Figure 1.3.4: A list of the nine essential amino acids and 11 non-essential amino acids.

Not all proteins contain every essential amino acid. Therefore, protein sources are classified as either **complete** or **incomplete**. **Complete proteins** contain **all nine essential amino acids**, whereas incomplete proteins do not. **Incomplete proteins** are also called partially complete proteins and **lack one or more of the nine essential amino acids**. It is important to note that complete proteins do not necessarily contain all of the non-essential amino acids, but our body can make these from the other amino acids we eat if required.

Helpful online resources

Free Animated Education: What are Proteins?

https://www.youtube.com/watch?v=vQo5taiq_5E

FuseSchool - Global Education: Protein in the Diet

https://www.youtube.com/watch?v=Fe5wHw3pnmY

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Sources of protein

Protein can be obtained through the diet from two sources: **animal products** and **plant-based products**.

Animal sources

Proteins from **animal sources** are generally known as **complete proteins** because they contain all nine of the essential amino acids that the body can't make; however, **gelatine** is an exception. Gelatine is derived from collagen in animals and is used to help thicken and solidify foods such as jelly, lollies, yoghurt and ice cream. It is also used in some cosmetics and drug capsules. Gelatine does not contain all nine essential amino acids in the correct proportions and is therefore considered an incomplete protein.

Furthermore, the **bioavailablity** of animal proteins is high, with **approximately 90-99%** of animal protein consumed being digested. This means that a high proportion of protein supplied by animal sources is absorbed and available for cellular use.

Table 1.3.1: Some examples of animal protein sources.

Source of Animal Protein	Examples
Meats	Beef, chicken, lamb, pork, turkey, duck
Smallgoods	Ham, bacon, chorizo, pepperoni
Seafood	Salmon, tuna, whiting, sardines, prawns
Dairy Products	Milk, cheese, yoghurt, cream
Eggs and egg products	Chicken eggs, mayonnaise, pancakes, breaded fried foods



Figure 1.3.5: Animal sources of protein include meat, smallgoods, seafood, dairy products and eggs.

Plant sources

Proteins from **plant sources** are generally known as **incomplete proteins** because they a missing one or more of the nine essential amino acids (EAAs) (or they have all the EAAs but not in the correct ratios); however, there are some exceptions. **Quinoa**, **buckwheat** and **soy** are three plant-based products that contain all nine essential amino acids and are considered complete proteins.

Plant-based proteins generally have a lower **bioavailability** than animal proteins. Most plant-based sources of protein have a digestibility of **70-90%**; however, over 90% of protein in legumes is generally absorbed. Plant based sources therefore provide less amino acids to the body compared to animal protein.

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Table 1.3.2: Some examples of plant-based protein sources.

Source of Animal Protein	Examples
Soy products	Tofu, soy milk, soy yoghurt, soy cheese
Grains & grain products	Quinoa, wheat, oats, flour, bread, cereals
Fruits	Apples, bananas, oranges, strawberries, grapes
Vegetables	Spinach, kale, carrots, broccoli, capsicum
Legumes	Kidney beans, black beans, chickpeas, lentils
Nuts	Almonds, cashews, peanuts, walnuts, pine nuts
Seeds	Chia seeds, flaxseeds, sesame seeds, pumpkin seeds



Figure 1.3.6: Plant sources of protein include nuts, seeds, fruits, vegetables and legumes.

Vegan diets and complementary proteins

A **vegan** diet consists entirely of **plant-based products**. Remember that plant-based products are generally sources of **incomplete proteins**. This means that vegans and people whose diet is based predominantly on plant sources of proteins (e.g. some vegetarians), must ensure they consume a **wide variety of plant foods** in order to prevent becoming deficient in any essential amino acid. Essential amino acids are also referred to as limiting amino acids. For example, lysine is a limiting amino acid in rice and methionine in legumes. Rice and legumes have different limiting amino acids, but when they are consumed together, all essential amino acids are supplied by the meal. This is referred to as **complementary proteins** (see Figure 1.3.7 and 1.3.8). Generally, a vegan diet needs to be carefully planned to include complementary proteins to ensure that all essential amino acids are being consumed.

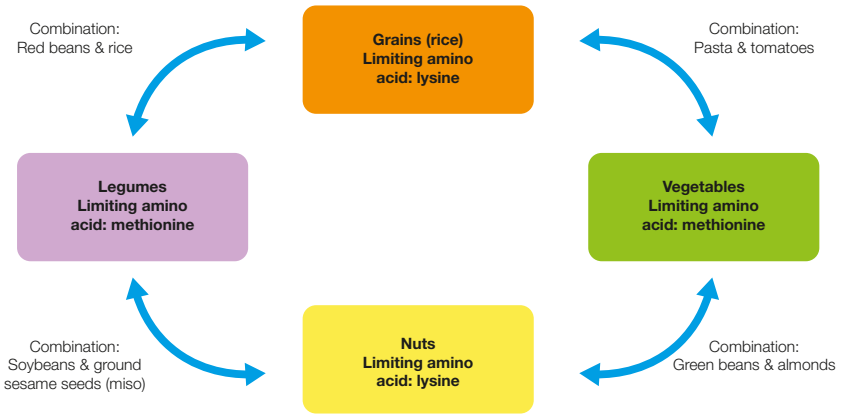


Figure 1.3.7: Some examples of plant-based meals that provide complete protein by combining different type of plant foods.

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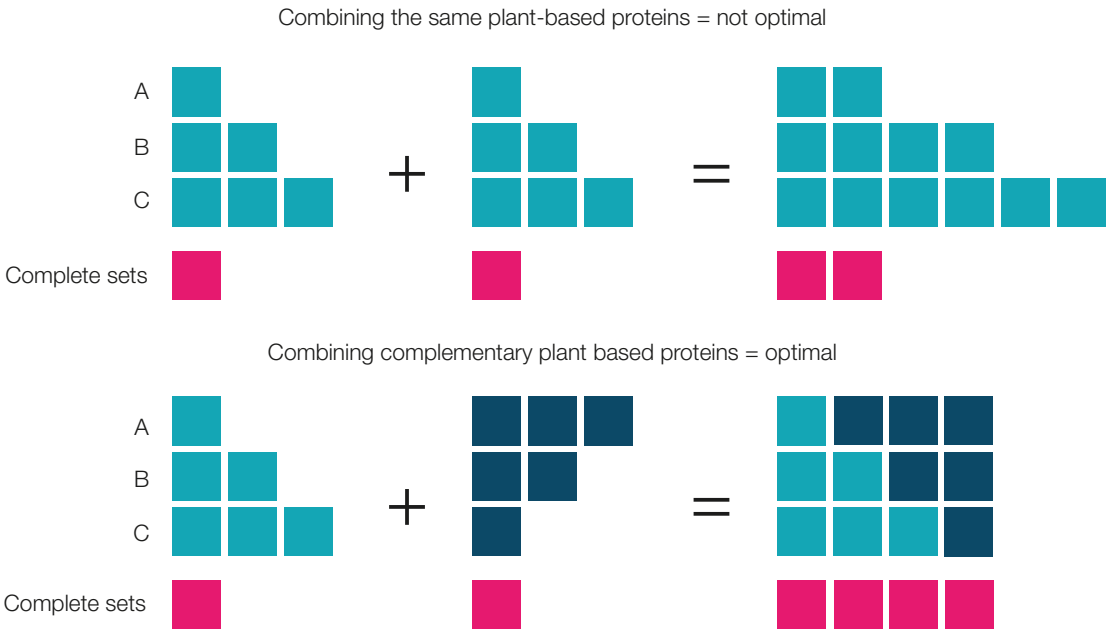


Figure 1.3.8: A visual representation of how complementary proteins can make up the 'missing pieces' or limiting amino acids to make a complete protein source. The number of complete 'sets' of the three amino acids (a, b and c) are doubled by eating two different plant based proteins in this example. In contrast, there is a limited amount of amino acid 'a' if the same plant-based protein is combined.

Functions of protein

The word **protein** is Greek for '**of prime importance'**. As mentioned earlier, scientists have determined that there are approximately 42 million proteins in the average cell. It is estimated that there are millions of different proteins in humans. Each of these proteins has a specific shape to perform a specific function. Proteins have **many structural** and **functional roles** in the body and are necessary for **growth**.

Growth and maintenance

Our body requires a constant supply of amino acids for **growth**, **maintenance** and **repair**. When proteins are consumed, they are broken down into amino acids, which are transported to cells so they can be used to make new specific proteins. New cells need to be produced and they **require proteins as part of their structure**, in order for the body to grow and develop. Additionally, our bodies are constantly replacing cells to maintain optimal performance (maintenance). For example, in an average adult, two million red blood cells are replaced every second, the entire lining of our intestinal epithelial (protective) lining is replaced every two to five days, our olfactory cells in our nose are replaced every 40 days and the cells on our tongue are replaced every ten days. The growth of hair and fingernails also require protein. Furthermore, our body requires protein to repair wounds. When a cut or graze occurs, the skin barrier is broken. This allows easier access for microorganisms to enter the body and cause infection or disease. The wound, therefore, needs to be repaired quickly and this requires new cells to be synthesised. Broken bones also require protein to repair, but these cells have a slower division rate and can take approximately six weeks to heal.

Enzymes

Enzymes are proteins that **catalyse (speed up) chemical reactions** in the body. They have a specific shape to perform their role. Enzymes are essential to perform a variety of chemical reactions in the body and direct metabolic pathways. For example, they are needed to synthesise any non-essential amino acids that the body might be low in. Furthermore, enzymes are needed in the digestive system to chemically break down our food, such as salivary amylase to break down carbohydrates in the mouth.

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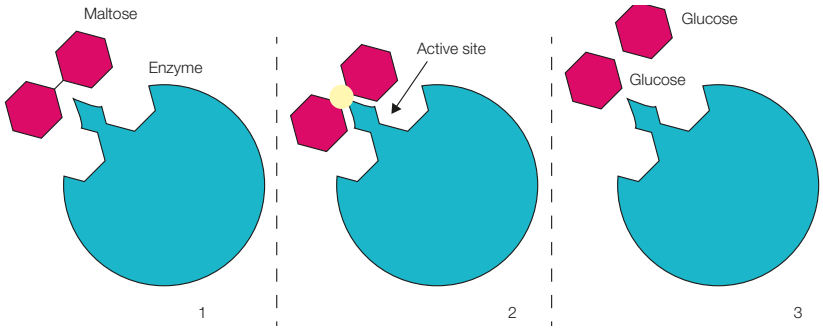


Figure 1.3.9: A visual representative of an enzyme maltase breaking down the disaccharide maltose into its two glucose subunits.

Hormones

The human body consists of trillions of cells. For the body to work efficiently, these cells need to **communicate** with each other. One way that they can do this is by synthesising specific protein **hormones**. Hormones are released into the blood, and travel through the circulatory system to cells that have the complementary receptor. When the hormone and receptor bind, the message is communicated, and this brings about a cellular response. An example is the hormone **insulin**. Insulin is released from the pancreas in response to detecting an increased blood glucose level. This hormone travels through the blood to liver and muscle cells resulting in glucose entering the muscle/liver cells and lowering blood glucose levels.

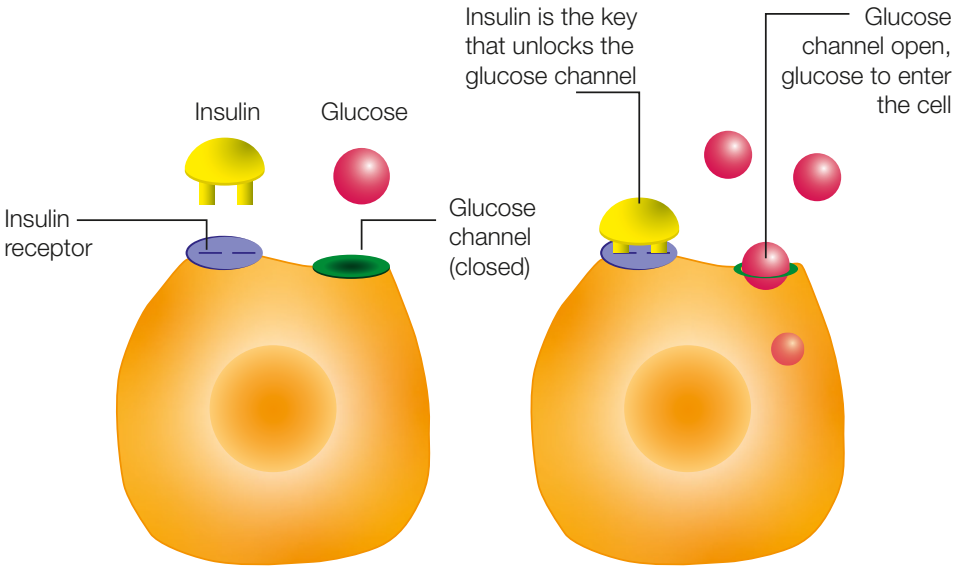


Figure 1.3.10: A visual representative of a protein hormone insulin binding to a specific receptor to open up glucose channels, which allows glucose to enter.

Antibodies

When a **disease-causing microorganism (pathogen)** enters our body, it is detected by special white blood cells. This activates a series of events that results in different white blood cells, called B-cells, synthesising and deploying **antibodies**. These antibodies are blood proteins that have a specific **complementary** shape to a specific protein on the pathogen, called an **antigen**. The antigens are unique to each pathogen and these antibodies bind to them slowing the spread of the pathogen, forming clumps and making it easier for other white blood cells to engulf them. This significantly speeds up the removal of pathogens from our body preventing sickness. B memory cells 'remember' the antigen and deploy antibodies when exposed to the same pathogen, providing immunity.

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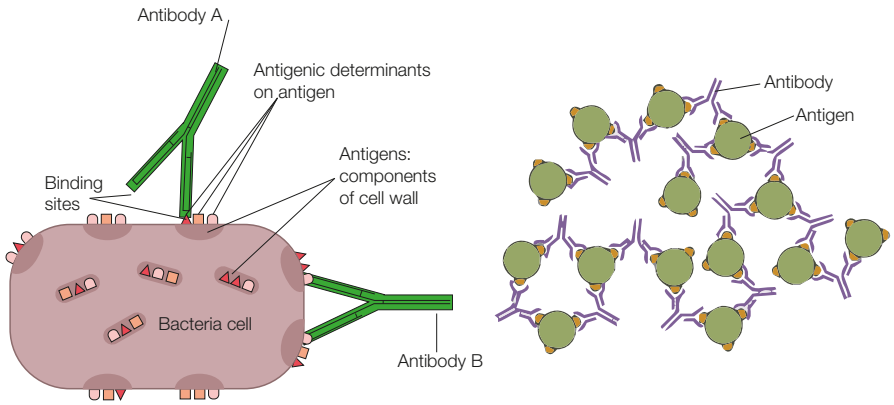


Figure 1.3.11: A pathogenic bacterial cell showing the complementary nature of antibodies binding to antigens. As antibodies bind to the antigens on pathogens, it slows down their movement forming clumps of the pathogen and antibodies making it easier for white blood cells to engulf and remove the pathogen from the body.

Haemoglobin

Haemoglobin is a protein that **makes up red blood cells**. Oxygen binds to haemoglobin so that red blood cells can deliver the oxygen to body cells to create energy. Red blood cells do not contain a nucleus so that they can consist of more haemoglobin to carry more oxygen. The omission of a nucleus is a contributing factor to their short life span of 120 days in an average adult.

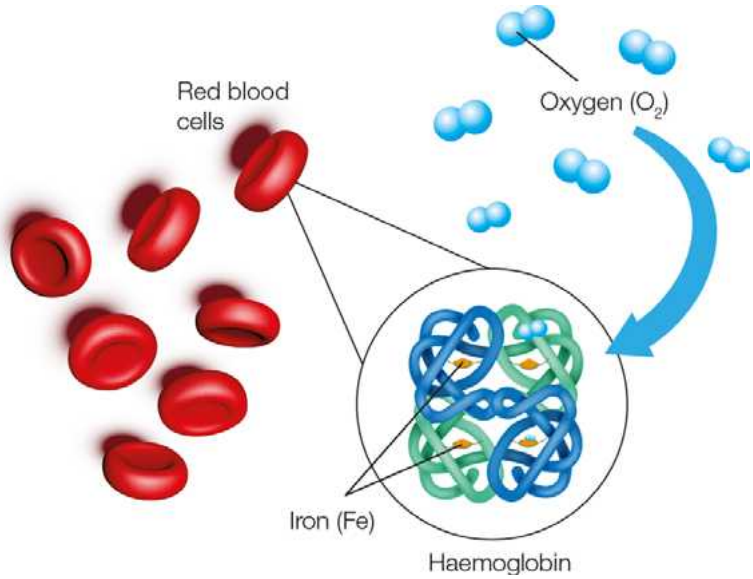


Figure 1.3.11: Red blood cells are made up of a protein called haemoglobin that oxygen binds to. Haemoglobin also consists of a mineral called iron.

Histones

Proteins can also play **structural roles** in cells; one example is in chromosomes. The chromosomes in each cell consist of a double helix DNA molecule that is tightly wrapped around **histone proteins**. This gives the DNA stability, protection and also plays a role in activating and deactivating the production of certain proteins.

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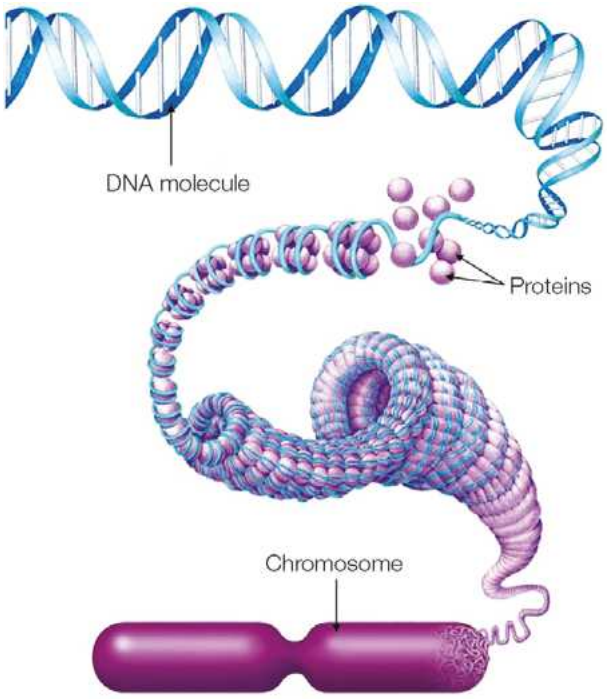


Figure 1.3.12: Chromosomes consist of a DNA molecule that is tightly wrapped around many histone proteins.

Muscle contraction and movement

There are over 600 muscles in the body, which are required for **movement**. Muscles are made up of specialised cells called muscle fibres. These fibres are composed of two different types of **protein**, actin and myosin, which allow our **muscles to contract**.

Blood clotting

Proteins are also required for **blood clotting**. When a blood vessel is damaged, the blood within the vessel escapes and this is known as **bleeding**. It is very important for the damaged blood vessel to be healed to prevent severe blood loss and bleeding out. This involves proteins called 'blood clotting factors' and blood cells called platelets that radiate long strands of protein to form a net that traps more cells and helps prevent blood loss.

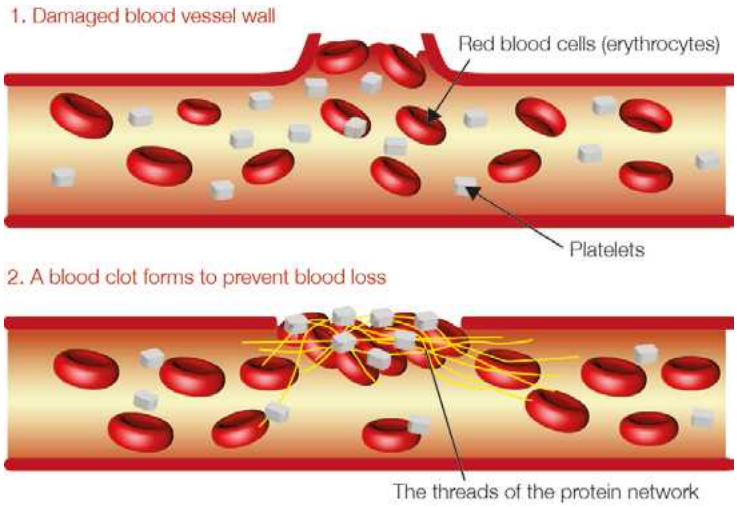


Figure 1.3.13: The formation of a blood clot, which involves a protein net being formed to trap cells and prevent blood loss.

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Secondary source of energy

If **insufficient carbohydrates are consumed**, then proteins can be used as a **secondary energy source**. This could be as a result of an individual undertaking a kilojoule restrictive diet, fasting and in extreme circumstances, starvation. Amino acids can be converted to glucose through a process called gluconeogenesis. This glucose can then be used by the brain and other organs to maintain vital functions in the body. Protein supplies approximately 16.7kJ/g.

Transport of fats

Proteins enable the **safe transport of fats** through the blood. Protein transporters called **lipoproteins** carry fats in the blood to deliver them to cells for cellular use. If fats were to travel through the blood without protein transporters, there is an increased risk that they could stick to imperfections in the internal lining of the blood vessels, increasing the risk of plaque build-up in blood vessels. Some drugs can increase the mobilisation of fat stores, such as caffeine. If too much caffeine is consumed, all the fat transport proteins can become saturated, and the excess fats can travel through the blood without transport proteins. Therefore, too much caffeine can increase the risk of plaque build-up in blood vessels and a condition called atherosclerosis (this is covered in Topic 2: Dietary disorders).

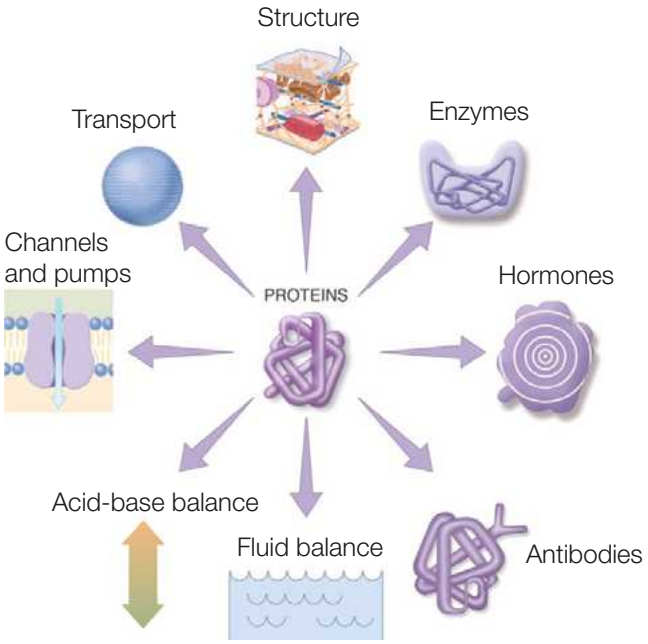


Figure 1.3.14: Proteins have many functions in the body.

Protein recommended dietary intake

As a percentage of our daily kilojoule intake, it is recommended that approximately **15% to 25%** of the total energy intake is supplied by protein. Consuming a healthy diet, consisting of high-quality proteins (along with sufficient carbohydrates and fats), can ensure that proteins are not being used as an energy source. This helps to maintain muscle mass and basal metabolic rate.

To be more specific, it is recommended that males consume 0.84 grams per kilogram of bodyweight per day and that females consume 0.75 grams per kilogram per day of protein. This means that a female who weighs 65kg should consume 48.75g of protein per day (65 × 0.75 = 48.75g). The amount of recommended protein is increased for infants, children, athletes, illness, pregnant women in the second and third trimesters of pregnancy and lactating women. These stages of life are associated with **growth**, which requires more protein.

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Deficiency of protein

In Australia, we are lucky that we have access to a wide variety and constant supply of food. As a result, it is not common for Australians to experience protein deficiency. Some groups of people that are at higher risk are the elderly and vegans. The **elderly generally have a reduced metabolic rate** and, therefore, decreased hunger. Combined with the fact that many protein sources are harder to chew (e.g. steak); this can lead to decreased intake of protein and consequently, a protein deficiency. As mentioned earlier, **vegans need to carefully plan their meals** to include complementary proteins to avoid being **deficient in one or more essential amino acids**.

In developing countries, protein deficiency is more common. It is estimated that approximately 30% of children in Africa and Asia are protein deficient and one billion people worldwide. There are two protein deficiency undernutrition conditions that can occur called **kwashiorkor** and **marasmus**. Kwashiorkor is an acute (severe and sudden) deficiency in protein and generally develops rapidly, whereas marasmus is caused by the chronic (long term) deficiency of protein and develops more slowly. Both of these conditions are more likely to occur in young children in areas where there is reduced food security and access to high quality protein.

Some **symptoms** of protein deficiency are:

- As protein is essential for growth, individuals may not reach their potential maximum height and weight.
- Muscles atrophy (break down) can occur to supply the body with amino acids to make other essential proteins for survival.
- Increased risk of bone fractures as protein is needed for strong bones.
- Impaired immune system, increasing risk of infections, as antibodies could not be produced quickly enough.
- Anaemia can develop as a result of insufficient haemoglobin in the blood.
- Impaired skin, hair and nail development, which all require protein.
- Females can experience amenorrhea, which is the absence of periods.

Excess of protein

There is a common belief that consuming excessive amounts of protein, such as five times the upper limit of the recommended intake, will lead to gaining more muscle. This line of thought is common among individuals who are looking to grow more muscle. The fact is, the majority of Australian's consume more than enough protein and the act of exercising (e.g. restrictive weights) is more important in growing muscle. Furthermore, excessive intake of protein can have consequences such as increasing risk of obesity and cardiovascular disease, adding strain to the liver and kidneys, dehydration and osteoporosis.

Obesity and cardiovascular disease

Amino acids **cannot be stored** so when the body has surplus to its needs, the liver converts them to glucose. This glucose can be stored as glycogen in the liver, but if glycogen stores are full the excess glucose is **converted to fats** and stored as adipose tissue (fat tissue). Chronic (long term) overconsumption of protein can therefore contribute to **weight gain and obesity**.

Furthermore, animal sources of protein are often **high in saturated fats** (bad fats), which provide more energy and can increase blood cholesterol levels. High blood cholesterol levels can increase the risk of developing **cardiovascular disease**. This will be discussed in more depth in Topic 2: Dietary disorders.

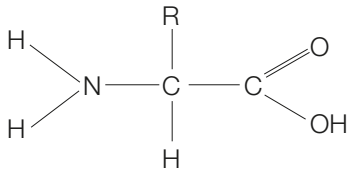
Dehydration and additional stress on liver and kidneys

Overconsumption of protein on a regular basis may lead to further health problems for people with existing liver and kidney disorders as these organs are involved in the removal of waste products from the metabolism of protein. This is because these organs have to work harder to process the increased levels of protein. The liver breaks down amino acids producing the **waste product urea** as a bi-product, which is released into the blood, where it is transported to the kidneys. Kidneys filter the urea from the blood and excrete it from the body in the urine. Furthermore, an excessive protein intake can lead to **dehydration** because more water is lost in the urine as a result of the increased urea production and excretion.

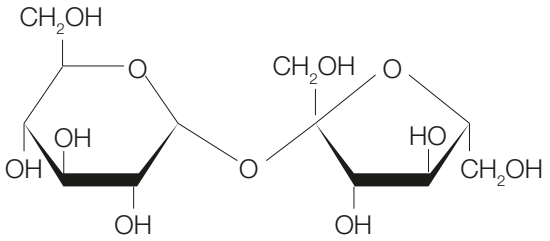
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1.3 Review questions

1. Identify which of the following two structures (A or B) is an amino acid **and** justify your answer.



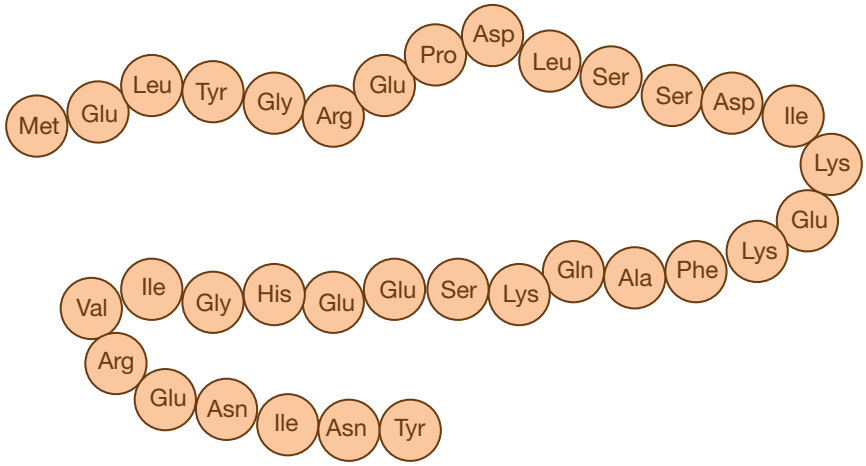
Structure A



Structure B

(2 marks)

2. With reference to the picture below, state the name of the unit that each of the circles in this chain represent.



(1 mark)

3. Refer to Table 1 to answer questions (a) and (b):

Table 1: The amount of energy and protein in various animal sources.

Animal protein source (85g serving)	Energy (kJ)	Amount of protein (g)
Skinless chicken	592	28
Steak	664	26
Lamb	722	23
Salmon	651	22
Lobster	319	16

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(a) Graph the amount of protein in the five animal protein sources on the following grid:

(5 marks)

(b) Determine the likely reason why the steak has a greater amount of energy than the skinless chicken, even though it only has 2g less protein.

(2 marks)

(c) Describe a consequence of a diet that consists predominantly of animal products, such as the sources represented in the table.

(2 marks)

4. Explain how an overconsumption of protein could lead to obesity.

(4 marks)

5. Explain why someone who is protein deficient is likely to be more prone to pathogenic infections.

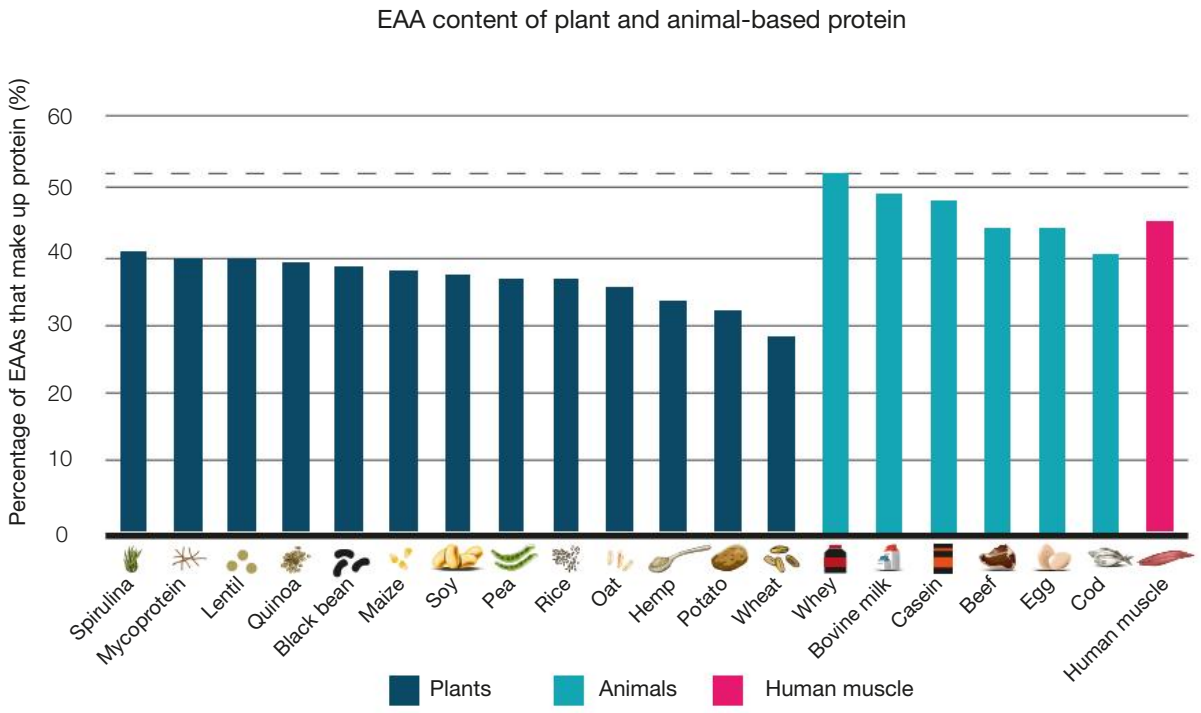
(4 marks)

6. Describe **three** functions of proteins in the body.

(6 marks)

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7. Refer to the following graph to answer questions 7(a) to (d):



(a) State the percentage of essential amino acids that make up protein in wheat.

(1 mark)

(b) State the percentage of essential amino acids that make up protein in beef.

(1 mark)

(c) Explain the general difference between the essential amino acids present in plant-based sources like wheat compared to animal products like beef.

(4 marks)

(d) The graph highlights that soy and rice have roughly the same percentage of essential amino acids at 37%. Describe how the composition of essential amino acids in soy and rice differs.

(2 marks)

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8. Describe **two** modifications to the recipe below to make the protein content more suitable for a vegan **and** justify your modifications:

Table 2: Three bean salad recipe.

Amount	Ingredient
1 can	Cannellini beans
1 can	Kidney beans
1 can	Chickpeas
¼ teaspoon	Black pepper
3 tablespoons	Olive oil
1/3 cup	Apple cider vinegar

(a)

(2 marks)

(b)

(2 marks)

9. Using information from Table 3 below, determine **two** different examples of complementary proteins, excluding soy and quinoa.

Table 3: The limiting amino acids in different types of plant foods.

Type of food	Tends to be low in
Legumes (except soy)	Methionine
Grains (except quinoa)	Lysine, threonine
Nuts/seeds	Lysine
Corn	Tryptophan, lysine

(2 marks)

10. People of Muslim faith only eat animal products that have been ritually slaughtered by a process known as 'halal'. In Australia, this type of meat might be more expensive or harder to obtain. Describe **two** symptoms that could develop if a Muslim individual had little access to 'halal' meat due to its prohibitive cost.

(4 marks)

E Extension question

Research the limiting amino acids in plant foods and design some meals that contain complete protein that are suitable for a vegan.

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1.4 Lipids

Nutrition Understanding

Fats are part of the lipid family. The terms 'fat' and 'lipid' are often used interchangeably. In society, fats often receive negative attention because they are associated with putting on weight and high cholesterol. However, this is an inaccurate reputation as there are many different types of fats, some of which are very important for good health. For example, omega 3 fats are integral to the formation of new brain and nerve cells. By contrast, saturated fats can result in unhealthy weight gain and high cholesterol. It is therefore important to understand the benefits and detriments of different kinds of fats and their sources.

Classification of lipids

Lipids are made up of three elements: **carbon (C), hydrogen (H) and oxygen (O)** (just like carbohydrates). Lipids are found in two main forms, **fats** and **oils**. **Fats are solid** at room temperature and are generally associated with **animal products**; for example, the saturated fat on a steak. Alternatively, **oils are liquid** at room temperature and are generally associated with **plants**; for example, canola and olive oil. The lipid family consists of three types of lipids:

- Triglycerides (fats and oils),
- Sterols (cholesterols), and
- Phospholipids (structural component of cell membranes).

Helpful online resources

TED-Ed: What is fat?–George Zaidan

https://www.youtube.com/watch?v=QhUrc4BnPgg

Free Animated Education: What are fats?

https://www.youtube.com/watch?v=X-CEkDycr6

Triglycerides

In the average diet, 95% of the fats and oils consumed are triglycerides. A triglyceride consists of a **glycerol backbone** and **three fatty acids.** The **'tri'** in triglyceride represents the **three** fatty acids in its structure.

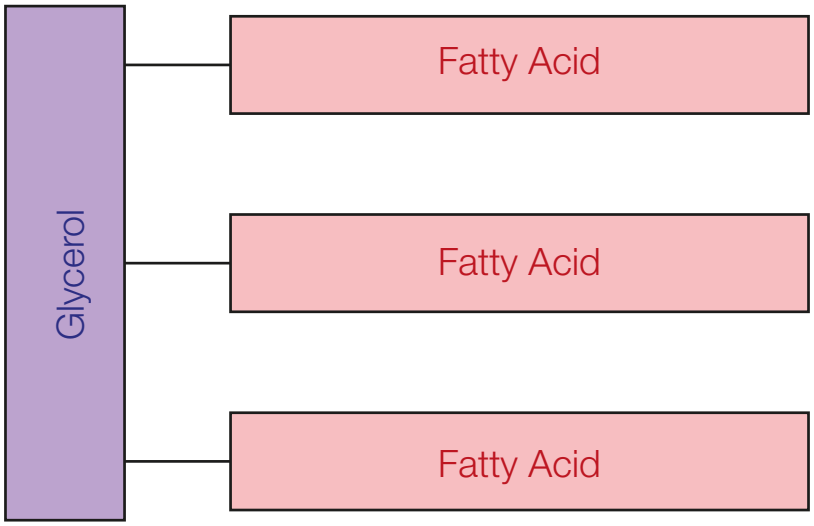


Figure 1.4.1: The basic structure of a triglyceride which consist of a single glycerol backbone and three fatty acid chains.

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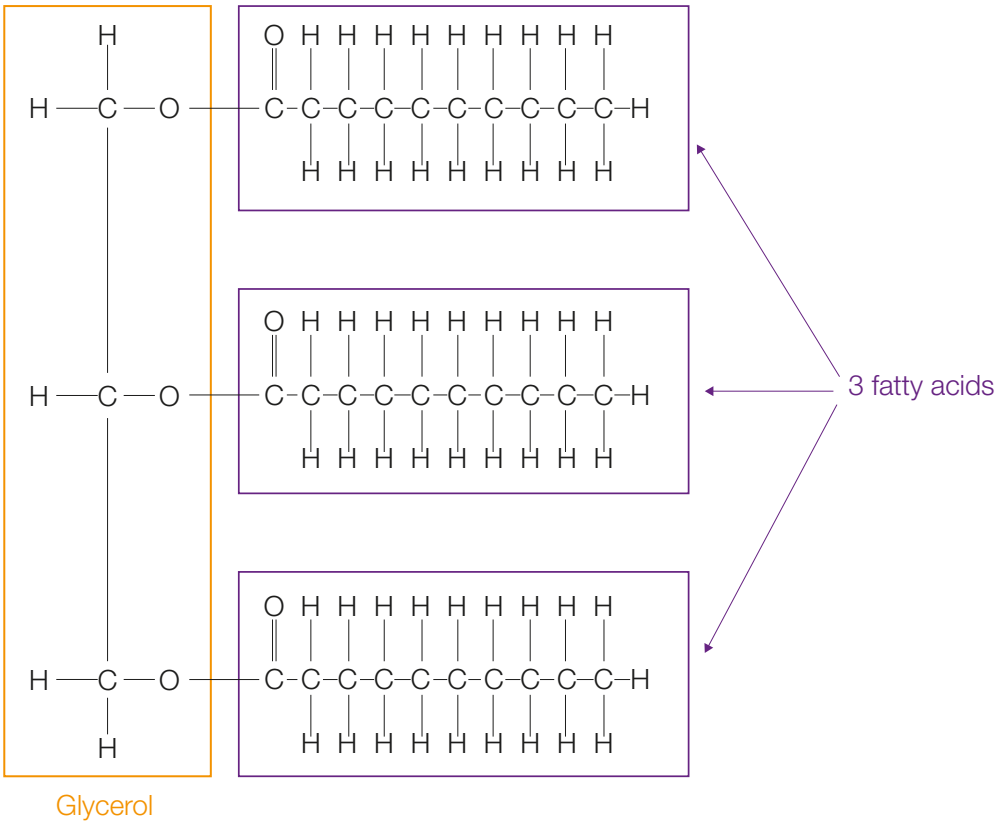
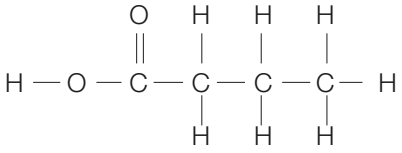
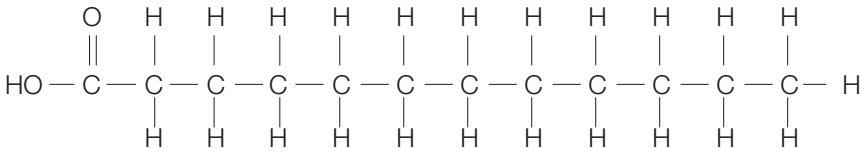


Figure 1.4.2: The structure of a triglyceride. Triglycerides consist of the elements carbon, hydrogen and oxygen.

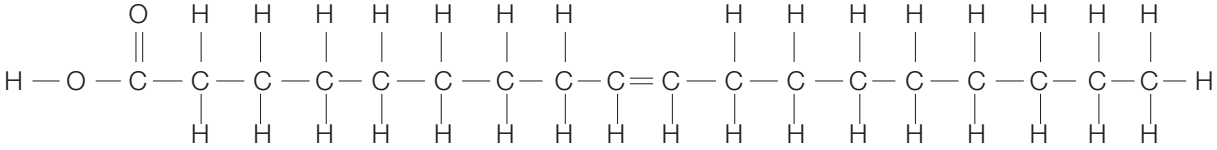
The type of fatty acids that make up triglycerides can differ. They also determine their physical properties such as whether they are solid or liquid at room temperature. Fatty acid chains generally contain an even number of carbons ranging from 4 to 24 carbon atoms. For example, butyric acid contains four and stearic acid has 18 carbon atoms. Fatty acids containing 18 carbon atoms are the most common type present in our food.



Butyric acid – contains 4 carbon atoms (found in milk)



Lauric acid – contains 12 carbon atoms (found in coconut oil)



Oleic acid – contains 18 carbon atoms (found in olive oil)

Figure 1.4.3: Three different fatty acid chains and the respective number of carbon atoms present.

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Fatty acids can either be **saturated** or **unsaturated**. A saturated fatty acid does not contain any double bonds because all carbon atoms are **'saturated' with single bonds to hydrogen atoms**. **Unsaturated fatty acids contain one or more double bonds** between carbon atoms. The double bonds are called **points of unsaturation** because the carbon atoms are not fully saturated with single bonds to hydrogen atoms. For example, stearic acid, oleic acid and linoleic acid all have 18 carbon atoms but they have different amount of hydrogen atoms (see Figure 1.4.4). Stearic acid is a saturated fatty acid and has the maximum 36 hydrogen atoms. However, because oleic acid has one double bond between hydrogen atoms, it contains 34 hydrogen atoms and not the maximum 36; hence, it is unsaturated. Finally, linoleic acid has two double bonds between carbon atoms in its chain and is unsaturated with only 32 hydrogen atoms. If a fatty acid contains **one double bond** it is called a **monounsaturated fatty acid** and if it has **more than one double bond** it is called a **polyunsaturated fatty acid**. Unsaturated fats are healthier than saturated fats and are easier for the body to break down.

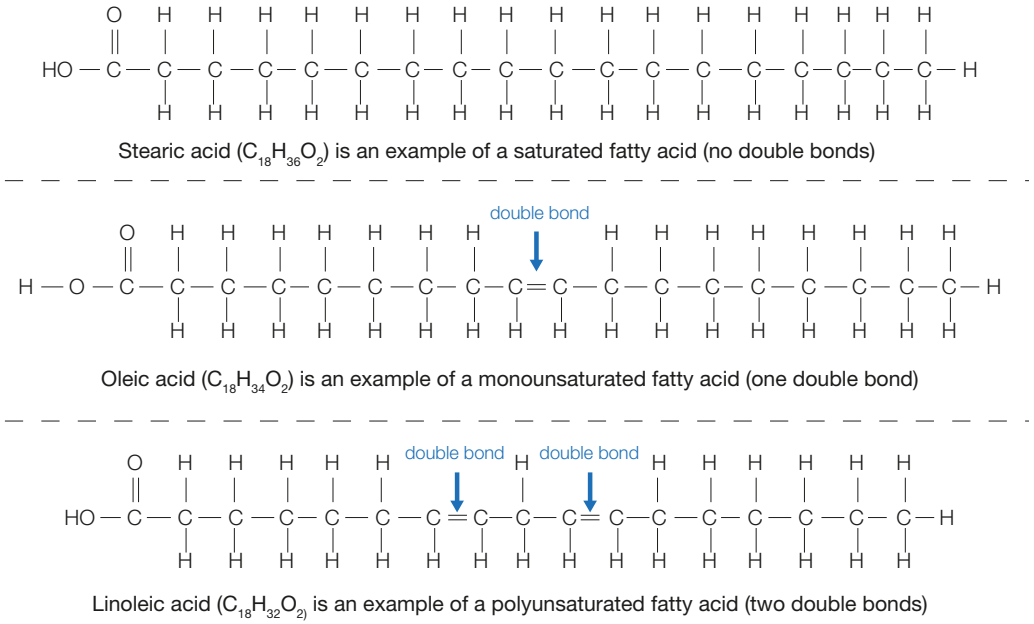


Figure 1.4.4: An example of an unsaturated, monounsaturated and polyunsaturated fatty acid. The saturated fatty acid has no double bonds, whereas the unsaturated fatty acids have one or more.

Triglycerides: Trans fatty acids

Trans fatty acids are predominantly artificially made fats through a process called hydrogenation. As a result, they are also known as **hydrogenated fats**. This process effectively converts unsaturated fats to saturated fats. The process of **hydrogenation** adds **hydrogen** atoms to the points of unsaturation. This results in unsaturated fats such as vegetable oils becoming **firmer in texture**. This allows liquid fats to be hardened and spread (e.g. margarine). Trans fats were thought to be healthier than saturated fats and to reduce cholesterol counts. However, by the 1990s, it was confirmed that trans fats increase bad cholesterol and decrease good cholesterol, increasing the risk of cardiovascular disease. They were deemed **unhealthier than saturated fats**.

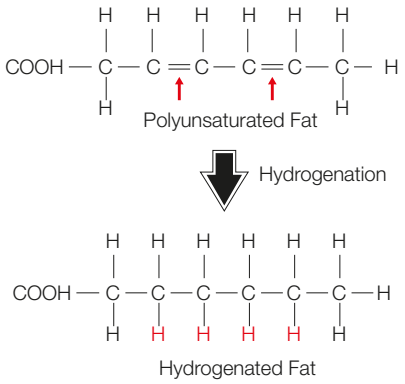


Figure 1.4.5: The process of hydrogenation adds hydrogen atoms to the double bonds of unsaturated fatty acids forming artificial trans fatty acids.

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Triglycerides: Essential fatty acids

Humans require fatty acids for a variety of reasons and our bodies can make all of them apart from two: linolenic acid (omega-3) and linoleic acid (omega-6). Because our body **cannot make** these two fatty acids, they are considered **essential fatty acids (EFAs)**. Essential fatty acids must be consumed through our diet.

Omega-6 (linoleic acid)

Linoleic acid (LA) is a polyunsaturated fatty acid and is the main **omega-6 fatty acid**. Our body does not have the enzymes to make linoleic acid, but it does have the enzymes to convert linoleic acid into the other omega-6 fatty acids. Therefore, a deficiency in linoleic acid could result in a deficiency in other omega-6 fatty acids. One omega-6 fatty acid that linoleic acid can be converted to is arachidonic acid (ARA). This fatty acid is important in **brain development** and the development of other vital organs. Linoleic acid is commonly found in sunflower and safflower oils. Sunflower oil is commonly used in processed foods and deep-frying fast foods; therefore, **most Australians consume enough omega-6** to meet their body's needs. Omega-6 fatty acids can also be used to produce chemicals that:

- Promote **blood clotting** formation to reduce blood loss and risk of infection;
- Are involved in the process of **inflammation** as a response to injury or infection; and
- Are involved in **blood vessel constriction**.

Some studies have also demonstrated that omega-6 fatty acids could reduce blood pressure and reduce the risk of developing osteoporosis (reduced bone loss).

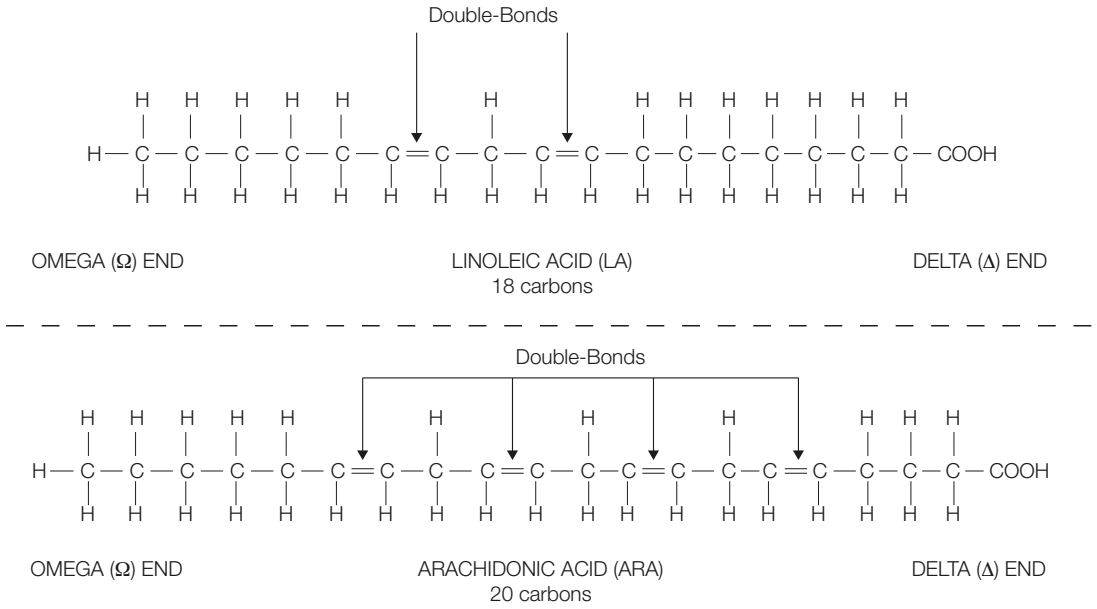


Figure 1.4.6: The structures of two of the important types of omega-6 fatty acids. They are called omega-6 fatty acids because the first double bond is six carbons from the omega end of the compound.

Omega-3 (alpha linolenic acid)

Alpha linolenic acid (ALA) is a polyunsaturated fat and is the main **omega-3 fatty acid**. ALA can be found in a number of food sources, such as walnuts, flaxseeds, chia seeds, canola oil and soybeans. It can be converted by the body into two other omega-3 fatty acids: eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). However, the body is not very efficient at converting ALA into EPA or DHA and has only an approximately 10% conversion efficiency. **EPA and DHA are vitally important in the development of cognitive (brain) and visual (eyes) function**; however, due to the body's inefficiency in converting ALA to EPA and DHA, most Australians have an insufficient intake of these omega-3 fatty acids. EPA and DHA can be consumed directly from fatty fish (including fish oil) but most Australians do not eat sufficient fatty fish to achieve this purpose. To obtain the recommended amount and types of omega-3 fatty acids, it is recommended that individuals consume two to three serves of fatty fish per week.

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Some other functions of omega-3 fatty acids are:

- **Decreasing bad cholesterol** in the blood and reducing the risk of plaque build-up in blood vessels (reduced risk of cardiovascular disease);
- Increasing fluidity of the myelin sheaths that make up nerve cells, improving the efficiency of nervous communication;
- Reducing inflammation that can contribute to chronic diseases such as rheumatoid arthritis, reduced insulin sensitivity and type two diabetes; and
- Can be converted to chemicals that decrease blood pressure.

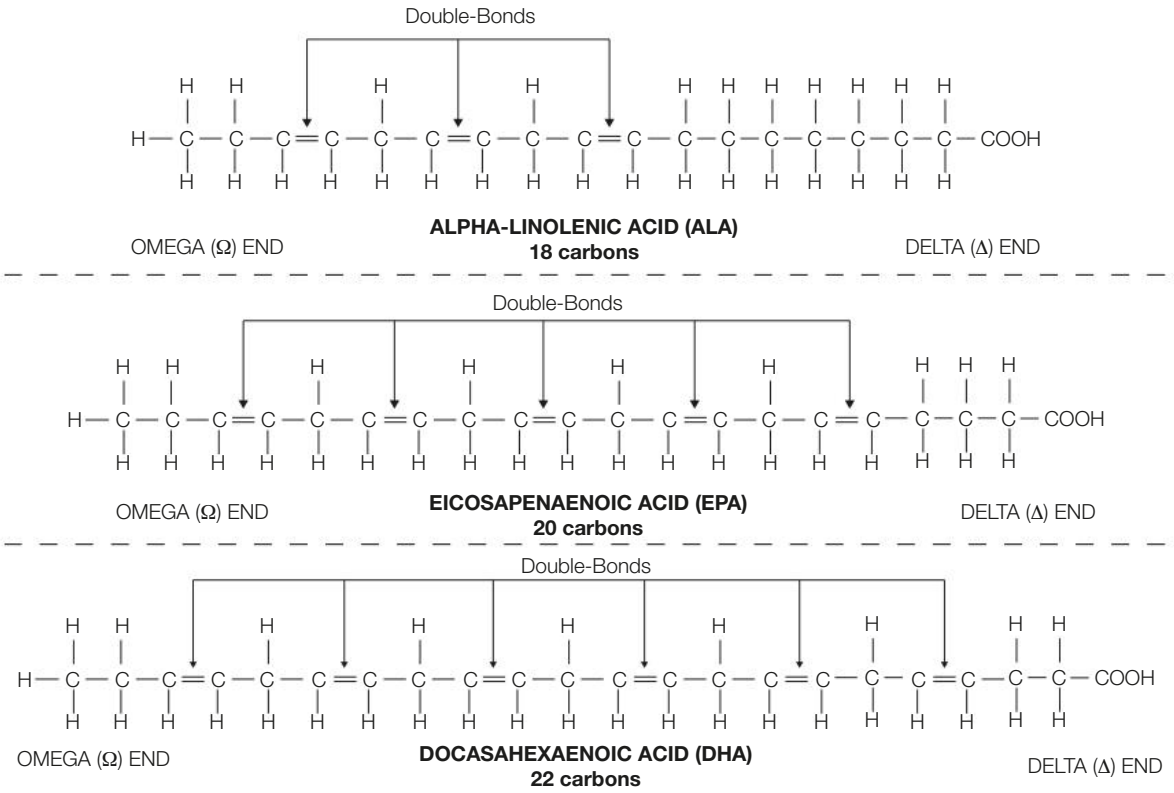


Figure 1.4.7: The structures of the three most important types of omega-3 fatty acids. They are called omega-3 fatty acids because the first double bond is three carbons from the omega end of the compound.

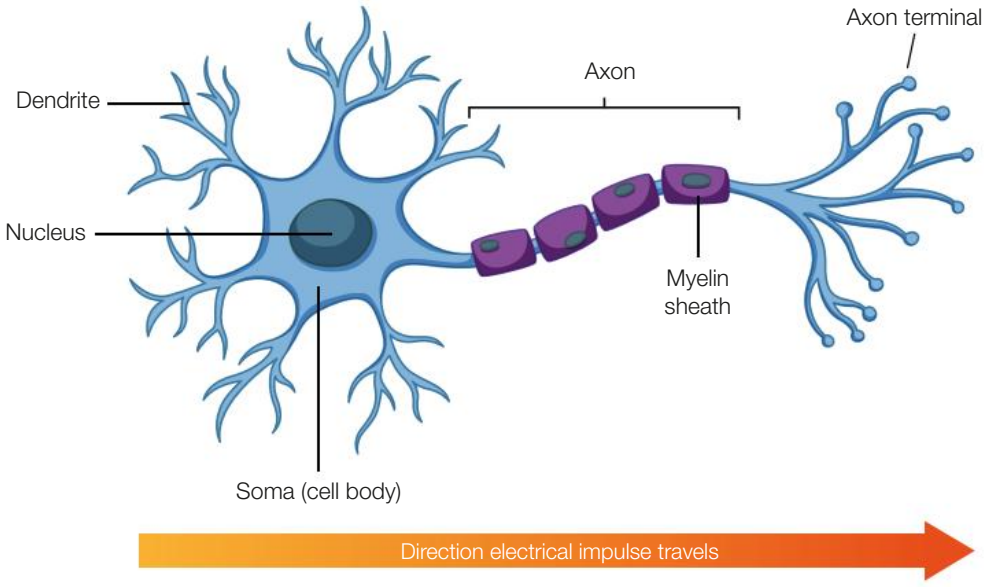


Figure 1.4.8: The structure of a nerve cell. Omega-3 fatty acids are an important component of the myelin sheath, which protects the axon and speeds up transmission of nervous messages.

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Helpful online resources

Medical Centric: Difference Between Saturated And Unsaturated Fat

https://www.youtube.com/watch?v=0QS0kudS5xg

Did you know?



Fish oil supplements are one of the very few supplements that have scientific evidence to back some of their health claims. However, overconsumption of fish oil supplementation (just like any supplement) can have harmful effects. Some side effects of high levels of omega-3s include a suppressed immune system and decreased blood clotting (increased bleeding gums and nosebleeds). **As always, it is recommended that a qualified medical professional, such as a doctor, be consulted before taking any supplements.** Some possible benefits of taking fish oil supplements are:

- EPA and DHA have an important role in developing a foetus' brain and eyes. Omega-3 fatty acids are also transferred to the infant through breastfeeding after birth. **Pregnant women in particular should consult their doctor prior to taking fish oil supplements and, if they choose to do so, should ensure that the brand they choose is mercury tested and approved because excess mercury consumption in pregnancy can be dangerous**.;
- Omega-3s preserve cell membrane health in the brain cells (myelin sheaths) and increase communication between brain cells;
- Diets deficient in omega-3 have been linked to deficient learning and memory;
- Fish oil may benefit mild memory conditions such as age-related cognitive decline;
- Fish oil may improve depression. Multiple studies have shown that fish oils have had similar benefits to antidepressants. However, the studies also suggested that the strongest benefits came from the study subjects who took antidepressants **and** fish oil, but they don't know why this is yet; and
- Fish oil may decrease the risk of cardiovascular disease by raising 'good' cholesterol in our blood.

In summary, it is generally not recommended that people who have an adequate intake of omega-3 from their diet take fish oil supplements. However, some doctors may recommend fish oil supplementation during pregnancy or lactation, for people with heart disease or for those not consuming enough through their diet.

Sources of lipids

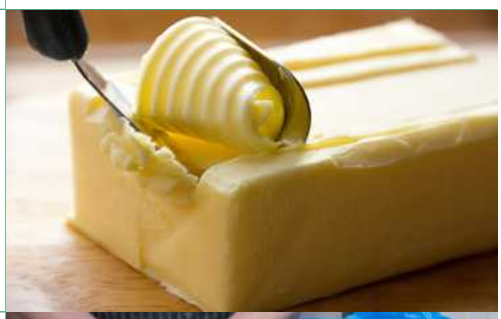
Most foods consist of a mixture of saturated, monounsaturated and polyunsaturated fatty acids, but we classify them according to the highest proportion in the food.

Saturated fat sources

Saturated fats are generally found in **animal products** (e.g. meats and dairy products) and most are **solid** at room temperature. Some plant-based products also contain saturated fats such as coconut oil and palm oil. Saturated fats are generally referred to as 'bad' fats. This is because they increase blood lipids including 'bad' cholesterol. Therefore, a diet high in saturated fats can increase the **risk of cardiovascular disease** by increasing the chance of cholesterol build up in the blood vessels. Any foods made with ingredients that are high in saturated fats are also likely to contain high amounts of saturated fats. For example, lard can be used to make pastry and cream can be used in cream-based pasta sauces and desserts. Saturated fats also take longer for the body to break down and contribute to **obesity**. Foods are classified as saturated fats if the greatest proportion of the total fat content is from saturated fats. Some examples of foods that are classified as saturated fats are:

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Table 1.4.1: Some examples of foods with high saturated fat content.

Food	Saturated fat content	
Coconut oil	Approximately 92% of the total fat is saturated fat.	
High fat dairy products	The total fat content of both cream and ice cream generally consist of 70% saturated fat. Whereas, 60% of whole milk total fat is from saturated fats.	
Palm oil	Approximately 50% of the total fat is saturated fat.	
Butter	Approximately 50% of the total fat is saturated fat.	
Lard	Lard is made from pork fat. Approximately 40% of the total fat is saturated fat.	
Fatty cuts of meat	It depends on the cut but up to 45% of the total fat can be from saturated fat in some cuts of beef and lamb.	

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Trans fats sources

As previously mentioned, the majority of trans fats we consume are artificially made and because of this our bodies do not have the necessary enzymes to process them effectively. Therefore, they **should be avoided** in the diet because they increase the risk of developing cardiovascular disease more than saturated fats. There are some trans fats that are naturally found in milk and some meat products; however, these are in relatively low levels and have little to no effect on cholesterol levels.

Trans fats used to be a significant proportion of the fats in margarine; however, most **margarine** spreads in Australia now have very little trans fats with an average of 0.2%. Trans fats were reduced significantly in the 1990s after trans fats were linked to an increased risk of cardiovascular disease. There is also some belief in society that butter is more natural and therefore healthier than margarine, but **butter** still contains approximately 4% trans fats.

Margarine and the use of hydrogenated oils (trans fats) are commonly used in the baking industry to extend the life of unrefrigerated **baked goods** such as cookies, pastries and cakes. They are also common in **deep fried foods** cooked in vegetable oils that have been partially hydrogenated, such as deep-fried chicken, battered fish and french fries. This type of oil is advantageous to restaurants because it doesn't have to be changed as regularly as other types and therefore saves them time and money. However, the trans fat content in the oil increases each time the oil is reused, and this can increase the amount transferred to the foods deep fried in it.



Figure 1.4.9: Baked goods such as cakes and pastries, and deep-fried foods can contain trans fats.

Monounsaturated fat sources

Unsaturated fats are mostly found in **plant-based products** and are generally **liquid** at room temperature. Monounsaturated fats have **one double bond** in the carbon chain, hence the 'mono' in monounsaturated fats ('mono' means one). The most common monounsaturated fat in our diet is oleic acid (approximately 90%). Good sources of monounsaturated fats are oils (such as olive, canola and peanut oil), avocados and nuts (such as almonds, cashews and macadamias). Monounsaturated fats are a type of **healthy fat** and are the main fat found in olive oil, which is a major component of the '**Mediterranean diet'**. It has been found that people who live in the Mediterranean region (e.g. Greece, Spain and Italy) have a **lower occurrence of cardiovascular disease** even though they generally consume a high fat diet. This is because the main fat consumed is monounsaturated and not saturated. It is recommended that unhealthy saturated and trans fats are replaced with monounsaturated and polyunsaturated fats in the diet for good health. Foods are classified as monounsaturated fats if the greatest proportion of the total fat content is from monounsaturated fats. Some examples of foods that are classified as monounsaturated fats are:

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Table 1.4.2: Some examples of foods with high monounsaturated fat content.

Food	Monounsaturated fat content	
Almonds	Approximately 80% of the total fat is monounsaturated fat.	
Olive oil	Approximately 73% of the total fat is monounsaturated fat.	
Avocado	Approximately 65% of the total fat is monounsaturated fat.	
Canola oil	Approximately 62% of the total fat is monounsaturated fat.	
Peanut oil	Approximately 50% of the total fat is monounsaturated fat.	

Did you know?

Cooking oils such as canola, sunflower and olive oil, should be kept away from light and heat sources. This is because light and heat can increase the risk of unsaturated oils oxidising and spoiling (smells and tastes rancid). Polyunsaturated fats spoil the easiest because they are the most unstable due to the greater number of double bonds. Saturated fats are the most stable due to the absence of double bonds. Once used for cooking, the quality of the oil deteriorates and should not be re-used. This is because it increases the risk of it spoiling and also increases our exposure to free radicals (oxidants) that can cause damage to our cells.

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Polyunsaturated fat sources

There are two types of polyunsaturated fats: **omega-3** and **omega-6** fatty acids. These fatty acids are also known as **essential fatty acids** (EFAs) because our body cannot make these fats and requires us to consume them in our diet. The two essential fatty acids are found in varying amounts in different foods. Good sources of omega-6 fats are soybean oil, sesame seeds, walnuts, sunflower seeds, pecans and peanuts. Whereas omega-3 rich sources include many types of seafood such as salmon, mackerel, swordfish and scallops, as well as plant-based sources such as flaxseed and chia seeds. The plant-based sources mainly contain the omega-3 alpha linolenic acid, which can be converted to eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), but not very efficiently (10% conversion). **EPA and DHA are mainly found in animal-based products**. Therefore, individuals who eat small amounts of animal products, especially fish and seafood, are likely to have lower levels of EPA and DHA. Because **vegans** don't eat animal-based products, they are more likely to have **lower levels of EPA and DHA**, which are important for maintenance and development of brain and nerve cells. However, vegans can obtain these omega-3 fatty acids from **supplements made from microalgae**. Foods are classified as polyunsaturated fats if the greatest proportion of the total fat content is from polyunsaturated fats. Some examples of foods that are classified as polyunsaturated fats are:

Table 1.4.3: Some examples of foods with high polyunsaturated fat content.

Food	Polyunsaturated fat content	
Chia seeds	Approximately 77% of the total fat is polyunsaturated fat (of which 58% is omega-3 and 19% is omega-6 fatty acids).	
Flaxseeds (linseed)	Approximately 73% of the total fat is polyunsaturated fat (of which 57% is omega-3 and 16% is omega-6 fatty acids).	
Walnuts	Approximately 72% of the total fat is polyunsaturated fat (of which 4% is omega-3 and 68% omega-6 fatty acids).	
Soybean oil	Approximately 60% of the total fat is polyunsaturated fat (of which 8% is omega-3 and 52% is omega-6 fatty acids).	

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Food	Polyunsaturated fat content	
Tahini (sesame seed spread)	Approximately 45% of the total fat is polyunsaturated fat (of which 1% is omega-3 and 44% is omega-6 fatty acids).	
Salmon	Approximately 40% of the total fat is polyunsaturated fat (of which 37% is omega-3 and 3% is omega-6 fatty acids).	

Did you know?

The brain is composed of approximately 60% fat. The main fatty acid that the brain is composed of is docosahexaenoic acid (DHA). This highlights the importance of consuming foods that contain omega-3 (especially DHA) such as fatty fish and seafood.

Functions of lipids

There are three members of the lipids family: triglycerides, sterols and phospholipids. Some of the functions of lipids are outlined below:

Provision of energy

The main function of triglycerides is **energy storage**. When triglycerides are consumed, they are packaged by the liver into lipoproteins and transported through the blood to the body's cells for use. They are also transported to the fat cells that make up **adipose (fat) tissue** for storage. When energy is needed, triglycerides are mobilised and released into the blood (carried by a protein), so that they can be transported to cells requiring energy (e.g. muscle cells). Triglycerides provide the body with 37.7kJ/g. One signal that can mobilise triglycerides into the blood is the hormone adrenaline. Adrenaline is part of the 'fight or flight' response that helps protect us from danger. Adrenaline activates many different responses in the body, but one of them is to increase triglycerides in the blood for our muscles to use as an energy source to 'fight' or 'run away' from the 'danger'.

Absorption of fat-soluble vitamins

Fats are carriers for fat-soluble vitamins and increase their absorption from the intestines into the body's cells. There are four fat-soluble vitamins: A, D, E and K and an adequate consumption of dietary fats can aid in an adequate supply of fat-soluble vitamins for cellular use. Fat-soluble vitamins are described in more detail in Topic 1.6: Vitamins.

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Provide insulation and protect vital organs

There is a layer of fat under the skin called subcutaneous fat that provides insulation from the heat and cold. Visceral fat, found in between the organs in our abdomen, also helps with insulation and acts as a protective layer of padding for our abdominal organs. This padding absorbs the pressure of impacts resulting in less physical impact to our important organs.

There are two main types of fat cells, white and brown fat cells. Brown fat cells are common in babies (also known as 'baby fat') because it helps keep them warm. When babies are born, they haven't developed the ability to shiver yet. Shivering helps create heat and keep us warm. The brown fat cells in babies readily burn fat, providing heat as a bi-product, which helps warm up the baby. It was originally thought that only babies have brown fat cells because as we age brown fat turns into white fat but research has since shown that almost everybody has some brown fat cells. Brown fat cells are activated by the cold and are thought to assist in warming up our blood.

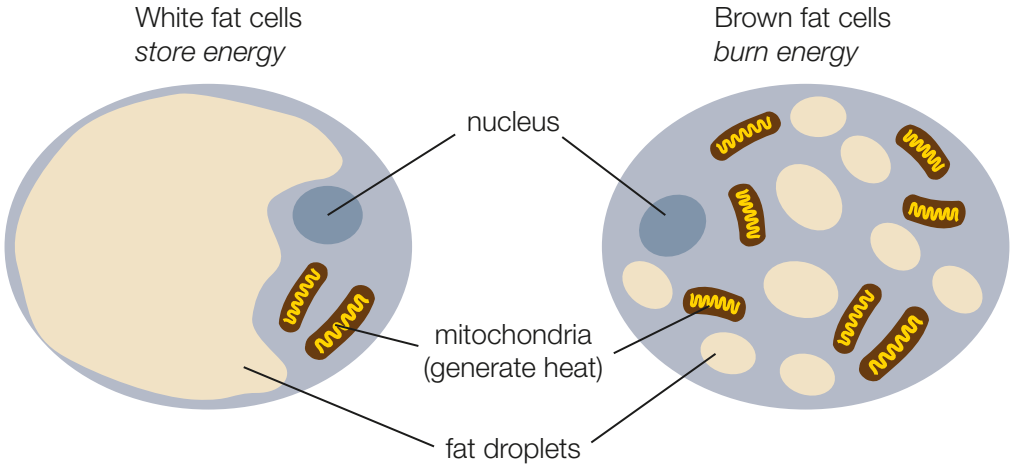


Figure 1.4.10: The two types of fat cells with opposing functions.

Science as a Human Endeavour 1

Fat burning patch

Scientists are researching the fat burning ability of brown fat cells. There are many studies being conducted in this area with some drugs already identified that can convert white fat to brown fat cells. There has long been an aim for a 'fat-burning' medication to be released to help fight obesity; however, an innovative team of scientists at Nanyang Technological University in Singapore have developed a different approach to delivering these fat converting drugs. They have developed a micro-needle patch that is applied to the skin. The micro-needles contain the fat converting drugs and the drugs are slowly released as the micro-needles degrade. The team has trialled the patches on mice. The mice were fed a high fat diet and the micro-needle patch reduced weight gain by over 30%. The innovative micro-patch method is more effective than oral medications because it delivers the drug(s) straight to the fat layers under the skin. It is also safer and has fewer side effects than the oral medication method because the drug is slowly released in small amounts (rather than all at once) and the drugs are delivered straight to the white fat cells. By contrast, oral or injected doses can build up in non-targeted cells and cause side effects. One of the drugs that can be used in the patch is a thyroid hormone called T3, which assists in the control of metabolism. It is widely used to treat an underactive thyroid in humans already, so this drug already has approval for use in humans. However, use of this drug in humans through the micro-needle patch method needs clinical trials and a separate approval. Biotechnology companies have shown interest in the team's research and hope to conduct further research with the aim of making the patch available to the market. The materials required to make the prototype patches cost approximately US$3.50 and this is a promising development in the ability to treat obesity.

In a separate study conducted in 2015, Aaron Cypess (the head of the Diabetes, Endocrinology and Obesity Branch at the National Institute of Diabetes and Digestive and Kidney Diseases in the United States of America) and his team of researchers discovered that a drug called mirabegron stimulates receptors on brown fat cells of the liver, activating them to burn more fat surrounding the liver. Further research is required but this drug could be used in the future to treat people with fatty liver disease. This was reported in the journal 'Cell'.

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Science as a Human Endeavour 1

Questions

1. Discuss how **collaboration and communication** is required to develop a fat-burning patch.

(4 marks)

2. Discuss how the micro-needle patch relates to the SHE concept of **development.**

(4 marks)

3. Discuss how the discovery of a fat-burning patch could **influence** society.

(6 marks)

4. Discuss two **limitations** of the studies on brown fat cells described in the text.

(4 marks)

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Contribute to cellular structure

Another type of lipid is **phospholipids**. Phospholipids differ to triglycerides and only have two fatty acid chains compared to the three of triglycerides. Phospholipids are a very important **structural component** of our cells. They are a vital component of the membranes that make up cell membranes and the membrane-bound organelles within cells, such as the nucleus. The **cell membrane** consists of a double layer of phospholipids and serves as a semi-permeable barrier that controls the movement of substances in and out of the cell. For example, cells need useful substances like oxygen moving into the cells but not waste products such as carbon dioxide and urea.

Another type of lipid, known as cholesterol (a sterol), is important for cell membrane fluidity. **Cholesterol** is embedded within the phospholipid bi-layer and **increases fluidity of the membrane**. This increases the permeability of the cell membrane making movement of substances across the membrane more efficient.

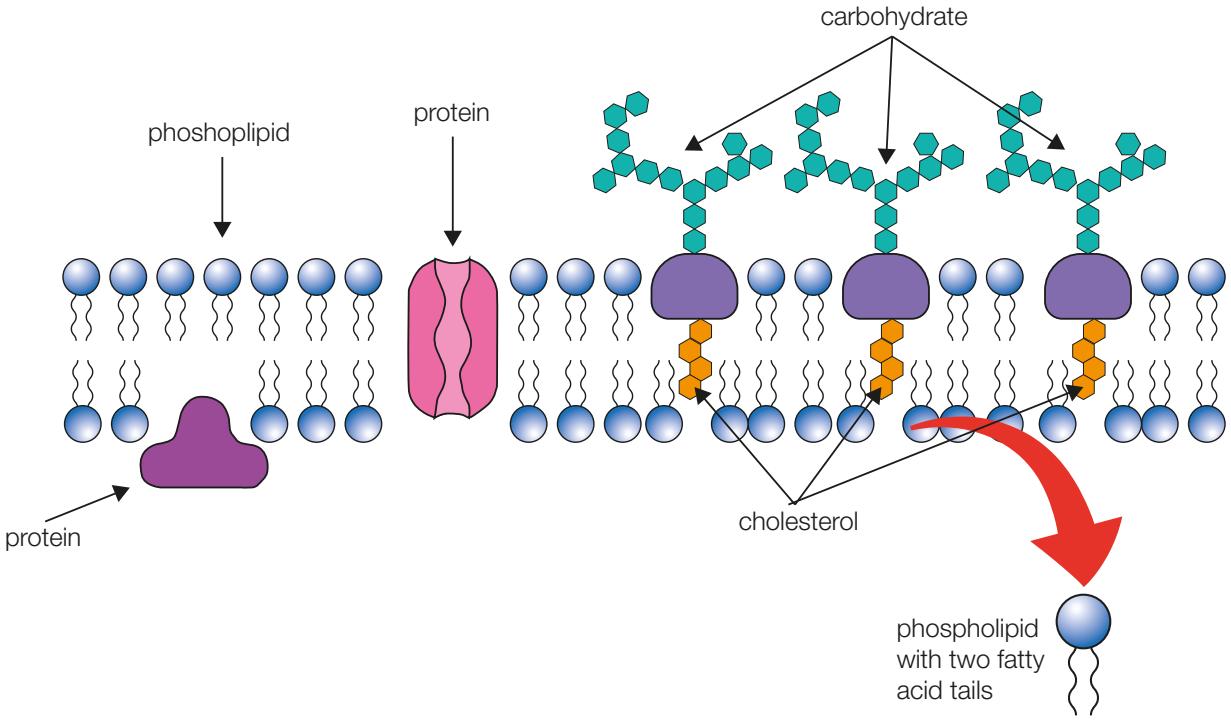


Figure 1.4.11: The structure of the cell membrane which consists of phospholipids and cholesterol.

Additional functions of lipids

- Fats provide the delicious flavours of foods, making them more palatable.
- Fats can increase satiety (makes us feel full after eating), which makes us feel satisfied and less likely to overeat.

Cholesterol

Cholesterol is a type of sterol that is present in all of our body cells. It is a waxy, 'fat-like' compound that is essential for many processes. For example, cholesterol is a structural component of cell membranes, increasing their fluidity, which allows substances to move in and out of cells efficiently. Cholesterol is also the **precursor** for the body to produce the **fat-soluble vitamin D**.

The average adult synthesises all the cholesterol the body needs in the **liver** but we can also consume it through our diet. Cholesterol is mainly found in **animal-based products** such as meats, fish, egg yolks and dairy products. When animal products are eaten, a little extra cholesterol is also consumed. For the average person, this equates to approximately 15% to 25% of the body's daily cholesterol intake and production, as the liver makes the majority of cholesterol. The vast majority of cholesterol is stored in our body's cells; however, a small proportion (less than 10%) circulates in the blood. Cholesterol does not flow through the bloodstream on its own, chemical transporters called **lipoproteins** carry them. Two major kinds of lipoproteins are:

- **Low-Density Lipoproteins (LDL)**
- **High-Density Lipoproteins (HDL).**

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Low-density lipoproteins

Low-density lipoproteins (LDLs) are often referred to as 'bad' cholesterol. This is because an elevated level of low-density lipoproteins in the blood is associated with an **increased risk of cardiovascular disease**. The liver makes cholesterol for the body's cells every day. This cholesterol is packaged with proteins to form lipoproteins, which **transport the cholesterol from the liver to the body's cells (through the blood)**. Low-density lipoproteins are a form of lipoprotein that is composed of a lot of cholesterol. An excess of low-density lipoprotein means there is an excess of cholesterol and this can increase the risk of cholesterol building up on the walls of blood vessels, such as arteries. This can narrow the arteries, which increases blood pressure and the risk of a total blockage of the artery. Depending on the location of the blocked artery, this could result in a heart attack, stroke or even gangrene. The consumption of **saturated and trans fats** can **increase the low-density lipoprotein** count in the blood, increasing risk of cardiovascular disease.

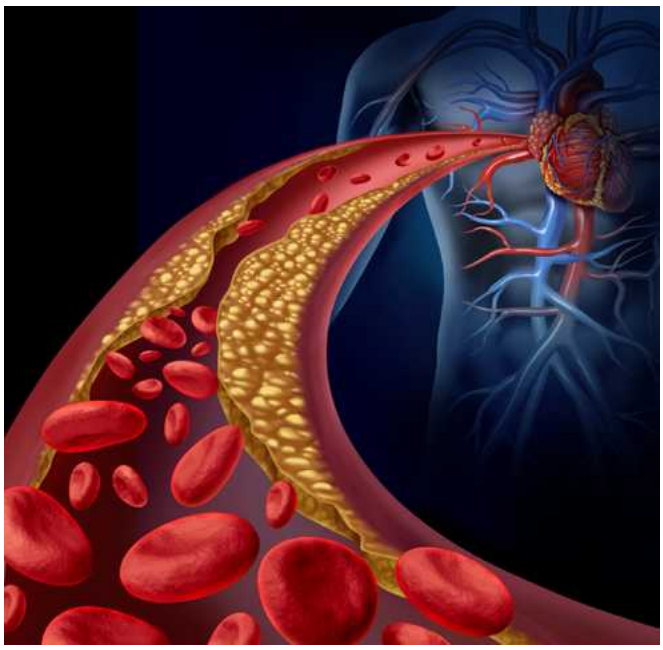


Figure 1.4.12: Increased levels of low-density lipoproteins can result in cholesterol deposits on the walls of arteries. This narrows the artery, preventing blood flow and can increase blood pressure.

High-density lipoproteins

The liver also makes another form of lipoprotein called high-density lipoproteins (HDLs). They are often referred to as 'good' cholesterol because high-density lipoproteins **reduce the risk of cardiovascular disease**. High-density lipoproteins consist of less cholesterol than low-density lipoproteins and their function is to **collect cholesterol from the body's cells and return it to the liver** for processing. As high-density lipoproteins collect excess cholesterol they **reduce the risk of excess cholesterol ending up in blood vessels such as arteries.** This is why adequate levels of high-density lipoproteins are associated with a decreased risk of cardiovascular disease. The consumption of **trans fats decreases high-density lipoprotein** counts increasing risk of cardiovascular disease. Conversely, the consumption of **omega-3 fatty acids increases the production of high-density lipoproteins**, decreasing the risk of cardiovascular disease.

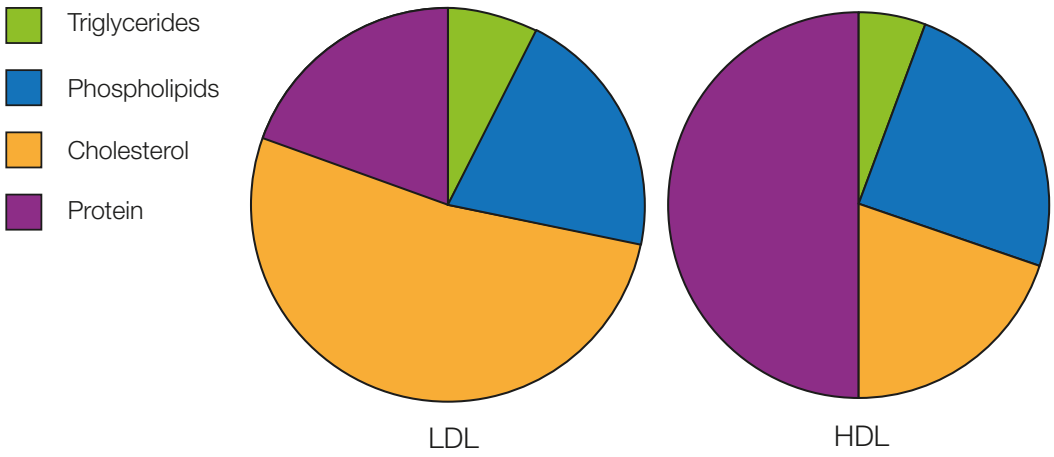


Figure 1.4.13: A comparison of the structural makeup of low-density lipoproteins and high-density lipoproteins. It is evident that low-density lipoproteins consist of significantly more cholesterol than high-density lipoproteins.

Helpful online resources

WebMD: How Your Body Uses Cholesterol

https://www.youtube.com/watch?v=tms4G6G1L3Y

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Lipid recommended dietary intake

It is recommended that **20% to 35%** of an individual's daily kilojoules (energy) comes from **lipids**. However, only 10% of that allowance should be saturated fats. For an average person consuming 8,700kJ per day, 47g (20%) to 82g (35%) of lipids can be consumed per day but only 24g of this should be from saturated fats. It is also recommended to keep the consumption of artificial trans fats to as little as possible.

The fat information of food items can be found on Nutrition information panels (NIP). Some food products will include the amount of trans fats, omega-3 and/or omega-6 fats; however, this is optional and is only required if the food product contains health claims with respect to these types of fats. For example, if a product advertises that it contains no trans fatty acids, then the trans fats content must be included on the NIP. To calculate the unsaturated fats, the saturated and trans fats can be subtracted from the total fats. Please see the Figure 1.4.14 and the example calculation below for more information.

NUTRITION INFORMATION		
Number of serves: 8 Serving size: ½ cup (82 g)		
	Average Qty Per Serve	**Average Qty Per 100g**
Energy	855 kJ	1043 kJ
Protein	3 g	4 g
Fat, total	14 g	17 g
- Saturated	9 g	11 g
- Trans	0 g	0 g
Carbohydrate	17 g	21 g
- Sugars	14 g	17 g
Fibre	1 g	1.2 g
Sodium	40 mg	49 mg

Figure 1.4.14: A nutritional information panel that shows the fat and cholesterol content of a food. The saturated and trans fats are indented under the total fat indicating that they are included in the total fat value.

Example calculation

Unsaturated fat = Total fat (g) – Saturated fat (g) – Trans fat (g)

Unsaturated fat = 14 – 9 – 0

= 5 g

Deficiency of lipids

When the diet is **deficient in triglycerides**, the body may use the stored triglycerides in adipose tissue to provide energy. This can result in **weight loss**. As weight is lost, there is a loss of adipose tissue insulating the organs. Excessive fat loss can lead to an individual **feeling cold**. Furthermore, triglycerides are needed to absorb the fat-soluble vitamins in our diet. This could result in a **deficiency of one or more fat-soluble vitamins** (vitamins A, D, E and K).

Excess of lipids

As triglycerides provide the most energy per gram with 37kJ/g, an overconsumption of fats and oils can lead to increased weight gain and **obesity**. Excessive triglyceride consumption can also contribute to cardiovascular disease and type 2 diabetes. This is discussed in more detail in Topic 2: Dietary disorders. Furthermore, fat-soluble vitamins can be stored in our fat tissue. Therefore, excessive fat consumption could lead to **toxic levels of fat-soluble vitamins** in the body.

Methods to reduce fats in the diet

A few possible ways of reducing saturated fats in the diet and avoiding excessive lipid consumption are:

- Cutting the fat trims off meat;
- Consuming reduced fat products, such as reduced fat margarine or skim milk;
- Bake, boil or grill food products and avoid deep frying;
- Use an air-fryer to reduce the amount of oils used;
- Eat extra lean meats (e.g. extra lean 'heart smart' mince not regular mince)
- Avoid cream and cheese-based sauces; and
- Eat more fish that contains healthy omega-3 fats instead of red meat.

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Did you know?

Some people try to avoid fats in their diet because they think that all fats are bad but as we've learnt in this topic, there are good and bad fats.

Low fat diets were popular in the 1990s and this gave rise to the sale of many low-fat products, such as low fat salad dressings, low fat mayonnaise and low fat yoghurt. However, low fat diets rarely work in the long term for multiple reasons. Firstly, we need to ingest the good monounsaturated and polyunsaturated fats to lower our 'bad' cholesterol levels (LDLs) and raise our 'good' cholesterol levels (HDLs). Without consuming these unsaturated fats, bad cholesterol levels could be raised increasing the risk of developing cardiovascular disease. These unsaturated fats are also needed for structural purposes. Omega-3 fatty acids are used to create the myelin sheath of nerve cells. This means that they are needed for creating new brain cells for forming new memories and maintaining efficient nervous communication. Secondly, low fat diets can result in unwanted structural responses in the body. When the diet is low in fats, extra receptors to detect fats can be created and inserted into the membranes of the cells in the small intestines. This is one of the body's responses to increase the absorption of fats to meet the body's requirements. However, this means that when the low fat diet is broken, more fat can be absorbed because the cells have extra receptors to recognise fats. Therefore, this type of diet can result in weight gain when the diet is broken. Finally, low fat foods don't taste very good without the fat, which is not surprising. Therefore, when these products are being made, the fat is substituted with additives, such as sugar, to improve their taste. For example, an olive oil-based salad dressing is considered healthier than a low fat salad dressing alternative because the monounsaturated fat is reduced and replaced with sugar in the low fat option. The higher sugar content in these low fat products accumulates over the course of the day and generally pushes people above their recommended 10% recommended sugar intake per day. This can contribute to a higher risk of obesity, type 2 diabetes and cardiovascular disease. Furthermore, the monounsaturated fats in the olive oil-based salad dressing assist in absorbing the fat-soluble vitamins from the salad. Without the fats available, the vitamins cannot be absorbed as effectively.

1.4 Review questions

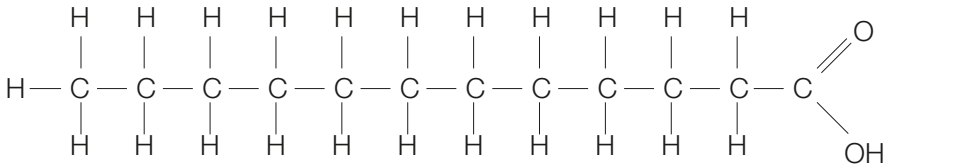
1. Describe how the structure of a triglyceride can be differentiated from the structures of carbohydrates and proteins.

(2 marks)

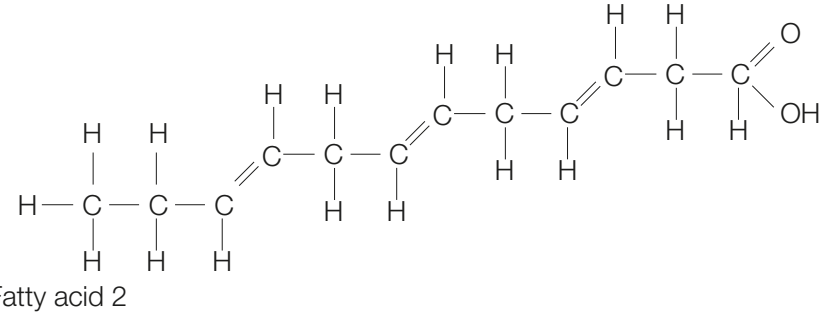
2. Describe **three** general differences between fats and oils.

(3 marks)

3. Refer to the following chemical structures to answer questions (a) and (b):



Fatty acid 1



Fatty acid 2

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(a) Identify each type of fatty acid (1 and 2) shown above.

(2 marks)

(b) State which fatty acid is healthier **and** justify your answer.

(4 marks)

4. Describe why polyunsaturated fats are referred to as essential fatty acids.

(2 marks)

5. There are many people that try to avoid fats in their diet and choose to consume a low fat diet.

(a) Describe **two** reasons people are concerned about eating fats and oils.

(2 marks)

(b) Describe **two** reasons why a low fat diet is not recommended.

(4 marks)

(c) State which type(s) of fats you would recommend people consuming a low fat diet to increase their consumption of **and** justify your answer.

(2 marks)

(d) State **three** different ways an individual could reduce the consumption of 'bad' fats in their diet.

(3 marks)

(e) Describe what trans fats are and outline why is it recommended to avoid consuming them.

(4 marks)

(f) State **two** sources of trans fats.

(2 marks)

6. The Heart Foundation recommends consuming 2-3 serves of oily fish per week and one gram of plant-sourced omega-3 every day.

(a) Describe why there is less concern regarding recommending omega-6 consumption to Australians.

(2 marks)

(b) Name **two** good sources of omega-3 fatty acids that are suitable for a vegan.

(2 marks)

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(c) Outline how a vegan can ensure they are consuming enough of all three major types of omega-3 fatty acids.

(1 mark)

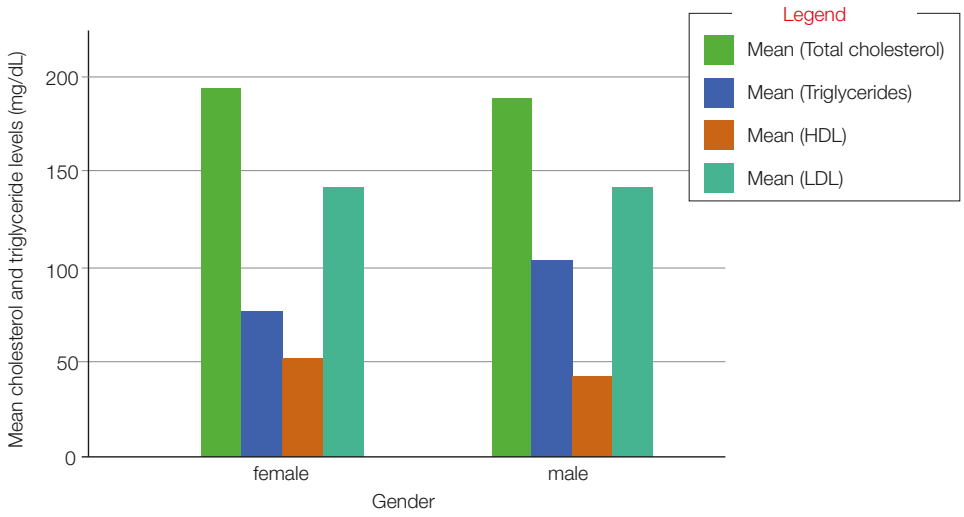
(d) Describe **two** functions of omega-3 fatty acids.

(4 marks)

(e) Explain the advantage of obtaining omega-3 fatty acids from both plant and animal sources, as opposed to just from plant-based sources.

(4 marks)

7. Refer to the following graph to answer questions 7(a) to (c).



Graph 1: The mean total, cholesterol, triglycerides, HDL and LDL levels by gender.

(a) Name **two** foods that contain cholesterol.

(2 marks)

(b) Identify which gender has the highest mean total cholesterol. Use data to justify your answer.

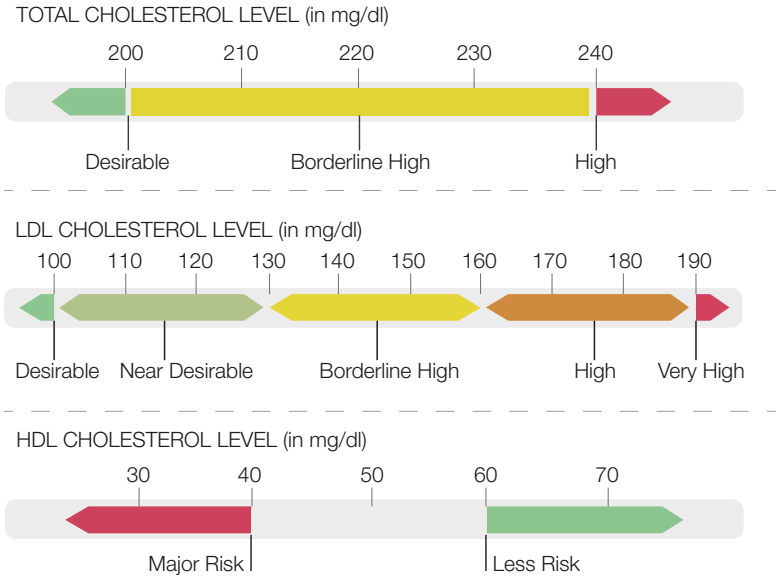
(2 marks)

(c) Males have a higher risk of developing cardiovascular disease than females. Using data from the graph only, explain **one** possible reason why this is the case.

(4 marks)

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(d) Using the data in Graph 1 and the chart below, determine the category that the mean total cholesterol levels and LDL cholesterol levels of females are.



(4 marks)

8. Describe **two** functions of lipids in the body.

(4 marks)

9. The World Health Organisation (WHO) have initiated a step by step strategy to eliminate artificial trans fats in the global food supply by the year 2023. Currently, more than five billion people are still at risk of consuming artificial trans fatty acids in the foods they eat every day. Many countries, including Australia, have yet to formalise or introduce regulations to reduce or eliminate this harmful fatty acid from their food production. Consuming trans fats can increase cholesterol levels and the risk of developing cardiovascular disease.

Use your understanding of the interaction between science and society to answer the following questions.

(a) Discuss the role that communication and collaboration plays in the World Health Organisation's goal of eliminating trans fats from the global food supply.

(4 marks)

(b) Discuss how the elimination of trans fats could influence society.

(4 marks)

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1.5 Micronutrients

Nutrition Understanding

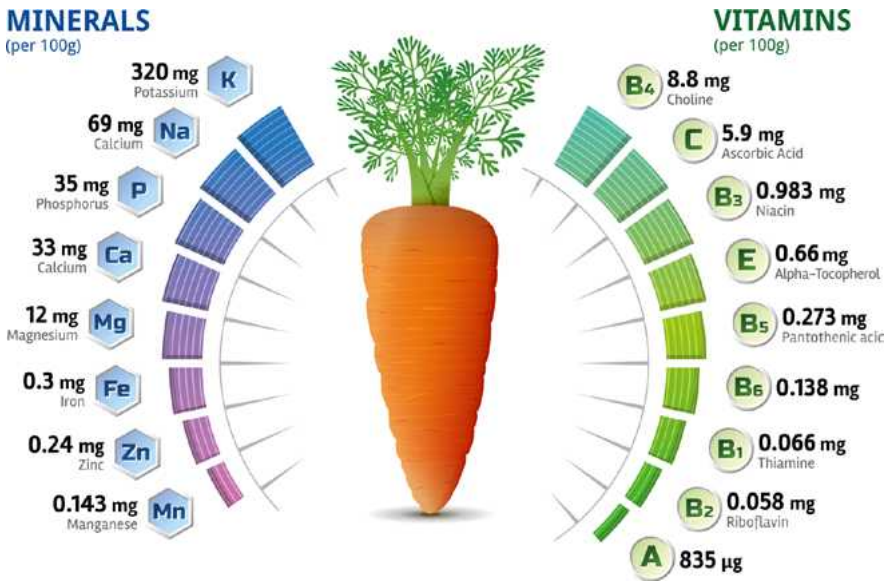
Micronutrients differ to macronutrients as they are needed in smaller amounts (as hinted by the 'micro' in micronutrients). There are two types of micronutrients: **vitamins** and **minerals**. Unlike macronutrients, micronutrients do not provide the body with energy. However, micronutrients are considered **essential** because our body cannot make all of them. Each micronutrient plays a specific and important role in our body. Therefore, to maintain optimal health, an adequate intake of each micronutrient must be consumed. Micronutrients allow the body to produce essential hormones and enzymes and play an important role in our **growth and development**. There is also another type of micronutrient called **phytonutrients** that we consume when eating plant-based foods. These chemicals are not considered essential for survival because humans can survive long periods without them; however, phytonutrients have been associated with increased health outcomes and a lower risk of developing certain diseases.

As micronutrients are needed in smaller amounts they are generally measured in milligrams (mg) and micrograms (µg).

π Formula

1000 µg = 1mg

1000mg = 1g



Did you know?

There are hundreds of different phytonutrients and each one has its own benefit(s) to the body. **Lycopene** is a phytonutrient found in tomatoes. This phytonutrient is of particular interest to scientists and has been shown to have many different health benefits. One particular study conducted by scientists at Harvard University found that the subjects who ate the highest amount of tomatoes had a 35% decreased risk of prostate cancer. However, further studies need to be conducted to determine if this was because of lycopene or another chemical in tomatoes. Another study that involved men consuming two tablespoons of concentrated tomato puree per day found that they had increased sperm quality. Other studies have also found that lycopene could help protect against cardiovascular disease and even sunburn.

Interestingly, lycopene is hard for our body to absorb when raw tomatoes are eaten. The bioavailability of this nutrient **doubles** if tomatoes are cooked because cooking increases access to the chemical (e.g. tomato soup, pasta sauce). Another study showed that lycopene levels in tomatoes stored at room temperature had double the amount of lycopene than tomatoes stored in the fridge. This was because the cold temperatures of the fridge inhibited particular chemical reactions associated with tomatoes ripening (and producing more lycopene). Finally, concentrated tomato puree has approximately 16 times more lycopene than the same volume of a normal tomato.

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1.6 Vitamins

Nutrition Understanding

Vitamins are organic compounds that are vital to life, hence the name vitamins (in Latin 'vita' means life). There are **13 essential vitamins** that are necessary for us to consume each day to maintain efficient vital functions. Vitamins are generally not made or not made in sufficient amounts, by the body and we are required to source them through our diet. Unlike macronutrients, vitamins do not contain any energy. There are two types of vitamins: **water-soluble** and **fat-soluble**. The B complex and C vitamins are water soluble and dissolve in water. The fat-soluble vitamins dissolve in fats and therefore require the presence of fats to be absorbed, transported and stored and there is four of them: A, D, E and K (remembered as ADEK). If too many vitamins are consumed and one or more build up to toxic levels, hypervitaminosis occurs. Conversely, a vitamin deficiency causes hypovitaminosis. Generally, any excess water-soluble vitamins are removed through the urine with water; however, excess fat-soluble vitamins can be stored with fat and can build up to toxic levels. In contrast to minerals (another micronutrient), vitamins are easily destroyed by heat, exposure to oxygen and light, through food processing, cooking and poor storage. Some vitamins are more susceptible than others, for example, water-soluble vitamins are generally more susceptible than the fat-soluble vitamins.

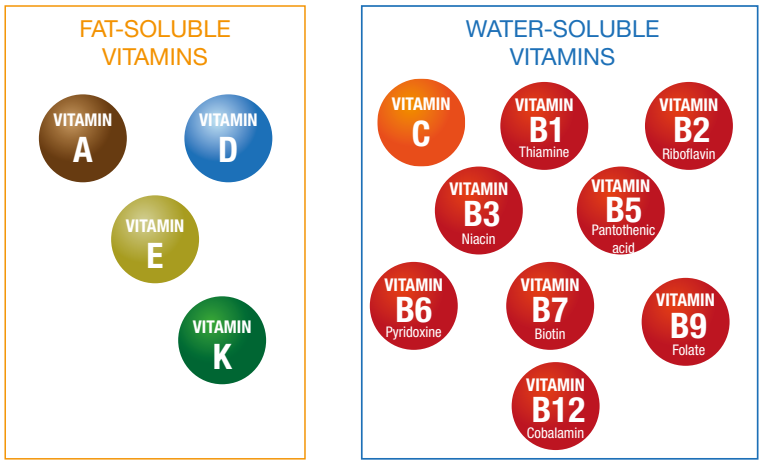


Figure 1.6.1: The 4 fat-soluble and 9 water-soluble essential vitamins.

Helpful online resources

TED-Ed: How do vitamins work?–Ginnie Trinh Nguyen

https://www.youtube.com/watch?v=ISZLTJH5lYg&t=150s

How vitamins can act as antioxidants and protect cells from free radicals

Some vitamins also function as antioxidants, such as vitamins A, C and E. There are many different antioxidants, including some phytochemicals, which are mainly found in different coloured fruits and vegetables. This is one of the reasons why consumption of a range of different coloured plant-based foods each day is recommended.

Free radicals, also called oxidants, are constantly being produced in our body every day. They can be produced as a bi-product of normal chemical reactions, such as respiration, or they can also arise from other sources, such as smoking and pollution. One example of a free radical is hydrogen peroxide (H_2O_2), which is a highly reactive free radical that can cause damage to our cells. These free radicals can react (through oxidation) with components of our cells such as proteins, lipids and DNA, and cause damage. If the free radicals react with our DNA, they can cause mutations and over time this could lead to cancer. Free radicals can also contribute to inflammation, premature ageing, neurodegenerative diseases and many other conditions. Another way to think of this is that free radicals 'rust' our cells. Antioxidants, as their name suggests 'anti', combat the oxidants thereby protecting our cells from damage. They 'sacrifice' themselves to protect the cells' components. Inadequate intake of antioxidants, such as vitamins C and E, can therefore lead to cell damage and could contribute to certain

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types of cancer and other diseases. Vitamin C generally protects the aqueous components of the cell as it is water-soluble and vitamin E generally protects the fat-based components, such as the cell membrane, as it is a fat-soluble vitamin (see Figures 1.6.2 and 1.6.3).

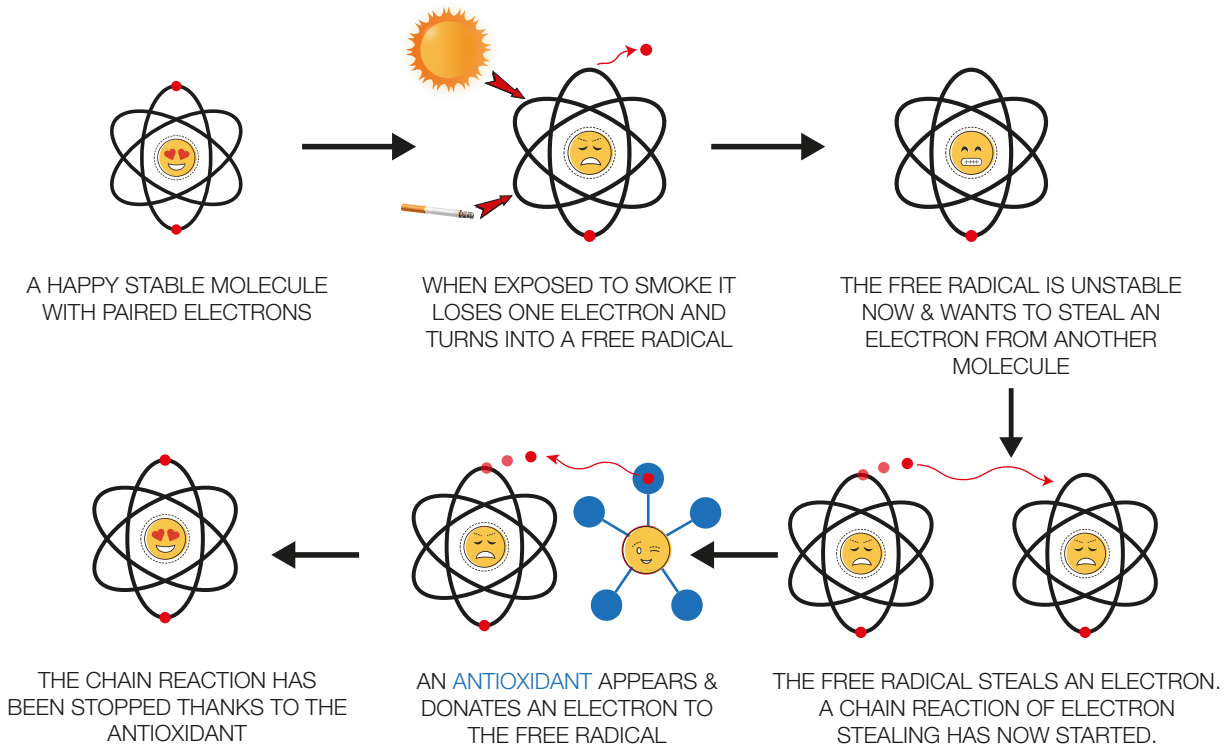


Figure 1.6.2: A basic explanation of how free radicals can form a chain reaction of free radical production and an antioxidant can stop the cycle.

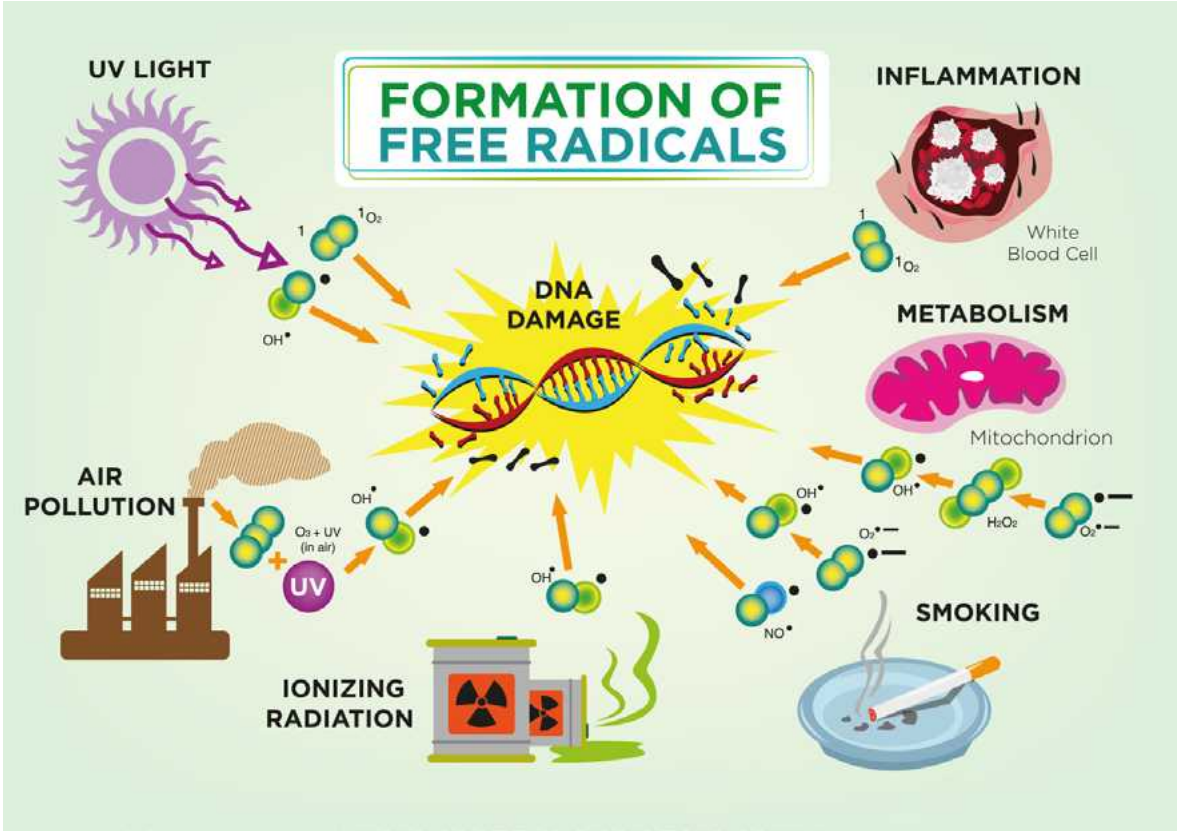


Figure 1.6.3: Some examples of sources that can increase free radical production.

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Did you know?

It is recommended that smokers consume an extra 35mg of vitamin C per day. This is because cigarette smoke contains many oxidants. Increased oxidants require increased antioxidants to combat their effects. People who live with smokers or are constantly exposed to second or third hand smoke should also increase their intake of vitamin C.

Helpful online resources

Free Animated Education: What are Vitamins?

https://www.youtube.com/watch?v=5FpcDSpDW_w

Vitamins B1, B2 and B3 in the metabolism of macronutrients

Vitamins B1 (thiamine), B2 (riboflavin) and B3 (niacin) are all involved in the **release of energy** from macronutrients. These vitamins are **not a source of energy** themselves but are required to metabolise carbohydrates, proteins and fats. Vitamins B1, B2 and B3 form **coenzymes**, which are molecules that are required for enzymes to perform their function (see Figure 1.6.4). Enzymes are proteins that catalyse (speed up) chemical reactions. There are many different enzymes involved in the metabolism of macronutrients. If an enzymes coenzyme is not present, the reaction cannot occur. Therefore, a deficiency in vitamins B1, B2 and B3 can be associated with decreased energy levels and feeling lethargic.

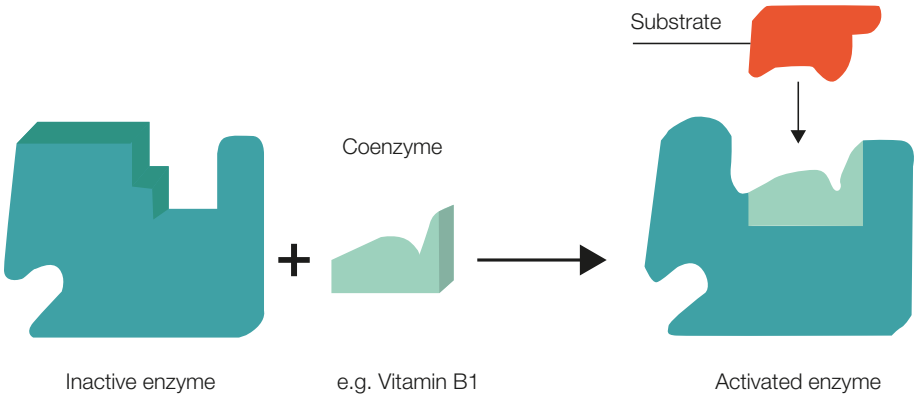


Figure 1.6.4: A coenzyme activating an enzyme. The reactant (substrate) cannot bind to the enzyme until the coenzyme binds to the enzyme. The chemical reaction can now be facilitated by the enzyme.

Sources of vitamins B1, B2 and B3

Whole grains and their products are good sources of these three vitamins. Wheat flour that is used to make bread is **fortified with vitamin B1** to prevent deficiencies in the Australian population (see Topic 8: Food processing for more information). Milk is a good source of vitamin B2, but it can be destroyed by UV light. Milk should therefore ideally be stored in a carton and in a fridge, away from direct sunlight.

Table 1.6.1: Some examples of good sources of vitamins B1, B2 and B3.

Vitamin B1	Vitamin B2	Vitamin B3
Whole grains such as wheat, oats, barley and rice (and their products)	Milk and milk products such as cheese and yoghurt	Beef, chicken and tuna
Fortified grain products such as bread, cereals and pasta	Whole grains such as wheat, oats, barley and rice (and their products)	Whole grains such as wheat, oats, barley and rice (and their products)
Pork	Liver	Liver

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Vitamin B9 (folate)

Table 1.6.2: The recommended daily intake of folate at various stages of life.

Age	Recommended Dietary Intakes (µg)
1 to 3	150
4 to 8	200
9 to 13	300
14 and over	400
Pregnancy	600

Sources of vitamin B9

Folate is found naturally in our foods but there is also a synthetic form called **folic acid,** which is used in supplements and to **fortify foods,** such as grain products. Most people eat grain products like bread and pasta so this is a good way to reach the majority of the population. The synthetic form has up to double the bioavailability (amount absorbed for the body to use) than the natural form. Vegetables, legumes and fruits are good sources of folate, whereas animal products generally are not. It is also important to note that up to half of the folate in foods can be destroyed through poor storage (exposure to oxygen) and heat when cooking. Some examples of good sources of folate are:

- Leafy greens, such as spinach, broccoli, kale, rocket and lettuce
- Legumes, such as lentils, pinto beans and kidney beans
- Asparagus and brussels sprouts
- Avocados
- Citrus fruits, such as oranges (including orange juice), grapefruit and lemons
- Fortified grain products, such as bread, cereals and pasta
- Nuts and seeds, such as walnuts and flaxseeds.

Functions of vitamin B9

Both folate (vitamin B9) and vitamin B12 are required for the **synthesis of DNA** (see Figure 1.6.5). Folate and vitamin B12 are dependent on each other for activation. Their activated forms allow them to perform their roles as **coenzymes** (see Figure 1.6.4) in the synthesis of DNA required to make new cells for growth and cell replacement. Without either of these vitamins, neither are activated and DNA synthesis cannot occur. This results in DNA damage and the abortion of cell division. Folate is also required for the production of **red blood cells** and preventing anaemia.

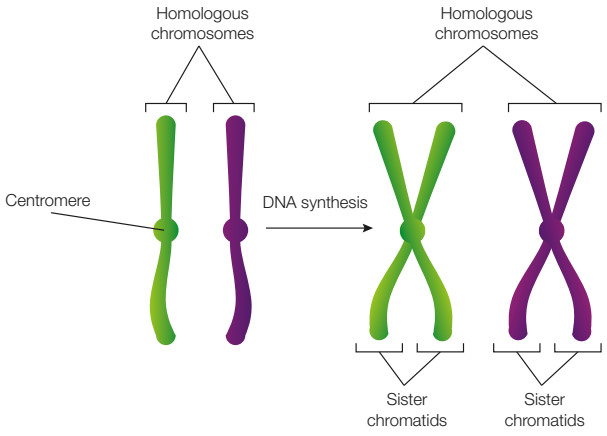


Figure 1.6.5: Folate is required for DNA synthesis to make identical copies of chromosomes for the formation of new cells and growth.

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Deficiency and excess of vitamin B9

Excessive vitamin B9 intake is rare and generally only occurs from the consumption of too many fortified foods or through supplementation. The body readily excretes excess folate through the urine but the main consequence of excessive folate is the prevention of vitamin B12 absorption, leading to B12 deficiency.

Folate is required for DNA and protein synthesis and is essential for cell division (required for growth, cell replacement and repairing wounds). A folate deficiency can therefore lead to serious conditions. Folate is an essential nutrient required for growth during the early stages of pregnancy to enable a baby's brain and spinal cord to form properly. A deficiency can lead to **neural tube defects** such as spina bifida. This is discussed further in Topic 6: Nutrition and food safety during pregnancy and lactation. Folate deficiency can also lead to problems with replacing cells, such as the lining of the gut, which is replaced every two to five days and red blood cells that are constantly being replaced (approximately two million every second). A lack of red blood cells can lead to **folate deficient anaemia** which is discussed further in Topic 2: Dietary disorders.

Vitamin B12 (cobalamin)

Table 1.6.2: The recommended daily intake of vitamin B12 at various stages of life.

Age	Recommended Dietary Intakes (µg)
1 to 3	0.9
4 to 8	1.2
9 to 13	1.8
14 and over	2.4

Sources of vitamin B12

Vitamin B12 is primarily found in **animal products** so meeting the recommended dietary intake can be an issue for **vegans**. Some food options for vegans that contain vitamin B12 include some forms of algae and some fortified products, such as nutritional yeast, some cereals and soy products. Vitamin B12 can also be taken as a supplement because it is sourced from bacteria (not animals); however, some supplement capsules may contain an animal product gelatin, so vegans must read the label prior to purchasing the supplement. As vitamin B12 is a water-soluble vitamin, some is destroyed through the cooking process; however, unlike other water-soluble vitamins, microwaving animal products destroys more than conventional cooking methods, such as the oven or cooktops.



Figure 1.6.6: Vitamin B12 is primarily found in animal products such as meats, seafood, dairy product and eggs.

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Functions of vitamin B12

Vitamin B12 is required for maintaining the integrity of the **myelin sheath** that covers the axon of nerve cells. The myelin sheath is responsible for protecting the axon and speeds up nervous messages. If the sheath is not maintained, it can lead to nerve damage and **irreversible neurological complications.** As mentioned previously, vitamin B12 is also essential for **DNA synthesis** and an inadequate supply can lead to vitamin B12 deficient anaemia (see 'Functions of vitamin B9' for information on vitamin B12's role in DNA synthesis).

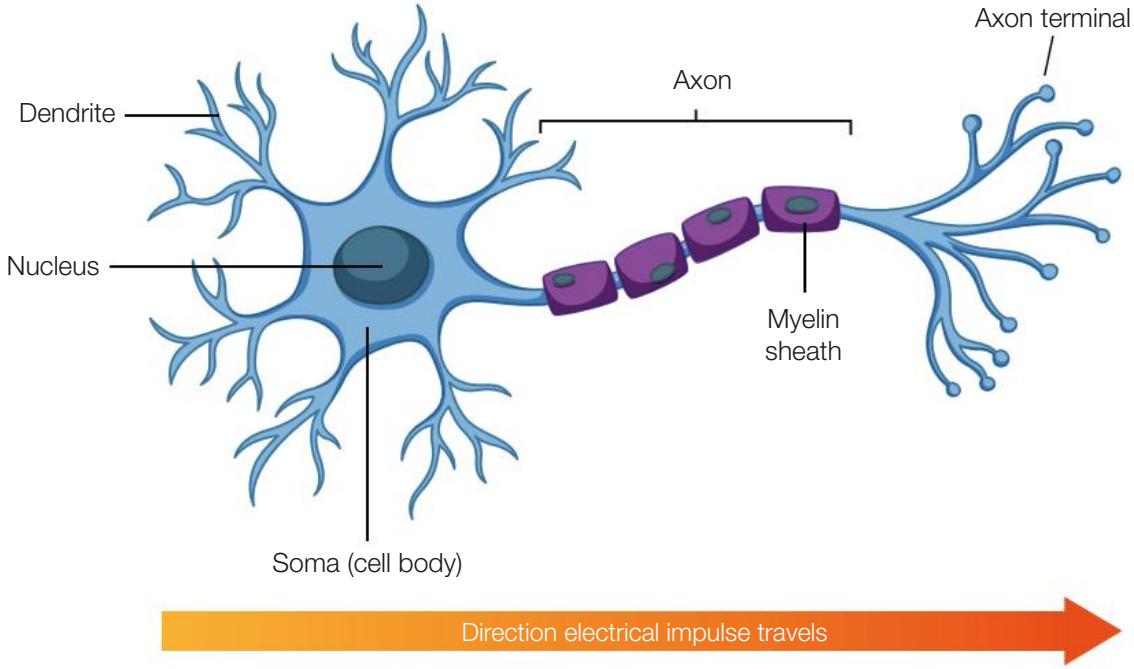


Figure 1.6.7: The myelin sheath covers the axon to protect it in a similar way that plastic is used to cover copper wiring in electrical products.

Deficiency and excess of vitamin B12

Fortunately, our bodies don't require a large intake of vitamin B12 because they can maintain a supply through reabsorbing and recycling it. However, we do require a very small top up amount each day and a chronic lack of vitamin B12 (or gastrointestinal problems that result in poor absorption) can lead to vitamin B12 deficiency. Vitamin B12 deficiency can result in anaemia and neurological complications, such as problems controlling mood, memory loss, visual complications, dementia and can even progress to paralysis. **Vegans** are at higher risk of deficiency especially without a well-planned diet that includes sufficient B12. Most vegans do consume an adequate amount of B12 to avoid anaemia and nerve damage but they may not consume the increased amount needed during pregnancy (this is discussed further in Topic 6: Nutrition and food safety during pregnancy and lactation). Furthermore, the **elderly** and individuals with **coeliac disease** are also at higher risk of vitamin B12 deficiency. This is because the elderly have an increased risk of damaged stomach cells that release a protein needed for the absorption of B12 and those with coeliac disease are at increased risk of intestinal cell damage responsible for absorbing vitamin B12. There are no reported consequences for an excessive intake of vitamin B12.

Vitamin C (ascorbic acid)

Table 1.6.3: The recommended daily intake of vitamin C at various stages of life.

Age	Recommended Dietary Intakes (µg)
1 to 8	35
9 to 18	40
19 and over	45

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Sources of vitamin C

Vitamin C is highly susceptible to being destroyed. It is easily destroyed by heat, oxygen, light and cooking with copper pans. Fresh fruit and vegetables will therefore contain higher concentrations than cooked and processed vegetables. Some examples of fruits and vegetables high in vitamin C are:

- Citrus fruits, such as oranges and lemons
- Strawberries and blackcurrants
- Capsicum
- Kiwi fruit
- Kale, broccoli and brussels sprouts.

Functions of vitamin C

Vitamin C can act as an **antioxidant** and **protect water-soluble substances** from oxidation by free radicals. Vitamin C is therefore important in reducing the risk of certain diseases developing, such as cancer and neurodegenerative diseases. See the aforementioned section on antioxidants for more information. Vitamin C can **increase non-haem iron absorption** by protecting it from being oxidised. Vitamin C also protects iron from oxidation once it has been absorbed. As iron is needed to make the protein collagen, which is important for bones, teeth and holding cells together, **vitamin C is also important in synthesis of collagen**.

Deficiency and excess vitamin C

A deficiency in vitamin C can cause a condition called **scurvy**. Vitamin C is required to make collagen (which holds our cells together) therefore, a lack of vitamin C can cause certain tissues in our body to start to break down. This can result in bleeding gums, capillaries breaking down under the skin causing small bruises, wounds not healing, and in extreme cases can result in death. Scurvy was a common disease in the past and is often associated with explorers who set out on long sea voyages and faced insufficient access to fruits and vegetables while at sea; however, there have been multiple cases recently in Australia due to poor diet.

An excessive consumption of vitamin C is possible and is generally a result of taking excessive supplements, possibly due to the misconception that taking vitamin C fights off the common cold. If vitamin C does build up to toxic levels, it can result in feeling nauseous, diarrhoea and the formation of kidney stones.



Figure 1.6.8: Wounds are unable to heal properly without vitamin C because collagen, needed to form scar tissue and hold cells together, cannot form.

Helpful online resources

Medical Centric: Scurvy : Symptoms, Causes, Treatment, And Prevention

https://www.youtube.com/watch?v=FW0tovbJ8ak

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Did you know?

It is commonly thought that taking vitamin C supplements once a common cold has developed will help with recovery. However, the scientific research is inconsistent with this commonly held belief. The majority of studies show that there are no benefits associated with taking vitamin C supplements to fight off the common cold. One study, however, determined that while vitamin C supplementation did not help lessen the severity or duration of developed colds, if it was taken continuously in advance of contracting a cold it could reduce the length of the cold by about one day in some circumstances. In summary, the scientific literature shows that vitamin C supplementation does not prevent colds and may only slightly reduce the length of colds in certain circumstances.

Vitamin A (retinol)

Table 1.6.4: The recommended dietary intakes of vitamin A at various stages of life.

Age	Recommended Dietary Intake (µg) per day (for males)	Recommended Dietary Intakes (µg) per day (for females)
1 to 3	300	300
4 to 8	400	400
9 to 13	600	600
14 and over	900	700

Sources of vitamin A

Vitamin A is a fat-soluble vitamin and is only found in its direct form in animal-based products. Because it is fat-soluble, low fat food options, such as skim milk and margarine, lose a lot of their vitamin A content as the fat (and stored vitamins) are removed. To compensate, they are generally fortified to increase vitamin A content. Vitamin A can also be sourced from plant-based sources but it is found as provitamin A (which is converted to vitamin A inside the body). There are multiple types of provitamin A but the most common is beta-carotene. Examples of good sources of vitamin A and provitamin A are:

Table 1.6.5: Some examples of foods that are good sources of vitamin A and provitamin A.

Good sources of vitamin A	Good sources of provitamin A
Beef liver (vitamin A is stored in the liver)	Sweet potato
Fatty fish oil	Squash
Fatty fish, such as mackerel, salmon and tuna	Carrots
Milk and cheese	Leafy greens, such as kale, spinach and romaine lettuce
Eggs	Red capsicum

Functions of vitamin A

Vitamin A has a diverse range of functions in the human body. Some of the major functions of vitamin A are:

- Assists in **vision** and the development of cells in the cornea and retina of the eye.
- Required for protein synthesis and cell division. This helps in maintaining cells that are regularly replaced, such as skin and epithelial tissue (e.g. gut lining is replaced every two to five days).
- Needed for the development of sperm in men and normal growth and development of the foetus in women during pregnancy.
- Improves immune system efficiency and the ability to fight infectious diseases.

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Deficiency and excess of vitamin A

Vitamin A is primarily stored in the liver and the average adult has enough to last for over a year; however, children are less developed and are more prone to vitamin A deficiency (VAD). This is a serious concern in developing countries where there is low availability of fresh whole foods. As vitamin A is important for eyesight, a lack of supply can cause total **blindness** (xerophthalmia). Vitamin A is also important for immune function and a **compromised immune system** increases susceptibility to infectious diseases, such as measles, pneumonia, malaria, HIV, Ebola virus, etc. Furthermore, **dry skin** can develop because there is not enough vitamin A for epithelial cell replacement, required for skin repair.

Vitamin A toxicity can develop when too much vitamin A is consumed, with the majority of toxicity cases due to overconsumption of fortified products or supplements. However, as approximately 90% of vitamin A is stored in the liver of animals, people who consume a lot of liver can be at increased risk of excessive vitamin A intake. Chronic excessive vitamin A can **reduce bone density** and increase risk of **osteoporosis** later in life. In pregnant women, excess vitamin A consumption can cause birth defects. If toxic levels of provitamin A are consumed, it is stored in the fat under the skin causing the skin to **become yellow**. This is where the belief that eating too many carrots can turn you orange comes from.



Figure 1.6.9: The yellow skin associated with eating too much provitamin A.

Vitamin D (cholecalciferol)

Table 1.6.6: The adequate intakes of vitamin D at various stages of life.

Age	Adequate Intake (µg)
1 to 50	5
51 to 70	10
70 and over	15

Sources of vitamin D

Vitamin D can be **synthesised by the body** when exposed to **sunlight**. This is because the body makes a vitamin D precursor from the cholesterol in our diet. When exposed to the sun it is converted into the active vitamin D. Vitamin D is available in a few food sources but in humans the majority is developed through exposure to sunlight. Exposure to sunlight for about **10 minutes per day** can provide most individuals with their recommended intake. Some sources of vitamin D in foods are:

- Fatty fish, such as salmon, sardines, tuna and herring
- Fortified butters and margarine
- Beef
- Egg yolks.

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Functions of vitamin D

The main role of vitamin D is to control blood concentrations of **calcium** and phosphorus for **bone formation and maintenance**. Vitamin D increases the absorption of calcium in the small intestine (from our food) and mobilises calcium from bones to increase concentration in the blood when required. Some other roles of vitamin D include:

- Vitamin D can promote **muscle growth** by stimulating protein synthesis in muscle cells. Stronger muscles can decrease the likeliness of falling and breaking bones.
- Vitamin D is an important constituent of the **immune system** and deficient levels can increase the risk of autoimmune diseases developing, such as type 1 diabetes and rheumatoid arthritis.
- Some studies have linked adequate vitamin D with a reduced risk of **depression**.

Deficiency and excess of vitamin D

As vitamin D is important for calcium absorption, a deficiency in vitamin D also results in a **deficiency of calcium**. This can compromise normal bone formation as calcium is needed to form the hard structure of the bone (with phosphorus). A deficiency can cause **rickets** in children, adolescents not to reach peak bone mass, osteomalacia in adults and **osteoporosis** in the elderly. Rickets is a disease where the bones fail to develop properly because there is not enough calcium. This results in skeletal abnormalities such as bowed legs. Osteomalacia generally occurs in adults and is caused by reduced bone density resulting in soft bones. Osteoporosis is also a result of reduced bone density and is associated with a very curved spine and increased risk of bone breakages. Bone density and osteoporosis are discussed in further detail in Topic 2: Dietary disorders.

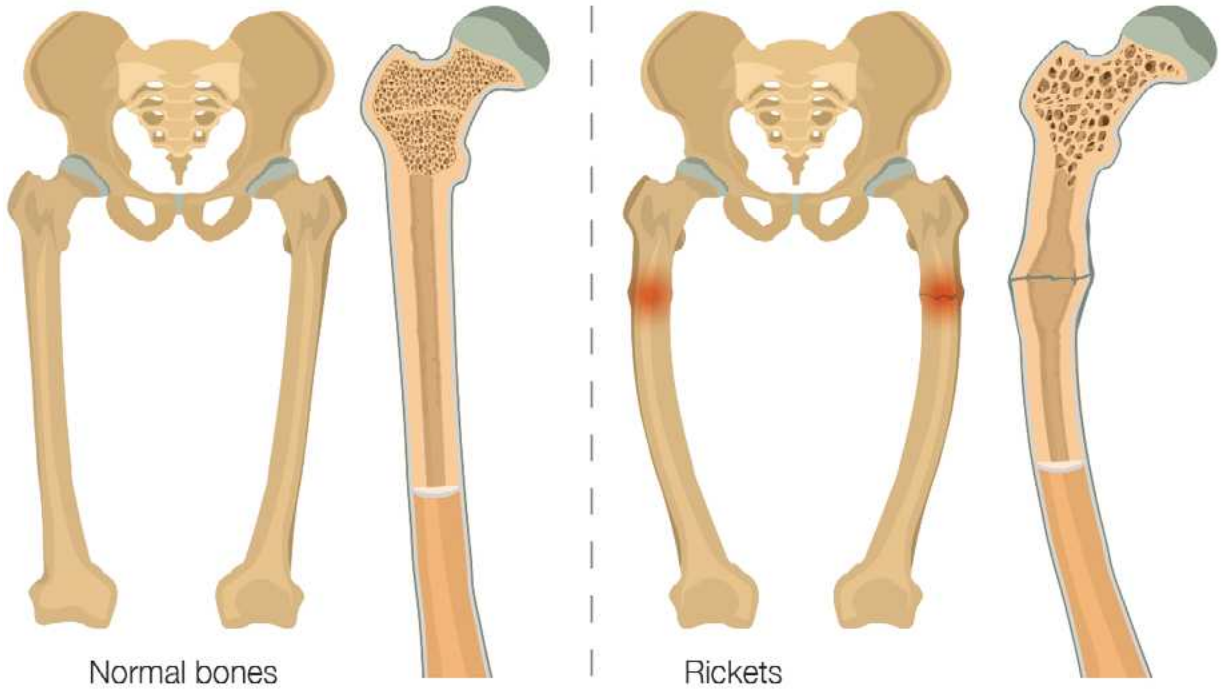


Figure 1.6.10: Bowed legs associated with rickets due to low levels of vitamin D in childhood.

Vitamin D toxicity is uncommon through diet and exposure to sunlight alone but can be caused by taking excess supplements. **Vitamin D supplements should only be taken with medical advice** because the consequences of excessive vitamin D can be severe.

Vitamin D toxicity can lead to increased calcium levels in the blood (hypercalcemia), which can calcify in the kidneys (causing **kidney stones**) and can result in the **hardening of blood vessels**. The hardening of blood vessels associated with the heart could lead to death.

Helpful online resources

Medical Centric: Rickets, Causes, Signs and Symptoms, Diagnosis and Treatment.

https://www.youtube.com/watch?v=sBar5TMhrBs

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Vitamin E (tocopherols)

Table 1.6.7: The adequate intakes of vitamin E at various stages of life.

Age	Adequate Intake (mg) per day (for males)	Adequate Intake (mg) per day (for females)
1 to 3	300	300
4 to 8	400	400
9 to 13	600	600
14 and over	900	700

Sources of vitamin E

One of the roles of vitamin E is to protect polyunsaturated fats from oxidation (acts as an antioxidant). Fortunately, polyunsaturated fat sources (such as plant oils) are generally rich in vitamin E. However, fish oil supplements may not contain enough vitamin E to protect the amount of fats consumed and more may be needed through the diet. Some good sources of vitamin E are:

- Polyunsaturated plant oils, such as wheatgerm oil, sunflower oil and almond oil
- Margarine and salad dressings made from plant oils
- Leafy green vegetables, such as kale, spinach and broccoli
- Egg yolks
- Nuts and seeds, such as sunflower seeds, almonds and peanuts
- Salmon.

Functions of vitamin E

The main role of vitamin E is its **antioxidant role in protecting lipids**. It is especially important in protecting polyunsaturated fats from oxidation by free radicals. Polyunsaturated fats are less stable because they have more double bonds and are more prone to oxidation. Additionally, it protects our cell membranes and vitamin A from oxidation. By protecting vitamin A from being oxidised, vitamin A is able to perform its roles, including improving efficiency of the immune system and preventing infectious diseases.

Deficiency and excess of vitamin E

Vitamin E deficiency is rare but it can lead to the destruction of red blood cells through the oxidation of polyunsaturated fats in their cell membranes. This is more likely to occur in infants and people with genetic conditions that cause problems with absorbing fats properly. Vitamin E toxicity is also rare. Generally, supplementation is safe and there are no adverse side effects unless they are taken in high doses (in which case it can interfere with the blood clotting process and can cause haemorrhaging).

Vitamin K (phylloquinone)

Table 1.6.8: The adequate intakes of vitamin K at various stages of life.

Age	Adequate Intake (µg)
1 to 3	25
4 to 8	35
9 to 13	45
14 to 18	55
19 and over	70 (men) & 60 (women)

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Sources of vitamin K

The **bacteria in our intestines** ferment the fibre we eat producing vitamin K for us. This is discussed in more detail in Topic 3: Digestion, malabsorption and the microbiome. It can also be sourced through the diet from foods such as:

- Leafy green vegetables, such as kale, spinach, broccoli and mustard greens
- Cabbage
- Brussels sprouts
- Liver.

Functions of vitamin K

The primary function of vitamin K is to assist in **normal blood clotting**. When damage occurs to blood vessels and bleeding occurs, the blood needs to clot to prevent blood loss. If the blood doesn't clot, too much blood could be lost and death could occur. Vitamin K is essential in activating proteins involved in the blood clotting process.

There is some evidence that vitamin K could also be needed for healthy bone formation. Some studies have demonstrated that low vitamin K could be associated with reduced bone density due to incorrect formation of bone proteins.

Deficiency and excess vitamin K

A deficiency in vitamin K is uncommon but it can be fatal because vitamin K is needed for normal blood clotting. If insufficient vitamin K is present and an injury occurs where the blood vessels are broken, this could lead to 'bleeding out', known as **haemorrhaging**. Some medications can result in vitamin K deficiency, such as antibiotics. This is because some antibiotics can kill the bacteria that produce vitamin K in our intestines. Vitamin K toxicity is also uncommon and no adverse effects have been identified.

Did you know?

Nearly 40% of the Australian population takes some kind of vitamin supplement. That's almost 10 million people. Some of these people have valid medical reasons, such as diagnosed deficiencies and deficiencies during pregnancy; however, many others are consuming supplements without professional advice. Unfortunately, the supplement industry is not strictly regulated and there are many unverified health claims that promote sales. Furthermore, vitamin supplements aren't seen as 'medication' by the general public, despite the fact there can be adverse consequences of overconsumption. It is important to read the labels of supplements and understand the upper limits of recommended dietary intakes. Some supplements can contain well over the daily allowance. It is also important to discuss vitamin supplementation with a qualified medical practitioner, such as a doctor, prior to commencing supplementation.

There is a misconception in the public that because vitamins are good for the body taking more of them will help prevent diseases, such as cancer and dementia. However, there is conflicting evidence, as some studies have shown that taking specific vitamins can increase the risk of some types of cancer. One study on 77,000 people showed a 30% to 40% increased chance of developing lung cancer when supplemented with excessive vitamins B6 and B12 (this study was not performed with multivitamins). Also, vitamin A supplementation has been linked with an approximate 30% increased chance of lung cancer. Another study on large doses of 'non-toxic' levels of vitamin E showed 1.6 times increase in prostate cancer in males. A possible reason for these findings is vitamins can interfere with cell death, called apoptosis. If precancerous cells are being programmed by the body to undergo apoptosis but vitamin supplementation interferes with this process and keeps the precancerous cells alive, this could contribute to the increased risk of cancer. This is of less concern in young healthy people but for people over the age of 30 whose bodies consist of older cells, vitamin supplementation could promote the survival of cells that should be programmed for cell death. Additionally, a large recent review was published in the *Annals of Internal Medicine,* which reviewed 27 trials of vitamins involving more than 400,000 people. It was concluded that taking vitamins did not increase life expectancy or reduce risk of cardiovascular disease or cancer.

In summary, some supplements are necessary and are recommended by qualified medical practitioners in response to a diagnosed condition or pregnancy. For example, vitamins B9 and D are essential for pregnancy to prevent neural tube defects and rickets, respectively. Vitamin B9 supplementation is recommended at least a month prior to conception and vitamin D levels are monitored through blood tests and recommended only if the levels are low. Vitamin B12 supplementation is also recommended for vegans. For the average person living in Australia, the required vitamin intake can be obtained through a balanced healthy diet (and they are generally absorbed more efficiently than through supplementation). Taking supplements should first be discussed with a qualified medical practitioner, such as a doctor.

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Helpful online resources

SciShow: Are Multivitamins Really Good For You

https://www.youtube.com/watch?v=5ODkZQ9JOaQ&t=39s

1

Science as a Human Endeavour 2

Vitamin deficiency wristband

Watch the video 'Futurism: This Wristband Tells You Exactly What Vitamins You Need' using the link below to find out more information and then answer the following questions.

Helpful online resources

https://futurism.com/videos/this-wristband-tells-you-exactly-what-vitamins-you-need

Questions

1. Discuss how the **application** of the vitamin deficiency wristband could affect society.

(4 marks)

2. Discuss **two limitations** of the vitamin deficiency wristband.

(4 marks)

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1.6 Review questions

1. State the category of vitamin that is likely to be found in olive oil in a greater amount.

(1 mark)

2. Identify the category of vitamin that is more likely to be toxic **and** justify your answer.

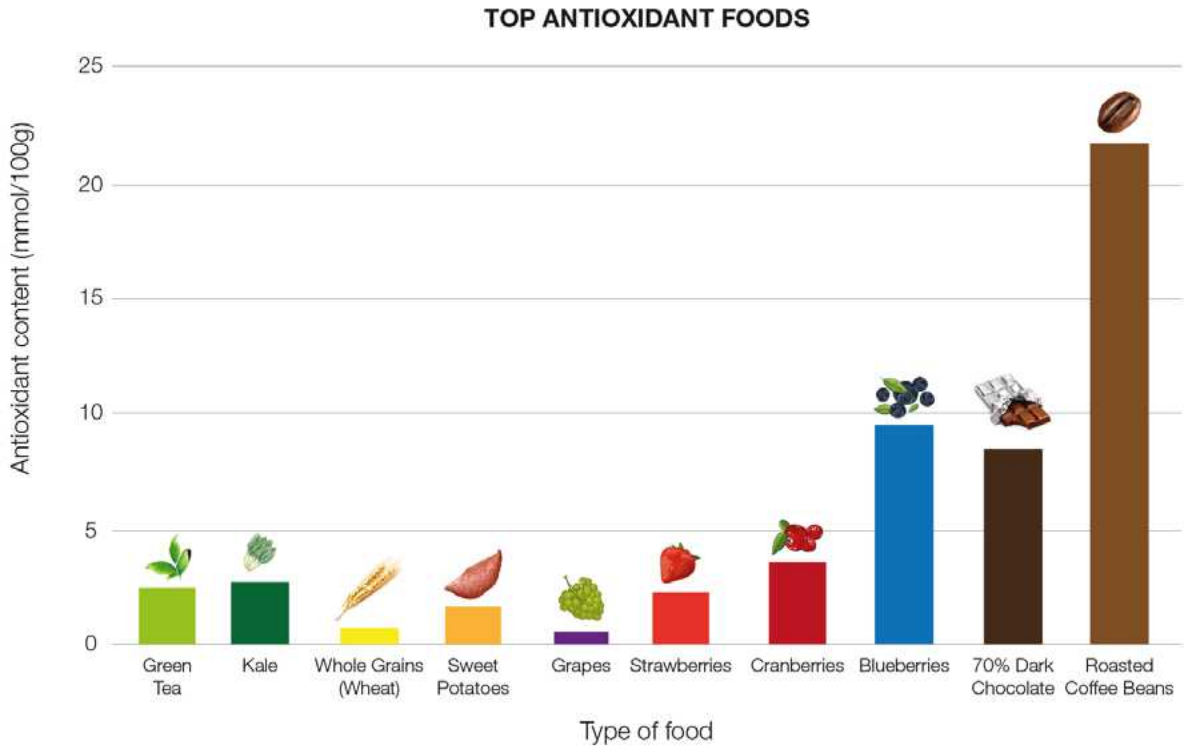
(2 marks)

3. Provide **two** good sources of the following vitamins:

Vitamin	Two Sources
B9	
B12	
C	
A	
D	
E	
K	

(7 marks)

4. Refer to the following graph to answer part (b) below:



(a) Describe what an antioxidant is.

(2 marks)

(b) Using data, identify the food that has the greatest antioxidant content.

(2 marks)

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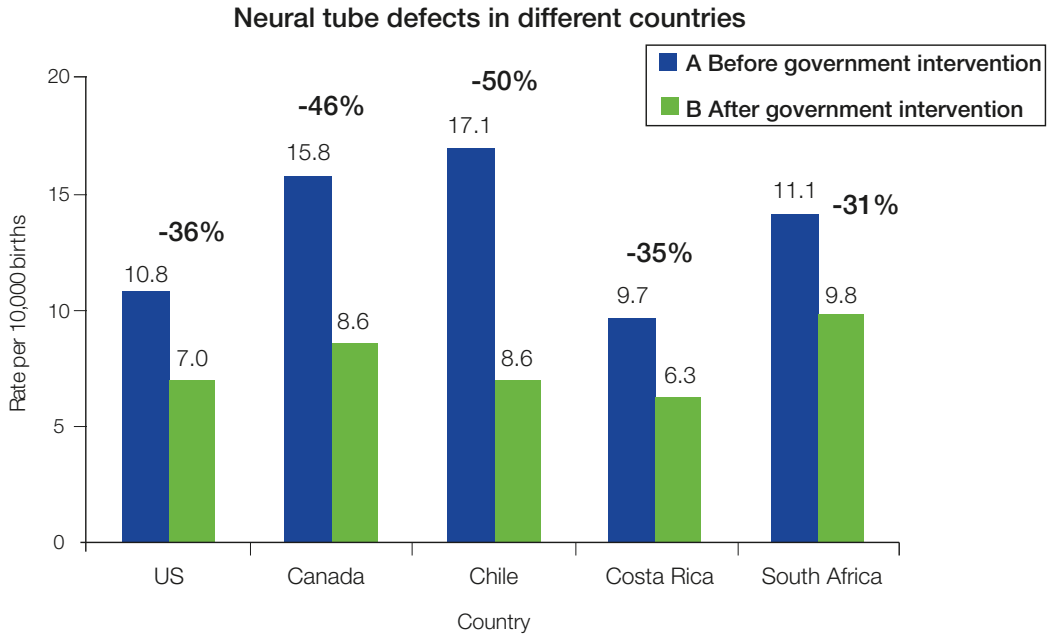
(c) Explain why it is important that the body has two powerful antioxidants in vitamin C and E and not just one.

(4 marks)

(d) Vitamin C is often added to cured meats by the manufacturers. With respect to vitamin C's functions, explain a possible reason that vitamin C would be added to cured meats.

(2 marks)

5. Refer to the following graph to answer part (b) below:



(a) State the vitamin deficiency in expecting mothers that can cause neural tube defects in their infants.

(1 mark)

(b) Identify **and** explain one possible reason why neural tube defects have decreased from A to B in all countries.

(3 marks)

(c) Explain why both folate and vitamin B12 are needed for growth and development.

(4 marks)

(d) Identify **one** other condition folate and vitamin B12 deficiency can cause.

(1 mark)

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(e) Name **two** groups of people that vitamin B12 deficiency is more likely to occur in and describe why.

(4 marks)

6. Identify the vitamin deficiency that is associated with the inability to heal wounds **and** state the common name of the condition associated with this vitamin deficiency.

(2 marks)

7. In the Philippines, vitamin A deficiency is prevalent and those that can afford it consume vitamin A supplements. However, scientists have developed a strain of rice called golden rice that has enough vitamin A to provide the recommended dietary intake.

(a) Describe **two** functions of vitamin A.

(4 marks)

(b) State **two** symptoms that the vitamin A deficient children of the Philippines are likely to exhibit.

(2 marks)

(c) Explain why the overconsumption of golden rice could lead to toxic levels of provitamin A **and** describe one sign of an excessive intake of provitamin A.

(3 marks)

8. (a) Describe why somebody native to Sudan is more likely to develop rickets than a Caucasian individual.

(2 marks)

(b) Wearing sunscreen can prevent the skin from synthesising vitamin D because the skin needs to be exposed directly to sunlight in order to do so. Identify **two** risks associated with extended exposures to sunlight.

(2 marks)

(c) Explain how the weather could contribute to vitamin D deficiency.

(2 marks)

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(d) Explain how a deficiency of vitamin D can lead to the deformed bone growth associated with rickets.

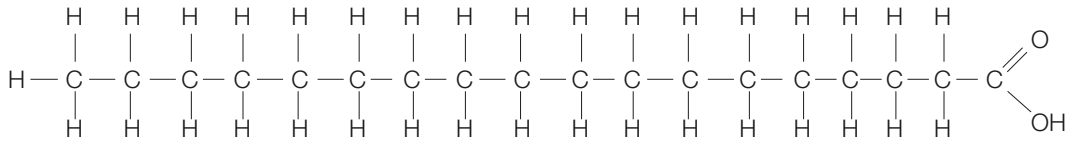
(4 marks)

9. Explain why taking antibiotics for an infectious disease could have a side effect of vitamin K deficiency.

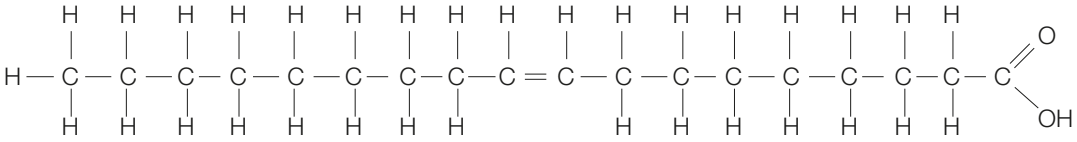
(3 marks)

10. Refer to the following chemical structures (A, B and C) below to answer part (a):

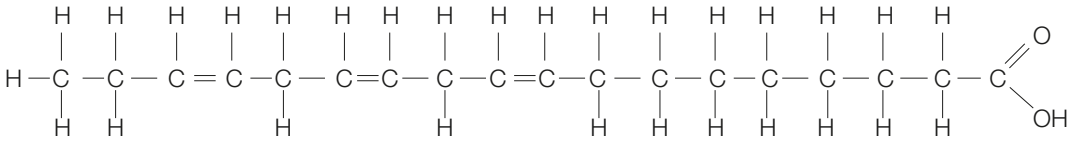
A



B



C



(a) State which type of fat A, B, or C is the most likely to be oxidised in the absence of vitamin E.

(1 mark)

(b) Preterm infants are more susceptible to vitamin E deficiency because they don't receive their stores until the final few weeks of pregnancy.

Identify how a baby born four weeks early could be treated for vitamin E deficiency.

(1 mark)

(c) Describe why people with fat malabsorption problems can experience vitamin E deficiency.

(2 marks)

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1.7 Minerals

Nutrition Understanding

Minerals are inorganic elements that account for approximately 5% of the total body mass. Minerals are an essential part of our diet and perform a variety of functions within our bodies. Some minerals are needed in large amounts and are referred to as **major minerals**, whereas others are needed in smaller amounts by the body and are known as **trace minerals**. Even though trace minerals are needed in smaller amounts than major minerals, they are no less important to the body. All minerals are of equal importance and must be consumed in adequate amounts. Not all of the minerals we eat in our food are absorbed from our intestines into the blood. For example, for the average person consuming a mixed diet of animal and plant products, less than 20% of the iron (iron is a trace mineral) is actually absorbed. One reason for this is that some minerals cannot be absorbed independently and require carriers to enter the body. Minerals are therefore generally absorbed more effectively when consumed as part of a healthy diet than as supplements. Minerals are not destroyed easily through poor storage and food processing methods like vitamins are; therefore, no special cooking requirements are needed to maintain concentration of minerals in our food.

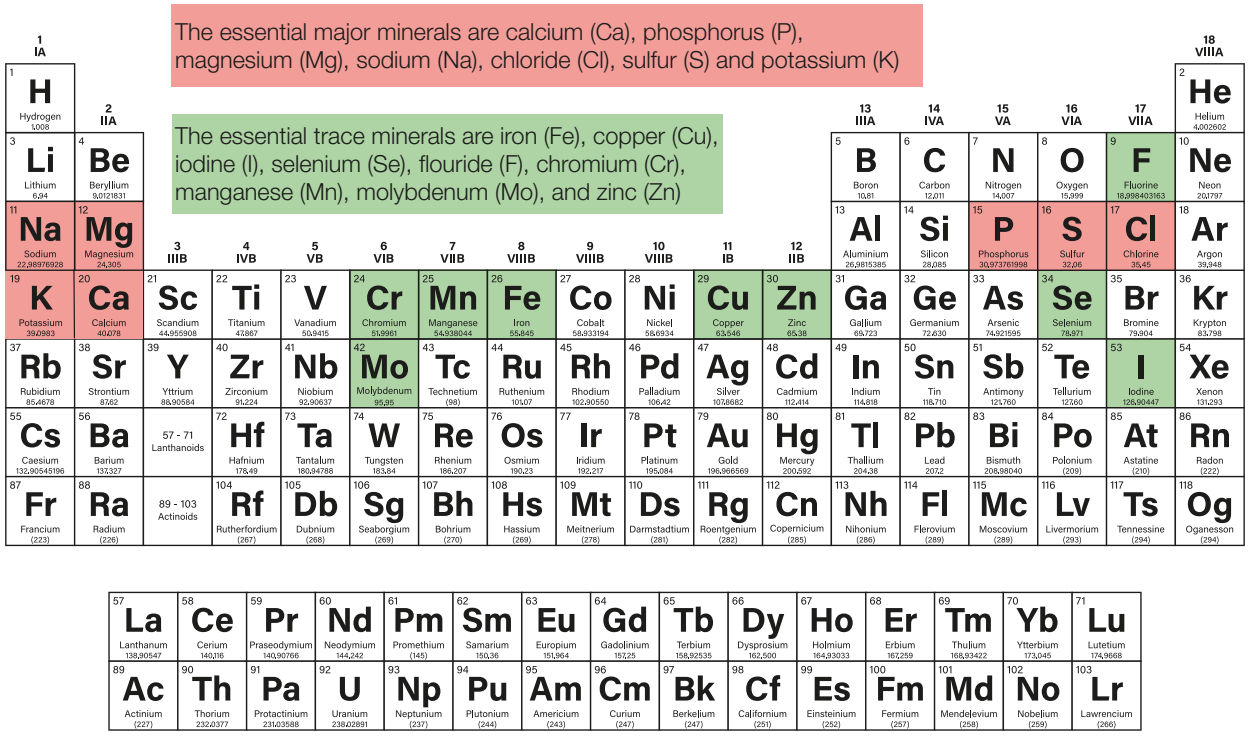


Figure 1.7.1: A periodic table highlighting the essential major and trace minerals required by our body in adequate amounts.

Calcium

Table 1.7.1: The recommended daily intake of calcium at various stages of life.

Age	Recommended Dietary Intakes (mg)
1 to 3	500
4 to 8	700
9 to 11	1000
12 to 18	1300
19 to 50	1000
51 to 70	1000 (males) and 1300 (females)
71 and over	1300

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Sources of calcium

Calcium is a major mineral that is essential for the development of strong bones and teeth. Dairy products are the major source of calcium in our diets but some groups of society cannot consume milk, such as vegans and lactose intolerant individuals. Calcium fortified milk-alternatives are available for people who cannot consume dairy but there are many other sources available, such as some nuts, seeds and dark green vegetables. For the average adult, approximately 30% of the calcium consumed per day is absorbed. However, vitamin D is also needed in order for calcium to be absorbed. Some examples of good sources of calcium are:

- Dairy products, such as milk, cheese and yoghurt
- Sesame seeds and poppy seeds
- Almonds
- Sardines (with bones)
- Seaweed
- Tofu
- Dark green vegetables, such as broccoli, kale and bok choy
- Fortified milk alternatives, such as soy milk.



Figure 1.7.2: Some foods and drinks that are rich in calcium.

Functions of calcium

The primary function of calcium in the body is the **development of strong bones and teeth**. However, calcium also has many other functions in the body, such as:

- Activates nerve impulses
- Regulates muscle contraction and relaxation
- Participates in blood clotting
- Activates some enzymes involved in chemical reactions.

Deficiency and excess calcium

Calcium is lost from the body every day through urine, faeces and sweat. The body requires this calcium to be replaced each day through diet. If sufficient calcium is not obtained from the diet, it is taken from the reserves in bones and released into the blood. Approximately 99% of calcium is stored in the bones and teeth and 1% in our blood. The calcium in the blood is important for sending nervous messages and for muscle contractions. Therefore, maintaining blood calcium in the blood is essential to maintain the muscle contractions of the heart. If blood calcium levels are low, the body prioritises exporting calcium into the blood rather than storing it in the

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bones. This keeps our heart beating and us alive but the negative consequence is **bone loss**. The reduction of calcium stores in our bones decreases their density making them more prone to fractures and it can increase the risk of developing **osteoporosis**. This is explored in more detail in Topic 2: Dietary disorders.



Figure 1.7.3: The comparison of a healthy dense bone (top) compared with a bone that has lost significant calcium stores, has reduced bone density and is more prone to fractures/breaking (bottom).

It is not common for an excess of calcium to occur but it can occur if too many calcium/vitamin D supplements are consumed. This can lead to hypercalcemia, which is too much calcium in the blood. Some possible complications of hypercalcemia are kidney stones, and irregular heart and brain activity.

Phosphorus

Table 1.7.2: The recommended dietary intakes of phosphorus at various stages of life.

Age	Recommended Dietary Intakes (mg)
1 to 3	460
4 to 8	500
9 to 18	1250
19 and over	1000

Sources of phosphorus

Phosphorus is a major mineral found in almost all food sources. This is because it is a component of DNA and the energy molecule adeno-tri phosphate (ATP) in all cells. Therefore, anything containing cells from plants or animals will also contain some phosphorus. Like calcium, vitamin D is also needed to absorb phosphorus. Some foods that are rich in phosphorus are:

- Meats and poultry
- Fish
- Dairy products, such as milk, cheese and yoghurt
- Eggs
- Legumes, such as pinto beans
- Nuts, such as cashews
- Seeds, such as sunflower seeds
- Soybeans and tofu
- Vegetables, such as broccoli, carrots and potatoes.

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Did you know?

The kidney 'activates' vitamin D so it can absorb calcium and phosphorus. If an individual has reduced kidney function, this can impair 'activation' of vitamin D and can lead to deficiencies in calcium and phosphorus absorption.

Functions of phosphorus

The primary function of phosphorus in the body is the **development of strong bones and teeth**. This is the same as calcium because a form of phosphorus, known as phosphate, binds to calcium to form calcium phosphate, to form the hard structure of the bone. Phosphorus also has many other functions in the body, such as:

- It is a structural component of DNA and RNA, which is the genetic material in our cells that code for all the proteins that make up the body. DNA and RNA consist of a sugar-phosphate backbone.
- Phosphorus is an essential part of the main energy molecule in our cells called ATP. ATP is formed from the breakdown of glucose in our cells and consists of three phosphates. When the bond between the second and third phosphate is broken, a consistent amount of energy is released, which is used to perform our daily activities.
- Phosphorus is also needed as a buffer to help maintain the acid/base (pH) balance in the blood and urine. The blood pH needs to be maintained between 7.35 and 7.45 and this is very important as the blood pH determines our breathing rate.
- It is part of the structure of phospholipids that make up the membranes of cells and organelles.

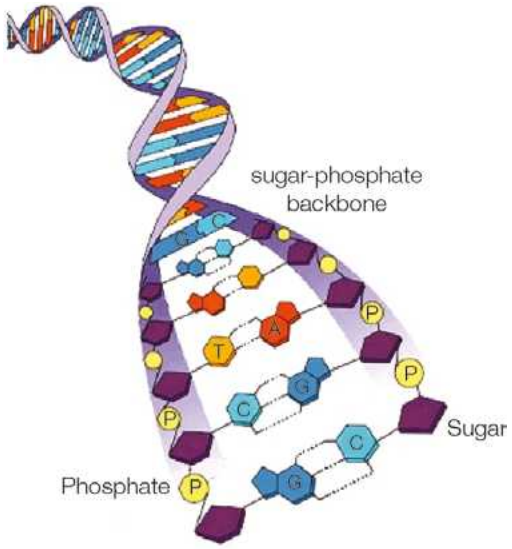


Figure 1.7.4: The structure of a DNA molecule includes a sugar-phosphate backbone that the DNA bases coding for proteins are bound to.

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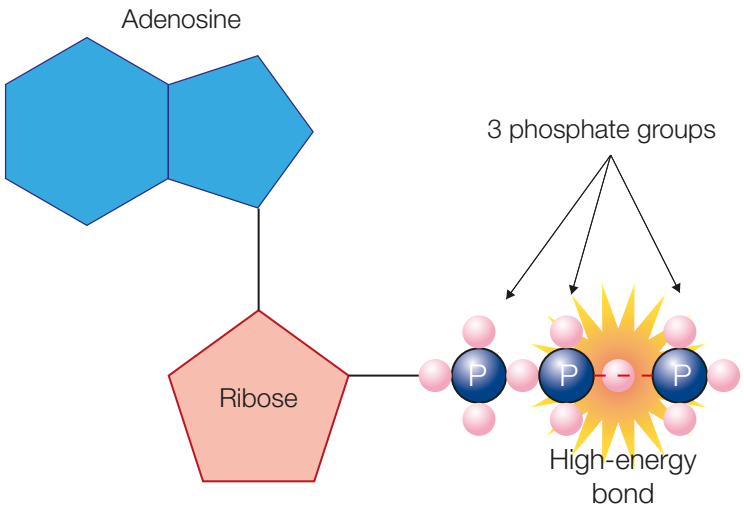


Figure 1.7.5: An ATP molecule consists of three phosphate groups. When energy is needed by cells, the high energy bond between the second and third phosphate group is broken providing the energy needed for cellular activity.

Deficiency and excess phosphorus

A deficiency in phosphorus can lead to poor bone development, especially in children. It can also be associated with bone pain, fatigue and muscular weakness. As phosphorus is present in almost all foods, this is not common and is generally a result of side effects of particular medications.

Iron

Table 1.7.3: The recommended dietary intakes of iron at various stages of life.

Age	Recommended Dietary Intake (mg) per day (for males)	Recommended Dietary Intakes (mg) per day (for females)
1 to 3	9	9
4 to 8	10	10
9 to 13	8	8
14 to 18	11	15
19 to 50	8	18
51 and over	8	8

Sources of iron

Iron is a trace mineral and is essential for making red blood cells. Iron is not very well absorbed by the body. In fact, the average adult male only requires 1mg and the average adult female only requires 1.5mg of iron per day. However, the recommended dietary intake for the average male is 8mg/day and 18mg/day for the average female. This higher recommendation is to account for the poor and varying absorption of iron by the body. Only small amounts of iron are needed because the body is good at retaining its iron and recycling it (especially from recycling red blood cells).

Iron absorption can also depend on the type of food eaten. There are two forms of iron: haem and non-haem iron. Haem iron is only found in animal meats, such as beef, pork, lamb and poultry. Animal meats also contain non-haem iron. However, plant-based products only contain non-haem iron. **Haem iron is more readily absorbed by humans** (approximately 25% absorption) than non-haem iron (approximately 17% absorption). The majority of iron we consume is non-haem iron. Because vegan diets only contain non-haem iron, vegans should be especially aware of foods that are high in iron and techniques that can promote iron absorption. One way to **increase non-haem iron absorption** is to consume the source of iron **with vitamin C.**

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Table 1.7.4: Some examples of foods that are good sources of iron.

Good sources of haem iron	Good sources of non-haem iron
Beef steak	Leafy greens, such as spinach and kale
Oysters	Whole grains, such as oats and quinoa
Minced meat	Soybeans and tofu
Chicken breast	Legumes, such as lentils and chickpeas
Tinned tuna	Seeds, such as pumpkin and sesame
Beef liver	Nuts, such as pine nuts and cashews

Functions of iron

Iron is mainly used in the body to make two proteins called **haemoglobin** and **myoglobin**. Haemoglobin is the protein that makes up red blood cells. The word haemoglobin translates to 'iron' (haem) and 'protein' (globin). The haem atom of the protein accepts oxygen as it diffuses from the lungs into the blood and delivers it to the body's cells to use it in aerobic respiration (makes energy). Therefore, iron is essential for the energy purposes of body cells. Myoglobin is a similar protein to haemoglobin in muscles. Myoglobin also consists of a haem atom and protein. Haemoglobin delivers oxygen to myoglobin in muscles. Myoglobin stores this oxygen and delivers it to the energy producing mitochondria in the muscle cells when energy is required.

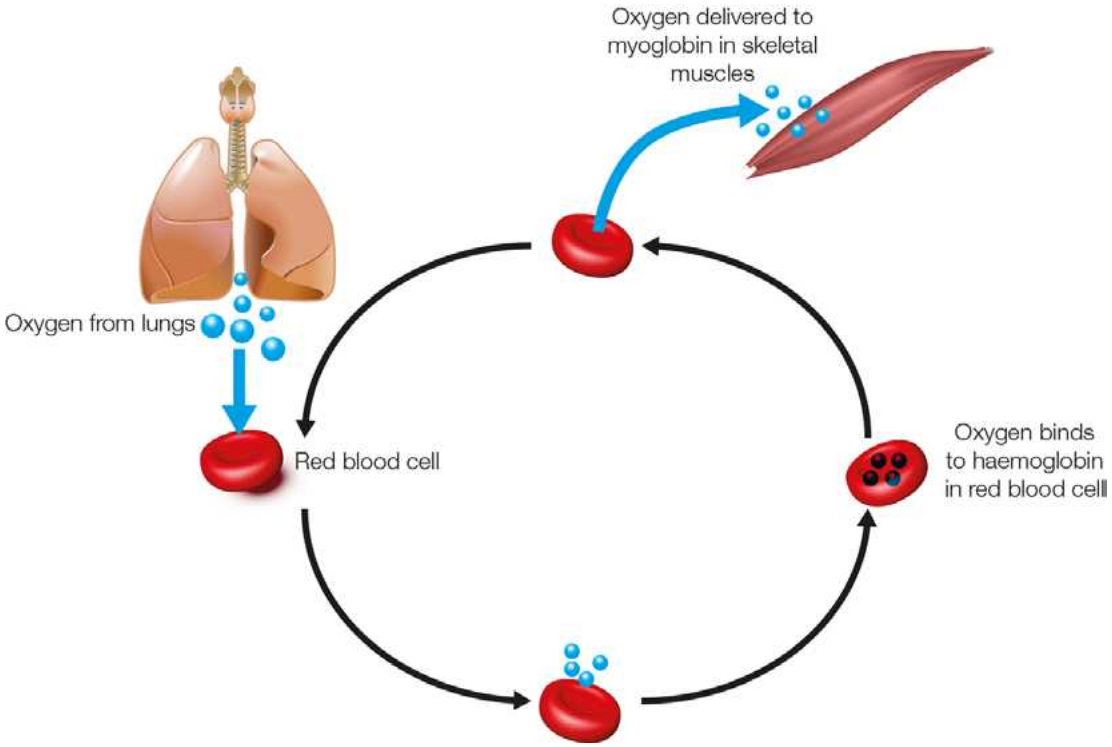


Figure 1.7.6: The transport of oxygen from our lungs to our skeletal muscles involves red blood cells carrying it to them through the blood.

Deficiency and excess iron

Iron deficiency is the most common deficiency disease worldwide. It is most prominent in developing countries but it is also very common in developed countries, including Australia. Iron deficiency can occur in all age groups but it is more common in adolescents due to rapid growth; women in their reproductive years due to loss of blood; and pregnant and lactating women who require extra iron for the development of the baby. If iron deficiency is severe, **iron deficient anaemia** can develop. The severe depletion of iron stores means that not enough haemoglobin can be made to make normal red blood cells. Due to the lack of haemoglobin, the red blood cells produced are much smaller in size and pale. This can result in many symptoms associated with a lack of energy, such as trouble concentrating, feeling irritable, behaviour problems and sometimes severe fatigue. This is discussed in more detail in Topic 2: Dietary disorders.

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Iron absorption is dependent on the body's requirements. If the body is low on iron, then absorption is increased and vice versa. Therefore, it is not common for toxic levels of iron to build up in the body. If this does occur, it is generally because of a disorder or excessive iron supplementation. Some symptoms of iron toxicity are nausea, vomiting, diarrhoea, irregular heartbeat and confusion. Too much supplementation can result in death, especially in small children.

Did you know?

In some iron deficient cases, a condition called **pica** can develop. Pica is a rare symptom where the sufferer wants to eat non-food substances like clay, hair, dirt or ice. This condition is poorly understood but it can be used as a sign that the body is trying to 'treat' a nutrient deficiency. Pica can be treated with medication or supplements, but if left untreated it can result in anaemia.

Science as a Human Endeavour 3

Genetically modified rice

According to the World Health Organisation (WHO), approximately 25% of the world's population is anaemic and half of these cases are due to iron deficiency. The majority of these cases occur in developing countries where the staple diet consists of rice but rice is not rich in iron. In 2018, Navreet Bhullar from the Institute of Molecular Plant Biology at ETH Zurich and his team of researchers were successful in genetically modifying rice that has increased iron and zinc in the white part of the rice grain. This is possible because edits to the rice genome resulted in increased uptake of iron through the roots and the rice plant mobilising its iron stores to increase the concentration of stores in the white rice grain. This modified rice plant can produce rice with approximately 90% of the recommended iron intake and 170% of recommended zinc intake. However, the rice plants have not had field trials yet so it is unknown how much iron and zinc will be mobilised to the rice grains when grown outside of lab conditions. Bhullar and his team are aiming to make a line of rice that incorporates increased iron and zinc as well as increased vitamin A. Their team has been partially successful. They have been able to produce a line of rice incorporating all three micronutrients but it has significantly lower levels of vitamin A than current golden rice lines.

Questions

1. Discuss how the **application** of the genetically modified rice that enriches iron and zinc in the rice grains could affect society.

(6 marks)

2. Discuss three **limitations** of the genetically modified rice studies mentioned in the passage.

(6 marks)

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Iodine

Table 1.7.5: The recommended dietary intakes of iodine at various stages of life.

Age	Recommended Dietary Intakes (µg)
1 to 8	90
9 to 13	120
14 and over	150

Sources of iodine

Iodine is an essential trace mineral that the body needs to make a hormone in the thyroid called thyroxine (also known as T4). The majority of iodine in our diet comes from the ocean, therefore foods associated with the ocean, such as fish and seafood, are good sources of iodine. Iodine is also found in our soil, particularly soils close to the ocean or that were once covered by the ocean. The amount of iodine in fruits and vegetables varies and depends on the soil it is grown in and the fertiliser used. Because mild iodine deficiency is re-emerging in Australia, it is **mandated that breads are to be fortified with iodine** (except for organic bread). It is also possible to buy and consume iodised table salt to use at home. Some good sources of iodine are:

- Fish, such as cod and tuna and seafood such as shrimp
- Dairy products, such as milk, cheese and yoghurt
- Seaweed
- Fortified breads (except organic bread)
- Iodised salt.



Figure 1.7.7: Using iodised table salt instead of normal table salt is a good way to increase iodine in the diet.

Functions of iodine

Iodine is an important constituent of thyroid hormones triiodothyronine (T3) and thyroxine (T4), which are involved in **regulating growth, development, metabolism and thermoregulation** (maintaining body temperature). Thyroxine is a hormone made in the thyroid that is released into the blood to communicate to cells to increase metabolism. The cells increase chemical reactions such as aerobic respiration in response to elevated levels of thyroxine, which burns energy and increases heat production. The excess heat produced helps to maintain the resting body temperature. As thyroxine is involved in regulating the metabolic rate and energy production, it is also important for the cell division required for growth and development.

Deficiency and excess iodine

Iodine is readily absorbed by the body, so deficiencies are generally linked to deficient intakes. If an individual is iodine deficient, there is less iodine available to make a sufficient amount of the hormone thyroxine. This can result in a condition called **hypothyroidism** ('hypo' means low and 'thyroidism' refers to thyroid hormones). Hypothyroidism can cause symptoms such as **weight gain, feeling cold and fatigue.** This is because there is not enough thyroxine hormone produced to communicate to the cells to burn energy, resulting in fatigue. The energy is being stored instead of burnt and less heat is produced because of the lower amount of chemical reactions occurring, leaving the body feeling colder. Another complication of iodine deficiency is the development of a **goitre**. When less thyroxine is produced, the thyroid is signalled to increase its uptake of iodine. As a result, the thyroid enlarges trapping more iodine and may become visible as a lump in the throat referred to as a goitre. Mild iodine deficiency has re-emerged in Australia. Some possible reasons for this are:

- There is **less iodine in soils today** due to poor farming techniques and nutrient leaching through irrigation, rain, wind and natural disasters like flooding;
- Salt is added to many processed foods but they generally do not contain iodised salt and are therefore not good sources of the mineral; and
- Australians are using less iodised salt when cooking at home and in restaurants.

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An excess of iodine can also result in a goitre. The deficiency in iodine accounts for the vast majority of goitre cases but a small amount of goitres can occur from an excess of iodine. This is because increased iodine can stimulate increased thyroxine production and swelling of the thyroid. Sometimes **hyperthyroidism** can develop due to an excess intake of iodine. Hyperthyroidism ('hyper' means over) is the overproduction of thyroxine, which results in an increased metabolic rate. Some symptoms that occur due to the increased energy consumption are weight loss, increased appetite and restlessness.



Figure 1.7.8: A picture of a goitre.

Did you know?

Hypothyroidism is not just caused by a deficient intake of iodine. There are more common causes of hypothyroidism, such as autoimmune disease and taking certain medications. Approximately 90% of hypothyroidism cases occur in females. It is not known why this condition affects females more than males. The common treatment is to take synthetic thyroxine but the correct amount has to be administered. Hypothyroidism can be managed and it is recommended to see a qualified endocrinologist (a doctor that specialises in hormones and how they affect the body) for the correct treatment advice.

Sodium

Table 1.7.6: The adequate intakes of sodium at various stages of life.

Age	Adequate Intakes (mg) per day
1 to 3	200 to 400
4 to 8	300 to 600
9 to 13	400 to 800
14 and over	460 to 920

N.B. The upper limit of sodium was set at 2300mg/day in 2006 but this was based on limited data. The upper limit was revised in 2017 to 'not determined' because a level at which a lower risk of high blood pressure would occur could not be determined.

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Sources of sodium

Sodium is a major mineral that is mainly **located in the extracellular fluid** (fluid outside of cells). It is mainly consumed as sodium chloride (table salt). Sodium chloride **dissociates to sodium (Na^+) and chloride (Cl^-) when dissolved in water** (see Figure 1.7.10). Table salt is often added to foods when processed to add flavour or to preserve them. Some examples of rich sources of sodium are:

- Processed meats, such as ham and salami
- Processed cheeses
- Pizza (as it generally contains processed meats and cheese)
- Sandwiches (as they generally contain processed meats and cheese)
- Stocks and sauces, such as beef stock and soy sauce
- Canned vegetables
- Pretzels
- Biscuits.



Figure 1.7.9: Processed meats are rich in sodium because it is used to add flavour and preserve the meats. Processed meats are commonly found in sandwiches and on pizzas, so they are also rich sources of sodium.

Functions of sodium

Sodium has multiple functions in the body. Two of the major functions are maintaining extracellular fluid balance and assisting in nerve stimulation and muscle contraction/relaxation. An example of sodium's important role in fluid balance is **maintaining blood volume**. Sodium attracts and holds water, therefore; higher levels of sodium in the blood equals higher levels of water. This can increase the blood volume. As sodium is excreted from the body through the kidneys, water follows the sodium into the urine and the normal blood volume can be restored. Sodium also works in conjunction with the mineral potassium (K) to **assist in nerve impulses and muscle contractions**. For example, the cell membrane of nerve cells coordinates differences in sodium and potassium concentrations between the internal and external environments. Sodium is more concentrated outside the cell and potassium is more concentrated inside the cell. For a nerve impulse to occur, proteins in the cell membrane transport sodium into the cell. For the nerve impulse to end, protein channels transport potassium out of the cell. This concentration gradient is then reset so future impulses can occur.

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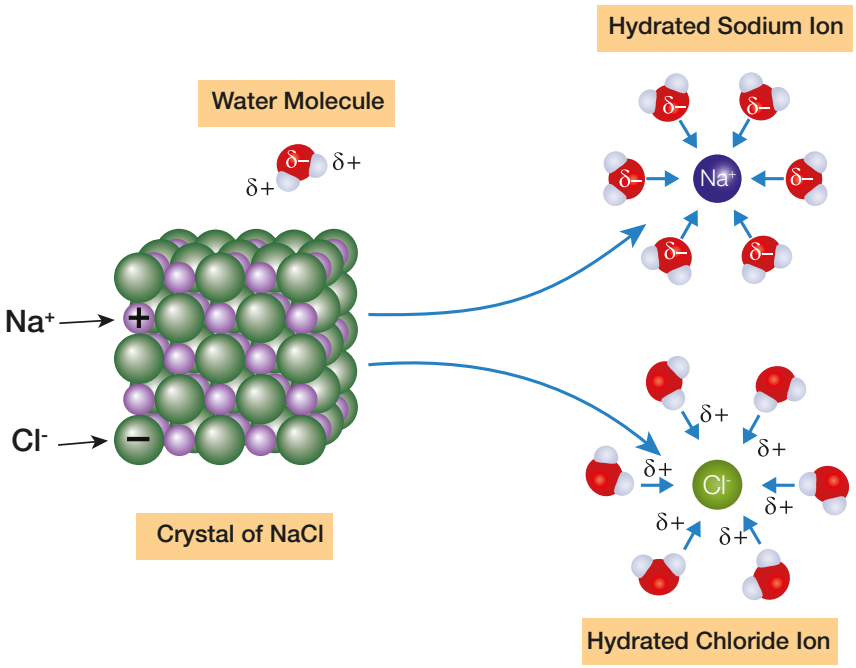


Figure 1.7.10: A visual representation of how table salt attracts and holds water. Table salt dissociates into its two ions (Na^+ and Cl^-) in water. As the two ions are charged, the slightly charged water molecules are attracted to the ions and multiple water molecules bond to the charged ions surrounding them.

Deficiency and excess sodium

Most Australians generally consume sufficient or excess sodium because sodium is 'hidden' in processed foods. For example, one ham and cheese sandwich contains approximately 1,300mg of sodium, which exceeds the daily adequate intake. Excessive consumption of sodium can increase blood pressure (**hypertension**) and the risk of developing cardiovascular disease. Increased sodium in the blood increases blood volume because sodium attracts and holds water in the blood. This increases blood pressure because it makes the heart work harder to push a greater blood volume around the body.

Decreased sodium levels in the blood can occur when individuals are sick or through eating disorders, resulting in large volumes of water and sodium loss through vomiting, diarrhoea and excessive sweating. The sodium deficiency must be replenished (along with water). The loss of sodium caused by excessive sweating during prolonged exercise can also contribute to muscle cramps.

Potassium

Table 1.7.7: The adequate intakes of potassium at various stages of life.

Age	Adequate Intakes (mg) per day (for males)	Adequate Intakes (mg) per day (for females)
1 to 3	2000	2000
4 to 8	2300	2300
9 to 13	3600	2500
14 to 18	3000	2600
19 and over	3800	2800

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Sources of potassium

Potassium is a major mineral that is a **constituent of intracellular fluid** (the fluid inside of cells). Good sources of potassium are whole foods that have not been processed. This is because all cells contain potassium. Some examples of whole foods rich in potassium are:

- Leafy greens, such as spinach
- Legumes, such as white beans and black beans
- Pumpkin
- Potatoes, including sweet potato
- Fruits, such as watermelon, bananas and avocados
- Meats.

Functions of potassium

Like sodium, potassium is important in **maintaining fluid balance** in the body and assisting in **nerve impulses and muscle contraction**. During nervous impulses and muscle contractions, potassium (inside cell) and sodium (outside cell) briefly exchange places. This assists in nervous messages being sent and muscles contracting. The cell then quickly pumps both elements back to their original places.



Figure 1.7.11: Both potassium and sodium are required for nerve impulses and muscle contraction, allowing us to perform our daily activities and exercise.

Deficiency and excess potassium

Like sodium, decreased potassium levels can occur through being sick due to vomiting and excessive sweating. However, it can also be caused by the use of diuretics (drugs that promote water loss in the urine). Potassium deficiency can lead to muscle weakness and irregular heartbeats because the heart is made of muscle which requires potassium to contract.

It is not common for a toxic level of potassium to be consumed unless potassium supplements are taken. Potassium supplements are not recommended because an excess of potassium can interfere with the muscle contractions of the heart causing irregular heartbeat.

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1.7 Review questions

1. Determine if the following statement is true or false **and** justify your answer.

   "Major minerals are more important than trace minerals because they are needed in greater amounts."

   (2 marks)

2. With regards to bone development, describe why it is important for both elements calcium and phosphorus to be consumed.

   (2 marks)

3. Explain why residents of the United Kingdom who work in an office job are more likely to be calcium deficient during winter.

   (3 marks)

4. Describe **two** reasons why adolescents require adequate iron intake.

   (2 marks)

5. Suggest a possible reason why Indigenous Australians could be at higher risk of anaemia than the average Caucasian adult.

   (2 marks)

6. (a) Explain the concern associated with a chronic excess amount of sodium in the diet.

   (4 marks)

   (b) Describe **three** ways that an individual could reduce their sodium intake.

   (3 marks)

7. (a) Name **two** foods that are good sources of *both* calcium and phosphorus.

   (2 marks)

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(b) Describe **two** functions of phosphorus.

(4 marks)

8. (a) Name **two** foods that are good sources of iodine, including one that is suitable for a vegan.

(2 marks)

(b) Describe why iodine is important for the body.

(2 marks)

(c) Describe **two** reasons why mild iodine deficiency is re-emerging in Australia.

(2 marks)

9. Identify the likely type of mineral deficiency that could occur in an individual that donates blood regularly **and** justify your answer.

(4 marks)

E Extension question

Research **and** explain why the recommended dietary intake of calcium increases for women aged between 51 and 70 but not for men.

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1.8 Bioavailability of nutrients

Nutrition Understanding

Many people have the misconception that all the essential vitamins and minerals that we eat are simply absorbed; however, **a lot of the micronutrients we consume don't get absorbed** and travel straight through our body and are excreted in our stools. Furthermore, it is commonly thought that only what we eat affects the nutrients available to our body. However, nutrient absorption, also known as **bioavailability**, can also be affected by other nutrients eaten at the same time. Some foods/nutrients can **increase** the bioavailability of other nutrients, whilst others can **reduce** their absorption.

Calcium, phosphorus and vitamin D

Calcium, phosphorus and vitamin D are all important for the **growth of healthy bones and teeth**. Magnesium and fluoride are also important minerals needed for building bone. Under normal circumstances, **only about 30% of the dietary calcium consumed is absorbed** by the average adult. **Calcium requires vitamin D** to be absorbed; in fact, calcium cannot be absorbed at all without some vitamin D. If there is not enough calcium available, the body will extract it from the bone and teeth to ensure there is enough calcium in the blood (needed for muscle contraction, e.g. by the heart). Phosphorus is found in all cells and is easily obtained in our diet through whole foods. Phosphorus absorption is also increased by vitamin D. **In Australia, it is mandated that margarines are fortified with vitamin D**. Therefore, an easy way to consume vitamin D is to spread margarine on toast for breakfast and consume toast with a glass of milk. Alternatively, some foods can **reduce the absorption** of calcium when consumed at the same time, such as large intakes of **protein**, **sodium, iron** and **caffeine**.

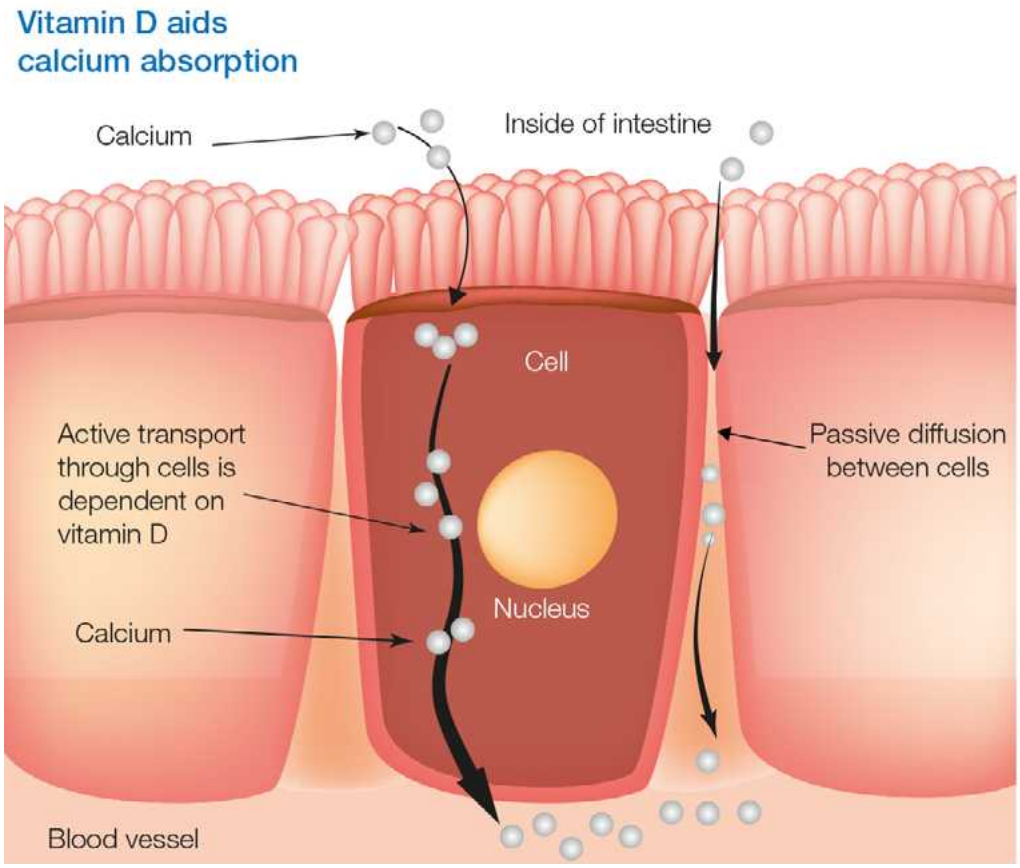


Figure 1.8.1: Calcium absorption occurring across an intestinal epithelial cell into the blood. The active transport process requires vitamin D to transport calcium.

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Iron, vitamin C and calcium

Iron is an important mineral needed for the production of red blood cells that deliver oxygen to our body's cells. Every second our body makes approximately two million red blood cells. **Approximately 18% of iron is absorbed** from a Western mixed diet (animals and plants) and only 10% is absorbed from a vegan diet. There are multiple factors that can affect the bioavailability of iron. Firstly, **haem iron** supplied by animal protein is **more readily absorbed** by the body than non-haem iron from plant sources. Also, **non-haem iron** absorption can be **increased by consuming vitamin C at the same time**. One study reports that non-haem iron absorption was **increased four-fold** by consuming 100mg of vitamin C with non-haem iron food sources. An easy way to do this is by squeezing citrus juice on a steak or by eating a salad at the same time as a piece of meat. Some foods can **reduce** the absorption of iron when consumed at the same time, such as **calcium, caffeinated beverages (including tannins)**, soy products (phytates), eggs, fibre (cellulose), and seeds and nuts containing phytic acid.

Calcium is the only known dietary **inhibitor of both haem and non-haem iron**. The method of inhibition is not clear at this stage. It is suspected that calcium could inhibit absorption of iron from the lumen of the intestines into the epithelial cells (through villi), but it could also inhibit iron transfer from the intestinal epithelial cells into the blood.

As iron deficiency is the most common deficiency worldwide, it is common for iron supplements to be administered to address it. It is important that iron supplements are not consumed with substances that can reduce iron absorption. One example is not to consume liquid iron supplements with flavoured milk (to hide the taste of the liquid iron), as milk contains high levels of calcium. A more suitable option is mixing the iron supplement with orange juice, which contains high levels of vitamin C and very low levels of calcium.

Tannins are a strong inhibitor of non-haem iron. Tannins are found in many plant-based products including tea and coffee. **Tea and coffee are generally deemed the strongest inhibitors of non-haem iron absorption**. Studies have found that one cup of tea can inhibit non-haem iron absorption by approximately 75 to 80%, while a cup of coffee inhibits approximately 60% of its absorption. It is therefore recommended that tea and coffee are not consumed within the 2 hours prior to and after eating, especially for individuals at risk of iron deficiency.



Figure 1.8.2: A steak served with salad. The vitamin C in the salad can increase the bioavailability of iron consumed.

Healthy fats and fat-soluble vitamins

There are four fat-soluble vitamins: A, D, E and K. These vitamins are absorbed better when consumed **with fats and oils**. Generally, leafy greens contain vitamin K and yellow/orange vegetables contain vitamin A. One way to increase bioavailability of fat-soluble vitamins is to add nuts/seeds or apply an oil-based dressing to salads. Where possible, it is better to consume healthy fats and oils, such as avocado, nuts and seeds. In Australia, it is optional for milk suppliers to fortify milk with vitamin D. Although this would help increase calcium absorption, vitamin D absorption requires fats so this would be less effective for low fat milk.

Helpful online resources

Science Insider: Foods That Get Healthier When You Eat Them Together

https://www.youtube.com/watch?v=s2wUJzfN5_0

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1.8 Review questions

1. There is 2.6mg of iron in 100g of beef. State whether all of this iron will be absorbed by the body if the 100g of beef is consumed, **and** justify your answer.

(2 marks)

2. (a) Name **and** justify **two** modifications that could increase iron absorption of the following salad:

Amount	Ingredient
1 cup	Iceberg lettuce
1	carrot
100g	cucumber
Half of	tomato

(4 marks)

(b) Identify **two** modifications to the salad that could increase the bioavailability of vitamin A? Justify your modifications.

(4 marks)

3. Name **two** sources that can inhibit the absorption of iron.

(2 marks)

4. Describe **two** reasons why not all calcium in a cappuccino is absorbed by the body.

(2 marks)

5. Describe why a female might need to be more aware of her iron absorption than a male.

(2 marks)

E Extension question

During pregnancy, an increased amount of micronutrients are needed for the production of the placenta, increased blood volume and the provision of nutrients to the growing foetus. However, the recommended amount of calcium for a woman over 18, regardless of whether she is pregnant or not, remains the same. Research and explain why the recommended calcium intake does not increase from 1,000mg per day as a result of pregnancy.

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1.9 Nutrient and energy density

Nutrition Understanding

All foods contain nutrients and energy but some foods are more beneficial to our body than others.

Nutrient density

The most useful way to compare a food's benefit to the body is by calculating its **nutrient density**. Nutrient density is a measure of the amount of nutrients a food supplies per kilojoule. Foods that supply a **high amount of nutrients per kilojoule** are termed 'nutrient dense'.

It can be very hard to compare foods' nutrient density because one food might contain more of one nutrient but less of another. There are multiple systems that have been derived to compare the total nutrient density of foods. One example is Dr Fuhrman's Aggregate Nutrient Density Index (ANDI) Score, which ranks foods based on how many nutrients the food supplies per kilojoule.

Helpful online resources

Refer to the link below to see how 72 different foods scored according to an example of a nutrient density scale - Dr Fuhrman's Aggregate Nutrient Density Index Scores.

https://www.drfuhrman.com/content-image.ashx?id=73gjzcgyvqi9qywfg7055r

A simple way to compare foods' nutrient density is to directly compare the amount of one particular nutrient per kilojoule. To do this, we need to use the following formula:

Formula

$$\text{Nutrient density} = \frac{\text{Nutrient (g/mg/µg)}}{\text{Energy (kJ)}}$$

Example question

One cup of skim milk provides 575kJ and 300mg of calcium, whereas half a cup of cooked spinach provides 189kJ and 122mg of calcium. Determine which of the two foods is more calcium dense.

Calcium density of skim milk $= \frac{\text{Nutrient (mg)}}{\text{Energy (kJ)}}$

$= \frac{300}{575}$

$= 0.52$ mg of calcium per kJ

Calcium density of cooked spinach $= \frac{\text{Nutrient (mg)}}{\text{Energy (kJ)}}$

$= \frac{122}{189}$

$= 0.65$ mg of calcium per kJ

Therefore, half a cup of cooked spinach is more calcium dense than a cup of skim milk by 0.13 mg/kJ.

This formula can be used to calculate the macronutrient or micronutrient density when comparing any foods. For example, the protein density of two foods could be compared.

Generally, foods that are considered nutrient dense are whole foods such as **plant-based foods.** The more foods are processed, the more nutrients they lose. Also, processed foods generally have added sugars, salts and fats to make them taste better. To avoid overeating, it is best to choose foods that are nutrient dense. This allows us to get the most nutrients for the least amount of energy.

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Figure 1.9.1: Some examples of nutrient dense foods.

Energy density

Alternatively, some foods are described as **energy dense**. Energy density is a measure of the amount of kilojoules per gram (or comparable size/weight). For example, 100g of fresh banana contains 363kJ, whereas 100g of dried banana chips contains 1,453kJ. Therefore, dried banana chips are more energy dense than fresh banana. Generally, foods that are low in nutrient density (such as **lollies**, **soft drinks** and **crisps**) are energy dense and deliver '**empty kilojoules**'. To compare the energy density of two foods, the following formula is used:

π Formula

$$\textbf{Energy density} = \frac{\textbf{Energy (kJ)}}{\textbf{Amount of food (g)}}$$

Example question

One cup (250g) of skim milk provides 575kJ of energy, whereas half a cup (113g) of cooked spinach provides 189kJ. Determine which of the two foods is more energy dense.

$$\text{Energy density of skim milk} = \frac{\text{Energy (kJ)}}{\text{Amount of food (g)}} = \frac{575}{250} = 2.3 \text{ kJ/g}$$

$$\text{Energy density of cooked spinach} = \frac{\text{Energy (kJ)}}{\text{Amount of food (g)}} = \frac{189}{113} = 1.7 \text{ kJ/g}$$

Therefore, a cup of skim milk is more energy dense than half a cup of cooked spinach by 0.6 kJ/g.



Figure 1.9.2: Some examples of energy dense foods.

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Energy values of macronutrients

Macronutrients provide the body with energy when they are metabolised. This energy can either be used or stored, depending on the body's need at the time. In Australia, the amount of energy our food and drink supplies us with is measured in **kilojoules (kJ)**. Another measurement of energy that is used (especially in America) is **calories (Cal)**. To convert calories to kilojoules, the number of calories needs to be multiplied by 4.2. To convert kilojoules to calories, the number of kilojoules needs to be divided by 4.2.

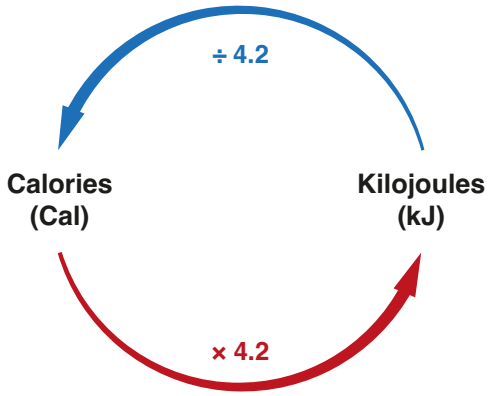


Figure 1.9.3: Kilojoules to calories conversion guide.

It is important to understand that macronutrients supply the body with different amounts of energy. **Lipids** are the **most energy dense** macronutrient, supplying the body with **37.7 kJ/g**. Whereas, **carbohydrates and proteins supply us with 16.7 kJ/g**. There is also another molecule that the body can extract energy from: **alcohol**, which supplies the body with **29.3 kJ/g**.

π Formula

Energy in carbohydrates (kJ) = amount of carbohydrates (g) × 16.7 kJ/g

Energy in protein (kJ) = amount of protein (g) × 16.7 kJ/g

Energy in lipids (kJ) = amount of lipid (g) × 37.7 kJ/g

Total energy in food (kJ) = energy in carbohydrates (kJ) + energy in protein (kJ) + energy in lipids (kJ)

Acceptable macronutrient distribution ranges (AMDR)

It is important that we eat a variety of the different macronutrients in our diet; however, there is **no international agreement** on the amount of macronutrients we should eat. In Australia, we are guided by the acceptable macronutrient distribution ranges (AMDR), one of the Nutrient Reference Values (NRV), to achieve an adequate intake of the macronutrients and support positive health outcomes. Currently, the suggested AMDRs are:

- **Lipid (fat)** consumption is between **20-35%** of daily energy intake (of which **saturated** fats make up **10%** or less).
- **Carbohydrate** consumption makes up **45-65%** of daily energy intake. This should mostly consist of complex carbohydrates (only **10-15%** should be from **simple sugars**).
- **Protein** should be between **15-25%** of daily energy intake (or one gram per kilogram of body weight).

It is also important to remember that our daily intake should also address the recommended **NRV** for **dietary fibre.** The NRV of fibre for females is 25 g/day and 30g/day for males.

Calculating the amount of energy and the energy distribution in foods

To calculate the **total amount of energy** in a particular food, the number of carbohydrates, proteins and lipids (in grams) is multiplied by the respective energy per gram each macronutrient supplies. These values are then added together to obtain the total energy supplied by that food. Furthermore, the **energy distribution** of each macronutrient can be calculated by determining the percentage of energy each macronutrient supplies and these values can be compared to the AMDRs. The following formula can be used to determine the percentage energy distribution of macronutrients:

π Formula

$$\textbf{Percentage energy distribution} = \frac{\textbf{energy provided by macronutrient}}{\textbf{total energy in food}} \times 100$$

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Example question

A pasty contains 43g of carbohydrate, 20g of lipid and 11g of protein.

(a) Calculate the number of kilojoules of energy provided from each of these macronutrients and the total energy in the pasty.

Energy in carbohydrates = amount of carbohydrates × 16.7 kJ/g
= 43 × 16.7
= 718.1 kJ

Energy in protein = amount of protein × 16.7 kJ/g
= 11 × 16.7
= 183.7 kJ

Energy in lipids = amount of lipid × 37.7 kJ/g
= 20 × 37.7
= 754 kJ

Total energy in pasty = energy in carbohydrates + energy in protein + energy in lipids
= 718.1 + 183.7 + 754
= 1655.8 kJ

(b) Calculate the percentage energy distribution of the three macronutrients in the pasty. Round your answers off to the nearest whole number.

$$\text{Energy distribution of carbohydrates} = \frac{\text{energy provided by carbohydrates}}{\text{total energy in pasty}} \times 100$$

$$= \frac{718.1}{1655.8} \times 100$$

$$= 43.37$$

$$= 43\%$$

$$\text{Energy distribution of protein} = \frac{\text{energy provided by protein}}{\text{total energy in pasty}} \times 100$$

$$= \frac{183.7}{1655.8} \times 100$$

$$= 11.09$$

$$= 11\%$$

$$\text{Energy distribution of lipids} = \frac{\text{energy provided by lipids}}{\text{total energy in pasty}} \times 100$$

$$= \frac{754}{1655.8} \times 100$$

$$= 45.54$$

$$= 46\%$$

Tip: To check that your calculations are correct, you can add the three percentages together and check if they add up to 100%.

Check: 43% + 11% + 46% = 100%

(c) Compare the energy distribution of the three macronutrients in the pasty to the acceptable macronutrient distribution ranges (AMDR).

Carbohydrates: The AMDR for carbohydrates is 45-65% and the energy supplied by carbohydrates in the pasty is approximately 43%. This is slightly less than the AMDR (by 2%).

Proteins: The AMDR for protein is 15-25% and the energy supplied by protein in the pasty is approximately 11%. This is less than the AMDR by 4%.

Lipids: The AMDR for lipids is 20-35% and the energy supplied by lipids in the pasty is approximately 46%. This is significantly higher than the upper limit of the AMDR by 11%.

(d) What recommendations would you make for an individual who ate a pasty for lunch, in terms of food selection, for the remainder of the day?

The individual would need to choose foods (especially for dinner) that are lower in fat and higher in protein and carbohydrates to align their total daily intake with the recommended AMDRs.

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1.9 Review questions

1. Describe the difference between nutrient density and energy density.

(2 marks)

2. Two slices of white bread fortified with folic acid provides 1,010kJ and 211µg of total folate, whereas 100g of cooked broccoli provides 114kJ and 200µg of total folate. Calculate the nutrient (folate) density of each food **and** state which food is more folate dense.

(2 marks)

3. A 360g block of chocolate contains 7,887kJ, whereas a 175g packet of potato crisps contains 3,661kJ. Determine which food is more energy dense by calculating the energy density of each food.

(2 marks)

4. State whether the foods shown below are nutrient dense or energy dense:



(a) A hamburger



(b) A salad



(c) An apple



(d) A milkshake

(a)

(b)

(c)

(d)

(4 marks)

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5. In a 375mL bottle of pale ale (beer), there is 7.9g of carbohydrates and 19.1g of alcohol. The beer does not contain any protein or lipids. Calculate the total energy in a 375mL bottle of pale ale.

(3 marks)

6. A chicken burger contains 22.3g of lipids, 41.3g of carbohydrates and 19.7g of protein.

   (a) Calculate the number of kilojoules of energy provided from each of these macronutrients **and** the total energy in the burger.

(4 marks)

   (b) Calculate the percentage energy distribution of the three macronutrients in the chicken burger. Round your answers to the nearest whole number.

(3 marks)

   (c) Compare the energy distribution of the three macronutrients in the chicken burger to the acceptable macronutrient distribution ranges (AMDR).

(3 marks)

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7. Please refer to the following table to answer questions (a) to (e):

Nutrient	100g of beef	½ cup of raw spinach
Energy (kJ)		
Carbohydrate (g)	0.00	4.7
Protein (g)	29.5	2.4
Fat (g)	16.4	0.3
Iron (mg)	2.60	3.2

(a) Calculate the total energy provided by the beef and the raw spinach **and** write your answer (rounded to the nearest whole number) in the table above.

(4 marks)

(b) Calculate the energy distribution of the three macronutrients in the 100g of beef. Provide your answer as rounded to the nearest whole number.

(3 marks)

(c) Compare the energy distribution of the three macronutrients in the 100g of beef to the acceptable macronutrient distribution ranges (AMDR).

(2 marks)

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(d) Calculate the nutrient density of iron in the 100g of beef and ½ a cup of raw spinach. State which food has a greater iron density.

(3 marks)

(e) Calculate the nutrient density of protein in the 100g of beef and ½ a cup of raw spinach. State which food has a greater protein density.

(3 marks)

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1.10 Water

Nutrition Understanding

Water is an **essential nutrient** and it is arguably the most important nutrient. This is because our bodies require more water per day than any other nutrient and we can **only survive days without water.** In contrast, we can survive a few weeks without food (provided we have water). Our bodies are made up of approximately 60% water; therefore, the average 70kg person contains roughly 41kgs of water. Within our body, different tissues have a different composition of water. Muscles generally contain 75% water, whereas fat tissue generally contains 25%. This is a contributing factor to why muscle weighs more than fat. Water is needed for many different processes and also provides the environment for many chemical reactions. If we are water deficient, it can alter the body's chemistry and metabolism, and result in decreased performance both mentally and physically. Water does not directly provide the body with any energy (0kJ/g).

Water balance

Every day we lose water through urine, sweating, breathing and our faeces. Water is very important and any water lost must be replaced otherwise it could cause **dehydration**. The amount of water needed differs from person to person. Men require more water than women; pregnant and lactating women require more water than women who are not; and all people require more water than usual after exercise or on hot days. If too much water is consumed, it can imbalance important electrolyte levels and cause **water intoxication,** which can lead to death.

Did you know?

When we travel in an airplane we can experience mild dehydration. This dehydration can contribute to jet lag and exacerbate the physical symptoms experienced. For example, it is estimated that we can lose up to 1L of water in a flight from Adelaide to Sydney. Therefore, when travelling by air, it is important to drink water before, during and after flights to prevent dehydration and possibly reduce symptoms of jet lag.

Dehydration

When water intake is inadequate, the blood becomes more concentrated. This high concentration signals the brain (hypothalamus) to increase **thirst**. One of the first signs of inadequate water intake is a **dry mouth** (due to the decrease in saliva production). If this thirst is not addressed, the **symptoms** can become progressively more severe ranging from weakness, exhaustion and delirium to death.

The easiest way to determine if we are dehydrated is to **check the colour and volume of our urine**. If our urine is clear and has a high volume, then we are hydrated. However, if our urine is **yellow and low in volume we are likely dehydrated** and need to consume more water. It is important to note that if a multi-vitamin is consumed, it can interfere with the simple urine test. A lot of vitamins require certain nutrients to be absorbed so many can pass through to the urine. Excess water-soluble vitamins are excreted in the urine and this can result in a yellow coloured urine (but high volume). This is **not** a signal of dehydration and is just a sign of vitamins that could not be absorbed (sometimes referred to as 'expensive urine'). See the following chart (Figure 1.10.1) for a more detailed analysis of urine colour and dehydration:



Figure 1.10.1: A colour analysis of urine and respective hydration levels.

Helpful online resources

ASAP Science: What Does Your PEE Say About You

https://www.youtube.com/watch?v=5GIfISN4-G8

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Water intoxication

Water intoxication is when somebody consumes too much water and becomes over-hydrated. This affects the **normal balance of important electrolytes** in the body. It is rare but it can occur with excessive consumption of water. Kidney disorders that reduce urine output can also cause water intoxication. The symptoms of water intoxication may include confusion, headaches, brain swelling, convulsions and even death.

Did you know?

In 2007, a 28 year-old woman who competed in a radio station's contest in America died of water intoxication. The contest was called 'Hold your wee for a Wii' and required the contestants to drink 225mL samples of water every 15 minutes without urinating. The contestant who drank the most water without urinating won a Nintendo Wii. Unfortunately, the young woman and mother of three died from **water intoxication** in the hours following competing in the contest.

Helpful online resources

TED-Ed: Is it bad to hold your pee?–Heba Shaheed

https://www.youtube.com/watch?v=Ze4Qmpq48AQ

Sources of water

The easiest way to consume water is by **drinking water**. However, this is not the only way our bodies can obtain water. **We also consume water in the foods we eat**. Most fruits and vegetables contain above 70% water, as highlighted by Figure 1.10.2. The average person generally requires two litres of water per day, which equates to eight 250mL glasses of water. However, the amount of water needed varies between individuals based on their body composition, activity levels, etc. You have probably heard the highly recognised nutritional advice that we should consume **eight glasses of water per day**. However, this advice is only a guide and not completely accurate because each individual needs a different amount of water and we also consume water through the food we eat. Additionally, our body produces small amounts of water through chemical reactions that occur in the body and this can provide approximately 10% of the body's daily water requirements.

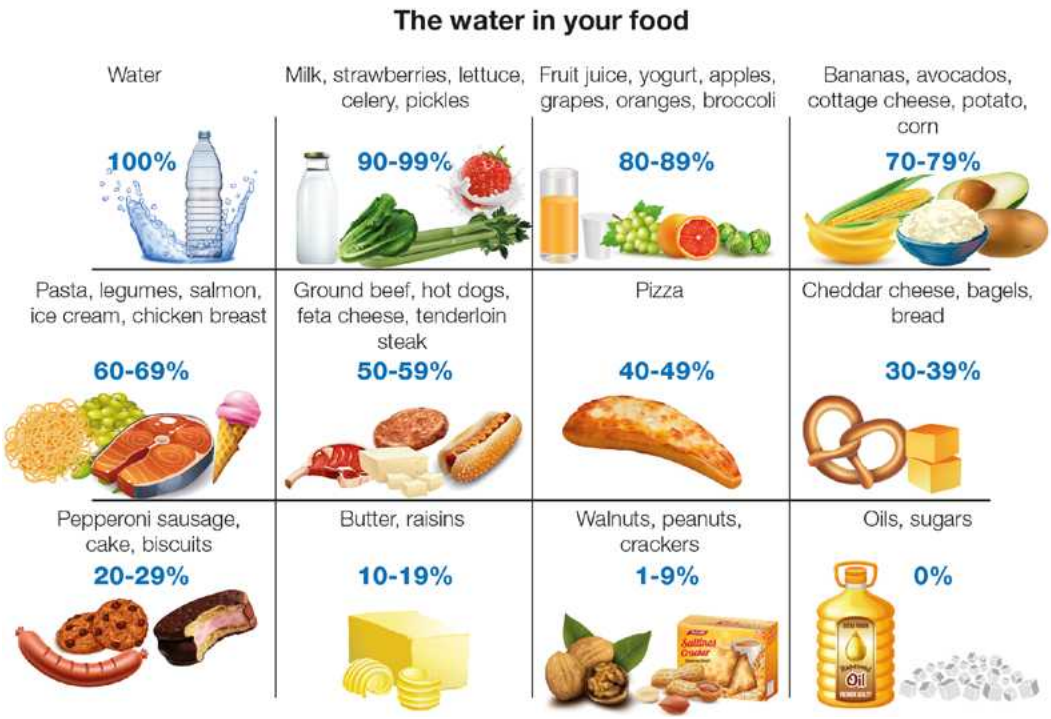


Figure 1.10.2: The percentages of water supplied by the various foods we eat.

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Functions of water

Water is essential for life as the majority of the body's chemical reactions take place within this substance. Water has many different functions within our body. Some important functions of water in the body are discussed below.

Transport of nutrients and maintaining blood pressure

Water makes up approximately 92% of blood volume. As the main constituent of blood, it helps **transport essential nutrients** around the body. Some of these nutrients are glucose and oxygen, which are needed for respiration, and amino acids needed for making proteins, growth and repair.

The amount of water in our blood also helps **maintain blood pressure**. The average volume of blood in an adult is 5.5L of blood. If the volume of blood changes, this causes a direct change in blood pressure. For example, if blood volume increased to 5.6L, this means the heart has to pump an extra 100mL around the body, increasing blood pressure.

Transport of waste products

The chemical reactions that occur in our body produce **waste products** such as **carbon dioxide** and **urea**. If these waste products build up in our body, they can cause complications. An example of this is if carbon dioxide levels rise within the blood, it can lower the blood pH. The pH of our blood is involved in controlling our breathing rate. If our blood pH lowers, this indicates a rise in carbon dioxide levels in the blood and our body responds by increasing our breathing rate. If too much carbon dioxide builds up, it can cause us to faint and may even lead to death. The **water** in our blood helps transport carbon dioxide to the lungs, and urea to the kidneys, so that they can be removed from the body.

Involved in thermoregulation

Water plays a significant role in helping us **maintain our internal blood temperature** of 37°C. When our blood temperature increases above 37°C, one of the mechanisms to help it return to normal is to sweat. **Sweat is mainly comprised of water and electrolytes**. When the sweat is evaporated off of our skin, it takes heat with it and we experience a cooling sensation.



Figure 1.10.3: The sweat produced when we are hot requires water and helps us maintain our internal temperature at 37°C.

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Acts as a lubricant and cushions joints

Water is part of the fluid that exists between our bones and it resists compression, acting as a shock absorber, and **cushioning sensitive joints** such as the spinal cord (see Figure 1.10.4). This allows us to move more freely and exercise without the pain of bones rubbing against one another.

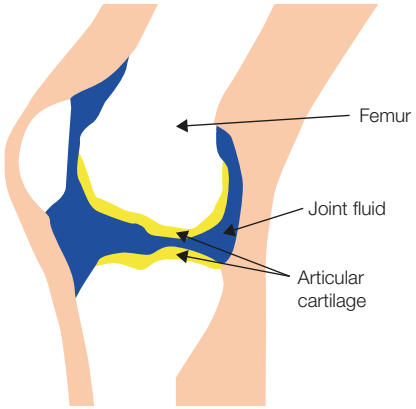


Figure 1.10.4: The fluid between bones can help cushion sensitive joints.

One of the reasons water is needed in the **amniotic sac** is to help to **cushion** the baby as the mother moves around in her everyday life (see Figure 1.10.5).



Figure 1.10.5: A baby born in an amniotic sac containing amniotic fluid.

Water can also act as a **lubricant** in our body. A few examples of this are:

- Water moistens our mouth through **saliva** so that dry foods can be swallowed and move through our digestive system easily.
- Water **lubricates our lungs** so that when they expand, they don't get damaged rubbing against our ribs.
- Water lubricates all tissues that are **moistened by mucus**, such as the digestive and respiratory systems.

Aids the digestive system

The food we eat is made up of complex molecules and it takes time for our body to break it down into more simple molecules that can be absorbed (see Topic 3: Digestion, malabsorption and the microbiome). Initially, water is needed for the production of **saliva** that **lubricates** our mouth and carries an essential enzyme into the mouth to help start the digestion of carbohydrates. It is also needed to help **digest soluble fibre** and **prevent constipation**.

Helpful online resources

TED-Ed: What would happen if you didn't drink water?–Mia Nacamulli

https://www.youtube.com/watch?v=9iMGFqMmUFs&t=17s

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1.10 Review questions

1. Describe why water is considered an essential nutrient.

(2 marks)

2. Explain why an overweight individual could be composed of less water than a bodybuilder.

(3 marks)

3. Discuss how an individual could conduct a simple test at home to determine if they are dehydrated **and** how they could ensure that the sign of dehydration is not caused by consuming a multivitamin.

(3 marks)

4. Most foods contain water. State **and** explain if we can obtain our water needs through eating alone.

(2 marks)

5. Identify which of the following foods would contain the most and least water.



(a) A cube of sugar (b) A slice of pizza (c) A banana

Most water

Least water

(2 marks)

6. Describe **two** roles that water plays within our bodies.

(2 marks)

7. State **two** symptoms of dehydration.

(2 marks)

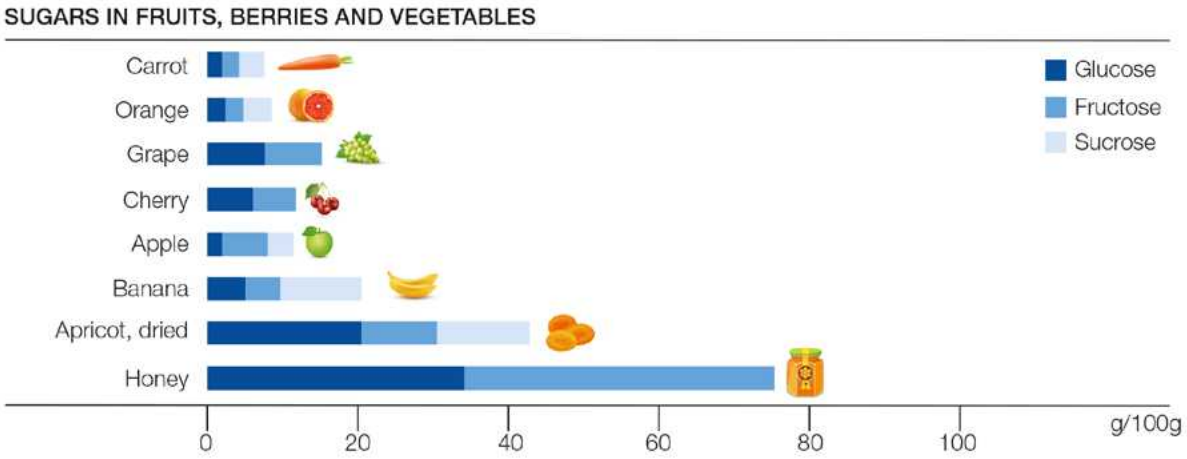
8. To maintain water balance, it is recommended for the average person to consume 2L of water per day. However, the amount of water required can differ depending on the requirements of the body. Explain **two** reasons why water needs could increase/decrease.

(4 marks)

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Topic 1 Review Test

1. Refer to the following graph to answer questions (a) to (d):



(a) State the total amount of simple sugars in bananas.

(1 mark)

(b) Identify which of the three simple sugars represented in the graph is a disaccharide.

(1 mark)

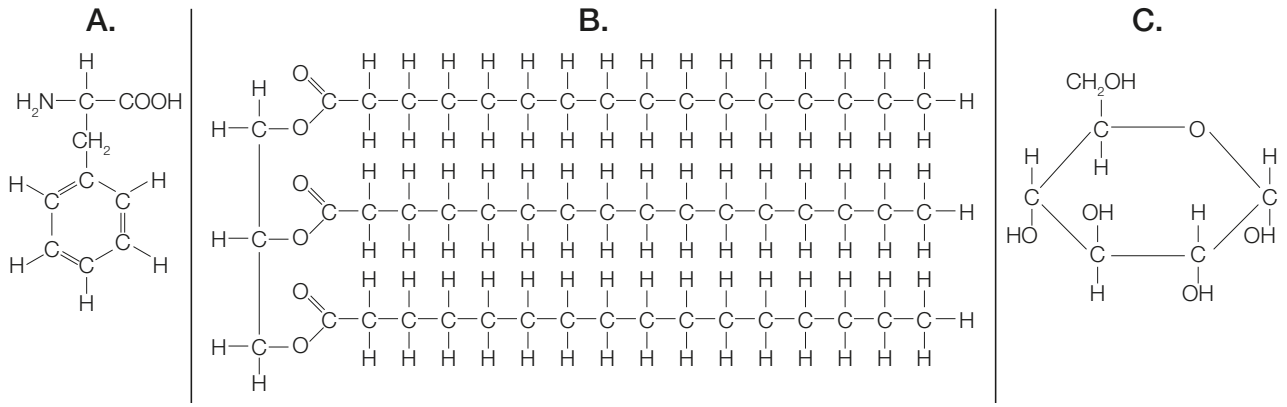
(c) State how much fructose is in honey.

(1 mark)

(d) State **and** explain which fruit, berry or vegetable represented would result in the lowest spike in blood glucose levels based on the information presented in the graph alone.

(2 marks)

2. The structure of the macronutrients can determine properties such as taste and energy potential.



(a) Identify each of the three macronutrients from the chemical structures illustrated above:

A =

B =

C =

(3 marks)

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(b) The table below shows the nutrition information per 100g displayed on the packaging of three breakfast cereals.

Table 1: Nutrition information of various cereals

Breakfast Cereal (per 100g)	Carbohydrate (g)	Sugars (g)	Protein (g)	Fat (g)	Salt (g)
Cereal A	84.0	8.0	7.0	0.9	1.80
Cereal B	68.4	4.4	11.5	2.0	0.65
Cereal C	75.2	21.6	8.1	3.9	1.20

(i) Breakfast cereals are usually high in carbohydrates. Outline **two** main functions of carbohydrates.

(1)

(2)

(2 marks)

(ii) Name a nutrient dense and an energy dense carbohydrate.

Nutrient Dense:

Energy Dense: *(2 marks)*

(iii) Explain which of the two foods listed below (1 or 2) is the healthier option:

(1) A cherry containing 10g of sugar; or

(2) A jellybean containing 10g of sugar.

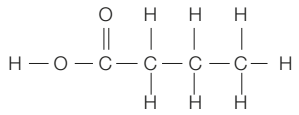
(3 marks)

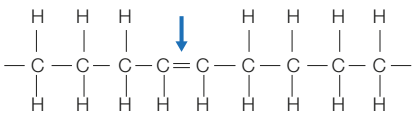
(iv) Using the information provided in Table 1, draw a graph displaying the carbohydrate and sugar content of the three breakfast cereals.

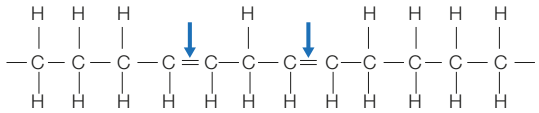
(5 marks)

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(c) Illustrated below are three different fatty acid chains.

A. 

B. 

C. 

Identify the letter corresponding to an illustration of saturated fat: *(1 mark)*

(d) (i) Name **one** fat-soluble vitamin.

(1 mark)

(ii) Describe the importance of this vitamin within the human body.

(2 marks)

(e) Many studies support the recommendations of health authorities that pregnant women consume 1 gram per day of omega-3 (α-linolenic acid).

(i) Outline **one** benefit of omega-3 to a developing foetus.

(1 mark)

(ii) State **two** examples of foods that are high in omega-3.

(1)

(2) *(2 marks)*

3. 'Superfoods' is a marketing term used to describe foods promoted as having nutritional benefits that other foods do not. Refer to the nutrition information in Table 2 below. The superfood green smoothie consists of bananas, milk, and two foods marketed as superfoods (kale and blueberries). The banana milk breakfast drink is a packaged commercial milk drink.

Table 2: Nutritional Information for a Green Smoothie and Banana Milk

Nutrition Information Superfood Green Smoothie			
	Average Quantity per 100mL Serving		Macronutrient Distirbution (%)
Energy		kJ	
Protein	10.4	g	13
Fat total	2.0	g	6
- saturated	1.1	g	
Carbohydrate	68.7	g	81
- sugars	56.2	g	

Nutrition Information Banana Milk Breakfast Drink			
	Average Quantity per 100mL Serving		Macronutrient Distirbution (%)
Energy	630	kJ	
Protein	10.0	g	
Fat total	2.5	g	14
- saturated	0.3	g	
Carbohydrate	23.3	g	59
- sugars	16.8	g	

(a) Using the data in Table 2, calculate the total energy content per 100 millilitre serving of the superfood green smoothie to the nearest whole number. Show all calculations and transfer your result to Table 2.

Total energy content = *kJ (5 marks)*

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(b) Calculate the percentage energy distribution of protein for the banana milk breakfast drink. Show all calculations, round your answer to the nearest whole number, and transfer your result to Table 2.

Percentage energy distribution of protein = % *(3 marks)*

(c) Refer to Table 3, which shows the acceptable macronutrient distribution ranges (AMDRs) (%):

Table 3: Acceptable macronutrient distribution ranges (AMDRs) (%)

	Carbohydrate	Fat	Protein
Recommended Range (%)	45-65	20-30	15-25

Evaluate the macronutrient distribution (%) for the superfood green smoothie and the banana milk breakfast drink in Table 2 against the AMDRs (%) in Table 3.

(6 marks)

(d) The micronutrient profile for kale, one of the superfoods in the green smoothie, is shown in Table 4 below:

Table 4: Micronutrient profile for kale.

Micronutrient	Amount	Daily value (DV)
vitamin C	80.4 mg	134%
vitamin K	547.0 µg	684%
folate	19.4 µg	5%
calcium	90.5 mg	9%
iron	1.1 mg	6%

Identify **one** micronutrient in Table 4 above that may be beneficial for the health of an adolescent female **and** justify your answer.

(2 marks)

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4. Aspartame is an artificial sweetener that is regularly used as a sugar replacement in foods and beverages. Aspartame consists of two amino acids, aspartic acid and phenylalanine as shown in Figure 1.

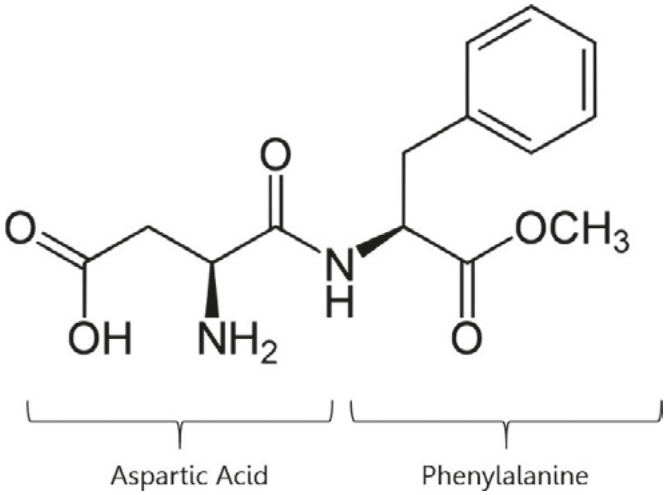


Figure 1: The chemical structure of aspartame.

Refer to Figure 1 to help answer (a).

(a) Name the element found in amino acids that is not found in simple sugars.

(1 mark)

(b) State the term given to amino acids that our bodies cannot synthesise.

(1 mark)

Phenylketonuria (PKU) is an inherited health disorder that prevents the normal breakdown of the amino acid phenylalanine. This results in a build-up of phenylalanine in affected individuals, leading to health issues.

(c) Name a food source that an individual with PKU should avoid consuming in large quantities.

(1 mark)

(d) PKU is treated by limiting protein intake. Identify **two** functions in the body that could be affected by a limited protein intake.

(2 marks)

Refer to Figures 1 and 2 to answer (e).



Figure 2: The nutrition information and ingredients list from a diet cola label.

(e) Using information shown in Figure 2, explain why individuals with PKU should not rely solely in on the Nutrition Information section of the label when determining if they are able to consume a product.

(4 marks)

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5. Recent studies suggest that 36% of women consume less than the average daily requirement of calcium.

   (a) State one function that calcium performs in the body **and** the direct consequence that could occur if an individual is deficient in calcium.

   (2 marks)

   (b) Name **one** vitamin that is necessary for the absorption of calcium and suggest a suitable food source that is rich in this vitamin.

   Vitamin: Food source: *(2 marks)*

6. Refer to Table 5 below to answer questions (a) to (c).

Table 5: Water balance

Water output each day		Water input each day	
Urine	*1.5 litres*	Water contained in food	*0.8 litres*
Faeces	*0.1 litres*	Water produced by the cells	*0.2 litres*
Breathing & sweating	*0.9 litres*	Water in drink	*1.5 litres*
Total	**2.5 litres**	**Total**	**2.5 litres**

   (a) Table 5 highlights the ideal situation of water balance but many people do not achieve this situation each day. Suggest **four** reasons why people do not achieve this level of water balance.

   (1)

   (2)

   (3)

   (4) *(4 marks)*

   (b) Describe the progression of symptoms that may occur if a person consumes less water than they require over several days.

   (3 marks)

   (c) Water is a vital nutrient. Describe **three** functions in the body that will be compromised if an 18 year-old man has insufficient water on a regular basis.

   (3 marks)

7. There are many people in society who choose to be vegan or vegetarian. Their choice could be for a variety of reasons, such as sustainability of food or animal welfare issues.

   (a) Describe the difference between a vegan and a vegetarian.

   (2 marks)

   (b) Vegans are more susceptible to being deficient in a particular vitamin. Name this vitamin **and** explain why they are more susceptible to this deficiency than somebody who eats a 'normal' Western diet.

   (2 marks)

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(c) Vegans also have to be mindful of the protein they consume. Explain why vegans need to take extra care when planning their meals to ensure they meet their protein requirements.

(2 marks)

(d) Name **two** foods that are good sources of calcium for a vegan.

(2 marks)

(e) Describe **two** modifications to the recipe below to make it more suitable for a vegan **and** justify your modifications:

Table 6: Spaghetti bolognese recipe.

Amount	Ingredient
1 tablespoon	Olive oil
500g	Spaghetti
500g	Beef
200g	Mushrooms
2	Tin of diced tomatoes
1 bunch	Basil leaves
1	Brown onion
Sprinkling of	Parmesan cheese

(1)

(2 marks)

(2)

(2 marks)

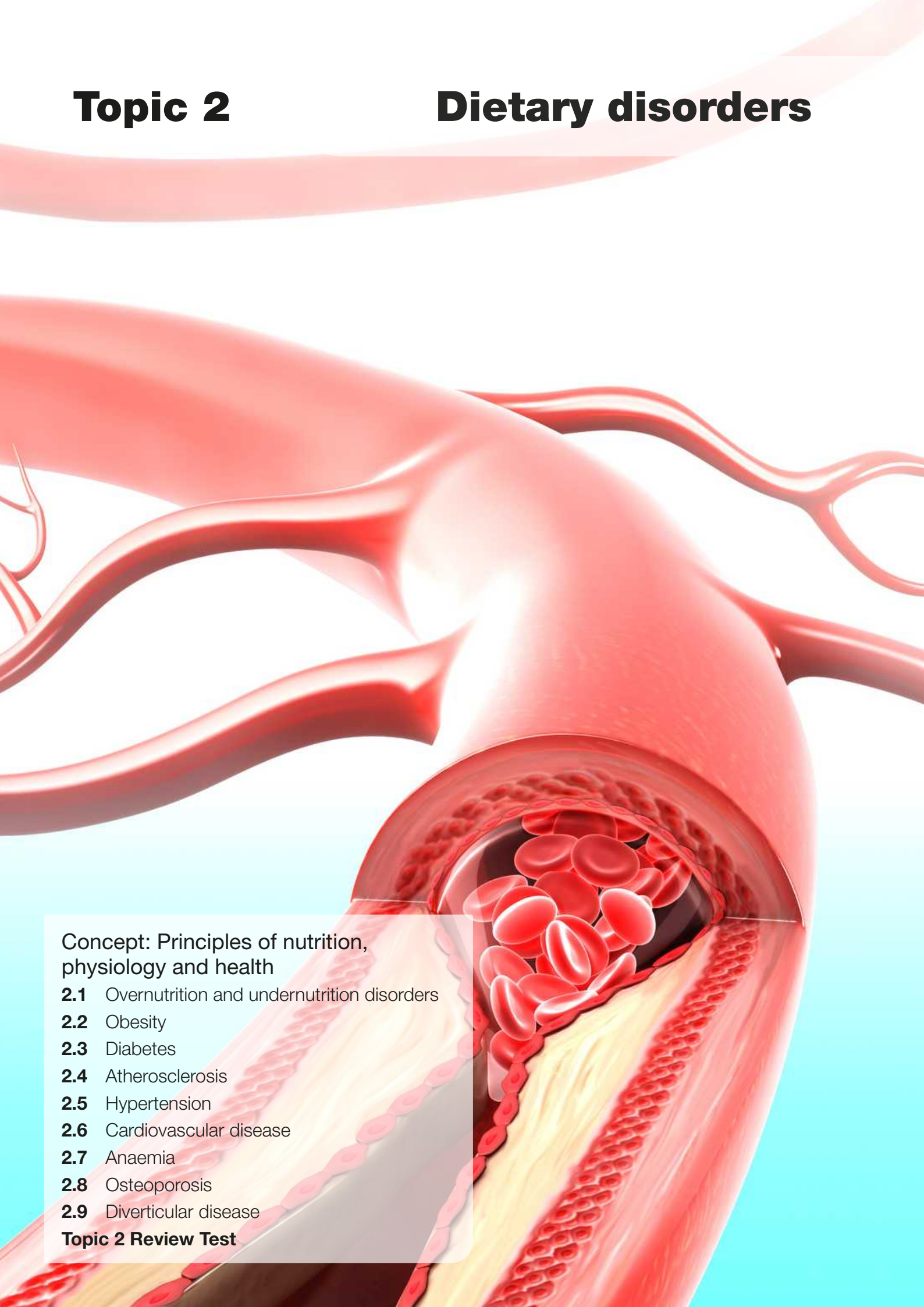
(f) The spaghetti bolognese was served with a side of salad. Explain how eating the salad with the spaghetti bolognese increases the bioavailability of fat-soluble vitamins.

(2 marks)

Total Marks = _____/80

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Topic 2 Dietary disorders



Concept: Principles of nutrition, physiology and health

2.1 Overnutrition and undernutrition disorders
2.2 Obesity
2.3 Diabetes
2.4 Atherosclerosis
2.5 Hypertension
2.6 Cardiovascular disease
2.7 Anaemia
2.8 Osteoporosis
2.9 Diverticular disease
Topic 2 Review Test

2.1 Overnutrition and undernutrition disorders

Nutrition Understanding

Overnutrition is a form of **malnutrition** where there is a regular oversupply of nutrients that can lead to **dietary disorders**. This form of malnutrition occurs when the intake of specific nutrients exceeds the recommended dietary intake (RDI) and the body is supplied with more than is required for its growth and development. Dietary disorders that develop due to overnutrition can negatively affect one's health, contribute to the development of additional disorders and reduce life expectancy. Overnutrition disorders can be exacerbated by a sedentary lifestyle and additional unhealthy lifestyle factors. Some dietary disorders associated with overnutrition are:

- Obesity
- Type 2 diabetes
- Cardiovascular disease (CVD)
- Atherosclerosis
- Hypertension.

Did you know?

Many people consider meat to be unhealthy, believing that it causes overnutrition diseases, such as obesity, diabetes, cardiovascular disease and some types of cancer (such as colorectal cancer). Watch the following video to find out the truth about meat and its link to overnutrition diseases.

Helpful online resources

Kurzgesagt: Is Meat Bad for You? Is Meat Unhealthy?

https://www.youtube.com/watch?v=ouAccsTzlGU

Did you know?

The World Health Organisation's (WHO) guidelines for physical activity for adolescents recommend adolescents perform one hour of moderate to vigorous physical activity per day. Research funded by the WHO and published in the Lancet in 2019 ranked adolescents from 146 countries in accordance with the WHO's guidelines for physical activity recommendations. The research discovered that Australia ranked 140 out of 146 countries in meeting the WHO's physical activity recommendations, with only six countries' adolescents performing less physical activity than Australians. The researchers predicted that only 1 in 10 Australian adolescents were meeting the recommended activity level in comparison to the global average of 1 in 5. This research is concerning because a lack of physical activity is one of the leading causes of death. The lack of physical activity in adolescents is attributed to many reasons, including the overuse of electronic devices, a lack of facilities to promote physical activity at high schools and in some cases, developing negative attitudes towards physical activity. The WHO aims to increase the physical activity of adolescents to a level where 1 in 4 adolescents meet their recommended guidelines globally by the year 2030.

There is a general misconception that **malnutrition** and **undernutrition** are interchangeable terms, but this is not the case. Undernutrition is a form of malnutrition that results from a chronic or recurrent deficiency in one or more nutrients, whereas malnutrition encompasses all disorders related to both overnutrition and undernutrition. A common form of undernutrition, especially in developing countries, is energy malnutrition. This results from a deficiency in food consumption, generally due to its unavailability. Mothers who are undernourished generally give birth to infants that are underweight. If children are undernourished it can lead to weight loss and underdevelopment, which can contribute to learning difficulties.

Undernutrition disorders can also develop in individuals who suffer from overnutrition disorders. This is because the body requires a balance of nutrients that are supplied from a variety of different foods. If an individual is over consuming unhealthy processed foods, they are likely to be over consuming macronutrients, leading to overnutrition disorders. However, if there is a lack of fresh whole foods in their diet, they could be deficient in one or more micronutrients and fibre. Some disorders associated with undernutrition are:

- Anaemia
- Osteoporosis
- Diverticular disease.

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Did you know?

Some brain degeneration diseases have been linked to undernutrition. These include general cognitive decline and specific brain degenerative diseases, such as Alzheimer's and dementia. Many individuals suffer from deficiencies of multiple nutrients due to poor or incomplete diets. This can be due to a range of different reasons such as poor choices, lack of nutritional literacy, busy lifestyle, stressful lifestyle, lack of supply or unaffordability. These deficiencies can involve some nutrients that are essential for brain health and over prolonged periods of time can lead to an accelerated cognitive decline.

The B group vitamins are of particular importance for the brain. More specifically, vitamin B6, B9 and B12 are associated with slowing the rate of cognitive decline because they play important roles in the folate cycle. The folate cycle is an important process required for the synthesis of DNA and the production of new brain cells. However, recent studies have shown that supplementation with the entire group of B vitamins is a more rational approach than selecting just B6, B9 and/or B12. This is because all the B group vitamins are essential for every aspect of brain function, and the B vitamins functions are interrelated. Even though a balanced diet that includes all vitamins is recommended, supplementation with B vitamins could be a viable option. Further research must be undertaken to investigate the effects of supplementation with the full range of B vitamins on brain health, at doses well in excess of the current governmental recommended dietary intakes.

Furthermore, a study published in the journal Neurology has shown that a diet consisting of one serving of leafy greens can slow cognitive decline. The study involved 960 adults with an average age of 8, all of whom were dementia free when the study began. The study was conducted over five years and involved the subjects performing rigorous cognitive tests throughout the five years. The results showed that when comparing the highest daily consumption of leafy greens (an average of 1.3 servings) with the lowest (an average of 0.09 servings), the individuals who ate the most leafy greens had a mental edge of 11 years on those who ate the least. Leafy greens are a rich source of vitamin B9, vitamin K, vitamin E, nitrate, kaempferol and lutein. All these nutrients were studied individually and were associated with a slower rate of cognitive decline. However, further investigation determined that folate, vitamin K and lutein were the nutrients with the greatest neuroprotective ability.

Science as a Human Endeavour 4

Tooth mounted sensor

There are many dieting applications that enable users to record their dietary intake and calculate their ongoing kilojoule count for the day. However, many of these applications are complicated, inaccurate and time consuming. Researchers at Tufts School of Engineering have developed a microchip sensor that is able to stick to tooth enamel and can monitor and record the daily nutrients an individual has consumed. The sensor then wirelessly transmits the data to a complementary application on a phone, which is significantly more efficient than recording it manually as required by current applications. This sensor chip is the smallest chip developed to date and is unobtrusive, especially in comparison to previous models developed, such as mouthguard sensors, sensors that required wiring and sensors that had to be replaced frequently. The prototype sensor has successfully detected water, apple juice, salt-laden soup, mouthwash and alcohol when tested. However, the sensor is currently unable to detect the amount of these substances consumed and requires further development to do so. The researchers' aim is to develop the sensor to detect a wide range of nutrients so that individuals can assess their diet efficiently and self-monitor for undernutrition and overnutrition. For example, the sensor could detect the amount of iron consumed over a given period and alert an individual if they have not met the RDI frequently. The individual could then be notified via the mobile application alert function that he or she is at risk of developing iron deficient anaemia. The sensor also has the capability of monitoring stress and psychological cues because it can detect other biochemicals, such as the stress hormone cortisol. This feature could allow individuals to develop a greater understanding of their dieting behaviours in response to stress, anxiety and depression. Researchers at Tufts School of Engineering are confident that in the near future these sensors will develop to the point that they can be released to the global market.

Science as a Human Endeavour 4

Questions

1. Discuss the **development** of the tooth mounted sensor.

(4 marks)

2. Explain two possible **applications** of the tooth mounted sensor being developed by Tufts School of Engineering.

(4 marks)

CS Possible case study 1

Choose an overnutrition or undernutrition disease and identify what diet and lifestyle changes an adult in his mid-twenties should make to reduce the risk of developing the chosen condition. For the purpose of this investigation, assume that the male is single, has little nutritional literacy and often eats convenient processed foods, such as take away food.

Ex Possible excursion 1

Sprout Cooking School in Thebarton, Adelaide, can tailor a session for school groups on the topic of 'Dietary Diseases' run by qualified dieticians. The sessions are followed by a demonstration and hands-on recipe modification session, which students can use as practice for their summative experiment. If schools do not have cooking facilities available, this session can also be tailored to run the summative experiment.

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2.1 Review questions

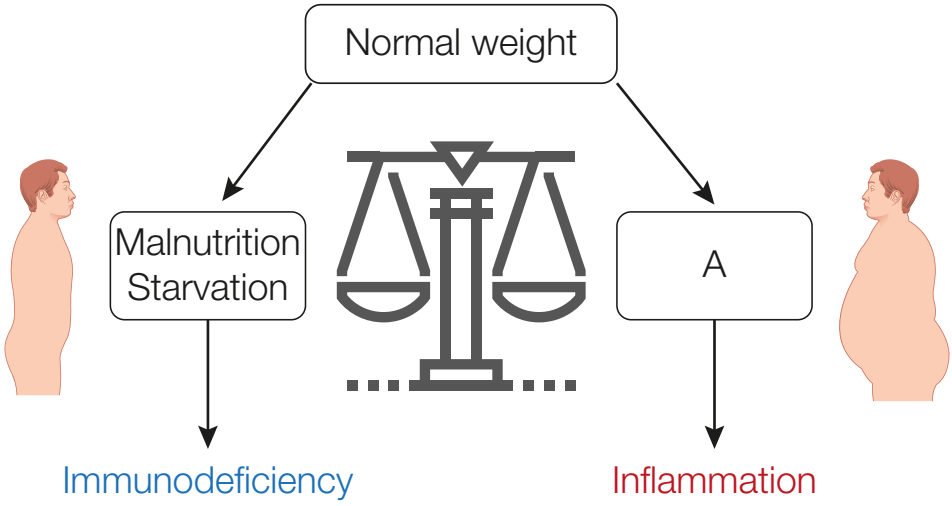
1. Describe the difference between undernutrition and malnutrition.

(2 marks)

2. Describe why undernutrition disorders are more likely to occur in developing countries.

(2 marks)

3. Refer to the diagram below to answer the following questions:



(a) Name the malnutrition disorder pictured at 'A'.

(1 mark)

(b) Describe how someone with a malnutrition disorder could be immunodeficient as shown in the diagram above.

(2 marks)

(c) Explain how somebody with an overnutrition disorder could also suffer from an undernutrition disorder.

(4 marks)

E Extension question

Research **and** explain the difference between the undernutrition disorders marasmus and kwashiorkor.

2.2 Obesity

Nutrition Understanding

According to the World Health Organisation (WHO), obesity has tripled globally since 1975. In 2016, an estimated 1.9 billion adults were **overweight**, with 650 million of them being **obese**. Overweight and obesity refers to an abnormal amount of body fat that has accumulated. Individuals who are overweight have accumulated some extra body weight, whereas obese individuals have accumulated a large amount of extra body weight. Being overweight or obese can increase the risk of developing additional disorders such as type 2 diabetes, cardiovascular disease and some forms of cancer.

A simple measure that is commonly used to classify individuals as overweight or obese is the **body mass index (BMI).** BMI is a scale from underweight to morbidly obese (see Figure 2.2.1). BMI is a measure of weight with respect to height and provides an estimate of the amount of body fat an individual has and the associated risk of developing weight-related diseases. BMI is calculated by using the following formula:

π Formula

$$\text{BMI} = \frac{\text{weight (kg)}}{\text{height (m}^2\text{)}}$$

Example question

(a) Calculate the body mass index of a male who is 178cm tall and weighs 75kg.

$$\text{BMI} = \frac{\text{weight (kg)}}{\text{height (m}^2\text{)}}$$

$$= \frac{75}{1.78^2}$$

$$= \frac{75}{(1.78 \times 1.78)}$$

$$= \frac{75}{3.1684}$$

$$= 23.67$$

(b) With reference to Figure 2.2.1. determine the body mass index weight category this male is currently in.

A BMI of 23.67 is in the category of normal weight (between 18.5-24.9).



Figure 2.2.1: The weight ranges of the body mass Index scale.

For many individuals, BMI can provide a reasonable approximation of body fat to determine whether their weight is normal or not. However, BMI does not directly measure body fat, so it does not distinguish between the **proportion of weight** due to muscle or fat. Muscle weighs more than fat due to its retention of water and because of this, the BMI of muscular athletes can classify them as overweight or obese even though they do not have excess body fat. This is a limitation of the BMI method. Another limitation of BMI is that it does not measure

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the **distribution of body fat**. Fat distribution differs between males and females and it is important to note how much of an individual's weight is fat and where the fat is located to accurately assess an individual's risk to weight related conditions. This is why many medical professionals measure an individual's **waist circumference** in addition to calculating their BMI, as the combination of these two diagnostics provide a greater prediction of weight related disorder risk. Men have a greater risk if their waist circumference exceeds 94cm; and women have a greater risk if their waist circumference exceeds 80cm. Excessive **visceral fat**, which is stored around the organs in the abdomen, increases the risk of developing cardiovascular disease, type 2 diabetes and can lead to a premature death. This is because visceral fat can contribute to increased inflammation that can damage arteries, increase insulin resistance and disrupt vital processes. There are two major types of fat distribution: android and gynoid. **Android** fat accumulates in the abdomen as visceral fat, giving rise to an **apple** shaped appearance (see Figure 2.2.2). **Gynoid** fat accumulates more around the hip, thighs and bottom and gives rise to a **pear** shaped appearance (see Figure 2.2.2). Gynoid fat is more common in women and is stored under the skin as subcutaneous fat (not visceral fat). This fat is **essential** and is deposited during adolescence in preparation for childbearing and acts as reserve storage for the energy demands of lactation.

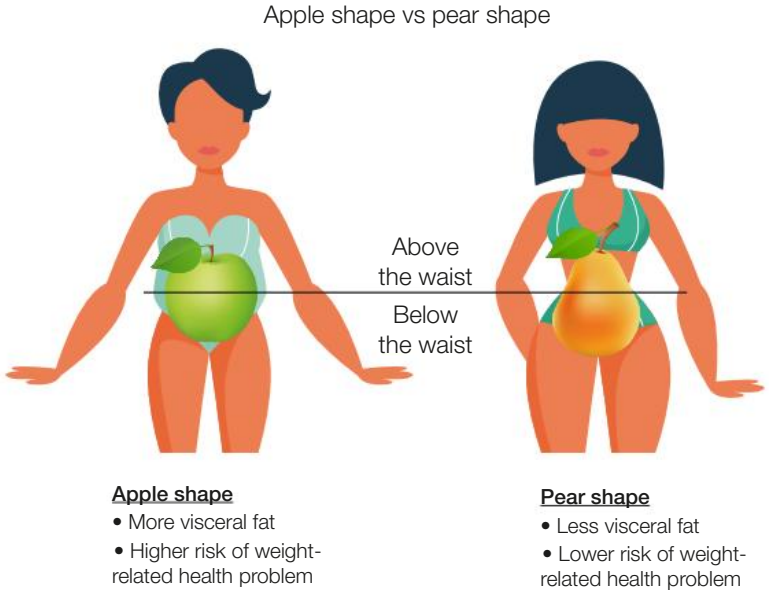


Figure 2.2.2: A comparison of the android fat distribution that produces an 'apple' shape compared with the gynoid fat distribution that produces a 'pear' shape.

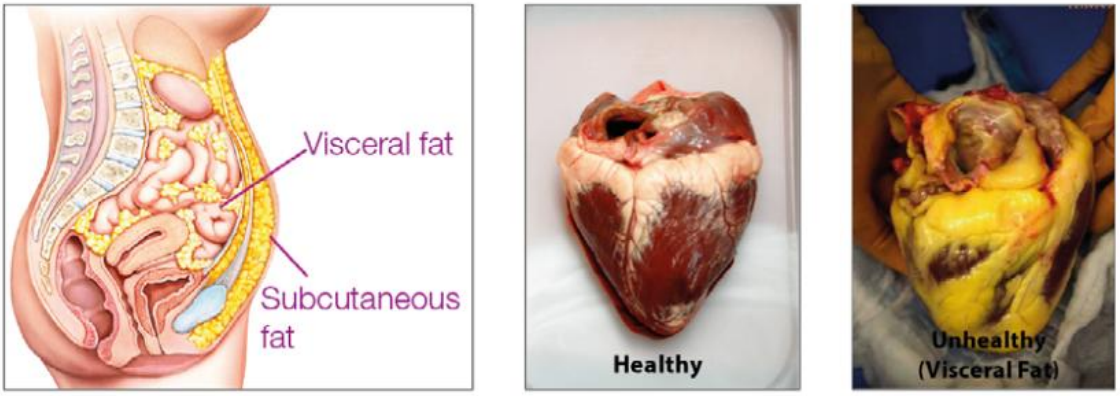


Figure 2.2.3: The difference between visceral and subcutaneous fat and an example of an unhealthy heart covered in visceral fat.

Helpful online resources

Ted-Ed: What is obesity?–Mia Nacamulli

https://www.youtube.com/watch?v=-vNVG7XJpVE

Did you know?

Donkeys have transported tourists on the Greek island of Santorini along its cobblestone roads and up its hills for decades. The Santorini locals have recently started cross breeding their donkeys with mules. They have resorted to this because their donkeys are not strong enough to transport the increasing number of overweight and obese tourists and are being crippled. The cross bred mules are stronger, and it is easier for them to carry fatter tourists. Bans have also been put in place limiting the weight of people wanting to ride a donkey.

Dietary and lifestyle risk factors

Obesity is a complex disease and there are many factors that can increase weight gain and contribute to obesity. Weight loss experts increasingly believe that obesity is not a single disease but rather there are many different types of obesity. An analogy is cancer, which is not one disease but rather several types with different characteristics, causes and treatments. It is not currently known how many types of obesity there are but researchers at the Massachusetts General Hospital have identified 59 different types of obesity. Each type of obesity can have different causes and requires different treatments to lose weight. This is why weight loss experts believe that a particular weight loss method will work for one person but not another. An underlying factor to our risk of obesity is our inherited **genetics**. Researchers have identified approximately 25 genes that increase the risk of developing obesity and an additional 300 genes that are associated with small gains in weight (a couple of kilograms). Our genetics is a risk factor that cannot be controlled, but our environment also plays a role in an individual's risk of becoming obese, including dietary and lifestyle factors. Some of these factors are discussed below.

Diet

An individual's diet plays a major role in gaining weight. Ideally, an individual's diet should meet the requirements of the Australian Guide to Healthy Eating (AGHE) and have a neutral energy balance (please refer to Topic 9.1 for a visual representation of this concept). When an individual has a **positive energy balance**, where the amount of food consumed supplies more energy than the body is burning, weight will be gained. If this is consistent over a long period of time, it could lead to obesity. Diets that lead to weight gain often consist of energy dense **processed foods** that are **high in fat and simple sugars**. Fats are the most energy dense macronutrient, providing 37.7 kJ/g. A diet high in fat, especially saturated fat, is therefore likely to increase weight gain and contribute to obesity. When simple sugars are consumed, they spike blood glucose levels resulting in their storage as glycogen and fat by the body (see Topic 2.3: Diabetes for more information). Carbohydrates are required by the body but it is recommended that they are sourced from complex carbohydrates that slowly release their energy and are less likely to be stored as fat. However, the overconsumption of complex carbohydrates and other macronutrients can increase one's energy intake and contribute to weight gain.

This can be a problem for some people who cannot control their **portion sizes**. Portion sizes have increased in modern society and with increased portions come increased energy supply. It is recommended that individuals listen to their body and not overeat just because extra food has been served. In addition, instead of going straight back for a second serving after eating, it is better to wait approximately 20 minutes for one's body to respond to the food just eaten. This is the amount of time it takes for the slow acting hormones to communicate fullness levels to the brain. Eating food within these 20 minutes can later result in an individual feeling like they have overeaten and unnecessarily increases the energy supplied to the body, leading to weight gain.

Helpful online resources

TED-Ed: How does your body know you're full–Hilary Coller

https://www.youtube.com/watch?v=YVfyYrEmzgM

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Yo-Yo dieting

Yo-yo dieting is a term used to describe the cyclical loss and gain of weight from on and off dieting. Yo-yo dieting often results in the dieter losing weight in the short term but putting weight on in the long term. Yo-yo weight loss diets are usually **kilojoule restrictive** and sticking to this type of diet will generally yield results and weight will be lost. However, it is not only fat that is lost; muscle is also lost. Because the body is not being supplied with sufficient energy, processes are activated to break down muscle and turn it into glucose to provide the body with energy for daily activities. The loss of muscle also results in a **reduced basal metabolic rate (BMR)**. If an individual subsequently stops dieting and returns to their previous diet, they will put on excess weight because their BMR is reduced and even less energy is required by the body than before they commenced the diet. The rise in weight eventually sparks another dieting phase, which reduces the BMR further and the cycle continues (see Figure 2.2.4 and Topic 9.1 Basal metabolic rate, energy balance and energy systems for more information).

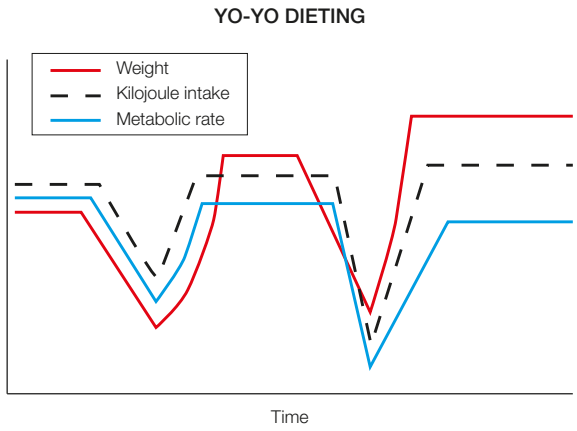


Figure 2.2.4: Yo-yo dieting is the cyclical loss and gain of weight but with every consecutive cycle, the basal metabolic rate decreases further contributing to greater weight gain.

Physical activity

Physical activity is important for several reasons. Physical activity increases **energy expenditure**, which can contribute to a negative energy balance to help lose weight when weight loss is required. Physical activity can also help decrease visceral fat, reducing the risk of additional weight-related disorders. Muscle strengthening activities, such as lifting weights, can increase muscle mass resulting in an **increased basal metabolic rate (BMR)**. This means that more energy is being burnt at rest, contributing to greater weight loss. Modern society is obsessed with technology and its development has led to many efficiencies. However, for many people, it has reduced the incidental exercise performed daily. An example of this is wirelessly controlled smart lights that can be controlled using a device so individuals do not have to stand up to press the light switch. A lack of physical activity can therefore increase weight gain and contribute to obesity.

Helpful online resources

ASAP Science: Exercise vs Diet

https://www.youtube.com/watch?v=ztiHRiFXtoc

TED-Ed: How playing sports benefits your body ... and your brain - Leah Lagos and Jaspal Ricky Singh

https://www.youtube.com/watch?v=hmFQqjMF_f0

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Did you know?

When fat is metabolised by the body, the fat disappears from the waistline but it doesn't just disappear into thin air, or does it? The majority of fat is converted into carbon dioxide that is breathed out, and water that is excreted by the body in the urine or lost through sweat. Watch the following video for more information.

Helpful online resources

SciShow: When You Burn Fat, Where Does it Go?

https://www.youtube.com/watch?v=C8ialLlcdcw

Stress

Chronic stress can also contribute to weight gain and obesity. A biological response to stress is the increased release of a stress hormone called cortisol. Cortisol activates many stress responses including increasing appetite and cravings, especially of energy dense foods rich in sugar and fats. This can result in overeating and a positive energy balance, leading to weight gain and obesity.

Alcohol

Alcoholic beverages are energy dense products that provide empty kilojoules. The alcohol within the beverage provides 29.3 kJ/g, which is almost double the amount of energy provided by the carbohydrates that accompany the alcohol. Alcoholic beverages are generally rich in simple sugars that can spike blood glucose levels and increase the risk of energy being stored as fat. Alcohol is therefore related to weight gain by providing surplus kilojoules. Alcohol can also increase one's appetite and therefore increase the risk of impulsively consuming energy dense foods, such as fast food. Individual's often consume alcohol socially and sometimes peer pressure can play a role in its consumption. Making lifestyle changes such as reducing the amount of exposure to these social situations/pressures can help with reduced alcoholic consumption.

Symptoms

The primary symptom of obesity is the visible excessive weight due to fat gain. Because of the excessive weight gain, obese individuals may also experience some daily complications such as:

- Breathlessness and difficulty exercising
- Increased sweating
- Feeling tired and lethargic
- Difficulty sleeping and increased snoring
- Joint and back pain
- Low confidence and low self-esteem.
- Arthritis
- Psychological disorders, such as increased anxiety and depression.

Treatment

There is no quick fix to treating overweight and obese individuals. The first line of treatment to lose weight is implementing dietary and lifestyle changes, such as eating a healthier diet, increasing physical activity, reducing alcohol intake and managing chronic stress. These risk factors were discussed in detail in the previous section. However, this can be unsuccessful for many individuals for a variety of reasons. For some of these individuals, weight loss surgery, also known as bariatric surgery, may be a suitable option. Two examples of bariatric surgery are gastric bypass and gastric banding surgery. A **gastric bypass** involves a surgeon cutting the stomach to form a small pouch, which is reconnected to the small intestine so that the food bypasses the majority of the stomach (see Figure 2.2.5). A **gastric banding** procedure involves the application of an adjustable band near the opening of the stomach, which separates the stomach into two pouches. The adjustable band can be inflated or deflated to increase or decrease the size of the channel between the two pouches (see Figure 2.2.5). Both procedures **reduce the size of the stomach** resulting in patients feeling fuller more quickly and subsequently, eating less. It is important to note that **liposuction is not considered a weight loss procedure** and is classified as cosmetic surgery. Liposuction changes the shape of targeted areas by removing fat and is not suitable for treating obese

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individuals who are overweight throughout their body. Bariatric surgery can help individuals lose excess weight but the degree of success ultimately depends on whether the patient also implements lifelong dietary and lifestyle changes too.

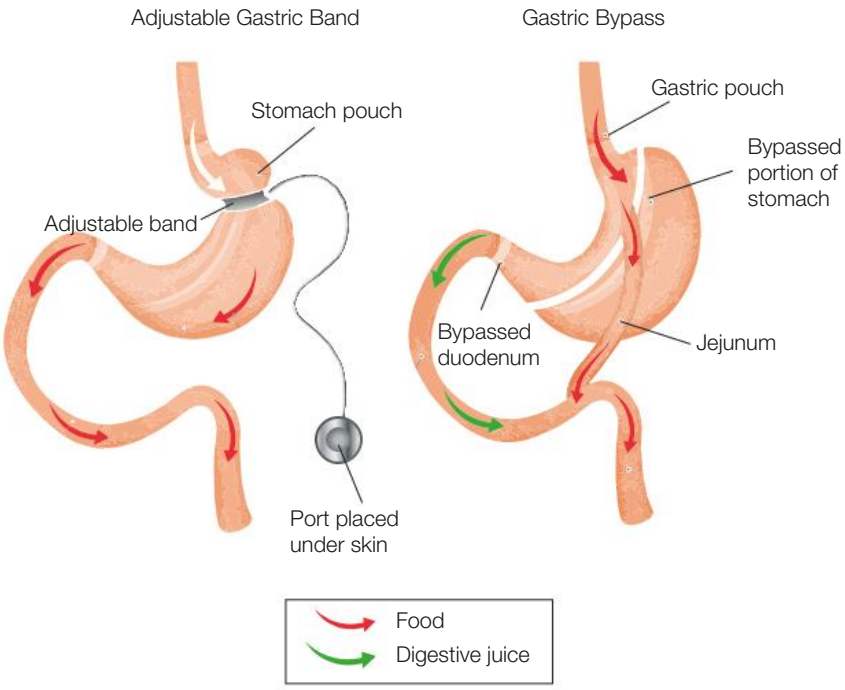


Figure 2.2.5: The difference between gastric bypass and gastric banding bariatric procedures.

An additional type of bariatric procedure is the insertion of **gastric balloons**, which is a **temporary weight loss procedure**. This procedure is non-surgical and involves the insertion of one or more soft, expandable balloons into the stomach (see Figure 2.2.6). The balloons are then filled with sterile saline solution. The filled gastric balloons then float in the stomach as they are too large to pass into the small intestine. The balloons make the patient feel fuller, reducing the amount of food eaten and can stay in place for up to nine months. This type of procedure is generally used as a short-term weight loss procedure to help people get started with their weight loss programs or to help people lose some weight to prepare for the aforementioned bariatric surgeries. Some people are refused bariatric surgery because they need to lose a certain amount of weight before the procedure can be performed to reduce the risk of serious complications during the surgery associated with being obese.

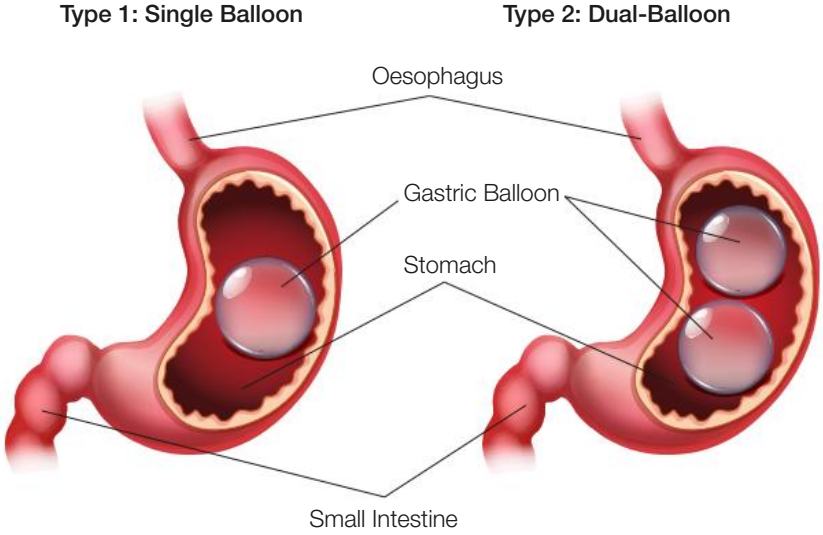


Figure 2.2.6: Gastric balloons can be inserted into the stomach temporarily to reduce the capacity of the stomach and make individuals feel fuller.

Helpful online resources

Insider: How a Stomach Balloon Makes People Lose Weight

https://www.youtube.com/watch?v=Q7FITF4HtK4

Science as a Human Endeavour 5

Exercise pill

Many people find exercise hard, and many others are unable to exercise due to a variety of reasons. To address this, scientists are trying to develop an exercise pill that can provide the metabolic benefits of exercise, without actually performing any physical activity. Scientists are researching a class of proteins called Sestrins, which may be able to provide some benefits of exercise without getting off the couch. The expression of Sestrins are increased naturally in human muscle through exercise training and are required for increased performance after exercise. In separate studies, scientists genetically altered fruit flies and mice to determine the effect of altering Sestrin levels. When fruit flies had their Sestrin supressed, they did not exhibit the same improved endurance after three weeks of training that fruit flies with a normal amount of Sestrin did. In addition, the fruit flies that were genetically modified to produce more Sestrin displayed endurance benefits without any training at all. The results in mice were similar. Mice that had their Sestrin suppressed did not exhibit any benefits in fitness and fat burning from exercising, and mice that were genetically modified to produce more Sestrin demonstrated less muscle breakdown even without exercising. This research indicates that Sestrins play a role in the coordination of metabolic pathways that is essential in producing some of the beneficial effects associated with exercise. Although it is encouraging that these results have been replicated in two species and it could affect other animals in the same manner, it is currently unknown how increased Sestrin levels affect humans. Further research is required.

Questions

1. Explain two possible **applications** of the development of an exercise pill using this protein that mimics the effects of exercise.

(4 marks)

2. Explain two **limitations** of the development of an exercise pill using this protein that mimics the effects of exercise.

(4 marks)

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2.2 Review questions

1. Body mass index (BMI) is an index that can be used to give an approximation of body fat and determine an individual's risk of developing weight related conditions.

   (a) Paul weighs 90kg and is 2.02m tall. Calculate Paul's BMI.

   (2 marks)

   (b) Determine Paul's BMI weight category.

   (1 mark)

   (c) Paul's son Luca weighs 102kg and is 182cm tall. Calculate Luca's BMI.

   (2 marks)

   (d) Determine Luca's BMI weight category.

   (1 mark)

   (e) Luca doesn't exhibit the typical symptom of obesity and does not show excessive weight gain in the abdominal region. Describe the likely reason that Luca's classification identified in (d) could be a misrepresentation of his weight status.

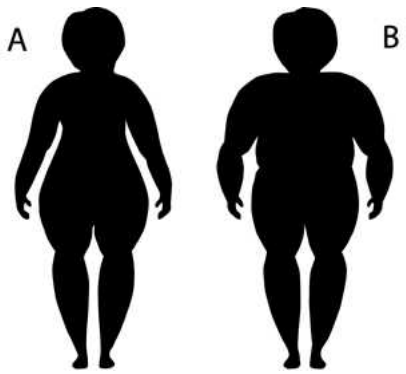
   (2 marks)

   Another limitation of BMI is that it does not measure the distribution of body fat.

   (f) Describe why an understanding of the distribution of body fat is important when assessing an individual's risk of weight related disorders.

   (2 marks)

   Refer to the following picture:



   (g) State the types of fat distribution represented by A and B.

A:

B:

(2 marks)

(h) State whether fat distribution A or B from (g) has a higher risk of developing weight related disorders and which gender this type of distribution is more common in.

(2 marks)

2. (a) Describe how stress can increase weight gain and contribute to obesity.

(2 marks)

(b) Describe how excess alcohol consumption can contribute to obesity.

(2 marks)

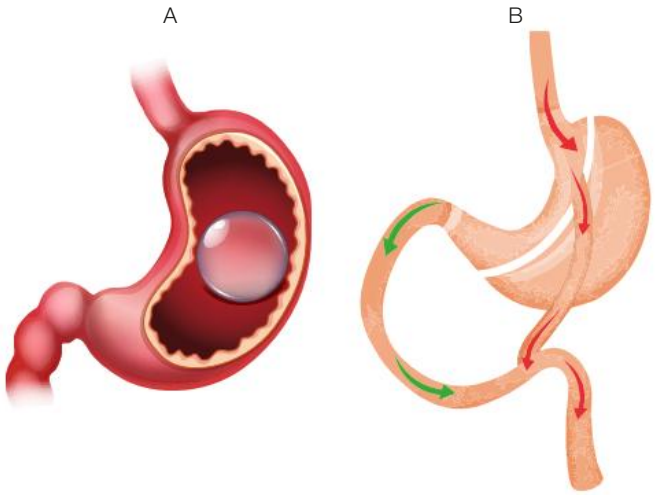
(c) A good way to relieve stress and lose weight is to exercise. Describe how exercise can decrease weight.

(2 marks)

(d) During the COVID-19 lockdowns in 2020, many people were isolated at home and ate excess processed snacks out of boredom. Describe how this could have led to weight gain.

(3 marks)

3. Refer to the diagram below to answer the following questions:



(a) Name the procedure represented by diagram A.

(1 mark)

(b) Name the procedure represented by diagram B.

(1 mark)

(c) Describe **two** differences between procedures A and B.

(2 marks)

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2.3 Diabetes

Nutrition Understanding

Diabetes is a metabolic disease where affected individuals cannot control their blood glucose levels effectively, resulting in **high blood glucose levels**. Blood glucose levels are predominantly controlled by the **pancreas** and **liver**.

After consuming a meal, the digestive system breaks down complex carbohydrates into simple sugars that are absorbed across the villi in the small intestine and into the blood (see Topic 3: Digestion, Malabsorption and the Microbiome for more information on the digestive process). This results in an elevated blood glucose level. It is important for the body to reduce blood glucose levels back to the normal range relatively quickly because high blood glucose levels can cause complications, such as increased blood pressure. It is also important for cells to take up glucose so they can use it as a source of energy and function properly. The pancreas detects changes in blood glucose levels and releases **insulin** into the blood in response to the elevated blood glucose level. Insulin is a hormone produced in beta (β) cells of the pancreas that reduces blood glucose levels by binding to receptors on cells, especially liver, muscle and adipose (fat) cells, and stimulating them to take up glucose from the blood (see Figure 2.3.1). Under normal circumstances, the blood glucose levels will return to the normal tolerated range as a result. The glucose can then be **used as a source of energy by these cells or stored**. The liver is the major store of carbohydrates, and converts excess glucose absorbed from the blood into a complex carbohydrate called **glycogen**. Glycogen stores are broken down when blood glucose levels decrease. A decrease in blood glucose levels is also detected by the pancreas, but instead of releasing insulin, the hormone **glucagon** is released into the blood. Glucagon is produced in the alpha cells (α) of the pancreas (see Figure 2.3.2). Glucagon binds to receptors on liver cells, which **stimulates them to break down their glycogen stores into glucose** and release the glucose into the blood, increasing blood glucose levels back into the normal tolerated range. As a result, body cells can access this glucose to fuel their activity and function properly.

The regulation of blood glucose is tightly controlled by insulin and glucagon. However, individuals with **diabetes** are unable to produce enough insulin or their body becomes resistant to the insulin it does produce (or a mixture of both). This impairs the body's ability to control its blood glucose levels as the body's cells cannot be stimulated to take up glucose effectively. There are two major types of diabetes: type 1 and type 2. There is also another type of diabetes that occurs temporarily called gestational diabetes. This type of diabetes occurs in pregnant women and is discussed in Topic 6: Nutrition and Food Safety During Pregnancy and Lactation.

Helpful online resources

FuseSchool - Global Education: Insulin and Glucagon

https://www.youtube.com/watch?v=y9Bdi4dnSlg

Cleveland Clinic: What Is Insulin Resistance?

https://www.youtube.com/watch?v=JIq-niyVJ2I

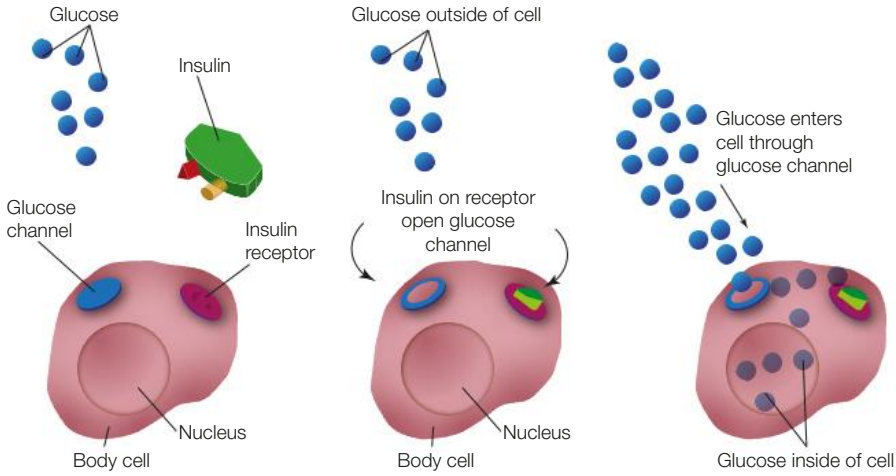


Figure 2.3.1: Insulin binds to its complementary receptor stimulating glucose channels to open so that body cells can take up glucose for cellular use.

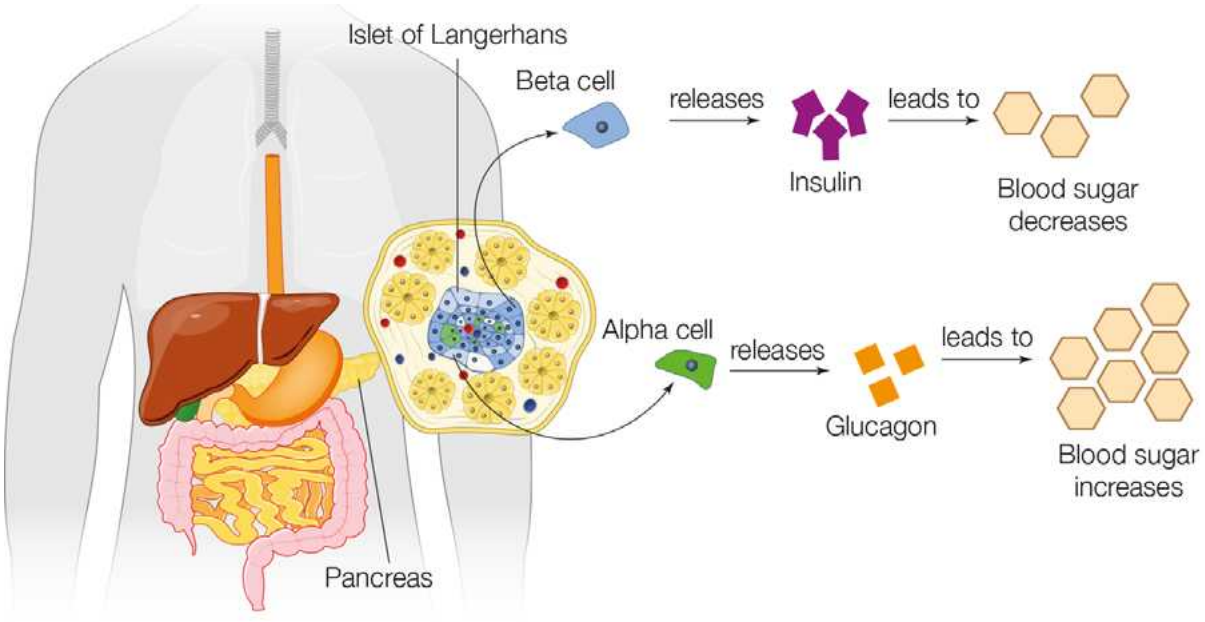


Figure 2.3.2: The pancreas produces and secretes the hormones insulin and glucagon, which regulate blood glucose levels.

Type 1 Diabetes

Type 1 diabetes is an **autoimmune** condition whereby the immune cells are activated to destroy the beta cells of the pancreas (see Figure 2.3.3). As the beta cells are destroyed, the affected individual cannot produce and release insulin to sufficiently control their blood glucose levels. Type 1 diabetics therefore have elevated blood glucose levels after consuming carbohydrates because the body's cells cannot be stimulated to take up glucose from the blood (see Figure 2.3.4). The cause of type 1 diabetes is unknown but some cases can be inherited and others can be caused by a pathogenic infection triggering an autoimmune response. Type 1 diabetes is **not** caused by poor lifestyle choices and cannot be prevented. Notwithstanding that type 1 diabetics cannot naturally produce enough insulin, their body is able to respond to insulin appropriately. For this reason, type 1 diabetes can be treated by administering exogenous insulin prior to consuming meals.

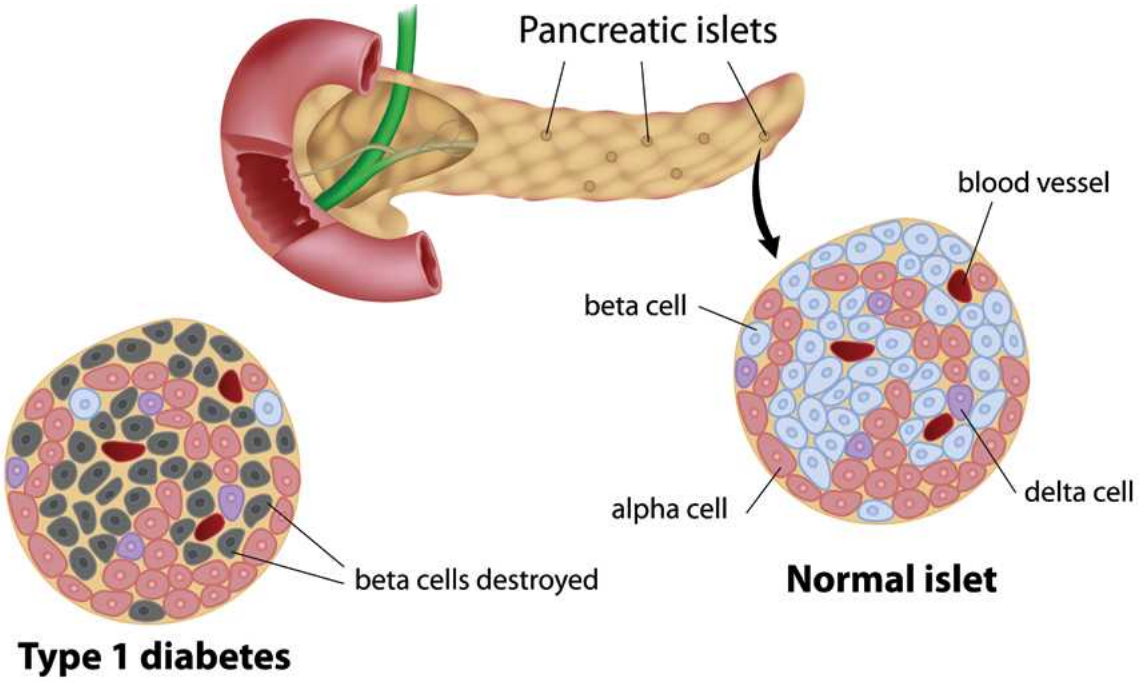


Figure 2.3.3: The immune system of type 1 diabetics attacks and destroys the insulin producing beta cells of the pancreas.

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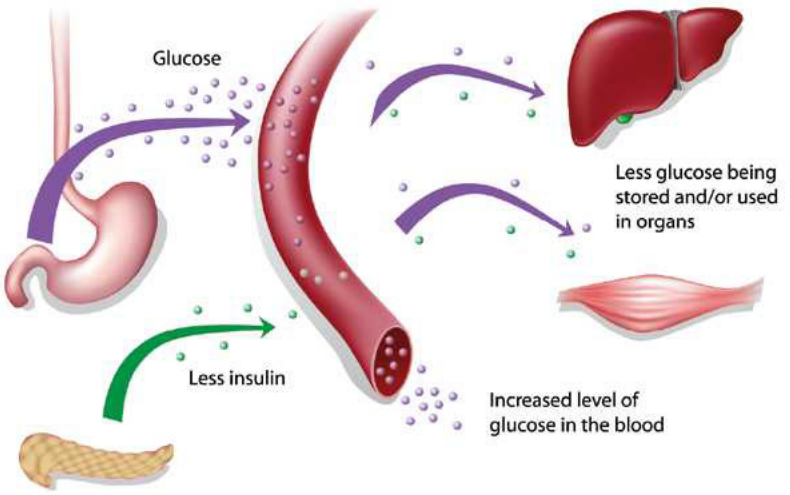


Figure 2.3.4: Type 1 diabetics cannot produce enough insulin to stimulate sufficient uptake of glucose into cells and this results in elevated blood glucose levels.

Type 2 Diabetes

Type 2 diabetes is a condition that develops over time and unlike type 1 diabetes, is predominantly attributed to poor diet and lifestyle choices. However, some individuals can have a genetic predisposition to developing type 2 diabetes. With type 2 diabetes, the body's cells progressively become resistant to insulin and cannot respond, resulting in increased glucose remaining in the blood (see Figure 2.3.5). To compensate for this **insulin resistance**, the pancreas produces greater amounts of insulin in order to reduce blood glucose levels. This overproduction of insulin places increased pressure on the beta cells of the pancreas, and over time, they can wear out, resulting in a significant **reduction of beta cells**. As a result, the pancreas produces significantly less insulin. The high blood glucose levels associated with type 2 diabetes are therefore generally caused by a combination of insulin resistance and not enough insulin being produced.

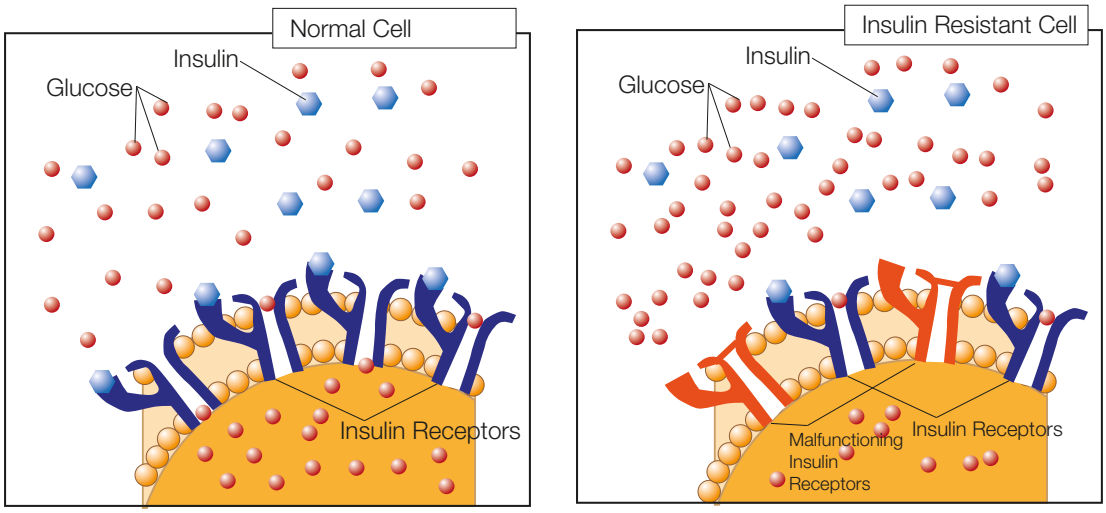


Figure 2.3.5: Insulin resistant cells cannot bind to insulin, which renders them unable to activate glucose channels to open to allow glucose to enter the cell. This results in elevated blood glucose levels.

Helpful online resources

FreeMedEducation: What is Diabetes Mellitus? - Understanding Diabetes - Diabetes Type 1 and Type 2

https://www.youtube.com/watch?v=Mko250V6PYI

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Dietary and lifestyle risk factors

As type 1 diabetes is an autoimmune disease and is not associated with modifiable diet and lifestyle factors, **the following information has a focus on type 2 diabetes**. Although some individuals with type 2 diabetes have a genetic predisposition, many cases can be prevented or delayed with good diet and lifestyle choices, some of which are outlined below.

Diet

A healthy diet that is **high in fat and simple sugars** can increase the risk of developing type 2 diabetes. A diet high in fat, especially saturated fat, can contribute to weight gain and individuals becoming overweight or obese. Being overweight or obese results in increased fatty acids in the blood and inflammation, which causes insulin resistance. In addition, fat can accumulate inside muscle cells, which interferes with the signalling process of their insulin receptors. This interference means that the presence of insulin is unable to activate these cells to open their glucose channels, resulting in insulin resistance.

A diet high in simple sugars can also contribute to the development of type 2 diabetes. Simple sugars have a high **glycaemic index (GI)** and are absorbed readily, resulting in significant blood glucose spikes. Under normal circumstances, the pancreas will respond by releasing a large amount of insulin to communicate to body cells to take up the excess glucose. Due to an excess supply of glucose, it is unlikely for all of it to be used at the time. As a result, the body will store the leftover glucose as glycogen and fat. Increased weight gain, especially in the abdominal area, causes insulin resistance and in turn type 2 diabetes.

Glycaemic index

The **glycaemic index (GI) is a scale from 0 to 100** that ranks foods based on how much they increase blood glucose levels. Foods that register above 70 on the GI scale are considered high GI because they are digested and absorbed quickly, producing large spikes in blood glucose levels (see Figure 2.3.6). High GI foods generally consist of simple carbohydrates and are associated with weight gain because the glucose is not used immediately and can be stored as fat (see Figure 2.3.7). In comparison, low GI foods generally consist of complex carbohydrates and produce smaller fluctuations in blood glucose and insulin levels due to a sustained release of glucose. Low GI foods take longer to breakdown in the intestines and therefore the glucose is released slowly into the blood and is more likely to be used and less likely to be stored as fat (see Figure 2.3.8). A diet high in low GI foods is therefore associated with reducing the risk of type 2 diabetes.

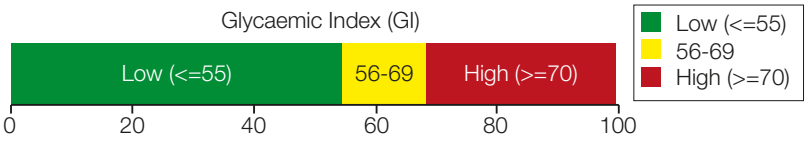


Figure 2.3.6: The glycaemic index (GI) is a scale from 0 to 100. Foods greater than 70 have a high GI and are readily absorbed, whereas foods lower than 55 have a low GI and glucose is slowly absorbed into the blood.

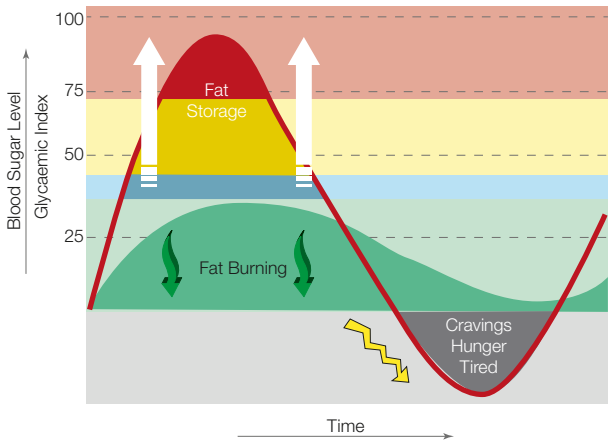


Figure 2.3.7: High GI foods result in a large blood glucose level spike and can result in the glucose being stored as fat contributing to weight gain and increased risk of type 2 diabetes.

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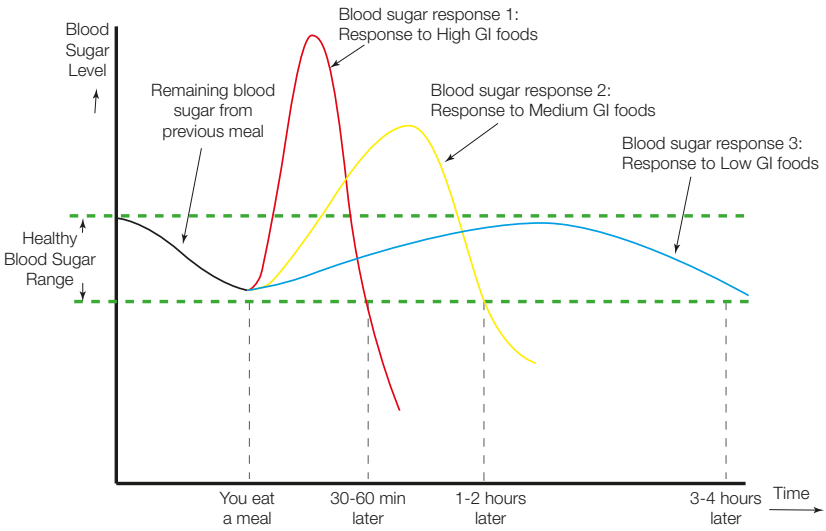
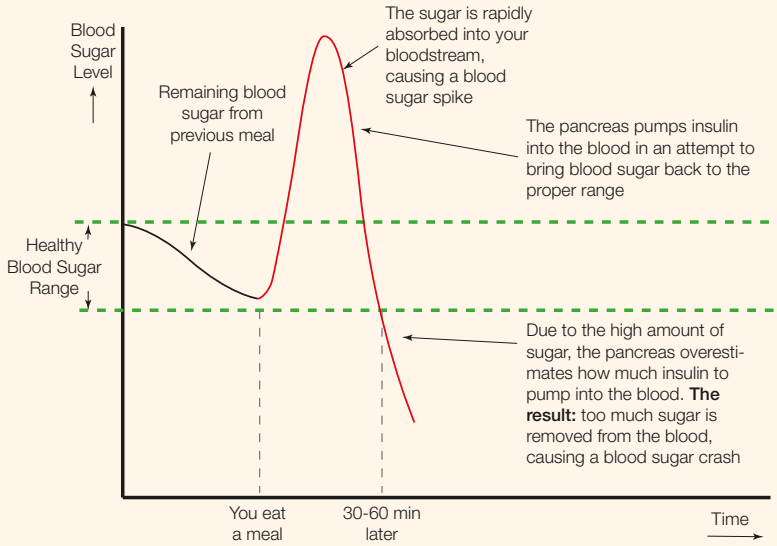


Figure 2.3.8: High GI foods (red line) result in a large spike in blood glucose levels compared to low GI foods (blue line) that result in a more sustained absorption of glucose from the digestive system.

Did you know?

High GI foods can cause a sugar crash. The consumption of high GI foods result in a rapid blood glucose level spike. In response, there is also a spike in insulin released into the blood to return blood glucose levels to a healthy range. However, the spike in insulin results in an overshoot of glucose uptake, resulting in blood glucose levels dropping below the ideal range and the individual becoming hypoglycaemic. The resultant low blood glucose levels cause fatigue, irritability, hunger and cravings.



Glycaemic load

A limitation of the glycaemic index (GI) scale is that it only tells you how rapidly a particular carbohydrate is digested into glucose and absorbed into the blood. The GI does not indicate the amount of carbohydrate per serving of a particular food. It is important to know both things to understand a food's full effect on blood sugar. For this reason, it is also important to understand the **glycaemic load (GL)** of foods. The glycaemic load value of a food represents the amount of carbohydrate in the food, as well as its glycaemic index. The GL is a scale of 0 to 60, where low GL foods are between 0 and 10 and high GL foods are greater than 20 (see Figure 2.3.9). Identifying the GL of foods can help individuals make more informed decisions about their food choices. For example, watermelon has a high GI, but it does not consist of a large amount of carbohydrate and therefore has a relatively low GL. This example highlights that high GI foods, which would normally be considered bad to eat can be healthy choices because they have little carbohydrates and therefore a low GL.

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Physical activity

Individuals who live sedentary lifestyles and rarely exercise have an increased risk of developing type 2 diabetes. A sedentary lifestyle can result in increased weight gain, which can increase insulin resistance. As exercise is energy intensive, it lowers blood glucose levels and burns fat resulting in weight loss and a reduced risk of developing type 2 diabetes. In addition, exercise can increase muscle gain, which raises the basal metabolic rate (BMR), resulting in additional weight loss. Exercise also increases the body's sensitivity to insulin counteracting any existing insulin resistance.

Sleep

A lack of sleep can also increase the risk of developing type 2 diabetes because it disrupts the natural cycle of certain hormones. Chronic lack of sleep can result in elevated levels of the stress hormone cortisol, which increases insulin resistance. A lack of sleep can also result in a reduced release of insulin following consumption of carbohydrates. Blood glucose levels remain elevated as a result, and the risk of type 2 diabetes is increased. In addition, reduced sleep can result in increased hunger and poorer food choices, which can accelerate weight gain. As highlighted above, increased weight gain, especially in the abdominal area, can increase insulin resistance and the risk of developing type 2 diabetes.

Alcohol

Excessive alcohol consumption can increase the risk of developing type 2 diabetes. Chronic excessive consumption can cause inflammation of the pancreas resulting in destruction of beta cells and the inability to produce enough insulin. In addition, alcohol can decrease insulin sensitivity and contribute to weight gain. Alcoholic beverages are energy dense and excessive consumption can lead to being overweight, which is associated with a higher risk of developing type 2 diabetes.

Symptoms

Elevated blood glucose levels, known as **hyperglycaemia**, can cause a range of symptoms in diabetics. As both type 1 and 2 diabetes can result in elevated blood glucose levels, the symptoms mentioned below in Table 2.3.1 can be applied to both conditions. These symptoms can also be early warning signs of diabetes.

Table 2.3.1: Examples of the symptoms diabetics can experience due to elevated blood glucose levels.

Symptom	Explanation
Excessive urination	Diabetics cannot reduce their blood glucose levels efficiently through the action of insulin so excess glucose is filtered by the kidneys and lost in the urine.
Thirst and dry mouth	As excess fluid is lost through increased urination, diabetics can feel very thirsty and have a dry mouth, promoting the consumption of water.
Hunger and tiredness	If a diabetic cannot produce enough insulin or their cells resist insulin, the cells cannot take up sufficient glucose to fuel their activity. This can result in a lack of energy and a feeling of hunger because the body's cells haven't been able to access enough energy.
Blurred vision	Excess blood glucose levels cause the lens in the eyes to swell, which increases refraction of light. As a result, the light does not hit the retina and a blurry image is seen.
Increased infections	Increased glucose levels provide suitable conditions for microorganisms such as bacteria and fungi. This can result in increased infections, especially urinary tract infections.

If diabetes is not suitably managed and the individual continues to experience chronic high blood glucose levels, it can lead to **further complications**. Some of these complications are outlined in Table 2.3.2 below.

Helpful online resources

Diabetes UK: Diabetes symptoms | Signs of all types of diabetes

https://www.youtube.com/watch?v=blhy-Rb2xp4

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Table 2.3.2: Some complications that diabetics can experience due to chronic high blood glucose levels when diabetes is not managed.

Complication	Explanation
Cardiovascular disease	The risk of cardiovascular complications is vastly increased for diabetics. This is because the increased glucose can have an abrasive effect on the internal walls of the blood vessels, causing imperfections that plaques can build up against and lead to atherosclerosis and further complications, such as a heart attack.
Nerve damage	The increased glucose can have an abrasive effect on the internal walls of the blood vessels that supply the nerves, injuring them. This can lead to nerve damage and result in tingling, numbness and pain in limbs, especially the lower legs and hands. If left untreated, it can result in loss of all feeling in the affected limbs (see Figure 2.3.10).
Eye damage	The increased glucose can have an abrasive effect on the internal walls of the blood vessels that supply the retina, injuring them. This can lead to decreased vision and blindness.
Kidney damage	The increased glucose can have an abrasive effect on the internal walls of the blood vessels that supply the kidney, injuring them. The kidney contains millions of small capillaries that filter the blood. Damage to these capillaries can impair the filtering system and can cause kidney disease or failure.
Gangrene	As previously mentioned, elevated glucose levels can cause nerve damage and lead to loss of sensation, especially in the legs. This can make it easier for injuries to develop. In addition, the elevated glucose levels damage blood vessels and can reduce blood flow to the legs. Less immune cells are delivered to the legs as a result, and wounds take longer to heal increasing the risk of infections occurring.

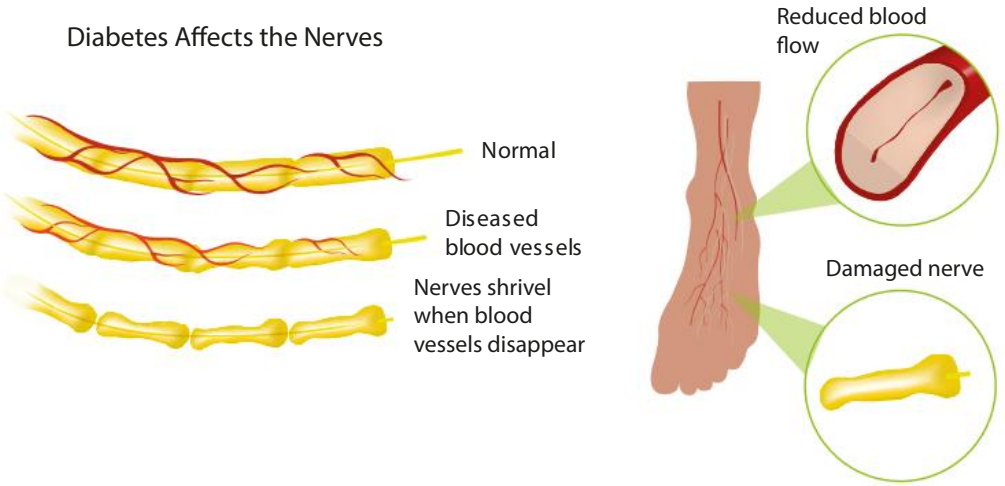


Figure 2.3.9: Diabetes can cause damage to the blood vessels that supply the nerves reducing blood supply to nerves, impairing the nerves.

Treatment

Type 1 Diabetes

Type 1 diabetics are still able to respond to insulin but the beta cells in their pancreas are destroyed by their immune system, so they cannot produce sufficient insulin. Because type 1 diabetics **can still respond to insulin**, they can be treated with insulin injections. These injections are generally administered prior to meals and contain a mixture of rapid-acting and long-acting insulin. Affected individuals can also use an insulin pump as an alternative to injections to administer insulin.

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Type 2 Diabetes

Type 2 diabetics generally exhibit insulin resistance and there is no current cure. For this reason, modifiable diet and lifestyle choices, such as healthy diet and increased exercise are required to manage type 2 diabetes. If blood glucose levels cannot be controlled by making changes to diet and lifestyle, medication may be prescribed, which aims to reduce insulin resistance. In some cases, when type 2 diabetes has progressed and the pancreas cannot produce enough insulin, insulin injections may be required to manage blood glucose levels.

Helpful online resources

Cognito: GCSE Biology - Type 1 vs Type 2 Diabetes - What is Diabetes and How to Treat It

https://www.youtube.com/watch?v=bFnO8Uc9gjQ&t=11s

Cleveland Clinic: 7 Insulin Resistance Diet Tips

https://www.youtube.com/watch?v=0v14REZt4JI

Science as a Human Endeavour 6

Type 1 diabetes vaccine

Scientists are currently researching the possibility of developing a vaccine for type 1 diabetes. Watch the following video and answer the SHE questions below

Helpful online resources

SciShow: Could a Vaccine Prevent Type 1 Diabetes?

https://www.youtube.com/watch?v=XoJWX0_TYKo

Questions

1. Explain how a type 1 diabetes vaccine could **influence** society.

(4 marks)

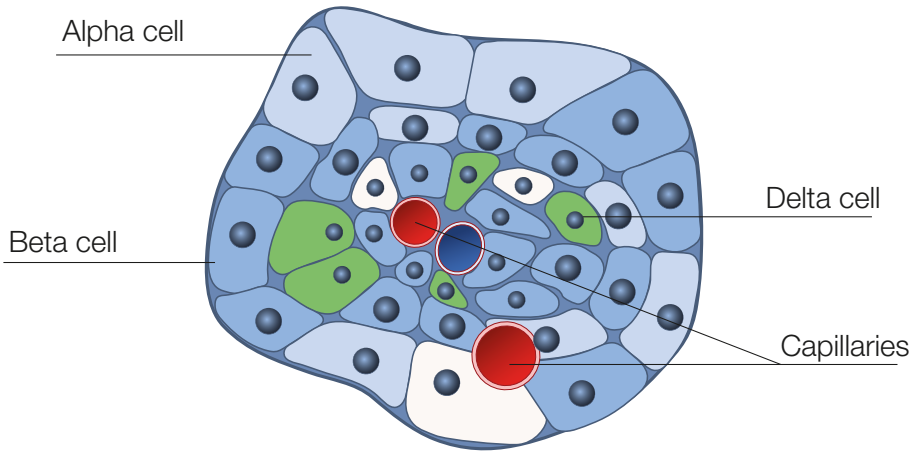
2. Explain two **limitations** of a type 1 diabetes vaccine.

(4 marks)

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2.3 Review questions

1. Refer to the following diagram to answer the following questions:



(a) Name the organ that the group of cells in the diagram above is from.

(1 mark)

(b) Name the hormone that alpha cells produce and explain the role of this hormone in controlling blood glucose levels.

(4 marks)

(c) Name the hormone that beta cells produce and explain the role of this hormone in controlling blood glucose levels.

(4 marks)

(d) Describe the effect of the destruction of beta cells on an individual's ability to control their blood glucose levels.

(2 marks)

(e) Name the condition that develops when the beta cells are destroyed by the immune system.

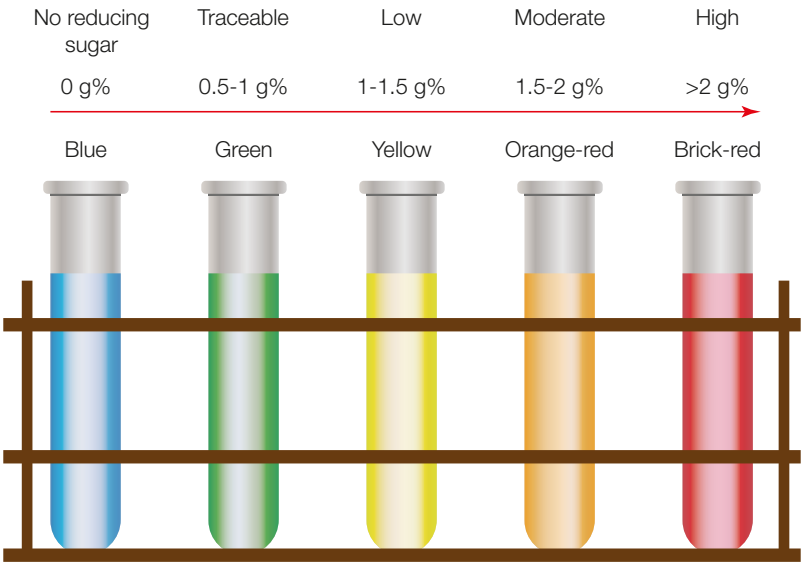
(1 mark)

(f) Explain why an individual who has developed the condition named in (e) can still respond to insulin when injected.

(3 marks)

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2. Benedict's solution can be used to detect the presence of glucose in urine. The diagram below indicates the possible results of a Benedict's glucose test.



(a) If a urine sample was tested and returned a brick-red result on the Benedict's test, is the patient more or less likely to have diabetes?

(1 mark)

(b) Describe why diabetics are likely to experience excessive urination.

(2 marks)

(c) Name another symptom that a diabetic might experience as a result of excessive urination.

(1 mark)

(d) Individuals who experience excessive urination can struggle to make it through the night without going to the toilet. This disrupts their sleep and can lead to a lack of sleep.

Describe how a lack of sleep can increase the risk of someone developing type 2 diabetes.

(3 marks)

(e) Chronic high blood glucose levels due to mismanaged diabetes can lead to kidney disease and in some cases kidney failure. Describe how this occurs.

(2 marks)

(f) Describe why a diabetic might experience fatigue.

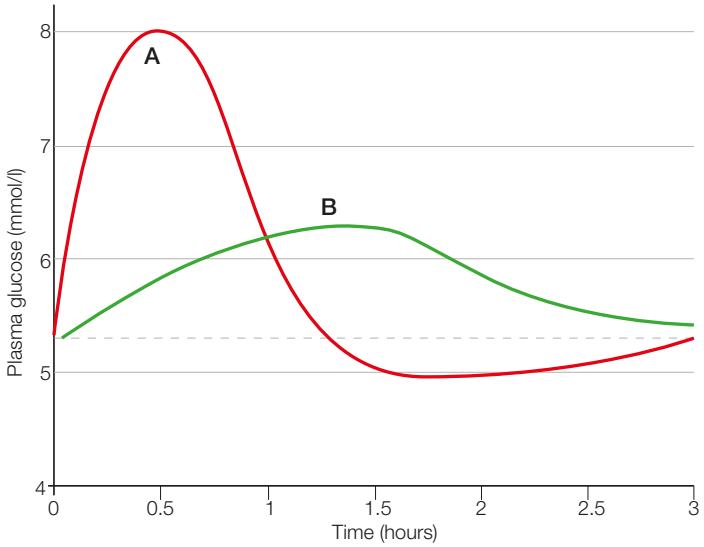
(2 marks)

(g) Explain why increasing physical activity level can be a good treatment option for some individuals with type 2 diabetes.

(3 marks)

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3. Refer to the graph below that represents the blood sugar response in healthy adults to answer the following questions:



(a) Label lines 'A' and 'B' with their respective glycaemic index labels.

A:

B: *(2 marks)*

(b) State **one** example of a food or drink that could elicit the blood glucose responses of 'A' and 'B':

A:

B: *(2 marks)*

(c) Explain why the blood glucose response produced by 'A' is more likely to result in weight gain than the blood glucose response produced by 'B'.

(4 marks)

(d) Chronic consumption of foods that produce the blood glucose response exhibited by line 'A' is associated with weight gain and insulin resistance.

Name the condition that insulin resistance is generally associated with.

(1 mark)

(e) Describe how insulin resistance affects blood glucose levels.

(2 marks)

(f) Describe how a diet high in saturated fat can contribute to insulin resistance.

(3 marks)

(g) Draw a line **on the graph above** to represent the blood glucose response of an individual who consumes the same food that produced the response at 'A' but the individual has significant insulin resistance.

(1 mark)

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(h) Describe **one** disadvantage of choosing foods based on their glycaemic index alone.

(1 mark)

4. Diabetics are generally recommended to reduce carbohydrates to help manage their symptoms, especially sources that are high in simple sugars.

   One such recommendation could be to reduce the consumption of products that sugars make up more than 10% of the product.

   Using data from the Nutrition Information table to the right, identify **and** explain if this product is suitable for a diabetic who has been presented with the above recommendation.

Nutritional Information		
Number of serves: 1		*Serving size: 100g*
Average Quantity	Per Serve	Per 100g
Energy	835.8 kJ	835.8 kJ
Protein	6.1 g	6.1 g
Fat, Total	12.2 g	12.2 g
- Saturated	1.6 g	1.6 g
Carbohydrate	35.7 g	35.7 g
- Sugars	14.2 g	14.2 g
Fibre	3.5 g	3.5 g
Sodium	355 mg	355 mg

(4 marks)

E Extension question

Research "type 3" diabetes and provide your thoughts on the link between diabetes and Alzheimer's disease.

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2.4 Atherosclerosis

Nutrition Understanding

Atherosclerosis is the build-up of fatty deposits in arteries, forming **plaques**, usually against an injury or imperfection in an artery wall. The accumulation of fatty deposits results in the thickening of artery walls, narrowing the channel of the affected arteries. The narrowing of arteries reduces the amount of blood that can flow through and deliver oxygen, glucose and other nutrients to connected organs, negatively affecting their function. The narrowing of arteries also increases blood pressure because there is less space in the channel for blood to flow through. Eventually, the plaque may rupture due to a sudden increase in blood pressure, which triggers a blood clot to form. The blood clot can further limit blood flow and in some cases, cut off blood supply completely, causing death of the tissue the affected artery supplies (see Figure 2.4.1). This leads to **cardiovascular diseases**, such as heart attack, stroke and peripheral artery disease. The type of cardiovascular disease that develops depends on the location of the artery blocked in the body (see Topic 2.6 Cardiovascular disease for more information). Poor dietary and lifestyle choices can accelerate fatty deposits in arteries and increase the risk of cardiovascular disease.

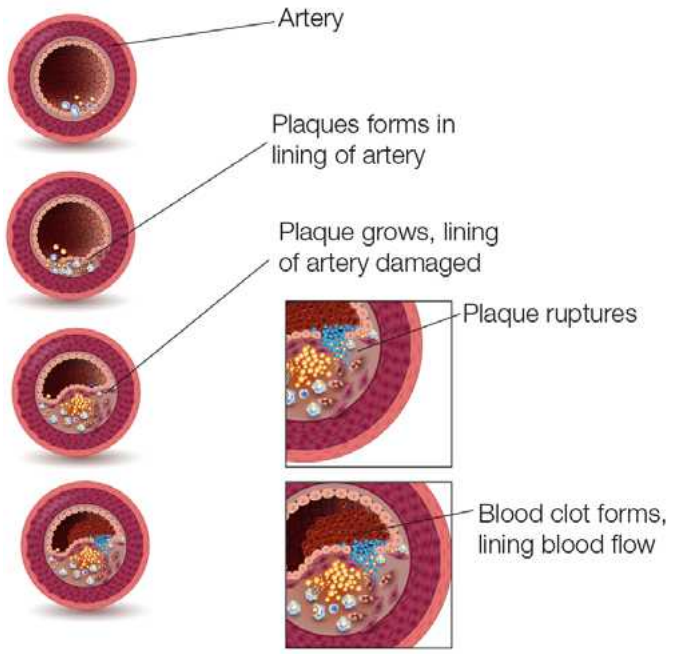


Figure 2.4.1: Atherosclerosis is the progressive build-up of plaques in arteries. When a plaque ruptures, it triggers a blood clot to form, further decreasing blood flow.

Dietary and lifestyle risk factors

Because atherosclerosis is exacerbated by hypertension and leads to certain forms of cardiovascular disease, the dietary and lifestyle risk factors for all three conditions are very similar. Some examples of dietary and lifestyle risk factors for atherosclerosis are outlined below.

Diet

A diet **high in saturated fats and trans-fatty acids** can increase the production of low-density lipoprotein (LDL) cholesterol levels in the blood. LDLs are a form of lipoprotein that are composed of a lot of cholesterol and are often referred to as 'bad' cholesterol. Elevated LDL levels in the blood can increase the risk of plaque build-up in the walls of blood vessels, contributing to atherosclerosis. In addition, a diet **low in omega-3 fats** can also play a factor in the development of atherosclerosis. This is because omega-3 fats can increase the production of the 'good' high-density lipoprotein (HDL) cholesterol. HDLs consist of less cholesterol than LDLs and their function is to collect excess cholesterol from the body's cells and return it to the liver for processing. This reduces blood LDL cholesterol levels, decreasing the risk of developing atherosclerosis. A diet rich in **soluble fibre** is also important because soluble fibre binds with cholesterol in the intestines, which means the cholesterol cannot be absorbed and is removed from the body with the soluble fibre through defecation. This can lower blood cholesterol levels.

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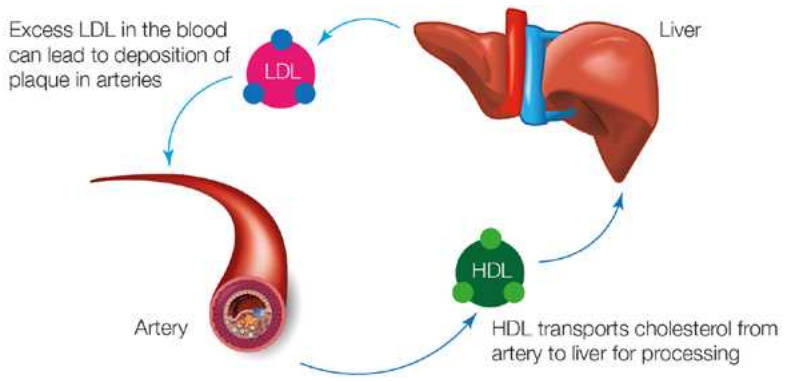


Figure 2.4.2: The opposing functions of low-density lipoproteins (LDLs) and high-density lipoproteins (HDLs).

Hypertension

Chronic hypertension (>140/90) can injure the arterial walls and accelerate the build-up of plaques associated with atherosclerosis. In doing so, the blood vessels are narrowed further, increasing blood pressure and the risk of atherosclerosis (see Topic 2.5: Hypertension for more information).

Diabetes

Diabetes is associated with high blood glucose levels. Over time, the high blood glucose levels damage the internal walls of blood vessels, causing imperfections that plaques can start building up against. The longer an individual has had diabetes, especially if it is uncontrolled, the greater the risk of damage to the blood vessels and therefore atherosclerosis.

Helpful online resources

Mechanisms in Medicine: Fatty Acids and Disease in Type 2 Diabetes

https://www.youtube.com/watch?v=PBB4SHQHTbY

Smoking

Smoking damages the internal lining of blood vessels, forming imperfections for plaques to start building up against. In addition, cigarette smoke contains nicotine that increases blood pressure, further exacerbating the risk of atherosclerosis. Smoking also increases the risk of clots developing and as a result, blockages of blood vessels.

Physical activity

Exercise increases the production of HDL cholesterol levels, which in turn lowers LDL levels in the blood, decreasing the risk of atherosclerosis. Exercise also reduces blood pressure, which is a risk factor for atherosclerosis. A **sedentary lifestyle** therefore **increases** the risk of developing atherosclerosis.

Symptoms

There are often no symptoms of atherosclerosis and the first warning sign for many people can often be when a blockage occurs. The blockage can result in a heart attack, stroke or other cardiovascular diseases associated with blockages of arteries (see Topic 2.6 Cardiovascular disease for more information). However, some symptoms that can be early indicators of atherosclerosis are chest pain, shortness of breath and fatigue. Confusion can occur if the plaque build-up occurs in arteries that supply the brain and muscle weakness in the arms or legs can occur if the arteries supplying them are affected.

Helpful online resources

Nucleus Medical Media: LDL and HDL Cholesterol | Good and Bad Cholesterol | Nucleus Health

https://www.youtube.com/watch?v=0U7YHRW5dyc

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Treatment

Atherosclerosis is initially treated by introducing diet and lifestyle modifications such as decreased saturated fat intake and increased physical activity. In cases where dietary and lifestyle interventions are not successful in managing atherosclerosis, or are not adhered to, medical intervention may be required. Medication may be prescribed, such as beta-blockers to lower blood pressure, statins to lower blood cholesterol or anticoagulants that inhibit blood clotting. However, surgical intervention may be required, such as bypass surgery that diverts blood around the blockage using synthetic tubes or an artery from another area of the body, or balloon angioplasty that uses a catheter to expand the blocked artery (see Figure 2.4.3).

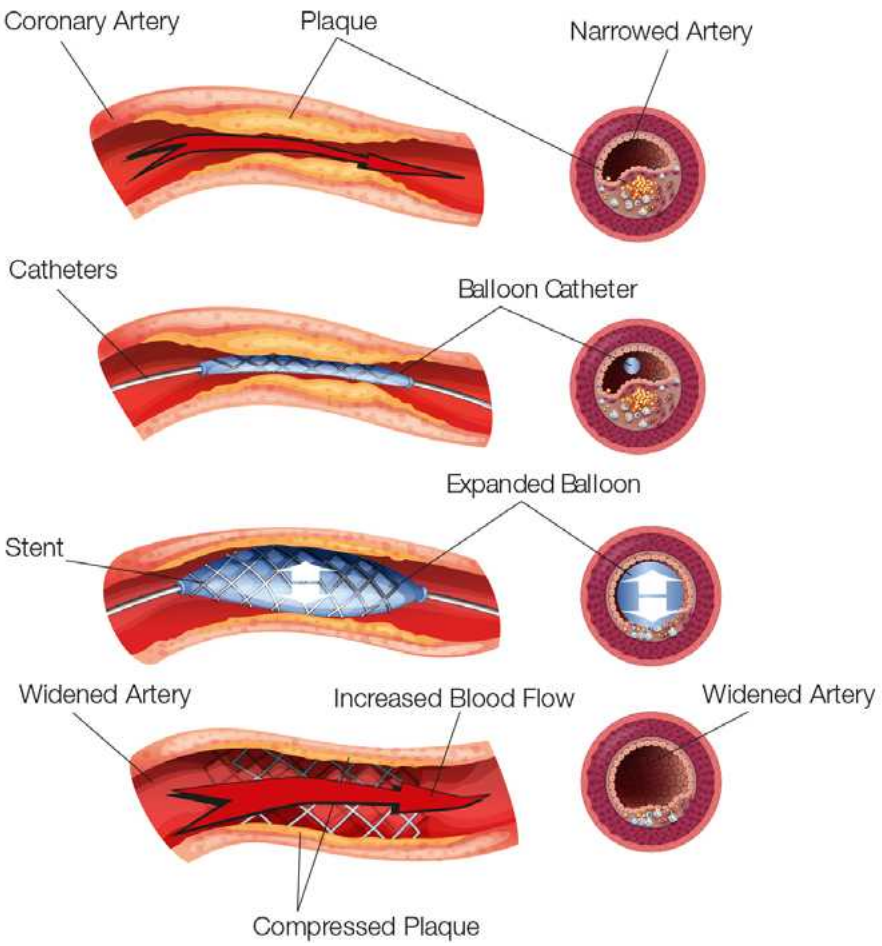


Figure 2.4.3: Balloon angioplasty is a surgical procedure used to treat coronary heart disease. A balloon catheter is inserted into the affected coronary artery and inflated at the site of plaque build-up to compress the plaque and widen the diameter of the artery to increase blood flow.In many cases a stent is also placed to help keep the artery open.

2.4 Review questions

1. Refer to the ingredient list for a Chicken Caesar salad below to answer the following questions:

Chicken Caesar Salad Ingredients
2 × rasher bacon
2 × crumbed chicken fillets
2 × hardboiled eggs
2 slices of white bread
2 × baby cos lettuce
½ cup whole egg mayonnaise

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(a) Suggest **and** justify **three** modifications to the ingredients that would make this Chicken Caesar salad more suitable for a person with atherosclerosis.

Modification 1:

(1 mark)

Justification

(2 marks)

Modification 2:

(1 mark)

Justification

(2 marks)

Modification 3:

(1 mark)

Justification

(2 marks)

(b) Explain how atherosclerosis could result in a heart attack.

(4 marks)

(c) Explain why eating salmon instead of chicken could be a more appropriate option for someone who has atherosclerosis.

(4 marks)

(d) Explain how a sedentary lifestyle can increase the risk of atherosclerosis.

(3 marks)

(e) Smoking is a risk factor for atherosclerosis that can accelerate plaque formation. Describe how smoking can contribute to plaque formation.

(2 marks)

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2.5 Hypertension

Nutrition Understanding

Hypertension is also known as **high blood pressure** and is a prevalent and serious condition that can lead to **cardiovascular disease** and premature death. Hypertension can affect various body organs such as the heart, kidneys, eyes, legs and the brain**.** Blood pressure is the force of circulating blood applied to the elastic walls of arteries as it flows through them. Blood pressure is represented by two numbers. The first number is a measure of the systolic pressure, which is the pressure against arteries when the heart is contracting. The second number is a measure of the diastolic pressure, which is the pressure against the arteries when the heart is at rest. The average blood pressure is 120/80 mmHg (see Figure 2.5.1).

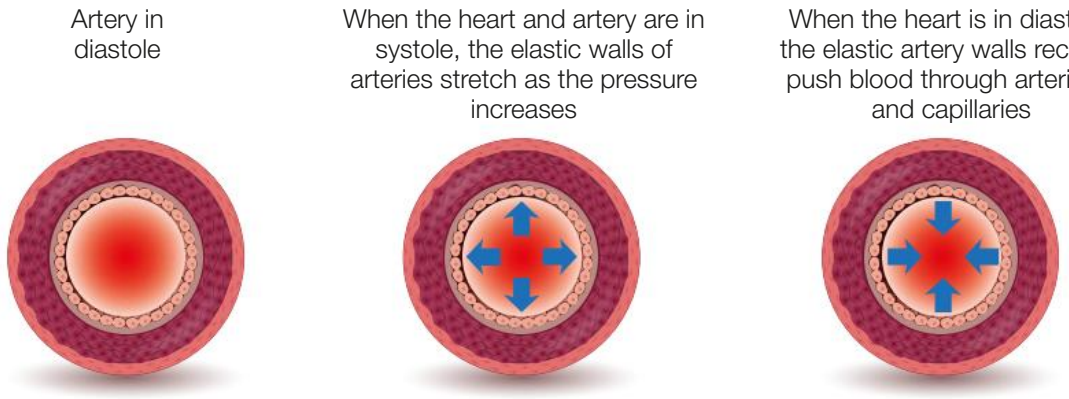


Figure 2.5.1: The average blood pressure is 120mmHg during systole as arteries stretch and decreases to 80mmHg during diastole when arteries recoil.

Hypertension is diagnosed when the blood pressure is greater than or equal to 140/90mmHg. **Chronic high blood pressure can stiffen and injure the walls of arteries**, which can accelerate plaque formation, narrowing arteries. This increases blood pressure further as narrow arteries increase the resistance to blood flow. The narrower the artery, the greater the blood pressure will be (see Figure 2.5.2). Atherosclerosis and hypertension are therefore two conditions that exacerbate each other and have a compounding effect on each other. If hypertension is left untreated, the heart can become enlarged and less efficient at pumping blood around the body, causing **heart failure** and other cardiovascular diseases (see Topic 2.6: Cardiovascular disease).

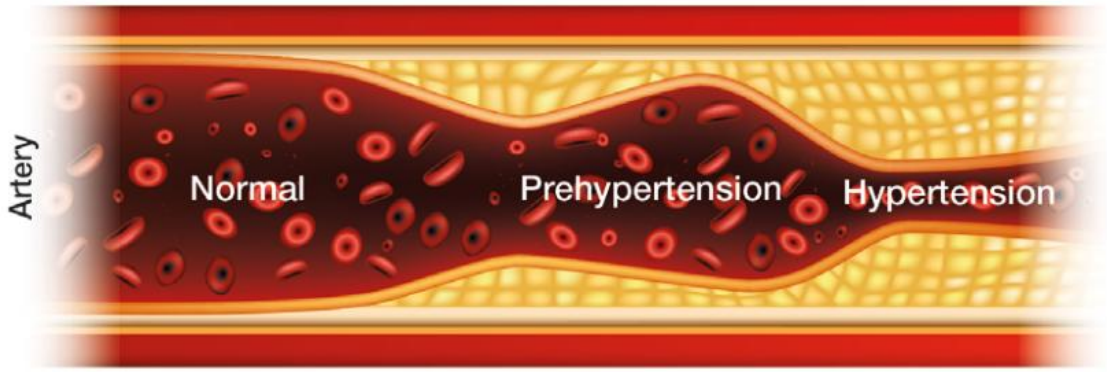


Figure 2.5.2: As the diameter of the artery lumen decreases, there is less space for blood to pass through, increasing resistance and the pressure on the artery walls.

Helpful online resources

Osmosis from Elsevier: Hypertension- causes, symptoms, diagnosis, treatment, pathology

https://www.youtube.com/watch?v=Qm5kB5X70oA

Dietary and lifestyle risk factors

There are many dietary and lifestyle factors associated with hypertension. The risk of hypertension increases with age because the blood vessels lose their elasticity and become stiffer. The higher the blood pressure is above the normal range, the greater the chance of **cardiovascular disease** occurring. Some risk factors that can be controlled are discussed below.

Salt intake

A **diet high in sodium** can increase the risk of hypertension. This is because the kidneys cannot excrete the sodium from the blood efficiently enough at high levels and water is retained by the body to dilute the sodium in the blood. This **increases blood volume**, which places increased stress on the heart and blood vessels, **increasing blood pressure**. Chronic high blood pressure can result in the stiffening of the arteries, reducing their ability to dilate, further increasing blood pressure. Table salt (sodium chloride) contains sodium and is used to flavour foods and can be added as a preservative to prevent microbial growth (see Topic 8: Food Processing for more information). Many **processed foods** therefore contain sodium, such as bread, cereals, ham, salami, pasta sauces, pretzels, crisps, gravy and soy sauce. A diet low in salt and processed foods can therefore help to reduce blood pressure. Implementing daily strategies, such as not adding extra salt to meals, reading labels and choosing products that are low or reduced salt and limiting processed foods can help to reduce daily salt intake. Even a small reduction in daily salt intake can help to reduce blood pressure.

High cholesterol

A diet high in saturated fats and trans-fatty acids coupled with a sedentary lifestyle can increase low-density lipoprotein (LDL) cholesterol levels in the blood. Elevated LDL levels in the blood can increase the risk of plaque build-up in the walls of arteries contributing to atherosclerosis. The narrowing of arteries decreases the space for blood to flow through it, increasing blood pressure.

Diabetes

Diabetes is associated with high blood glucose levels, which can result in an increased blood volume and therefore, increased blood pressure. If diabetes is left unmanaged, blood glucose levels are more likely to remain high and can result in chronic high blood pressure.

Smoking

Cigarette smoke contains nicotine that increases blood pressure by stimulating the release of adrenaline, which constricts blood vessels and hardens arterial walls. The hardening of arterial walls reduces the ability of blood vessels to expand as blood is pumped through, increasing blood pressure.

Alcohol

Alcohol consumption increases blood pressure but the molecular mechanisms behind this are unknown. In some cases, alcohol can lower inhibitions leading individuals to make poor food choices that are often high in salt and sugar, which can result in an increased blood volume and therefore blood pressure. In addition, these food choices can be high in saturated fats and salt leading to increased cholesterol, which is a risk factor for hypertension.

Stress

Chronic stress can increase blood pressure due to the release of stress hormones such as cortisol and adrenaline. These hormones activate pathways that increase heart rate and blood pressure.

Physical activity

Regular physical activity can reduce blood pressure by making the heart stronger. The stronger the heart is, the more easily it can pump blood through the arteries, reducing blood pressure. Exercise also reduces cholesterol levels and stress, which are risk factors for hypertension. A sedentary lifestyle therefore increases the risk of developing atherosclerosis.

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Symptoms

Hypertension is often referred to as a silent condition because many individuals do not exhibit any symptoms and are not aware that they are suffering from hypertension until they exhibit severe symptoms. Severe symptoms may not be experienced by everyone and even if an individual does experience them, they may be mistaken for symptoms of other conditions. As a result, hypertension may continue to go undiagnosed. Some examples of severe symptoms of hypertension are: headaches, dizziness, shortness of breath, nosebleeds, flushed face, chest pain, blood in the urine, blurred vision.

Treatment

Hypertension can be controlled by introducing diet and lifestyle modifications such as the ones mentioned previously. In cases where dietary and lifestyle interventions are not successful in managing hypertension, or are not adhered to, medication may be required. Medication may be prescribed, such as angiotensin-converting enzyme (ACE) inhibitors to help relax arteries, increasing their diameter; diuretics to increase excretion of salt and water by the kidneys; and calcium channel blockers that also help relax artery walls.

2.5 Review questions

1. Describe how the narrowing of arteries affects blood pressure.

(2 marks)

2. Refer to the ingredient list for a supreme pizza below to answer the following questions:

Supreme Pizza Ingredients	
Pizza dough	1 can of sardines
120g tomato paste	1 cup of chopped onion
250g Mozzarella cheese	1 medium red capsicum
250g shredded ham	250g sliced mushrooms
120g pepperoni	1 can of pineapple pieces

(a) Suggest **and** justify **three** modifications to the ingredients that would make this supreme pizza more suitable for a person with hypertension.

Modification 1:

(1 mark)

Justification

(2 marks)

Modification 2:

(1 mark)

Justification

(2 marks)

Modification 3:

(1 mark)

Justification

(2 marks)

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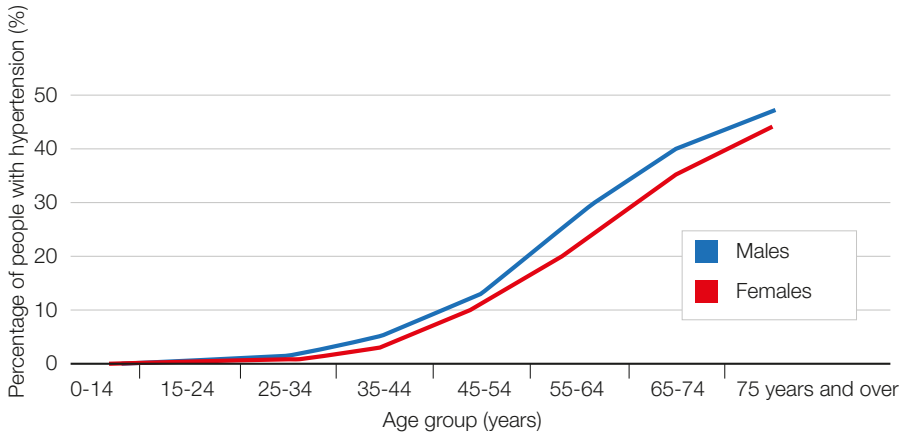
(b) Describe how hypertension could result in heart failure.

(2 marks)

(c) Explain why somebody with diabetes has a greater risk of developing hypertension than an individual without diabetes.

(2 marks)

3. Refer to the following graph that shows the prevalence of people with hypertension in Australia in 2014-15 according to the National Health Survey.



(a) Using data from the graph, determine which gender has the greater prevalence of hypertension.

(2 marks)

(b) Using data from the graph, describe the prevalence of hypertension as people age.

(2 marks)

(c) Explain the pattern identified in part (b).

(2 marks)

(d) People diagnosed with hypertension can control their blood pressure by making changes to their lifestyle, such as increasing physical activity. Explain how increasing physical activity can help to control hypertension.

(2 marks)

(e) When dietary and lifestyle interventions are unsuccessful at managing hypertension, medical professionals may prescribe angiotensin-converting enzyme (ACE) inhibitors to lower blood pressure. Describe how ACE inhibitors work.

(2 marks)

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2.6 Cardiovascular disease

Nutrition Understanding

Cardiovascular disease (CVD), also referred to as heart disease, is a collective term for the variety of conditions that affect the heart and blood vessels. There are many different heart and blood vessel conditions that are covered by the term cardiovascular disease and many of these conditions are associated with **atherosclerosis**. For example, atherosclerosis of the coronary artery, called coronary heart disease, can lead to angina, heart attack and heart failure. Cardiovascular disease is the number one cause of death worldwide and a significant number of these cases could be prevented by modifying poor diet and lifestyle behaviours. Some examples of cardiovascular disease are outlined in Table 2.6.1.

Table 2.6.1: Examples of cardiovascular disease.

Example of cardiovascular disease	Description
Coronary heart disease	The narrowing of the blood vessels that supply the heart, restricting blood supply to it (see figure 2.6.1).
Angina	Chest pain associated with a lack of blood supply to the heart (see figure 2.6.1).
Heart attack	Occurs when blood supply to part of the heart is completely blocked by a blood clot and the cardiac muscle in this part of the heart starts to die (see figure 2.6.2).
Stroke	The most common form of stroke occurs due to complete blockages of blood vessels that supply the brain, resulting in the death of some brain cells that the blocked vessels supply. Strokes can also occur when blood vessels rupture, generally due to uncontrolled **hypertension**. This can result in bleeding in the brain and brain cells receiving less nutrients.
Heart failure	When the heart cannot supply enough blood to the body's cells. This can because it cannot fill with enough blood or cannot pump with enough force.
Arrhythmia	The abnormal rhythm of the heart, such as beating too fast, too slow or irregular beat.
Peripheral artery disease	Atherosclerosis of the blood vessels supplying the arms and legs. This can lead to numbness, gangrene and in serious cases, amputation.

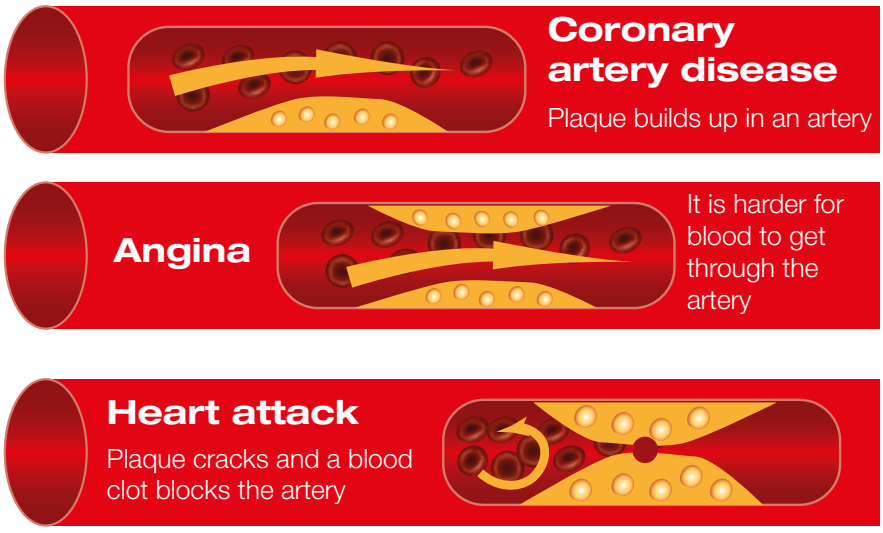


Figure 2.6.1: How coronary artery disease leads to angina and heart attack.

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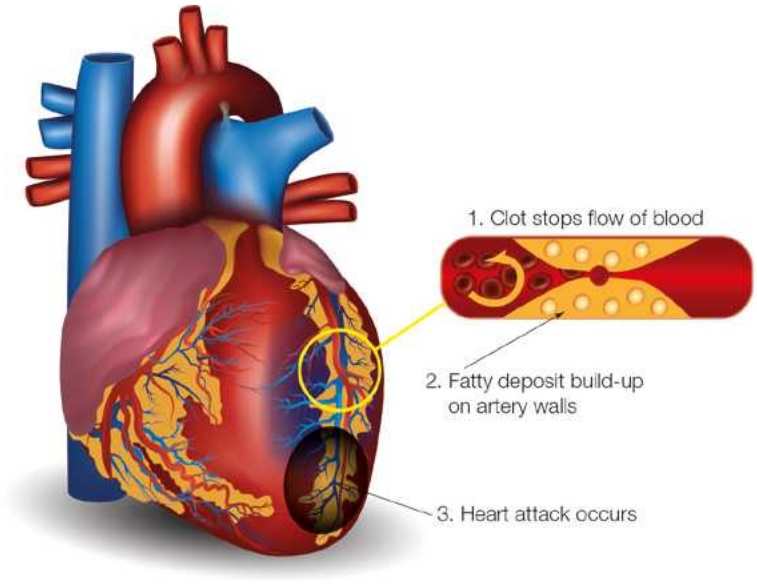


Figure 2.6.2: A heart attack occurs when a coronary artery that supplies the heart with blood becomes blocked due to atherosclerosis and blood clots. The area of the heart supplied by the blocked artery, in this case indicated in grey, is denied oxygen and glucose resulting in the cells in this area dying.

Helpful online resources

FreeMedEducation: What Happens During A Heart Attack? - What is Coronary Heart Disease?

https://www.youtube.com/watch?v=xBAvxnT0ZvI

FuseSchool - Global Education: Heart Disease

https://www.youtube.com/watch?v=u7k6sqTxOCU

Ted-Ed: What happens during a stroke?–Vaibhav Goswami

https://www.youtube.com/watch?v=-NJm4TJ2it0

Dietary and lifestyle risk factors

There are many dietary and lifestyle factors associated with cardiovascular disease. Some factors cannot be controlled such as the increased risk associated with ageing, and males being more prone due to greater storage of adipose tissue in the abdomen. However, some risk factors can be controlled and are discussed below.

High cholesterol

A diet high in saturated fats and trans-fatty acids coupled with a sedentary lifestyle can increase low-density lipoprotein (LDL) cholesterol levels in the blood. Elevated LDL levels in the blood can increase the risk of plaque build-up in the walls of blood vessels, contributing to atherosclerosis, increased blood pressure and an increased risk of cardiovascular disease.

Hypertension

Chronic hypertension (>140/90mmHg) can injure the arterial walls and accelerate atherosclerosis. In doing so, the blood vessels are narrowed further increasing blood pressure. If hypertension is left untreated, it can result in the heart becoming enlarged and less efficient at pumping blood around the body, causing **heart failure**. The risk of hypertension increases with age because the blood vessels lose their elasticity and become stiffer. The higher the blood pressure is above the normal, the greater the chance of cardiovascular disease occurring.

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Diabetes

Diabetes is associated with high blood glucose levels. Over time, the high blood glucose levels damage the internal walls of blood vessels, causing imperfections that plaques can start building up against. The longer an individual has had diabetes, especially if it is uncontrolled, the greater the risk of damage to the blood vessels and cardiovascular disease.

Smoking

Individuals who smoke are approximately 50% more likely to develop cardiovascular disease than non-smokers. Smoking damages the internal lining of blood vessels, forming imperfections for plaques to start building up against. In addition, cigarette smoke contains nicotine that increases blood pressure, further exacerbating the risk of atherosclerosis. Smoking also increases the risk of clots developing and as a result, blockages of blood vessels.

Physical activity

Individuals who are **inactive** have approximately **double the risk** of developing cardiovascular disease than those who get enough exercise. Exercise can increase metabolism and burn fat, helping individuals lose weight. Exercise also increases high density lipoprotein (HDL) levels, which lower LDL levels, decreasing the risk of atherosclerosis and hypertension.

Symptoms

There are often no symptoms of underlying cardiovascular disease and the first warning sign for many people can often be a heart attack or a stroke. However, some symptoms that can be early indicators of cardiovascular disease are shortness of breath, fatigue and light-headedness. The symptoms of a heart attack may include **pain and discomfort in the chest and left arm**. The symptoms of a stroke may include face drooping, jumbled or slurred speech and arm weakness.

Treatment

Cardiovascular disease is initially treated by introducing diet and lifestyle modifications, such as reducing saturated fat intake, quitting smoking and increasing physical activity. In cases where dietary and lifestyle interventions are not successful in managing cardiovascular disease, or are not adhered to, medical intervention may be required. Medication may be prescribed, such as beta-blockers to lower blood pressure, statins to lower blood cholesterol or anticoagulants that inhibit blood clotting. However, surgical intervention may be required, such as bypass surgery that diverts blood around the blockage using synthetic tubes or an artery from another area of the body, balloon angioplasty that uses a catheter to expand the blocked coronary artery (see Figure 2.4.3), or a heart transplant.

Helpful online resources

Cognito: GCSE Biology - Why Do We Get Heart Disease and How to Treat It? - Cardiovascular Disease (CVD)

https://www.youtube.com/watch?v=UN5BlPfMUkg

2.6 Review questions

1. Describe how coronary heart disease could lead to angina and in time, a heart attack.

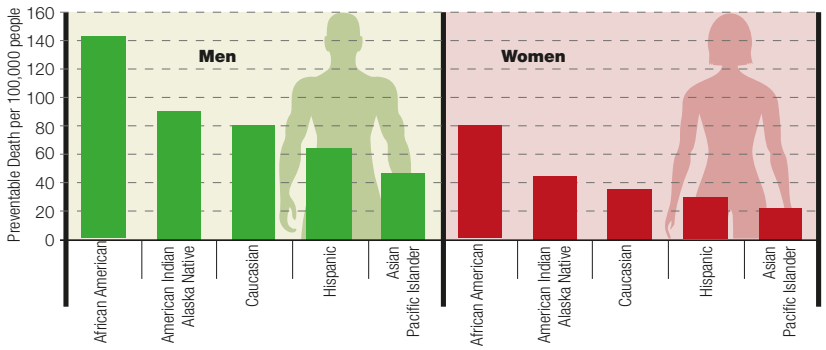
(3 marks)

2. Describe the difference between heart failure and a heart attack.

(2 marks)

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3. Refer to the following graph, which shows the number of preventable deaths from cardiovascular disease for specific groups of people in the US:



(a) State the risk factor for cardiovascular disease that the graph above is displaying.

(1 mark)

(b) Using data from the graph, identify the group of males and females that are at the highest risk of developing cardiovascular disease.

(2 marks)

(c) Using data from the graph, identify if males or females are at a greater risk of developing cardiovascular disease.

(2 marks)

(d) Some groups in society have a greater risk of developing type 2 diabetes. Explain how type 2 diabetes can increase the risk of cardiovascular disease.

(2 marks)

(e) State **two** ways that smoking increases the risk of developing cardiovascular disease.

(2 marks)

E Extension question

Follow the link below to access the article "*Women have heart attacks too, but their symptoms are often dismissed as something else.*" Read the article and provide your thoughts on the inequity between male and female diagnosis of cardiovascular disease.

Helpful online resources

https://theconversation.com/women-have-heart-attacks-too-but-their-symptoms-are-often-dismissed-as-something-else-76083

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2.7 Anaemia

Nutrition Understanding

Anaemia is a disease that involves the **deficiency in the number or quality of red blood cells**. Red blood cells transport oxygen from the lungs to our body's cells so they can respire and produce **energy**. A reduced number or lack of quality red blood cells, therefore, results in the reduced transport of oxygen to cells and reduced energy availability (see Figure 2.7.1). The production of red blood cells requires **sufficient protein, iron, folate and vitamin B12**.

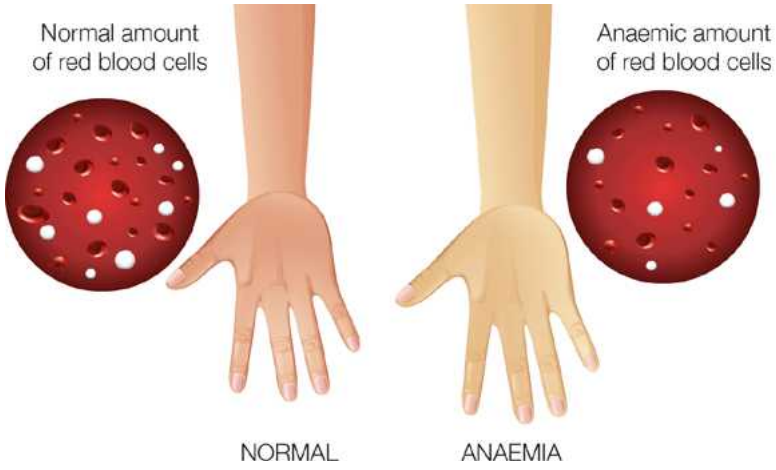


Figure 2.7.1: Individuals with anaemia can have a reduced number of red blood cells flowing through blood vessels. A paler complexion can therefore be a symptom of anaemia.

Dietary and lifestyle risk factors

Iron deficiency anaemia is a worldwide health problem that is especially common in **young women**, **pregnant women** and **sportsmen and sportswomen**. Iron is an essential nutrient because it is a central part of the protein haemoglobin, which makes up red blood cells. Oxygen molecules bind reversibly to the iron in the haemoglobin molecule at the lungs and the red blood cells then carry the oxygen to the body's cells where oxygen can be offloaded for cellular use (see Figure 2.7.2). There is a high turnover of red blood cells, with approximately two million replaced every second. A lack of iron can contribute to a reduced red blood cell count and in turn, reduced supply of oxygen to cells.

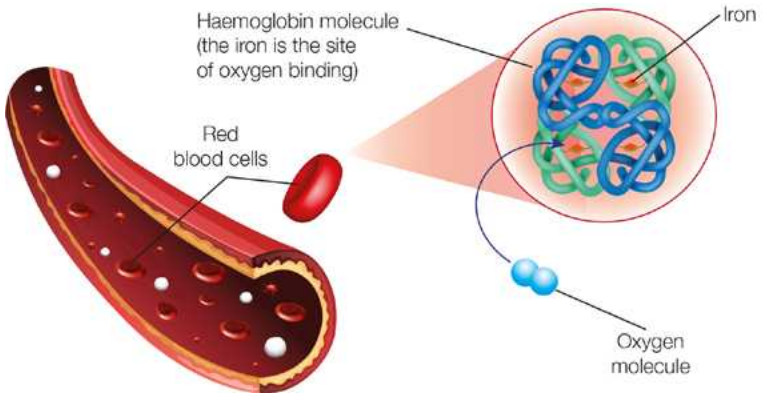


Figure 2.7.2: Red blood cells are made up of haemoglobin that contain iron. Oxygen binds reversibly to the iron molecules so they can be delivered to the body's cells.

The type of food eaten can affect iron absorption. There are two forms of iron: **haem** and **non-haem** iron (see Figure 2.7.3). Haem iron is only found in animal meats, such as beef, pork, lamb and poultry. Animal meats also contain non-haem iron. Plant-based products, however, only contain non-haem iron. Haem iron is more readily absorbed by humans (approximately 25% absorption) than non-haem iron (approximately 17% absorption). The majority of iron we consume is non-haem iron. Because **vegan diets only contain non-haem iron**, vegans should be especially aware of foods that are high in iron and techniques that can promote iron absorption. One way to **increase non-haem iron absorption** is to consume the source of iron with **vitamin C.**

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Some foods and drinks can **reduce** the absorption of iron are outlined in Table 2.7.1 below:

Table 2.7.1: A list of some factors that can reduce calcium absorption and the likely explanation.

Factor	Rationale
Phytic acid	Binds to calcium and forms insoluble complexes, reducing its bioavailability.
Oxalates	Forms insoluble calcium oxalate crystals, reducing calcium absorption
High fibre diet	Excessive dietary fibre can bind to calcium, reducing its availability for absorption.
Excessive caffeine	Interferes with calcium absorption and increases its excretion through the kidneys.
High salt intake	Increases urinary calcium excretion, potentially leading to decreased calcium levels.
Excessive protein intake	High animal protein intake can increase urinary calcium excretion, affecting calcium balance.
Medications	Certain medications can interfere with calcium absorption or increase calcium excretion.
Vitamin D deficiency	Vitamin D is necessary for calcium absorption. Insufficient levels can Impair absorption and utilisation.
Age	As people age, their ability to absorb calcium decreases, requiring higher intake or supplementation.

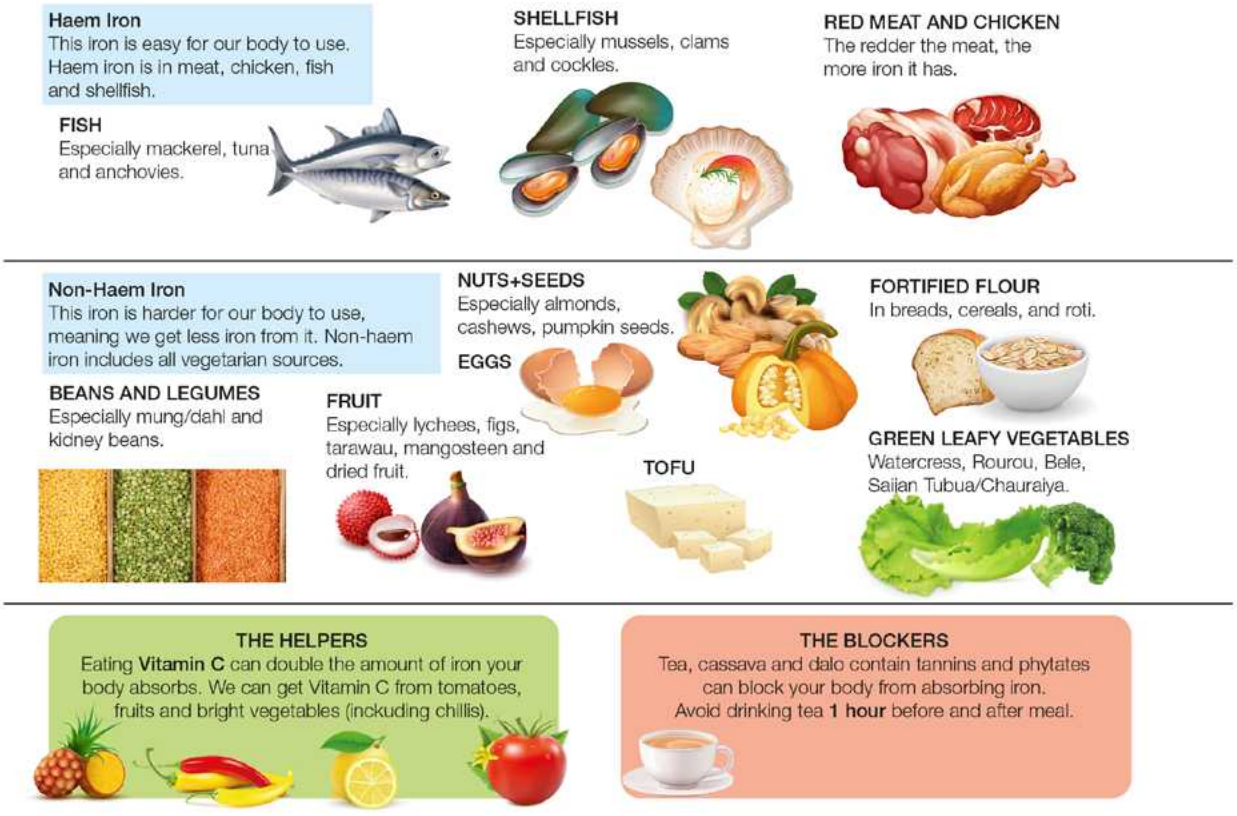


Figure 2.7.3: Some sources of haem and non-haem iron.

The production of red blood cells also requires sufficient folate and vitamin B12. A **deficiency in folate** can lead to the production of large oval shaped, immature blood cells, which cannot carry oxygen through the capillaries as efficiently as normal blood cells. However, this is not common in Australia, partly because of the mandated folic acid fortification of wheat flour used to make breads and the education surrounding the importance of **folic acid supplementation** prior to and during pregnancy.

A deficiency in vitamin B12 can lead to pernicious anaemia. This also results in the production of abnormally large immature blood cells reducing the amount of viable oxygen carrying red blood cells. Although uncommon, **vegans** are at higher risk of vitamin B12 deficient anaemia. This is because vitamin B12 is almost only found in animal products, which vegans do not consume. **Coeliac sufferers** are also at a higher risk of developing vitamin B12 deficient anaemia because they can experience reduced absorption of vitamin B12 due to the flattening of villi in the small intestine. However, vitamin B12 deficiency can be easily treated with vitamin B12 supplements, injections or nasal spray.

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Protein is also needed to make red blood cells, for this reason a diet deficient in **complete protein** can also contribute to anaemia. This is not common in the developed world because there are many protein options available. However, vegans and vegetarians who do not plan their meals to ensure they are consuming enough complementary proteins are at risk of becoming deficient in one or more essential amino acids required to make proteins, such as haemoglobin in red blood cells.

Menstruating females are at higher risk of developing anaemia than males because they naturally lose more blood each month through menstruation. Therefore, women require a greater amount of nutrients to replace the lost red blood cells. In addition, **adolescent** females are also going through a **significant growth period**, which can enhance their risk. If a female is also very active, she may be at even greater risk of developing anaemia. **Sportsmen and sportswomen** require greater blood supply due to increased energy requirements. They also require more iron for the development and repair of muscles, and any blood lost through internal and external bleeding through injury. Iron is also lost through heavy sweating during training and playing sport, especially at the elite level. It is common for **pregnant women** to have mild anaemia during pregnancy but severe anaemia can also occur and can result in complications. As pregnancy requires additional red blood cells to carry oxygen to the baby, anaemia can delay the development of the foetus. It can also result in the baby being born prematurely, resulting in a low birth weight or other complications. In addition, the baby could also be born with anaemia.

Symptoms

Some symptoms of anaemia are:

- Tiredness
- Reduced energy
- Loss of appetite, motivation and enthusiasm
- Behavioural problems, generally due to lack of attention and being tired
- Paleness
- Reduced physical work capacity/productivity
- Premature births (if the mother is a severe anaemia sufferer)
- Pica (which is a rare symptom in which the sufferer wants to eat non-food substances like clay).

Treatment

For diagnosed cases of anaemia, there are treatment options. Initially, a review of the individual's diet by a qualified nutritionist or dietician could be warranted and could alleviate any nutritional deficiencies associated with anaemia. This could result in a **new diet** being trialled or increasing the amount of foods consumed to meet the developmental needs. If required, **supplements** can be administered. These supplements can be purchased over the counter but should only be consumed after seeking professional medical advice. Iron, folate and vitamin B supplements are all available. If an individual is iron deficient and cannot absorb enough iron or needs a large dose of iron quickly, a medical professional might recommend an iron infusion, which is delivered through an intravenous (IV) drip. Vegans are highly likely to require vitamin B12 supplementation because they do not consume animal products. This can also be administered through a nasal spray or through injection. Folate is highly recommended as a daily supplement for pregnant women for at least one month prior to conception, and for the first three months of pregnancy. Folate is needed for increased blood supply during this period but is also required by the developing foetus for brain and neuron development.

Helpful online resources

Cognito: GCSE Biology - Iron deficiency anemia

https://www.youtube.com/watch?v=6RbuFyt5Wpo

FuseSchool - Global Education: Iron Deficiency

https://www.youtube.com/watch?v=H-IY53XBORo

Healthline: 5 Signs and Symptoms of Vitamin B12 Deficiency

https://www.youtube.com/watch?v=i3A7PLhrDck

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2.7 Review questions

1. Define the term anaemia.

(1 mark)

2. Refer to the following diagram:



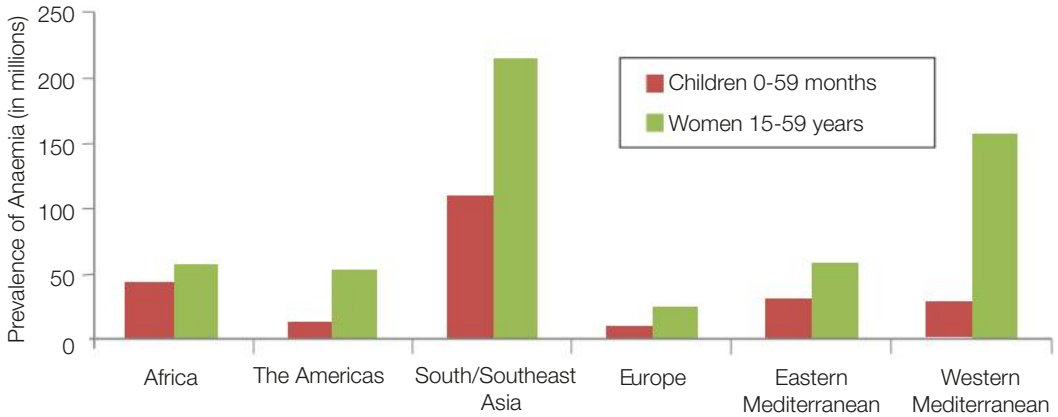
(a) Identify whether individual A or B is more likely to be anaemic **and** explain why.

(3 marks)

(b) State **two** additional symptoms of anaemia.

(2 marks)

3. Refer to the following graph:



WHO Geographic Region

(a) Using data from the graph, determine the prevalence of anaemia of women (15-59 years) in South/Southeast Asia.

(1 mark)

(b) Using data from the graph, identify the prevalence of anaemia in women (aged 15-59 years) in Europe.

(1 mark)

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(c) Identify **one** possible reason that could explain the difference in prevalence of anaemia of women (15-59 years) in South/Southeast Asia and Europe.

(1 mark)

(d) Describe why women are more likely to develop anaemia than men.

(2 marks)

(e) Sportswomen who are very active have an increased risk of developing anaemia. Explain why this is so.

(2 marks)

4. (a) Apart from iron, name **three** other important nutrients that are required to make red blood cells.

(3 marks)

(b) Describe **two** reasons why vegans can be at higher risk of developing anaemia.

(4 marks)

(c) Describe the treatment options for someone diagnosed with iron deficient anaemia.

(3 marks)

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2.8 Osteoporosis

Nutrition Understanding

Osteoporosis is a condition where bones become weak and fragile. Bone is constantly being broken down and replaced in the body but osteoporosis occurs when there is more bone loss than creation of new bone. This results in the reduced density of bones, increasing the risk of bone fractures and breakages from daily activities, such as walking, bending over and coughing (see Figure 2.8.1). Minor bumps and falls can also result in bone fractures and breakages, such as spine, hip and wrist fractures. The risk of developing osteoporosis increases with age and women who have experienced menopause are at the highest risk.

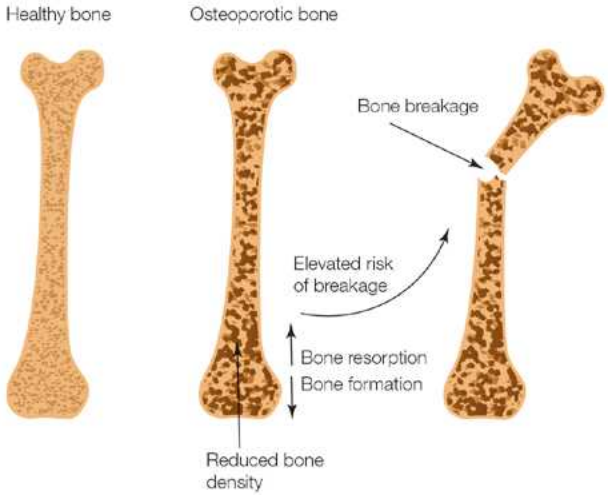


Figure 2.8.1: Reduced bone density increases the risk of bone fractures.

Bones are constantly being renewed, meaning old bone is constantly being broken down and new bone replaces it. The process of replacing old bone is more efficient when we are young, resulting in new bone being made faster than old bone is broken down. This results in bone growth (see Figure 2.8.2). The rate of bone replacement slows during our early twenties and most people achieve **peak bone mass** by their late twenties or early thirties. Bone density subsequently declines after 30, where bone mass is lost faster than it can be replaced. In some cases, the risk of developing osteoporosis can depend on race and inheritance but in many cases, it can depend on how much bone mass was gained during an individuals' first 30 years and how close he/she got to reaching their potential genetic peak bone mass. Peak bone mass can be affected by diet and lifestyle choices made during the first thirty years of life, and poor choices can result in a reduced peak bone mass (see Figure 2.8.2). The greater the peak bone mass achieved, the less likely an individual is to develop osteoporosis, because they have a greater mass of bone to lose to begin with.

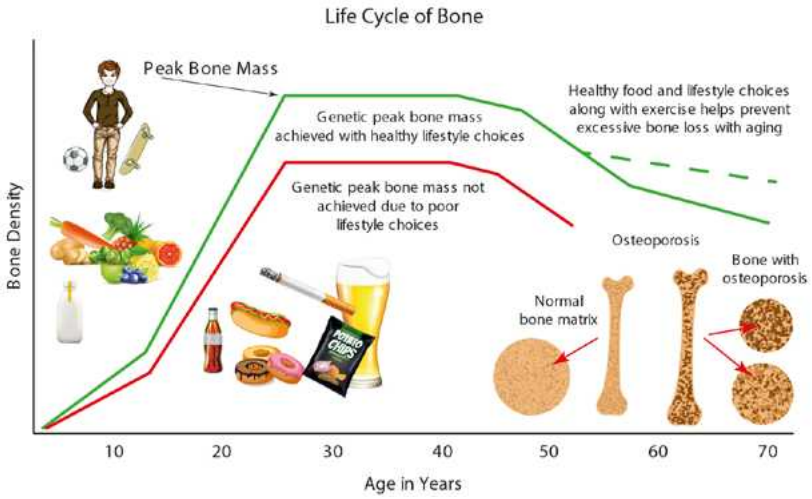


Figure 2.8.2: Poor diet and lifestyle choices can reduce the likeliness of individuals achieving their potential genetic peak bone mass (indicated by the red line).

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Dietary and lifestyle risk factors

There are many dietary and lifestyle factors that can affect the risk of developing osteoporosis, such as diet, exposure to sunlight, gender, physical activity, the amount of caffeine consumed, alcohol and smoking.

Diet

A diet that is **deficient in calcium and phosphorus** can increase the risk of developing osteoporosis. This is because the primary function of calcium and phosphorus in the body is the **development of strong bones and teeth**.

In our bodies, approximately 99% of calcium is stored in the bones and teeth and 1% in our blood. The calcium in the blood is very important for muscle contraction and relaxation, enabling the heart to contract and transport blood around the body. It is therefore essential that blood calcium levels be maintained because a decreased level in the blood could result in an irregular heartbeat or heart failure or death. Consequently, if there is not enough calcium in the blood, the body will **reabsorb it from the bones** to ensure the heart can continue to beat efficiently. Ordinarily, when **calcium intake is inadequate**, calcium is exported into the blood resulting in reduced bone density. Therefore, the body requires a calcium balance, where calcium absorbed into the intestine is equal to that lost.

Chronic inadequate calcium intake can lead to reduced peak bone mass and continued bone loss. This progressively makes the bones more fragile with age, increasing the risk of osteoporosis and **fracturing or breaking bones**. Dense bones are the best protective agent against age-related bone loss and fractures.

As phosphorus is present in almost all foods, a deficiency in phosphorus is not common and is generally only a result of side effects of particular medications.

Exposure to sunlight

Getting regular sun exposure can be important for strong bones. Our skin can make its own vitamin D when it is exposed to sunlight. Vitamin D is just as important as calcium for strong bones. The main role of vitamin D is to control blood concentrations of calcium and phosphorus for bone formation and maintenance. Vitamin D increases the absorption of calcium and phosphorus in the small intestine and mobilises calcium from bones to increase concentration in the blood when required. Without vitamin D, calcium cannot be absorbed. Under normal circumstances, approximately 30% of calcium consumed is absorbed, however, if not enough vitamin D is available, less than 30% is absorbed.

Vitamin D can be sourced from the diet and through **sunlight exposure.** Exposure to sunlight for about **10 minutes per day** can provide most individuals with their recommended intake. However, individuals with darker skin generally require greater exposure to sunlight than 10 minutes for their body to produce sufficient amounts of vitamin D. People aged 50 and older cannot make enough vitamin D from sun exposure alone and need to ensure they obtain enough through their diet and if necessary, supplements. In addition, individuals who reside in high latitudes where there is very little sunlight during winter are at greater risk of vitamin D deficiency (see Figure 2.8.3). A vitamin D deficiency can cause adolescents not to reach their peak bone mass, reduced bone density in adults and **osteoporosis** in the elderly.

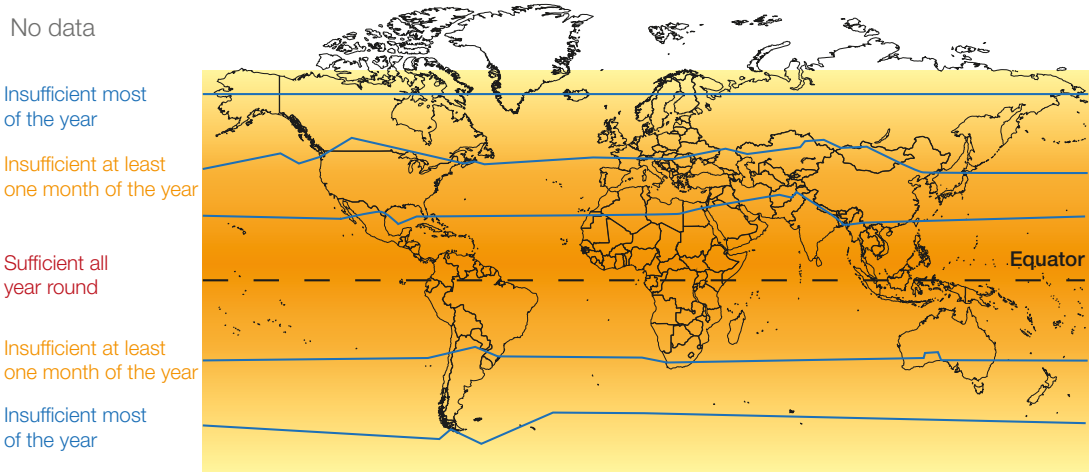


Figure 2.8.3: The UV intensity required for vitamin D synthesis in the skin differs at varying latitudes.

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Gender

Males generally have a greater peak bone mass at maturity than females (see Figure 2.8.4). However, males who have low testosterone levels are at greater risk of developing osteoporosis. This is because testosterone plays an essential role in building and maintaining bone density. Some males may have naturally low testosterone levels but certain chemicals and treatments can also decrease testosterone levels and increase the risk of reduced bone density. Male testosterone levels naturally decrease with age but at a slower rate than women's oestrogen levels.

Oestrogen plays an essential role in building and maintaining bone density in females. Some women can experience menstrual abnormalities and have lower oestrogen levels. This can result in a reduced peak bone mass. Oestrogen levels drop in women during **menopause** and this results in accelerated bone loss and can result in approximately 10% loss of bone mass in the first five years after menopause (see Figure 2.8.4).

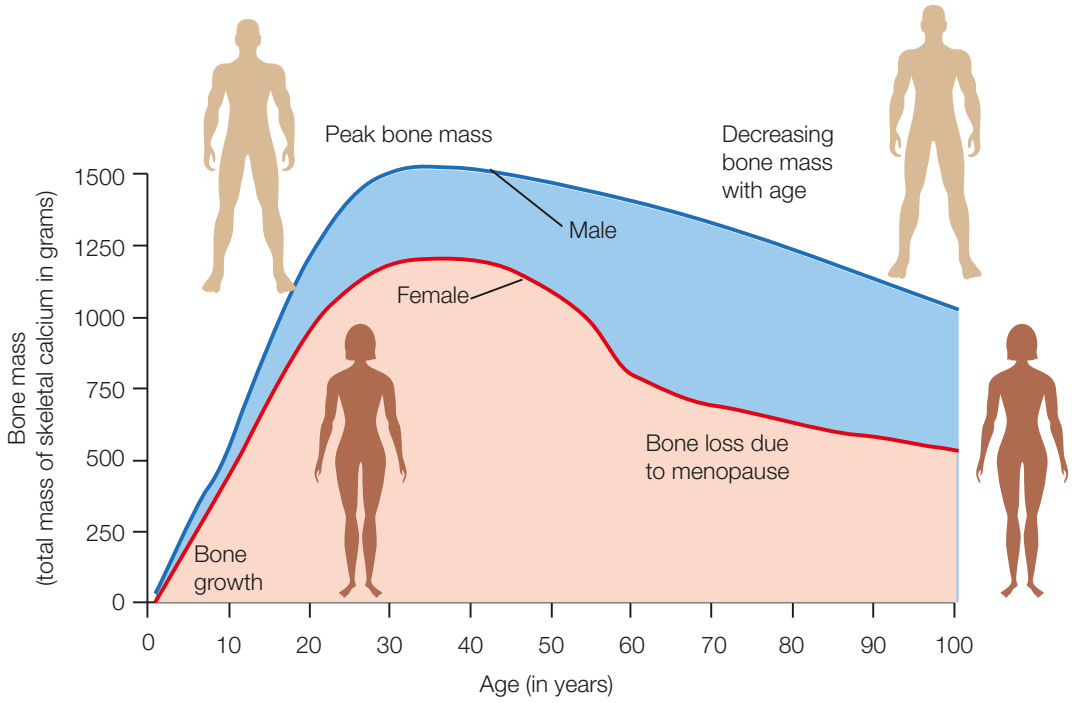


Figure 2.8.4: Males generally have a greater peak bone mass than females. Following the peak, a reduction of sex hormones results in bone loss especially in females after menopause.

Physical activity

An **active lifestyle** consisting of regular and varying weight bearing exercises **decreases** the risk of developing osteoporosis. When weight bearing exercises are performed, muscles are stimulated to work, which pull on the bones promoting bone strength. This results in increased bone density and muscle mass. In fact, the best way to maintain bone density is to perform weight bearing exercises. Some examples of weight bearing exercises are walking, running, dancing, hiking, stair climbing and weightlifting. In addition, performing balance exercises such as tai chi, Pilates and yoga can also help the elderly to reduce the risk of falling and fracturing less dense bones. Although non-weight bearing activities such as swimming and cycling are great for cardiovascular health, they do not improve bone health.

Caffeine, alcohol and smoking

Caffeine can inhibit the absorption of calcium consumed. This is because caffeine is a diuretic and limits absorption of vitamins and minerals, due to promoting urine formation. Consuming large amounts of caffeine will therefore reduce the amount of available calcium to the body and can result in a decreased bone density and increased risk of osteoporosis. For this reason, it is recommended not to drink more than three cups of tea, coffee or cola per day.

Excessive alcohol consumption also increases the risk of developing osteoporosis. Alcohol can kill the cells that make bone, called osteoblasts, and increase hormones, such as cortisol and parathyroid hormone, which increase the breakdown of bones.

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Smoking also increases the risk of osteoporosis. Many individuals who smoke started smoking before their peak bone mass was reached and this can result in them not reaching their potential peak. Smoking does this by reducing the blood supply to bone and reducing the production of osteoblasts (the bone producing cells). This can result in less bone formation and bone density, increasing the risk of fractures.

Symptoms

There are generally no symptoms of osteoporosis until the damage has already been done. Some symptoms that may be noticed once the bones have already been weakened are a curved posture, decreased height and bones that fracture more easily than normal (see Figure 2.8.5).

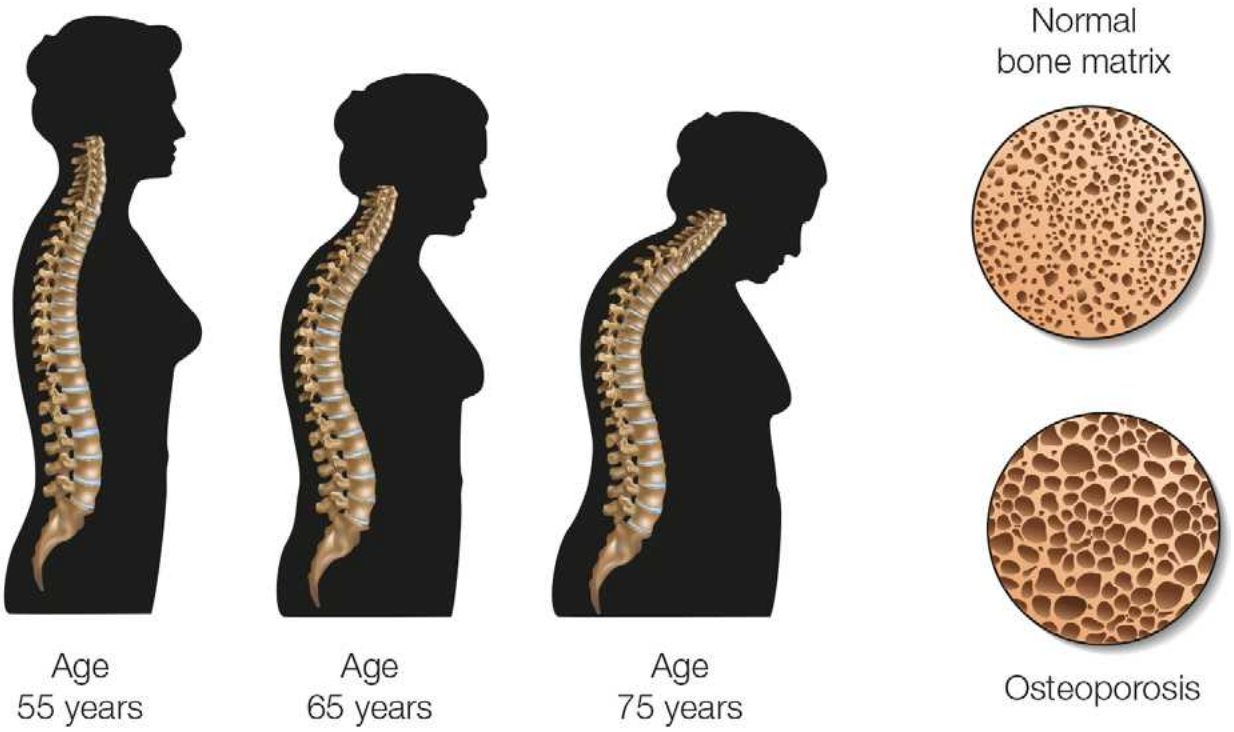


Figure 2.8.5: Some symptoms of osteoporosis such as a curvature of the spine and decreased height become evident once the bone density has already been reduced.

Treatment

When an individual is diagnosed with osteoporosis, the treating doctor will often prescribe **medication** to strengthen bones. This medication targets the cells that break down bone, called osteoclasts, making them less active. The cells that make bone cells, called osteoblasts, remain active and this reduces the amount of bone loss and risk of fractures over time. In addition, calcium and vitamin D levels are likely to be checked and a change in diet and/or **supplements** may be recommended. Lifestyle changes, such as increased exercise and the cessation of alcohol consumption and smoking will generally also be advised.

Helpful online resources

FreeMedEducation: Osteoporosis: The Silent Thief of Bone Health

https://www.youtube.com/watch?v=XHRRCaY_H9E

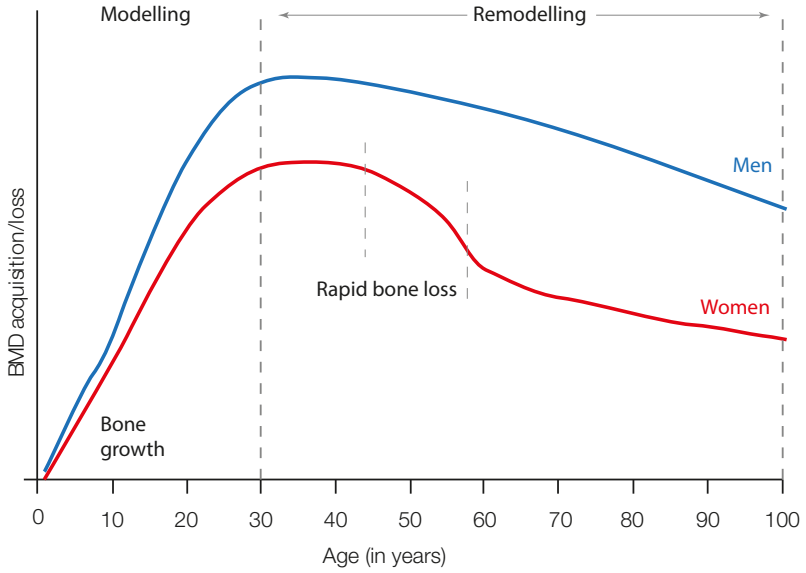
TED: Why healthy bones are about so much more than milk | Body Stuff with Dr. Jen Gunter

https://www.youtube.com/watch?v=1Zh045t0xcE&t=3s

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2.8 Review questions

1. Refer to the graph below to answer the following questions:



(a) Describe why bone growth is most rapid between birth and the age of twenty.

(2 marks)

(b) State what the vertical dashed line at 30 years of age represents.

(1 mark)

(c) When a 30 year old falls over and experiences a minor impact, they are unlikely to be affected and will continue on with their daily activities. However, a 70 year old who experiences a similar fall with the same level of impact can fracture or break bones such as their hip or leg. Explain why this is possible.

(4 marks)

(d) State what is occurring in women that causes the rapid bone loss indicated in the graph.

(1 mark)

(e) Describe how your answer to (d) causes this rapid bone loss.

(2 marks)

(f) Describe how inadequate calcium intake during adolescence can affect peak bone mass.

(2 marks)

(g) Explain how exercise can reduce bone loss.

(3 marks)

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(h) Draw a line on the graph to represent the effect of suboptimal lifestyle factors on the bone density of a woman from birth to 100 years of age.

(1 mark)

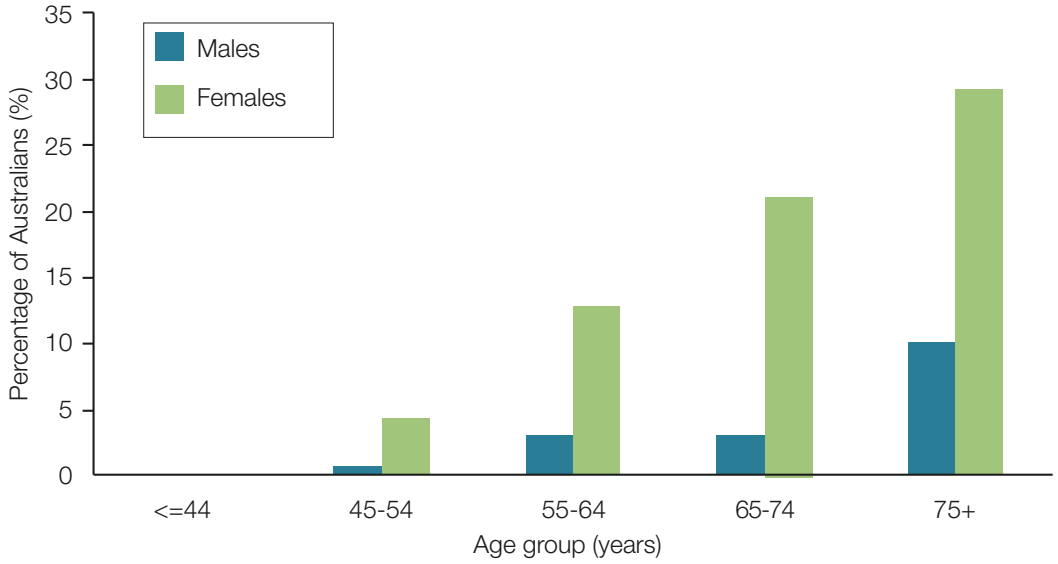
(i) Explain why a male who has lived his whole life in Northern Finland may not have reached his potential peak bone mass.

(4 marks)

(j) Describe why an individual who consumes eight cups of tea and coffee per day could have an increased risk of developing osteoporosis.

(3 marks)

2. Refer to the following graph that highlights the prevalence of self-reported osteoporosis cases by age and sex in Australia for 2017-18.



(a) Using data, describe the prevalence of self-reported osteoporosis between males and females from 45 to 75+.

(2 marks)

(b) Identify **one** possible reason why the percentage of males with osteoporosis seen in the graph could be misleading.

(1 mark)

(c) State **three** symptoms that a 74 year old woman with osteoporosis might experience.

(3 marks)

(d) Medical professionals often prescribe medication to individuals diagnosed with osteoporosis. Describe how this medication works to strengthen bones.

(1 mark)

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2.9 Diverticular disease

Nutrition Understanding

Diverticular disease, also known as **diverticulosis**, is a very common condition that affects the digestive system. Diverticulosis is identified by the presence of **diverticula**, which are small pouches that balloon out of weak spots in the muscle, generally in the large intestine (see Figure 2.9.1). These diverticula are thought to form due to increased pressure in the intestines and increased straining during defecation, especially when constipated. If the diverticula become inflamed or infected it can become very painful and this is called **diverticulitis**. Diverticulitis most commonly occurs in the descending colon, which results in pain presenting in the lower left part of the abdomen (see Figure 2.9.2).

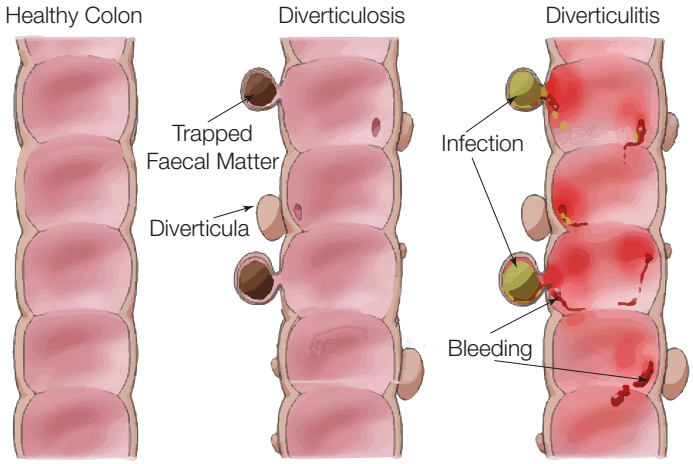


Figure 2.9.1: Diverticulosis is diagnosed by the presence of diverticula that balloon out of weak spots in the intestinal wall where faecal matter can get trapped. If they become inflamed or infected it can become painful and result in diverticulitis.

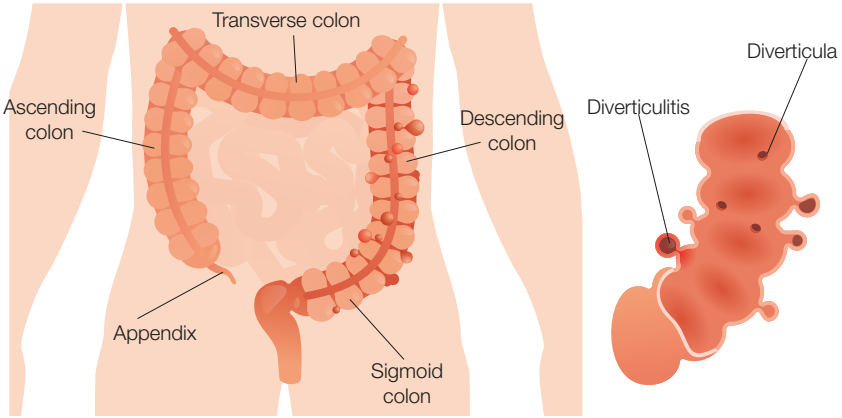


Figure 2.9.2: Diverticulitis more commonly occurs in the descending colon of the large intestine.

Helpful online resources

Gastrointestinal Society: Diverticular Disease | Diverticulitis

https://www.youtube.com/watch?v=j57TBHSaL-w

Zero to Finals: Understanding Diverticulosis and Diverticulitis

https://www.youtube.com/watch?v=dfk5MEbyZtI

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Dietary and lifestyle risk factors

The prevalence of diverticular disease **increases with age**. More than half of adults over the age of 70 have diverticulosis and many are unaware that they have the condition due to not experiencing any symptoms. The exact cause of diverticular disease is unknown at present but the condition is more prevalent in individuals who consume diets low in fibre. Some additional diet and lifestyle risks are diet, physical activity, water consumption and caffeine and alcohol.

Diet

The best way to reduce the risk of developing diverticular disease is to eat a healthy diet that is **high in dietary fibre**. Dietary fibre is only found in plant-based products and not animal products. If an individual is consuming a diet high in animal products, they may not be getting enough fibre in their diet, increasing the risk of diverticular disease. Fibre helps to soften stools, which speeds up its movement through the bowels, reducing pressure on the intestinal walls and the likeliness of **constipation** occurring. Constipation is the discomfort bought about by the inability to pass soft stools regularly. Constipation can cause the pressure in the intestine to increase and result in straining to pass the firm stools. The combination of increased pressure and straining can cause irritation and inflammation of the intestines and over many years can increase the risk of diverticula forming and becoming infected.

Physical activity

A sedentary lifestyle can increase the risk of diverticular disease. Exercise can increase the muscle tone of the gastrointestinal tract. This increased muscle tone can improve the motility of the gut and reduce the pressure, promoting the stool to move through the intestines more quickly and easily. This helps to prevent constipation and therefore diverticular disease.

Water consumption

The average adult requires between 1.5L and 2.5L of water per day, depending on factors such as their size, activity level and the climate lived in. Inadequate water intake can lead to **dehydration**. Dehydrated individuals are at an increased risk of experiencing constipation as less water is available to soften stools. Constipation can cause the pressure in the intestine to increase and result in straining to pass the firm stools, increasing the risk of diverticular disease.

Caffeine and alcohol

Caffeine and alcohol are diuretics, which trigger an increased loss of water from the body through urine. Caffeine and alcohol inhibit the release of anti-diuretic hormone (ADH) from the brain. ADH acts on the kidneys resulting in an increased reabsorption of water to the blood and less water excreted through urine. If the release of ADH is inhibited by caffeine or alcohol, less water is reabsorbed, and more water is lost to the urine. Due to the excess water lost from the body, this has a dehydrating effect. As previously mentioned, dehydration can increase the risk of constipation and the risk of diverticula forming.

Helpful online resources

TED-Ed: How do your kidneys work?–Emma Bryce

https://www.youtube.com/watch?v=FN3MFhYPWWo

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Symptoms

Individuals with diverticulosis do not usually exhibit any symptoms but they might experience some changes in bowel movements, such as constipation and diarrhoea. However, if one or more of the diverticula become inflamed and/or infected causing diverticulitis, the affected individual can experience more serious symptoms, such as:

- Pain
- Abdominal cramps
- Bloating
- Bleeding
- Diarrhoea
- Vomiting
- Fever
- Chills
- Nausea.

Treatment

Because most people have no or few symptoms from diverticula, diverticulosis does not require intense treatment. Diverticulosis can be managed with changes to diet and lifestyle factors such as:

- Gradually adding fibre to the diet
- Drinking plenty of water
- Eating regular meals under relaxed circumstances
- Exercising daily
- Avoiding straining when passing a bowel movement
- Not ignoring the urge to defecate.

If diverticulitis occurs, medical professionals will often prescribe antibiotics to kill the bacteria causing the infections in the diverticula. In some cases, surgical intervention is required. The recurrence of diverticulitis is high, and it is therefore recommended that the same prevention methods used to manage diverticulosis be implemented to reduce the risk of recurrent infections.

Helpful online resources

Nucleus Medical Media: Colon Problems: Diverticular Disease

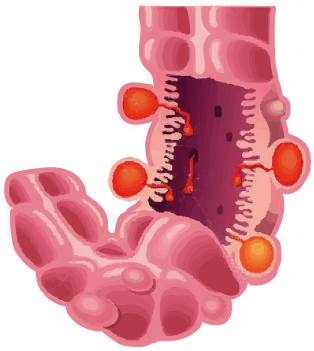
https://www.youtube.com/watch?v=efKlSy_dx-4

2.9 Review questions

1. Describe the difference between diverticula, diverticulosis and diverticulitis.

(3 marks)

2. Refer to the following picture:



(a) Name the condition represented by the diagram above.

(1 mark)

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(b) Justify your answer to part (a).

(2 marks)

(c) State **three** symptoms that an individual diagnosed with the condition answered in part (a) might experience.

(3 marks)

3. Describe why consuming a diet high in animal fats increases the risk of developing diverticular disease.

(2 marks)

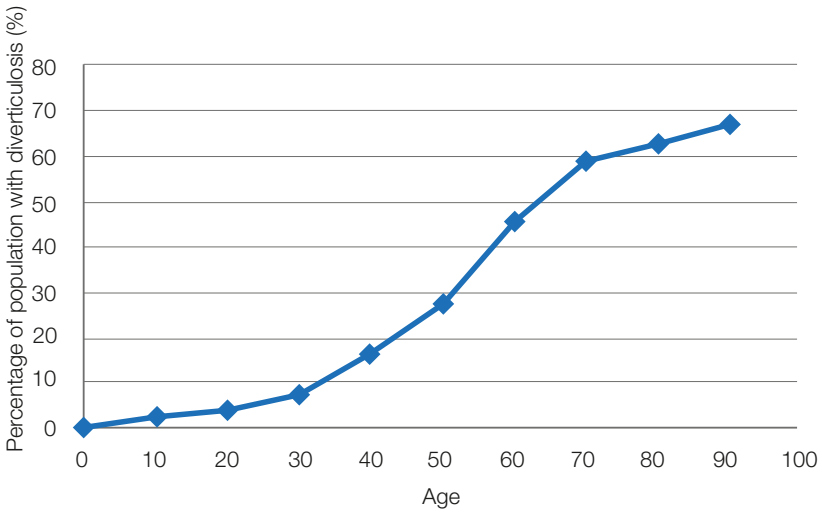
4. Explain how chronic constipation can increase the risk of diverticulitis over time.

(4 marks)

5. Explain why chronic dehydration can increase the risk of developing diverticular disease.

(3 marks)

6. Refer to the following graph, which shows the incidence of diverticulosis by age.



(a) Using data, describe the incidence of diverticulosis by age.

(2 marks)

(b) Explain how exercise can decrease the risk of developing diverticulosis.

(3 marks)

Topic 2 Review Test

1. *A survey was conducted to determine if there was a difference in knowledge of recommended carbohydrate intake between males and females. The researchers conducting this survey recommend that carbohydrates should make up approximately 55% of an individual's daily food intake. It should be noted that some people surveyed chose not to respond to this question. Refer to the table below for a summary of the surveys results.*

Knowledge of recommended intake of carbohydrates, by gender

Question: How much of a person's diet should be made up of carbohydrates?	*Percentage of males who chose this response (%)*	*Percentage of females who chose this response (%)*
Less than a quarter	7	7
About a quarter	34	51
About half	31	26
About three-quarters	8	4

(a) Using data from the table above, state whether the recommended intake of carbohydrates was more correctly identified by males or by females.

(2 marks)

(b) A person whose diet contains significantly more or less than the recommended intake of carbohydrates can develop disorders related either to overnutrition or to undernutrition.

(i) Describe how a person could develop a specific disorder of overnutrition from such a diet.

(2 marks)

(ii) Describe how a person could develop a specific disorder of undernutrition from such a diet.

(2 marks)

(c) Foods are increasingly being classified as having a high or a low glycaemic index (GI).

(i) *Refer to the following list:*

- Baked beans
- Jellybeans
- Apple
- Matured cheese
- White rice
- Cola

(1) From the list above, identify **one** example of a food with a high GI rating.

(1 mark)

(2) From the list above, identify **one** example of a food with a low GI rating.

(1 mark)

(ii) Describe **one** feature that determines the classification of a food as having a high GI.

(2 marks)

(iii) Name **one** group of people who can benefit from knowing the GI ratings of foods.

(1 mark)

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(d) Explain **one** advantage of using glycaemic load instead of GI to evaluate an individual's diet and health status.

(2 marks)

2. Daniel is a 37 year old executive who lives alone, works long hours, smokes and consumes alcohol regularly. He usually exercises for 15 minutes every day. His dietary intake is based on processed food (for example, frozen ready-to-heat meals or takeaway food) or restaurant meals with clients. Although he has a healthy body mass index (BMI), he has recently been diagnosed with hypertension.

(a) Hypertension is one possible consequence of atherosclerosis.

Outline what atherosclerosis is.

(2 marks)

(b) State **two** poor health consequences that uncontrolled hypertension might lead to.

(i) *(1 mark)*

(ii) *(1 mark)*

(c) Smoking and alcohol are two risk factors for the development of hypertension.

Choose **one** of these risk factors **and** explain how it might contribute to hypertension.

Risk Factor:

Explanation:

(2 marks)

(d) Much of Daniel's diet consists of processed foods that are high in sodium.

(i) State **one** processed food that is high in sodium.

(1 mark)

(ii) Describe **two** behavioural strategies that would help Daniel to reduce his intake of sodium.

(1)

(2 marks)

(2)

(2 marks)

A medication that is normally used to treat hypertension called rilmenidine has shown to slow down aging in worms by an international team of researchers. Although worms have some genetic similarities with humans, it is unknown whether this medication could also be used on humans to slow down ageing and improve health as we age.

(e) Discuss how this example demonstrates one or more key concepts of science as a human endeavour.

(4 marks)

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Refer to the following recipe for a savoury pancakes that serves two people:

Ingredients

1 cup white self-raising flour
2 eggs
⅔ cup water
½ small cabbage, finely shredded
2 spring onions, sliced
2 middle bacon rashers, cut into thin strips
1 tablespoon whole-egg mayonnaise
pinch of salt

Method

- Whisk the flour, eggs, and water together in a miring bowl
- Stir the cabbage and spring onions into the mixture.
- Heat a non-stick frypan.
- Pour the mixture into the frypan and use a spatula to form a pancake 1.5 centimetres thick.
- Sprinkle the strips of bacon over the pancake.
- Cook for 3 minutes, then turn the pancake and cook for 4 minutes on the other side.
- Turn the pancake again and cook for 3 minutes, or until set.

Serving

Slide the pancake onto a serving plate. Drizzle with the mayonnaise, and sprinkle with a pinch of salt. Cut into wedges and serve with optional accompaniments (soy sauce, seaweed flakes, shrimp flakes, and fried shallot flakes).

(f) The total sodium content of the pancake (without optional accompaniments) is high.

Suggest **and** justify **one** modification to the ingredients that would make the pancake more suitable for a person with hypertension.

Modification:

Justification:

(2 marks)

(g) The pancake has a low fibre content.

Suggest **and** justify **one** modification to the ingredients that would increase the fibre content.

Modification:

Justification:

(2 marks)

(h) Explain how a lack of fibre in the diet can contribute to the development of diverticular disease.

(4 marks)

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3. Food labels may include the terms 'Light' or 'Lite'.

Refer to the following nutrition information panels for Lite butter and Original butter:

Lite butter	Quantity Per serving	Quantity per 100g
Protein	0.0g	0.0g
Fat (total)	2.2g	44.0 g
- saturated	0.4g	8.0g
- polyunsaturated	0.9g	18.0g
- monounsaturated	0.7g	14.0g
Cholesterol	0mg	0mg
Carbohydrate	0.0g	0.0g
Sodium	15mg	300mg

Original butter	Quantity Per serving	Quantity per 100g
Protein	0.0g	0.0g
Fat (total)	4.2g	84.0g
- saturated	1.5g	30.0g
- polyunsaturated	1.8g	36.0g
- monounsaturated	0.9g	18.0g
Cholesterol	0mg	0mg
Carbohydrate	0.0g	0.0g
Sodium	15mg	300mg

(a) Using data from the table, explain why this Lite butter could be considered **more** suitable than this Original butter for consumers who are at risk of atherosclerosis.

(3 marks)

(b) Using data from the table, compare the unsaturated fat content between these two butter products **and** explain the impact unsaturated fats generally has on cholesterol.

(3 marks)

Consuming lots of processed foods can contribute to obesity.

(c) Explain why the overconsumption of processed foods can contribute to weight gain and obesity.

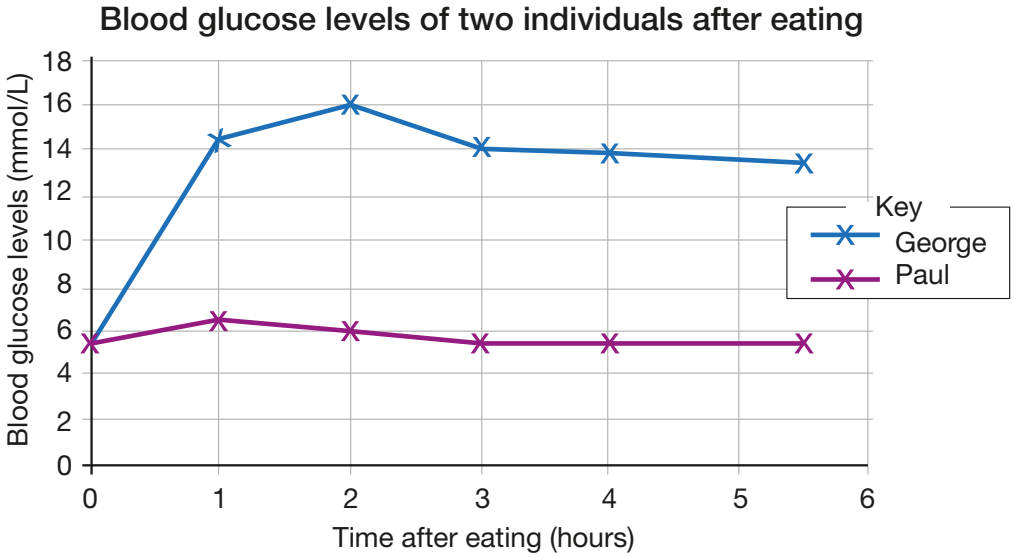
(2 marks)

(d) Describe **two** *dietary strategies* that an individual could introduce to reduce their weight gain.

(4 marks)

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4. George is a 58 year old male who was diagnosed with type 2 diabetes following a test that measured his blood glucose levels after eating a meal. His blood glucose levels were compared with those of Paul — a 58 year old male who does not have diabetes — as shown in the following graph.



(a) Using data from the graph, describe the blood glucose levels of the two individuals between 0 and 2 hours after eating a meal.

(2 marks)

(b) Explain why it is important for blood glucose levels to return to the normal tolerance zone of between 4 and 7 mmol/L after consuming carbohydrates.

(3 marks)

(c) Explain how overconsumption of saturated fats may contribute to an individual developing type 2 diabetes.

(2 marks)

(d) Identify **and** explain **one** symptom that George may be experiencing due to his type 2 diabetes.

(2 marks)

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George consulted a dietitian to learn how best to manage his type 2 diabetes.

(e) *Refer to the following consultation notes made by the dietician:*

Date: *29/05/2018* **Time:** *1·30 pm*
Age: *58 years old*
Weight: *115 kg* **Height:** *161 cm*
Occupation: *Cafe owner*
Blood glucose level: *16·0 mmol/L (high) 2 hours after eating*
Exercise: *1–3 hours of light exercise per week*
Smoker status: *Non-smoker*
Alcohol intake: *3–5 glasses a week*
Current diet habits: *Regularly consumes pre-packaged and convenience foods, or eats at work. Doesn't like the taste of most vegetables.*
Client goals: *Lose weight and modify diet and lifestyle habits to manage his Type 2 diabetes.*

(i) Using the formula below, calculate George's body mass index (BMI).

Show your calculations and state your answer to the nearest whole number.

$$\text{BMI (kg/m}^2\text{)} = \frac{\text{weight (kg)}}{\text{height (m}^2\text{)}}$$

BMI = *kg/m² (2 marks)*

(ii) Explain **one** diet modification that would help George to manage his type 2 diabetes.

(2 marks)

(iii) Identify **two** strategies that George could implement to assist in maintaining lifestyle changes that will help him to manage his type 2 diabetes.

(1)

(1 mark)

(2)

(1 mark)

5. A study has found that middle-aged women (aged 40–60 years) have a high risk of developing osteoporosis.

(a) Identify **one** mineral that can reduce the risk of developing osteoporosis.

(1 mark)

(b) State **two** specific foods, from *two* different food groups, that contain high amounts of the mineral that you identified in part (a).

(1) *(1 mark)*

(2) *(1 mark)*

(c) Explain **two** lifestyle strategies that could reduce or eliminate the risk of middle-aged women developing osteoporosis.

(i)

(2 marks)

(ii)

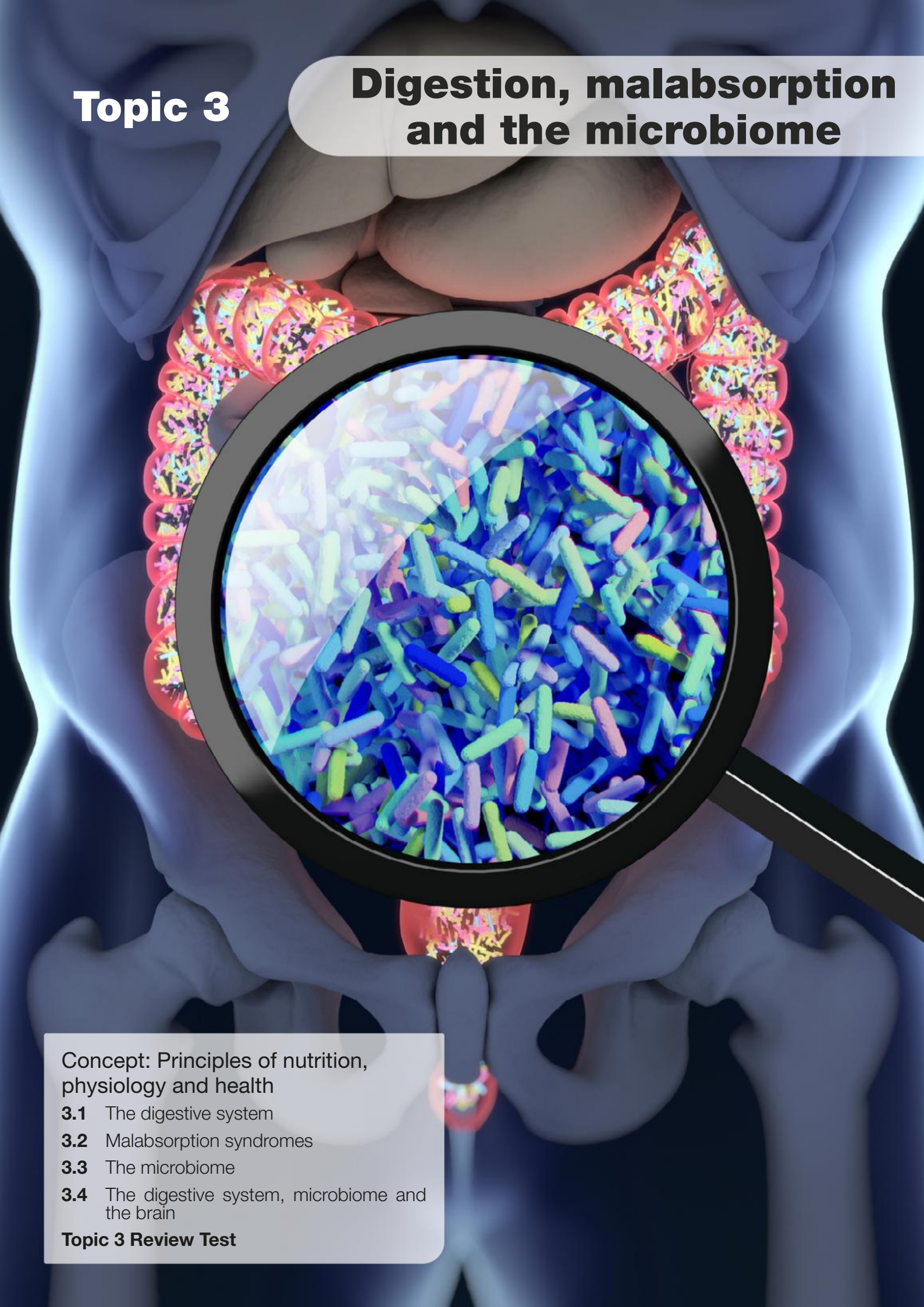
(2 marks)

Total: /70

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Topic 3

Digestion, malabsorption and the microbiome



Concept: Principles of nutrition, physiology and health

3.1 The digestive system

3.2 Malabsorption syndromes

3.3 The microbiome

3.4 The digestive system, microbiome and the brain

Topic 3 Review Test

3.1 The digestive system

Nutrition Understanding

Digestion is the process by which the macronutrients (carbohydrates, proteins and lipids) in our food and drink are broken down into their basic subunits in the gastrointestinal tract. Digestion is required because large molecules are unable to be absorbed into microscopic cells; the macronutrients are simply too big. Once digested, the body can then absorb these nutrients and transport them to cells to provide energy, grow, repair and divide into new cells.

There are two types of digestion, chemical and mechanical. **Chemical digestion** involves **enzymes** that chemically break down large nutrients into smaller nutrients by facilitating the breaking of chemical bonds between subunits. Chemical digestion produces new products, for example, the enzyme lactase chemically breaks down lactose (reactant) into glucose and galactose (products). **Mechanical digestion** involves physically breaking food into smaller pieces. Mechanical digestion results in the same product but because the pieces are smaller, the **surface area of the food is increased**. This allows the enzymes to access a greater proportion of the food and increases the efficiency of chemical digestion. Both forms of digestion are very important and they work together to maximise the digestion of nutrients, increasing the availability of nutrients for the body.

Organs of the digestive system

The digestive system consists of the **gastrointestinal tract** and **accessory organs**. The gastrointestinal tract is a series of connected hollow organs starting from the mouth and ending at the rectum. The gastrointestinal tract consists of the mouth, pharynx, oesophagus, stomach, small intestine, large intestine, rectum and anus. The organs of the gastrointestinal tract contain muscles that enable their walls to move. The movement of organ walls can propel food and liquid and can also mix the contents within each organ. Typical movement of the oesophagus, stomach, and intestine is called **peristalsis**. Accessory organs are connected to organs of the gastrointestinal tract and perform vital functions for the digestion of food but food does not pass through them. Some of the major accessory organs are salivary glands, epiglottis, gall bladder, liver and pancreas. Figure 3.1.1 highlights the major organs in the digestive process and some of their major functions.

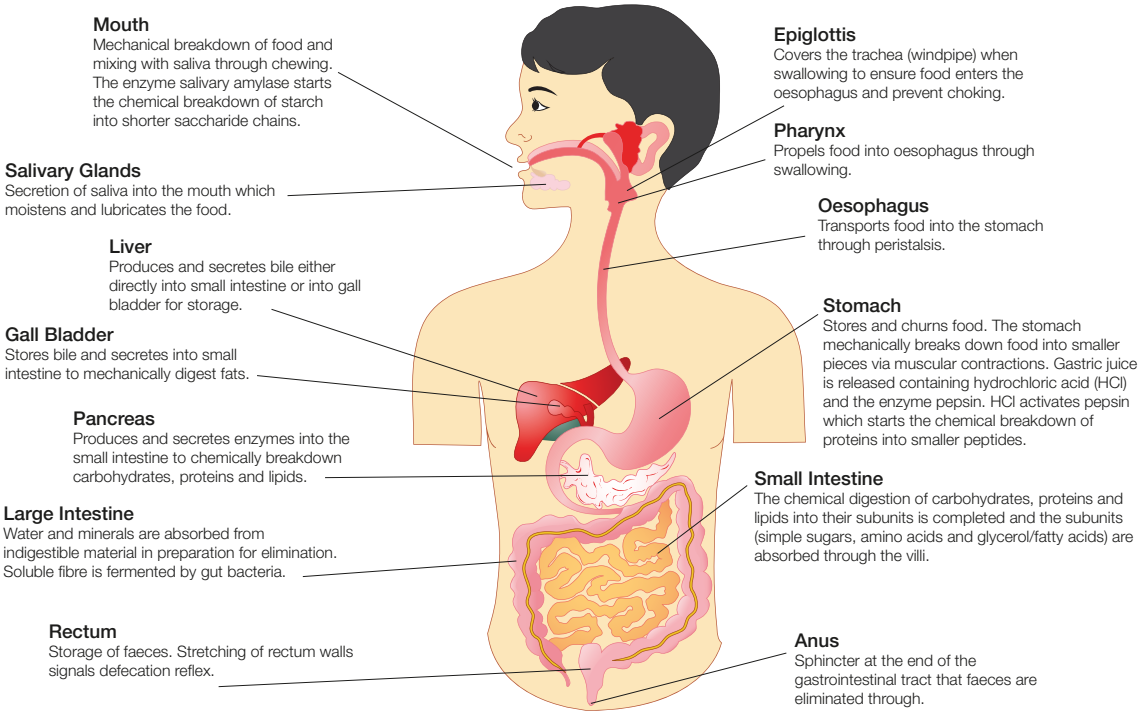


Figure 3.1.1: A summary of the major organs involved in the digestive system and a brief overview of their functions.

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Digestive process

Digestion begins in the mouth where food is mechanically broken down by teeth through **chewing** (also known as **mastication**). Chewing also mixes the food with saliva released from the salivary glands. This lubricates the food making it easier to swallow and increases the surface area for the enzyme **salivary amylase** to start chemically breaking down the complex carbohydrate starch into shorter polysaccharides and maltose (see Figure 3.1.2).

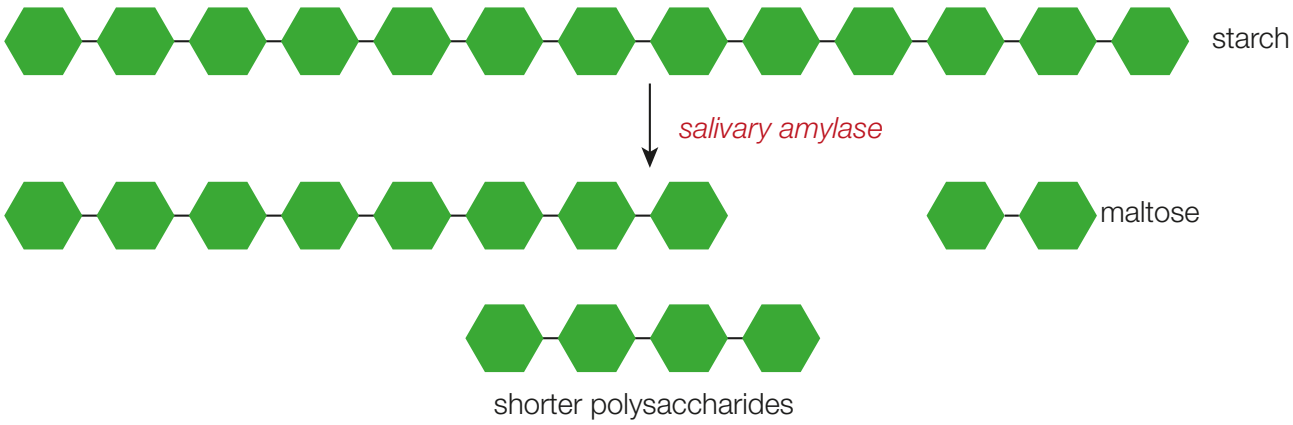


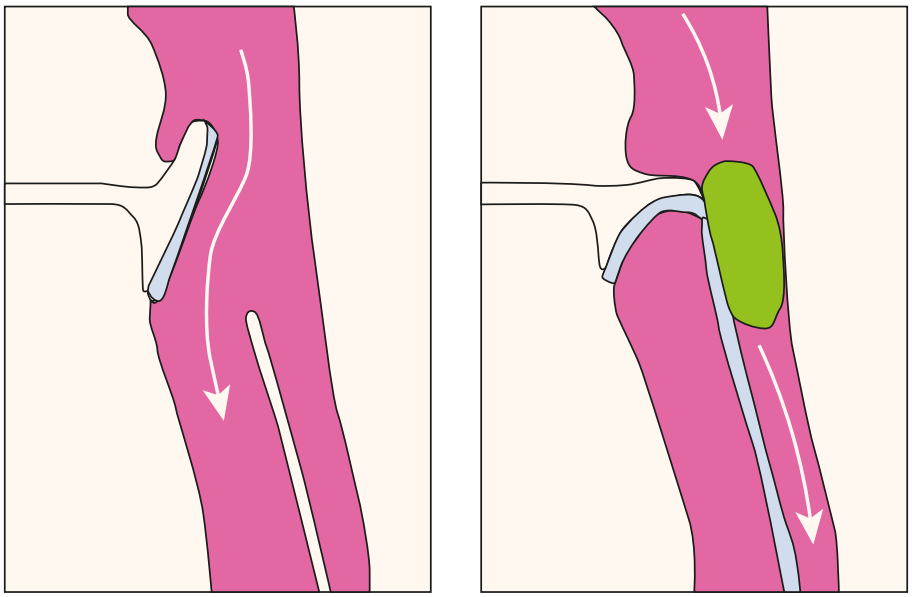
Figure 3.1.2: Salivary amylase initiates the chemical breakdown of starch in the mouth.

Helpful online resources

Score Booster Academy: Role Of Salivary Glands In Digestion in Stunning 4K

https://www.youtube.com/watch?v=BftPhABCZIQ

Food is then swallowed through the pharynx into the oesophagus. During the swallowing reflex the epiglottis covers the trachea (windpipe), guiding the food down the oesophagus (see Figure 3.1.3). If food was to enter the trachea, it could block air entering the lungs and result in choking.



Position of epiglottis for breathing | Position of epiglottis for swallowing

Figure 3.1.3: The epiglottis covers the trachea during swallowing to guide food down the oesophagus and prevent choking.

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In the oesophagus, **peristalsis** propels the bolus of food quickly to the stomach through the lower oesophageal sphincter. Peristalsis is the involuntary wave of smooth muscle contractions that pushes food down the oesophagus into the stomach (see Figure 3.1.4).

Cells lining the stomach release gastric juices consisting of mucus, **hydrochloric acid** and pepsinogen. Mucus lines the stomach protecting the internal epithelial cells from the hydrochloric acid. The hydrochloric acid lowers the pH of the stomach to between 1.5 and 3.5. The acidic environment of the stomach kills pathogens such as bacteria on our food and activates pepsinogen into its active form, **pepsin**. Pepsin is an enzyme that initiates the breakdown of protein in our food. It starts breaking down protein into partially digested protein (see Figure 3.1.5). The acidic environment of the stomach deactivates salivary amylase and, as a consequence, the chemical digestion of carbohydrates does not occur in the stomach.

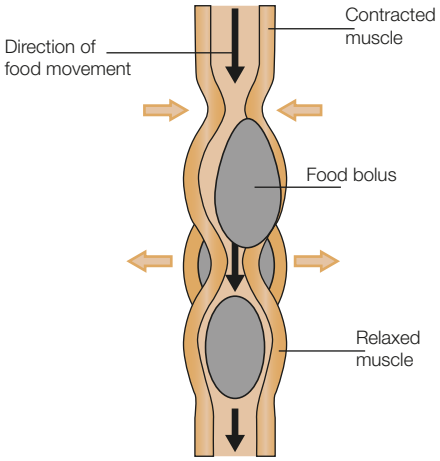


Figure 3.1.4: Peristalsis involves a wave of smooth muscle contractions pushing food down into the stomach.

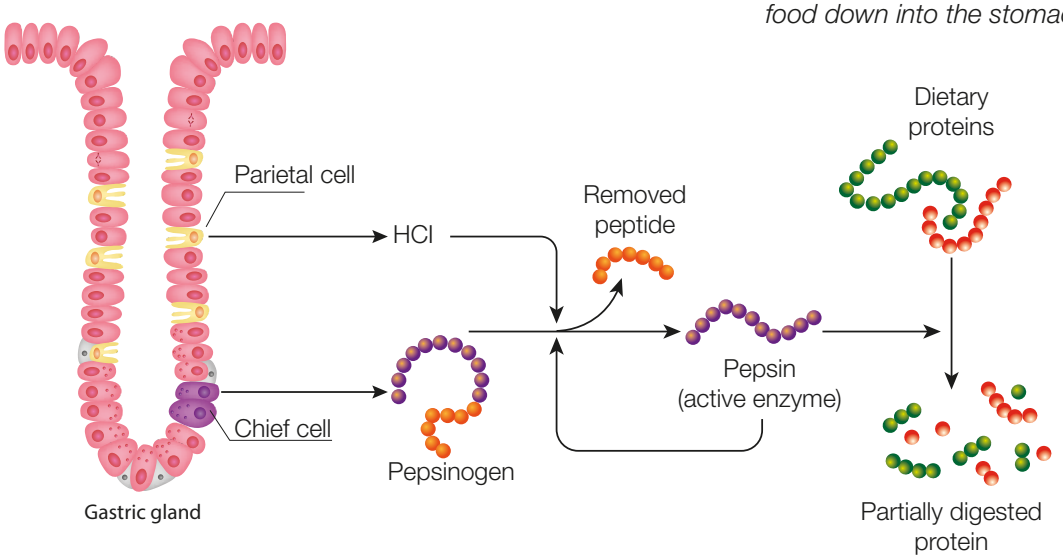


Figure 3.1.5: Hydrochloric acid activates pepsinogen into the enzyme pepsin, which can then start digesting proteins in the stomach.

Did you know?

Non-steroidal anti-inflammatories (NSAIDS) are a class of drugs that include drugs such as ibuprofen (e.g. Nurofen), aspirin and diclofenac (e.g. Voltaren). NSAIDs work by inhibiting prostaglandins that cause inflammation and pain in the body. However, some prostaglandins protect the lining of the stomach by decreasing acidity and increasing mucus production. Taking NSAIDs can therefore also inhibit the prostaglandins protecting the stomach thereby causing damage to the stomach lining and ulceration. Consuming NSAIDs on a full stomach can slow the absorption of the anti-inflammatory and reduce the risk of damage to the stomach lining. This is why it is generally recommended not to consume NSAIDs on an empty stomach; however individuals should always follow the directions of a qualified medical practitioner and pharmacist prior to taking any medication.

Mechanical digestion also occurs in the stomach. Peristaltic waves mix the food bolus with gastric juices, increasing the surface area that pepsin can access. The end result of the physical and chemical digestion of a food bolus in the stomach is a partially digested fluid like substance called chyme. The stomach temporarily stores the chyme and slowly releases small amounts of it through the pyloric sphincter into the small intestine through peristaltic contractions (see Figure 3.1.6). It is very important that only small amounts are expelled because it ensures the small intestines are only processing a small amount of food at a time, maximising the digestion and absorption of nutrients. Otherwise the intestines would not cope with the load and a significant proportion of the nutrients would pass straight through without being digested and absorbed.

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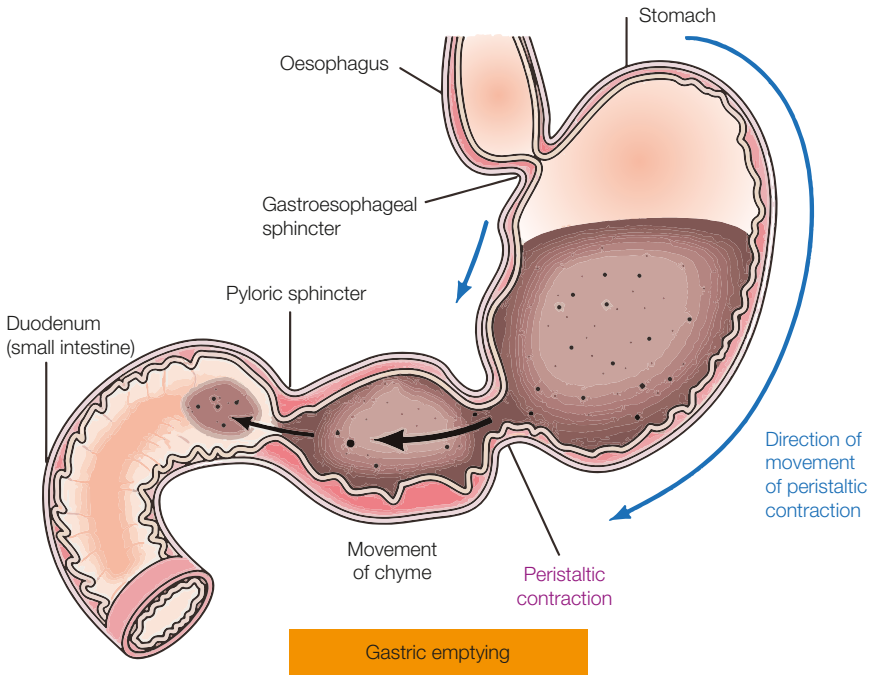


Figure 3.1.6: The stomach stores chyme and releases small amounts into the small intestine intermittently through peristaltic contractions.

Did you know?

There are several factors that affect the speed in which the stomach empties. Meals that are high in carbohydrates and/or fats decrease the rate at which the stomach empties. Certain drugs such as narcotic drugs (e.g. morphine) and analgesics (e.g. aspirin) can also decrease stomach emptying. The temperature of our food also affects stomach emptying. The hotter our food is, the more quickly the stomach empties it into the small intestine. Interestingly, our body position can also affect stomach emptying. Lying down on our left side can decrease the emptying rate. Sleeping on your left side also has many other health benefits. The lymphatic system connects to the left side of the heart and sleeping on your left allows natural draining of the lymphatic system into the heart. Also, the aorta curves to the left and then down to the abdomen, so lying on your left side allows blood to be pumped out of the heart 'downhill' to the abdomen more easily.

The duodenum is the first section of the small intestine; it is also the shortest section. **Pancreatic juice** and **bile** are both secreted into the duodenum to help with the digestion of the macronutrients in our food. Both these secretions are alkaline, which helps neutralise the acid from the stomach. This raises the pH of the small intestine, providing a more suitable environment for the pancreatic enzymes to function. The pancreas produces and secretes the pancreatic juice which consists of **pancreatic amylase, trypsin** and **pancreatic lipase**. The liver produces bile and can secrete it directly into the duodenum or into the gall bladder for storage. The gall bladder can then secrete the stored bile into the duodenum (see Figure 3.1.7).

Helpful online resources

FuseSchool - Global Education: What Does The Stomach Do?

https://www.youtube.com/watch?v=0lr-82ey1_I

FuseSchool - Global Education: Bile and Emulsification

https://www.youtube.com/watch?v=TNG-RRzwBVU

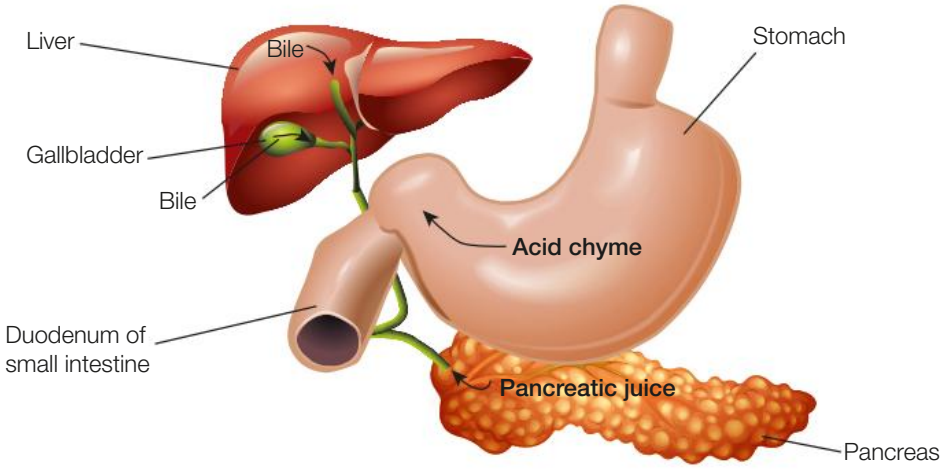


Figure 3.1.7: Bile and pancreatic juice are produced by accessory organs and released into the first section of the small intestine (duodenum) through ducts.

The majority of chemical digestion occurs in the duodenum by the pancreatic enzymes. Pancreatic amylase digests complex carbohydrates into simple sugars (see Figure 3.1.8); trypsin digests amino acids and partially digested proteins into amino acids (see Figure 3.1.9); and pancreatic lipase digests fats into glycerol and fatty acids (see Figure 3.1.10). Additionally, the enzymes sucrase, lactase and maltase digest the disaccharides sucrose, lactose and maltose respectively into their monosaccharide subunits.

It should be noted that the chemical digestion of macronutrients is more complex than this but this is the level of detail covered in SACE Stage 1 Nutrition.

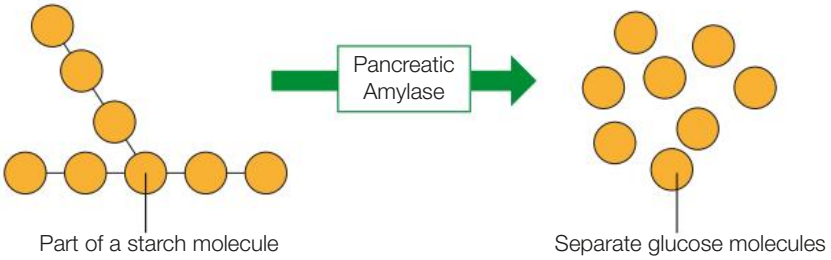


Figure 3.1.8: Pancreatic amylase finishes the chemical digestion of starch and shorter saccharide chains into simple sugars in the small intestine.

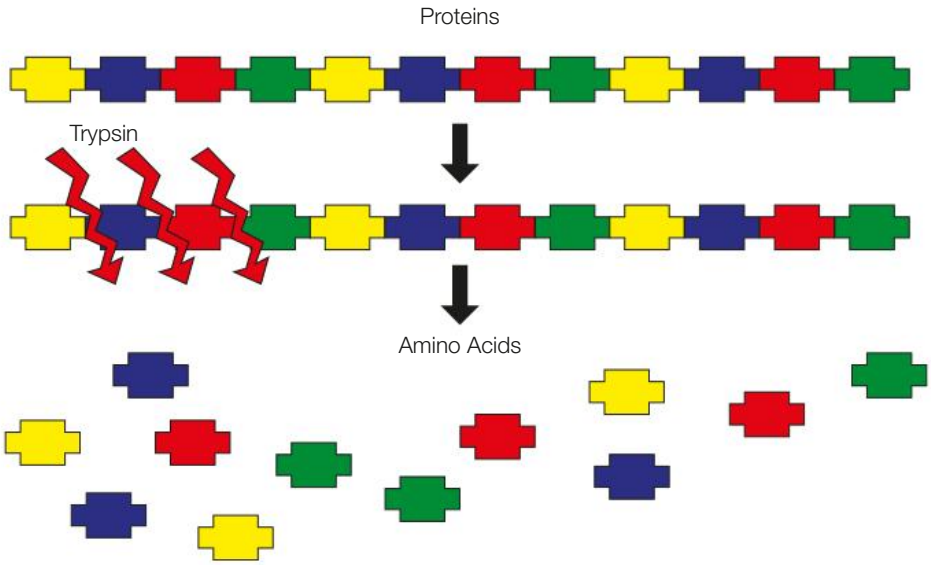


Figure 3.1.9: Trypsin finishes the chemical digestion of proteins and shorter polypeptide chains into amino acids in the small intestine.

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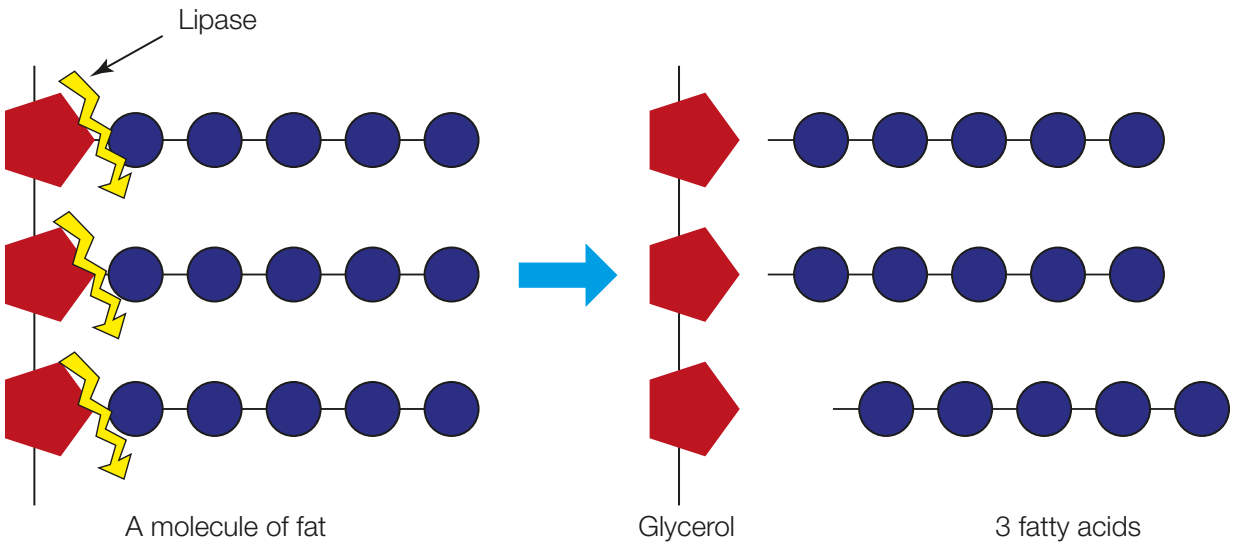


Figure 3.1.10: Pancreatic lipase chemically digests fats into their glycerol backbone and three fatty acid chains in the small intestine.

The digestion of fats in the small intestine also involves bile. Bile **emulsifies** large fat droplets into many smaller fat droplets. This **emulsification is a form of mechanical digestion** increasing the surface area of the fat droplets so pancreatic lipase can chemically digest fat more efficiently (refer to Figure 3.1.11).

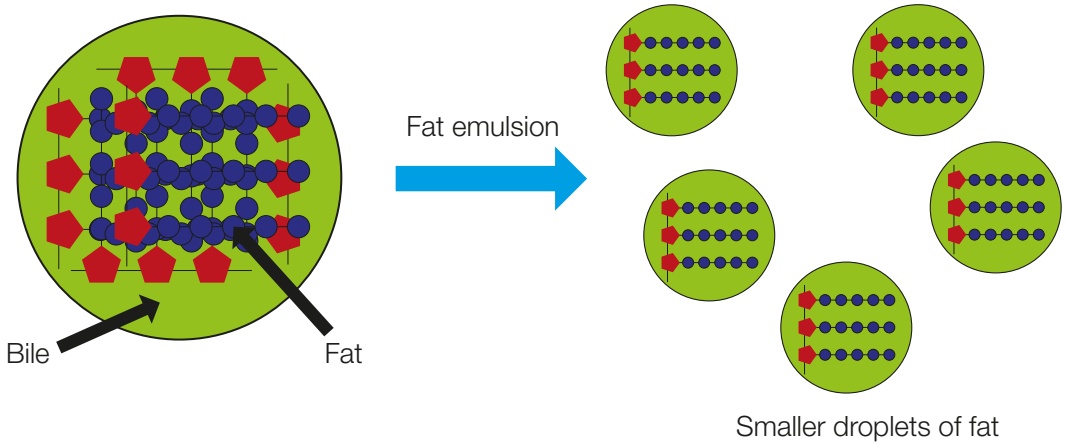


Figure 3.1.11: Bile mechanically digests large fat droplets into many smaller fat droplets.

In addition to digestion of macronutrients, the small intestine is also responsible for **absorbing** the digested nutrients. The walls of the small intestine are covered with finger like projections called **villi** (see Figure 3.1.12), which increase the surface area of the small intestine resulting in more efficient absorption of nutrients. Simple sugars and amino acids are absorbed into the blood capillaries of the villi, while fatty acids and glycerol are absorbed into the lacteal. The lacteal is a lymph capillary which is part of the lymphatic system. These nutrients are then processed by the liver and are available to the body for use in various functions.

Helpful online resources

FuseSchool - Global Education: Digestive Enzymes

https://www.youtube.com/watch?v=a0yGDipKWIo

FuseSchool - Global Education: Small intestine and food absorption

https://www.youtube.com/watch?v=cEh2Qip0-E4

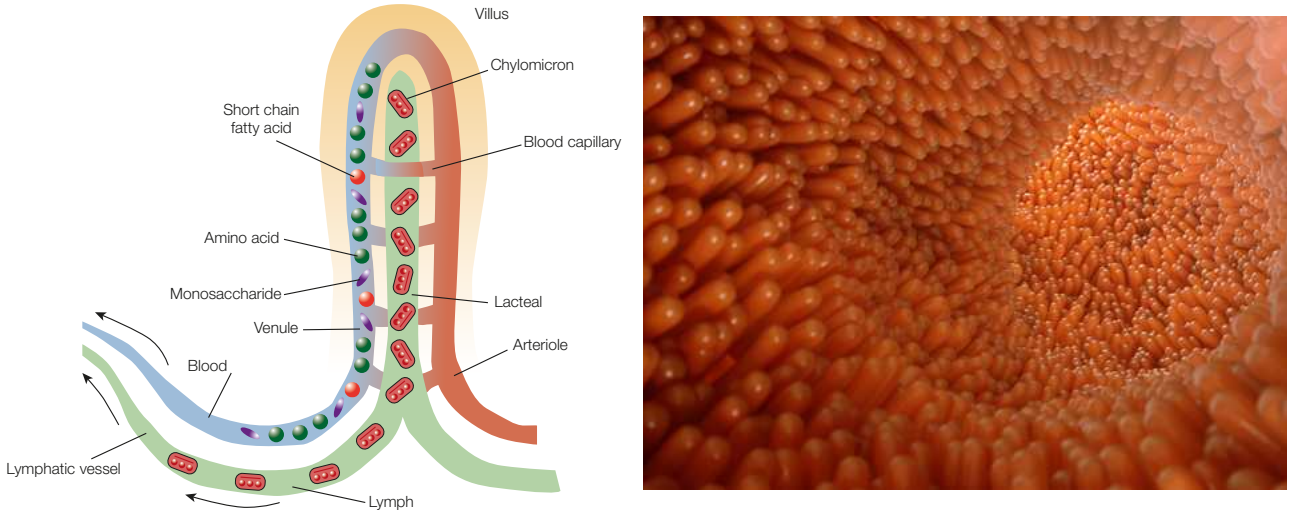


Figure 3.1.12: A single villus (left) and a 3D illustration of the intestinal lining showing many villi (right), which are responsible for absorbing digested nutrients.

The remaining contents that reach the large intestine, also known as the colon, include undigested materials such as dietary fibre, water, a few dissolved salts and older cells that have been shed from the lining of the gastrointestinal tract. The colon absorbs water and dissolved salts from the undigested materials and transports the stool to the rectum in preparation for elimination. Intestinal bacteria ferment dietary fibre in the large intestine producing short chain fatty acids, vitamin K, water and gases. The indigestible material known as faeces is stored in the rectum until it is expelled by a bowel movement via the anus.

Helpful online resources

Ted-Ed: How your digestive system works – Emma Bryce

https://www.youtube.com/watch?v=Og5xAdC8EUI

TED-Ed: What does the liver do?–Emma Bryce

https://www.youtube.com/watch?v=wbh3SjzydnQ

Mechanical and chemical digestion summary

Mechanical digestion starts in the mouth where food is chewed. Chewing physically breaks up all macronutrients into smaller pieces. Peristalsis then propels food down the oesophagus and into the stomach. Peristaltic waves churn the stomach, mixing the food bolus with gastric juices. Peristaltic waves also propel small amounts of chyme from the stomach into the small intestine. In the small intestine, bile mechanically digests large fat droplets into many smaller fat droplets, increasing the surface area of fat for chemical digestion to occur.

Table 3.1.1: A summary of the chemical digestion of macronutrients through the gastrointestinal tract.

Food Material	Sites of Chemical Digestion	Products of Digestion	How it is Transported Around the Body
Carbohydrates (e.g. starch)	Starts in the mouth (salivary amylase) and finishes in the small intestine (pancreatic amylase)	Simple sugars such as glucose	Blood
Proteins	Starts in the stomach (pepsin) and ends in the small intestine (trypsin)	Peptides or amino acids	Blood
Lipids	Starts and finishes in the small intestine (pancreatic lipase)	Fatty acids and glycerol	Lymph

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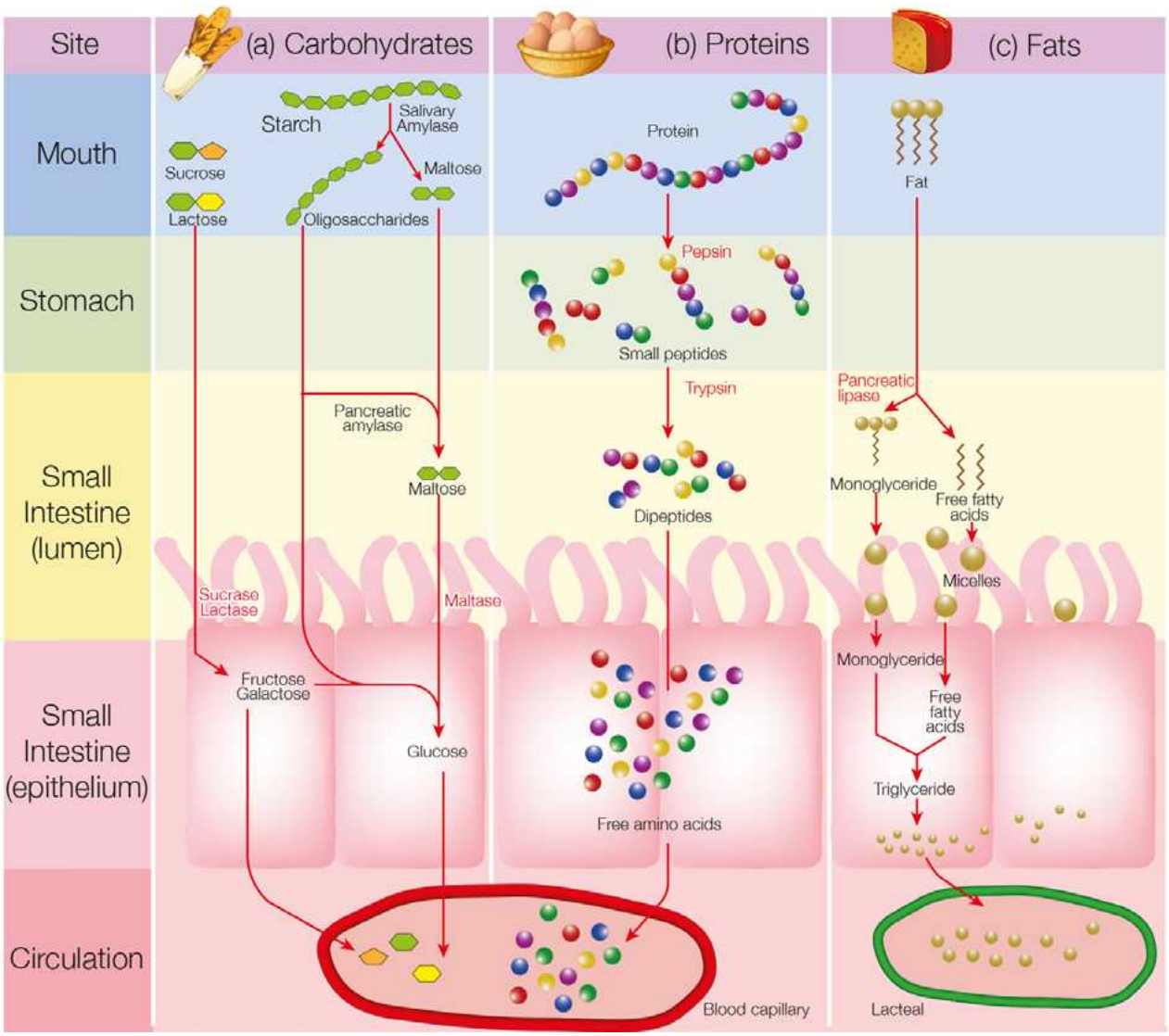


Figure 3.1.13: A visual summary of the chemical digestion of carbohydrates, proteins and fats.

Metabolism of macronutrients

The chemical reactions that occur in the body are necessary to maintain life. Metabolism is the collection of all chemical reactions that occur in the body and includes **catabolic** and **anabolic** reactions. Catabolic reactions involve the breaking down of large molecules into simpler molecules. For example, the chemical digestion of carbohydrates, proteins and fats in the digestive system are catabolic reactions. During catabolic reactions, energy is released in the form of adenosine triphosphate (ATP). ATP is a molecule that provides a constant amount of energy for cells to use. In contrast, anabolic reactions involve synthesising larger molecules from smaller ones. Anabolic reactions require an energy input (from ATP) to synthesise larger molecules, for example, protein synthesis or synthesising glycogen.

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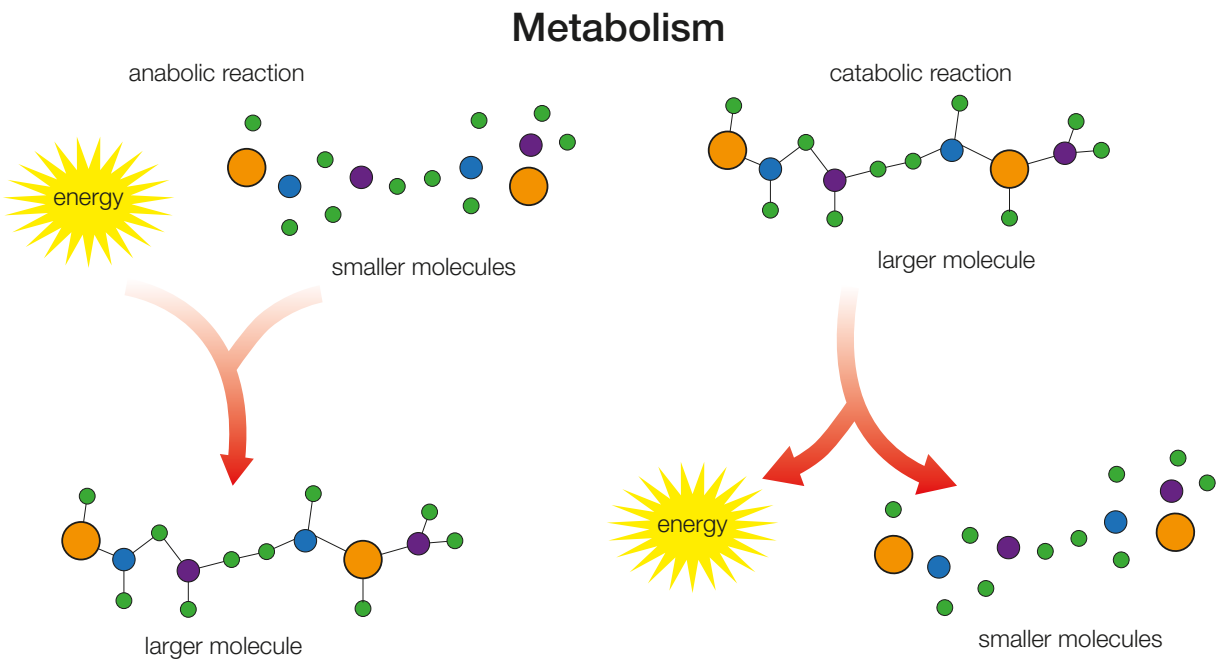


Figure 3.1.14: Anabolic reactions synthesise larger molecules from smaller molecules, whereas catabolic reactions involve the breakdown of larger molecules into smaller molecules.

Carbohydrate metabolism

Complex carbohydrates are broken down into simple sugars in the digestive system and absorbed across the villi into blood capillaries. The circulatory system transports the simple sugars to the liver via the hepatic vein where they are processed. What happens next depends on the needs of the body. Three common responses are:

1. When energy is required, the simple sugars re-enter the blood so that body cells can absorb them and use the glucose to create energy (ATP) through aerobic respiration (catabolic reaction) for cellular use.
2. If the body is resting and the cells are well supplied with glucose, the liver stores excess glucose as glycogen (anabolic reaction). Glycogen can be broken down later when it is needed to be released into the blood to increase blood glucose levels and supply cells with glucose for energy purposes.
3. If the body is at rest, energy is not immediately required and if glycogen levels are full, the excess glucose can be converted to fat and stored as adipose (fat) tissue. This can then be broken down when extra energy is needed.

Protein metabolism

Proteins are broken down into amino acids in the digestive system and absorbed across the villi into blood capillaries. The capillaries transport the amino acids to the liver where they are processed. Amino acids can be transported to all body cells via the circulatory system where they can be used to synthesise proteins; for example, synthesising the hormone insulin in the pancreas or repairing microtears in muscles after exercise. If the body does not have enough glucose, the liver can convert amino acids to glucose through a process called gluconeogenesis so that it can be used to for energy (ATP) purposes. The breakdown of amino acids in the liver also creates nitrogenous waste products, such as urea and uric acid, which are excreted through the kidneys.

Lipid metabolism

Lipids from food are broken down into fatty acids and glycerol in the digestive system and absorbed across the villi into the lacteals (lymph capillaries). The intestinal cells assemble many of the products of fat digestion into larger molecules (triglycerides) and cluster together with proteins to form chylomicrons. Chylomicrons are lipoproteins that carry fats through the blood and deliver triglycerides to the body's cells. The triglycerides can be used in a variety of ways. A few ways they can be used by the body are:

1. If the body is at rest and well supplied with energy, they can be stored as adipose (fat) tissue.
2. If there is not enough glucose in the body, the liver can convert fatty acids to ketone bodies, which are then released into the blood and used by the other cells (e.g. brain cells) as a source of energy (ATP).
3. Fats can also be used for structural purposes, such as synthesising cell membranes or steroid (lipid) hormones.

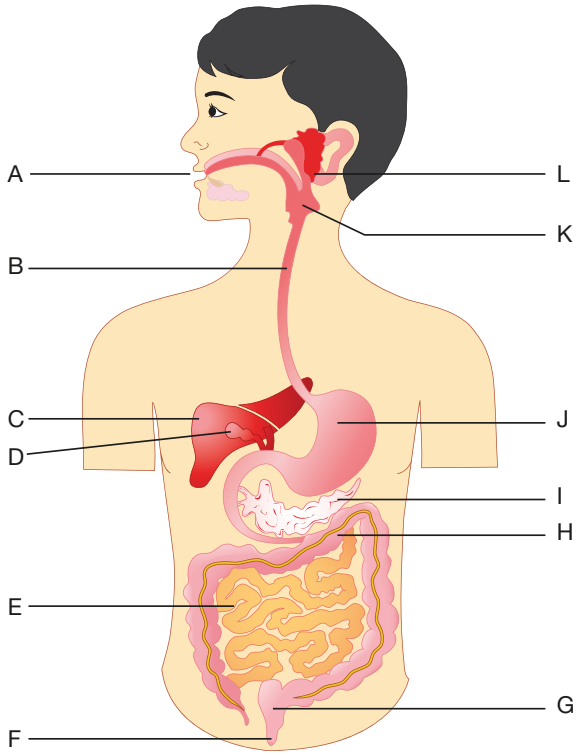
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3.1 Review questions

1. Explain the difference between mechanical and chemical digestion.

(4 marks)

2. Refer to the following diagram to answer the following questions:



Identify the organs in the picture above **and** describe their major function(s).

Organ	Organ Name	Functions
A		
B		
C		
D		
E		
F		
G		
H		
I		
J		
K		
L		

(24 marks)

3. Describe the chemical digestion of protein.

(4 marks)

4. Explain how the mouth and salivary glands aid in the swallowing of dry foods.

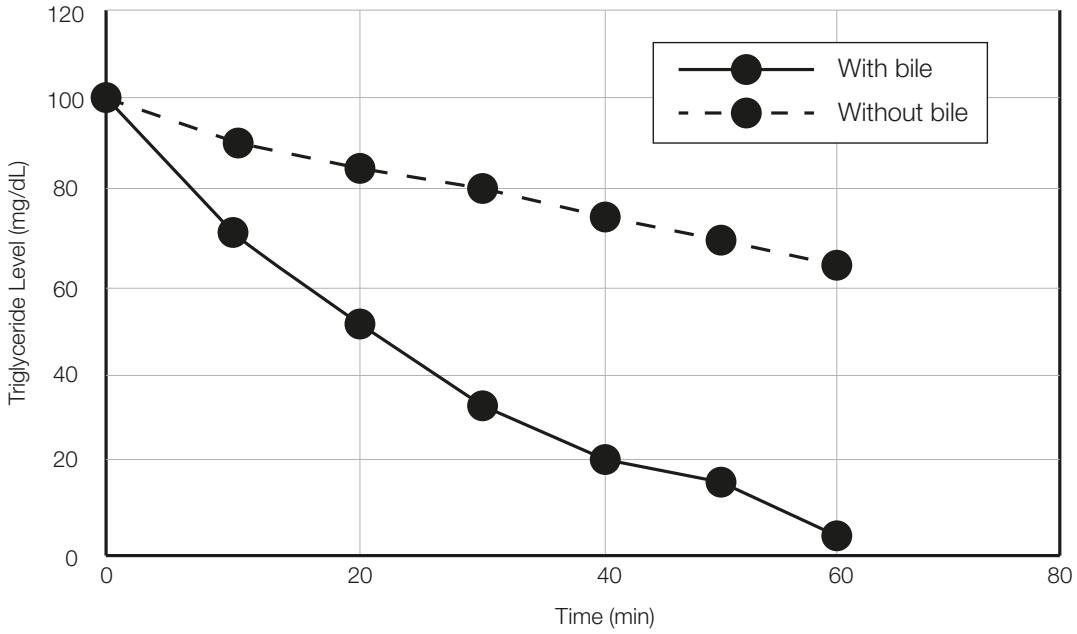
(3 marks)

5. The chemical digestion of starch starts in the mouth by the enzyme salivary amylase. Explain why the chemical digestion of starch does not continue in the stomach after being swallowed.

(2 marks)

6. Refer to the graph below to answer the following questions:

Effect of Bile Salts on Lipid Digestion



(a) Use data to describe the pattern of results with and without bile.

(3 marks)

(b) Explain the difference in triglyceride levels with **and** without bile present.

(4 marks)

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7. Identify the organ where the majority of chemical digestion occurs **and** justify your answer.

(3 marks)

8. Name **and** describe the process that transports the food bolus to the stomach after swallowing.

(2 marks)

9. The small intestine is highly folded to increase surface area for digestion to occur.
   (a) Name the structural feature of the small intestine that increases its internal surface area.

   (1 mark)

   (b) What is the main function of this structural feature of the small intestine?

   (1 mark)

10. Describe how the excess consumption of carbohydrates could be stored as fat.

(2 marks)

11. Proteins are digested into their monomers, amino acids, through the process of digestion.
   (a) Describe the transport of amino acids from the villi and **two** ways they can be used by the body.

   (3 marks)

   (b) Describe how the transport of glycerol and fatty acids from the small intestine differ to the transport of amino acids following absorption.

   (2 marks)

E Extension question

Research **and** explain how the pancreas controls blood glucose levels.

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3.2 Malabsorption syndromes

Nutrition Understanding

There are people in the community who have difficulty absorbing the nutrients they digest due to autoimmune diseases, food intolerances and allergies. This may prevent them from eating certain categories of foods or require a modified diet to reach optimum nutrient levels. The impairment of absorption of one or more nutrients across the gastrointestinal tract is known as **malabsorption** and can lead to increased risk of developing particular conditions, such as anaemia and osteoporosis. Two common malabsorption syndromes are **coeliac disease** and **lactose intolerance.**



Figure 3.2.1: Malabsorption can cause abdominal pain and discomfort.

As mentioned above, food intolerances can result in nutrient malabsorption and are generally a result of sensitivity to a particular chemical, which may be present in a variety of foods. **Food intolerances work on a dose threshold**. This means that for an individual to exhibit food intolerance symptoms, they generally have to consume enough of the specific chemical throughout the day to meet their individual threshold. There may not be enough of the natural chemical in one food to cause a reaction immediately. As a result, the last food eaten, which breaches the threshold and results in the onset of symptoms, is generally blamed for the food intolerance. Figure 3.2.2 demonstrates an example of this. Multiple foods containing natural amines are consumed throughout the day, slowly building up in the body until the last food eaten, in this case chocolate, exceeds the personal threshold and symptoms develop. In this example, chocolate would often be blamed for the reaction but the reaction is actually due to the excessive amount of amines consumed in multiple foods across the course of the day.

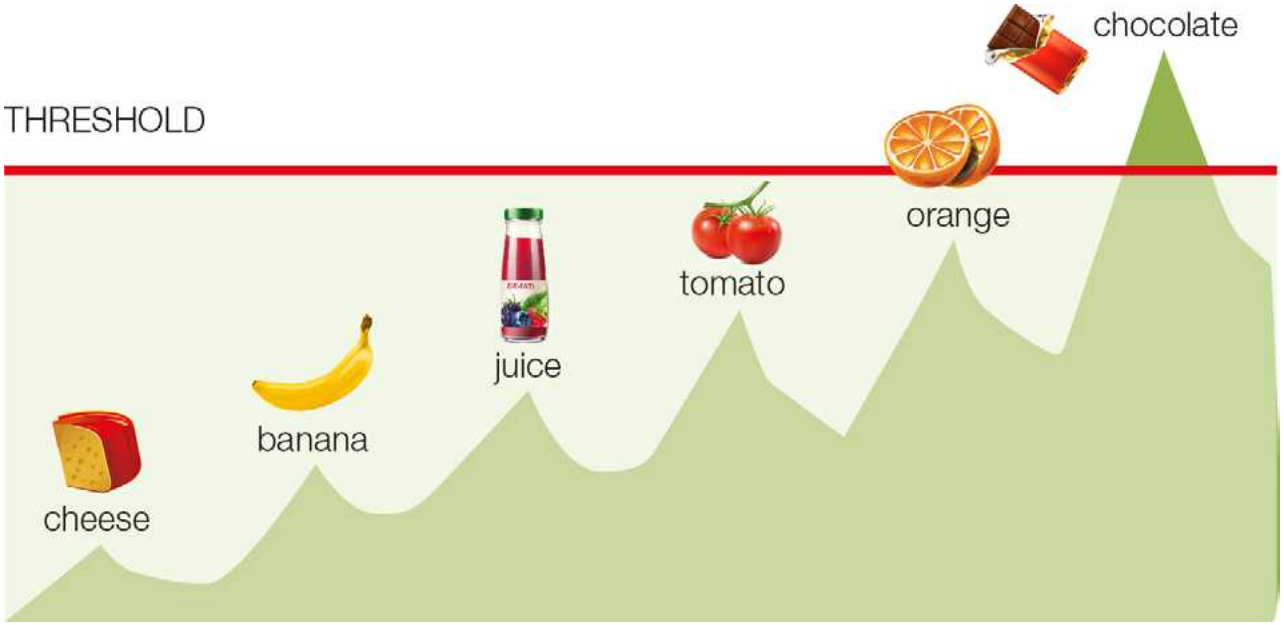


Figure 3.2.2: The accumulation of amines in an individual through the consumption of multiple foods across the course of the day that eventually exceeds the personal threshold and causes a reaction.

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Did you know?

One in four Australian's have a dietary requirement, such as an allergy or food intolerance. It is therefore very important for the hospitality industry and other businesses that supply food (such as schools and childcare centres) to be able to accommodate individuals' dietary needs. The consequences of serving incorrect food orders to individuals with dietary requirements can be severe. For example, pregnant women need to avoid certain foods and require high levels of food safety measures to be met to ensure they do not get food poisoning that could cause pregnancy complications or hinder the development of the foetus. This highlights the importance of education of all employees in the food service industry in dietary requirement management, so that all Australians are able to eat with confidence.

Dietary Hawk is an Adelaide based company that provides the only nationally certified program for dietary requirement management. The certification is designed to ensure that individuals working in food services are trained and have processes in place to manage their customer's dietary requirements. For further information about Dietary Hawk, you can visit their website: www.dietaryhawk.com.au

Helpful online resources

Dietary Hawk

www.dietaryhawk.com.au

Coeliac disease

Coeliac disease is an **auto-immune disease** where the body's immune system reacts abnormally to the presence of **gluten** and attacks the lining of the guts. This results in **inflammation** and **flattening of the villi** that line the internal lumen of the small intestine. This then reduces the surface area in which absorption can occur across in the small intestine (see Figure 3.2.3). With reduced numbers of villi, coeliac suffers can experience **malabsorption** of nutrients such as proteins, vitamins and minerals (see Figure 3.2.4).

Coeliac disease is a **genetic disease**, but inheriting the genes associated with it does not mean that an individual will develop the disease. Approximately 50% of the population carries one or both of the genes associated with coeliac disease but only 0.025% of these individuals will actually develop the disease. Currently, there is no cure for coeliac disease. The only way to treat coeliac disease is for sufferers to **avoid ingesting gluten**. This removes the stimulus for villi destruction and allows the intestinal lining to heal. Gluten is a protein, which is found in wheat, rye, barley and oats so foods products containing these need to be avoided. Some examples of food products that contain gluten include breads, pasta, pastries, biscuits, cakes and cereals. Coeliac sufferers have to be extremely careful not to consume any gluten because even a small amount, such as a bread crumb, can cause the symptoms to return. It is important to note that gluten intolerance and coeliac disease are not the same diagnosis. If an individual diagnosed with coeliac disease ingests gluten, their immune system will attack the villi and cause long term damage. However when someone with gluten intolerance consumes gluten they might exhibit short term bloating and abdominal pain.

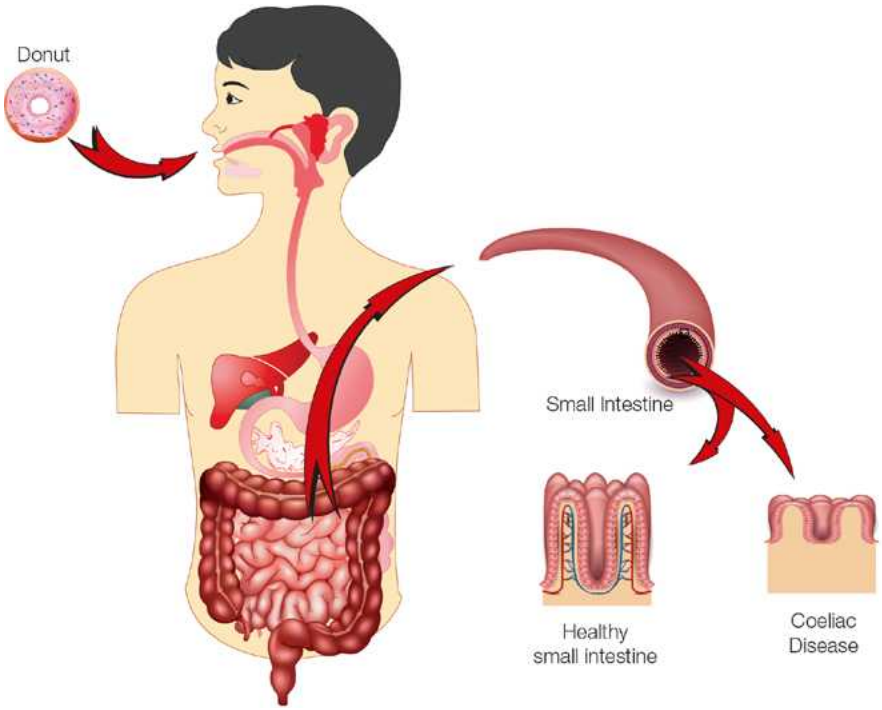


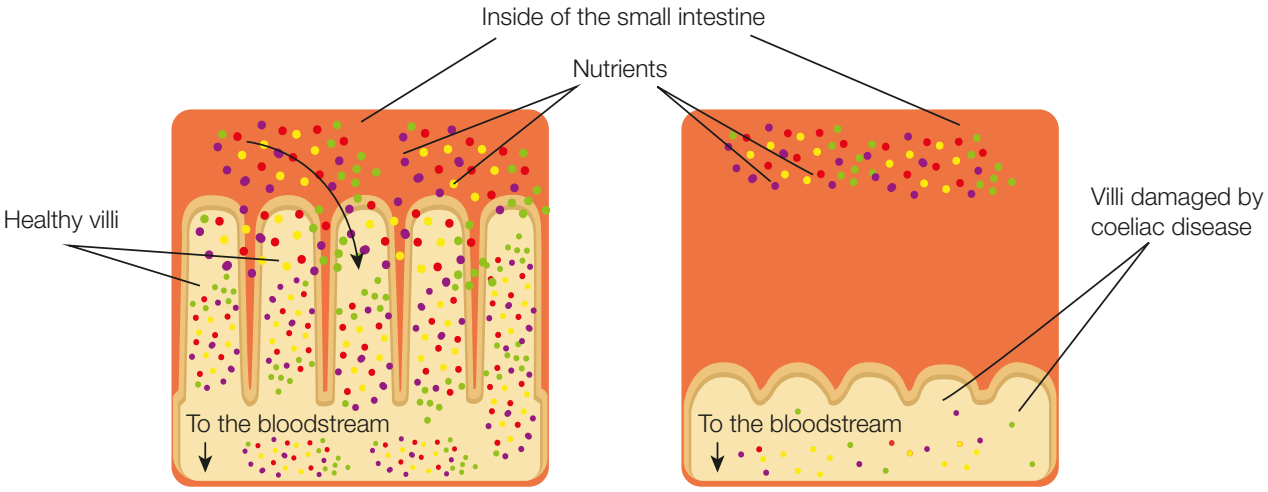
Figure 3.2.3: The consumption of gluten by coeliac sufferers results in inflammation and flattening of villi in the small intestine.

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Symptoms of coeliac disease vary between sufferers but gastrointestinal problems, such as **diarrhoea, gas, bloating and abdominal pain,** are the most common. These symptoms are due to gluten being unable to be broken down and remaining in the intestines, impaired water absorption and irritation from unabsorbed fatty acids. Some additional possible symptoms of coeliac disease include:

1. Fatigue, weakness, irritability and lethargy due to a lack of carbohydrate, vitamin and mineral absorption.
2. Anaemia due to malabsorption of folate, vitamin B12, iron and protein.
3. Weight loss due to decreased fat, carbohydrate, and protein absorption.
4. Muscle cramping due to decreased calcium and potassium absorption.

Additionally, coeliac sufferers also have an increased risk of developing osteoporosis due to the malabsorption of calcium and vitamin D.



A. In a healthy person, nutrients get absorbed by villi in the small intestine and go into the bloodstream.

B. In a person with coeliac disease, the villi have been damaged by inflammation, so fewer nutrients pass into the bloodstream.

Figure 3.2.4: The flattening of villi results in a reduced surface area for absorption of nutrients and can lead to nutrient deficiencies such as anaemia and osteoporosis.

Did you know?

Approximately 11% of Australians follow a gluten free diet by choice but do not have coeliac disease and/or have not been tested. It is important not to confuse coeliac sufferers (approximately 1% of the Australian population) with the fad trend of consuming less gluten containing products. Gluten free products are generally not healthier than their gluten containing counterparts for people without gluten intolerance. Manufacturers of gluten free products often replace gluten with sugar so that it still tastes appealing. They can also use refined flours made from rice, potato and corn. It has also been reported that an increase in consumption of gluten free products can increase the risk of developing type 2 diabetes due to the increased sugar content of gluten free products, which raise blood glucose levels sharply.

Helpful online resources

National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK) : Gluten and Coeliac Disease

https://www.youtube.com/watch?v=0d3FjMgYSzY

Ted-Ed: What's the big deal with gluten?–William D. Chey

https://www.youtube.com/watch?v=uEM2iDT-VAk&t=9s

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Science as a Human Endeavour 7

Coeliac disease vaccine

In 2018 the world's first vaccination to protect coeliac sufferers from the harmful effects of gluten was trialled in Australia. The vaccination has the potential to reprogram the abnormal autoimmune response to gluten exhibited by coeliac sufferers. It works by targeting specific immune cells known as T cells and preventing them from responding to the presence of gluten and attacking the villi. The vaccine is based on research that identified three specific peptides in gluten that trigger the autoimmune response in 90% of people who have the disease. Dr Jason Tye-Din, the lead researcher from the Walter and Eliza Hall Institute of Medical Research (WEHI) and Royal Melbourne Hospital, conducted an analysis and discovered that 10% of 160 'gluten free' meals from 127 businesses contained gluten. This highlights that the vaccination could be a more reliable treatment option than gluten free diets.

The vaccine is based on initial research conducted at the WEHI in Melbourne. Phase 1 global trials were conducted by a privately held United States based biotechnology company, ImmusanT Inc. The results of the Phase 1 international trial demonstrated that the vaccine was safe in humans and was well tolerated at high doses. Phase 2 trials were held in Australia, starting at the Royal Melbourne Hospital Clinical Trials Centre in Melbourne and subsequently rolled out in Perth, Adelaide, Brisbane, Mackay and the Sunshine Coast. At the time of writing, the vaccine remains in development and is not yet available.

Questions

1. Explain two **limitations** of the above coeliac vaccine.

(4 marks)

2. Discuss how the above coeliac vaccine could **influence** society.

(4 marks)

3. Discuss why **communication and collaboration** is important in the development of the above coeliac vaccine.

(4 marks)

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Lactose intolerance

Lactose intolerance is the **inability to digest the disaccharide lactose,** commonly found in milk and milk products. This type of intolerance occurs in individuals who cannot produce enough of the enzyme **lactase** in the small intestine. When present, lactase digests lactose in the small intestine into its two subunits, glucose and galactose. If lactose is not digested, it is not absorbed across the villi and travels through to the large intestine. The **bacteria in the large intestine ferment the undigested lactose**, producing gas and acids that irritate the cell lining (see Figure 3.2.5). Lactose also retains water in the large intestine. The increased gas production and retention of water can result in **symptoms** such as bloating, wind, pain and diarrhoea. People who are lactose intolerant can generally consume small amounts of lactose without experiencing symptoms but if they exceed their lactose threshold, they will experience symptoms. Generally, lactose intolerant individuals need to avoid eating products that contain lactose or take lactase enzyme medication prior to consuming these products.

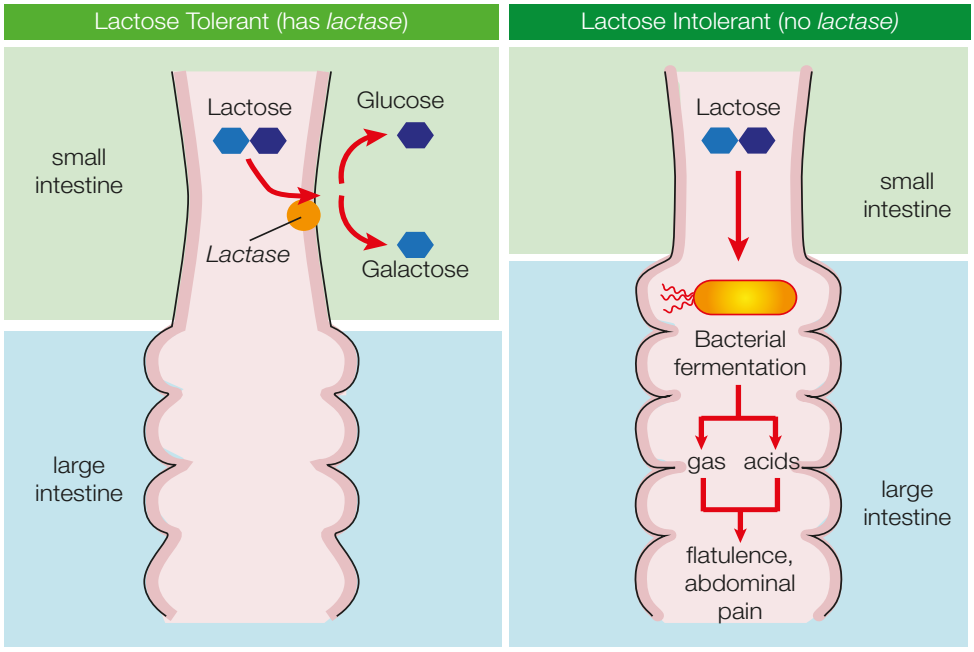


Figure 3.2.5: If the enzyme lactase is not present in the small intestine, lactose cannot be digested and it passes into the large intestine where bacteria ferment it, producing gas.

Did you know?

Historically, all human adults were lactose intolerant. This is because the enzyme lactase was only produced for a short amount of time as an infant to break down the lactose in breast milk. The production of this enzyme historically ceased in humans between two and five years of age. However, approximately 3,000 to 7,000 years ago a random genetic mutation, originating near modern day Hungary, resulted in lactase not being 'switched off' in childhood. This resulted in lactose tolerance and was a selective advantage because it increased the variety of sources nutrients could be obtained from. The ability to consume milk also resulted in descendants being more fertile, therefore, tolerance to lactose spread. Modern day adults who are lactose tolerant are descendants of cattle herders in central Europe that originally adapted to continue producing lactase as adults.

As Australia was settled by Europeans, our lactose intolerant levels are low. It is estimated that approximately 15% of the Australian community is lactose intolerant; however, rates are higher in our Indigenous communities. Scandinavians have a very low lactose intolerance of approximately 1%, whereas it is high in areas that don't have a rich history of consuming cow's milk, such as South East Asia, where up to 90% of people are lactose intolerant. Overall, approximately 75% of the global population is lactose intolerant.

Helpful online resources

Osmosis: Lactose intolerance - causes, symptoms, diagnosis, treatment & pathology

https://www.youtube.com/watch?v=_i2cclGYPx0

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As milk and milk products (such as yoghurt and ice cream) are generally rich sources of **calcium**, lactose intolerant individuals are at higher risk of being calcium deficient and developing conditions associated with calcium deficiency, such as muscle cramps and **osteoporosis**. Calcium is important for bone and teeth development, so lactose intolerant individuals need to consume other foods rich in calcium to ensure they are getting enough of these nutrients. Some alternative sources of calcium are:

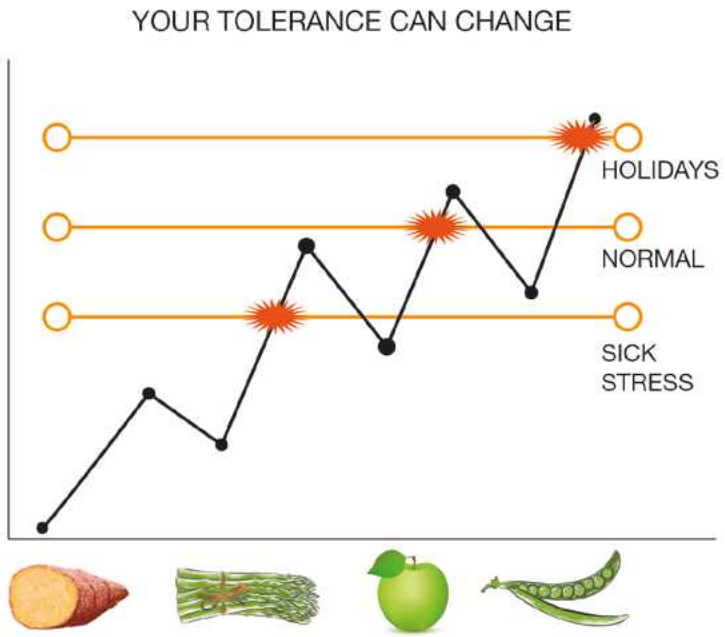
- Fortified soymilk
- Tofu
- Almonds
- Broccoli
- Sesame seeds
- Sardines.

Did you know?

Some recent studies have demonstrated that the symptoms associated with lactose intolerance can be mitigated by altering the microbiome in the intestines. By ingesting a probiotic containing lactose digesting bacteria that produce lactic acid instead of gas, lactose tolerance can increase. This can also reduce the gastrointestinal symptoms associated with lactose intolerance. Unfortunately, these lactose-digesting bacteria do not always survive long term in the intestines. However, scientists are currently trialling feeding the bacteria a complex sugar, known as a prebiotic, that humans cannot digest. Initial reports from clinical trials of the prebiotic demonstrate increased lactose tolerance and greater persistence of lactose-digesting bacteria in the microbiome of subjects. This has the potential to be a treatment for lactose intolerant individuals in the future, potentially allowing them to consume milk and milk products without experiencing unpleasant symptoms.

3.2 Review questions

1. Refer to the graph below to answer the following question.



(a) The graph above shows the tolerance to the chemical salicylate. Using information from the graph, explain why someone might think they are intolerant to snow peas and comment on whether they are likely to be or not.

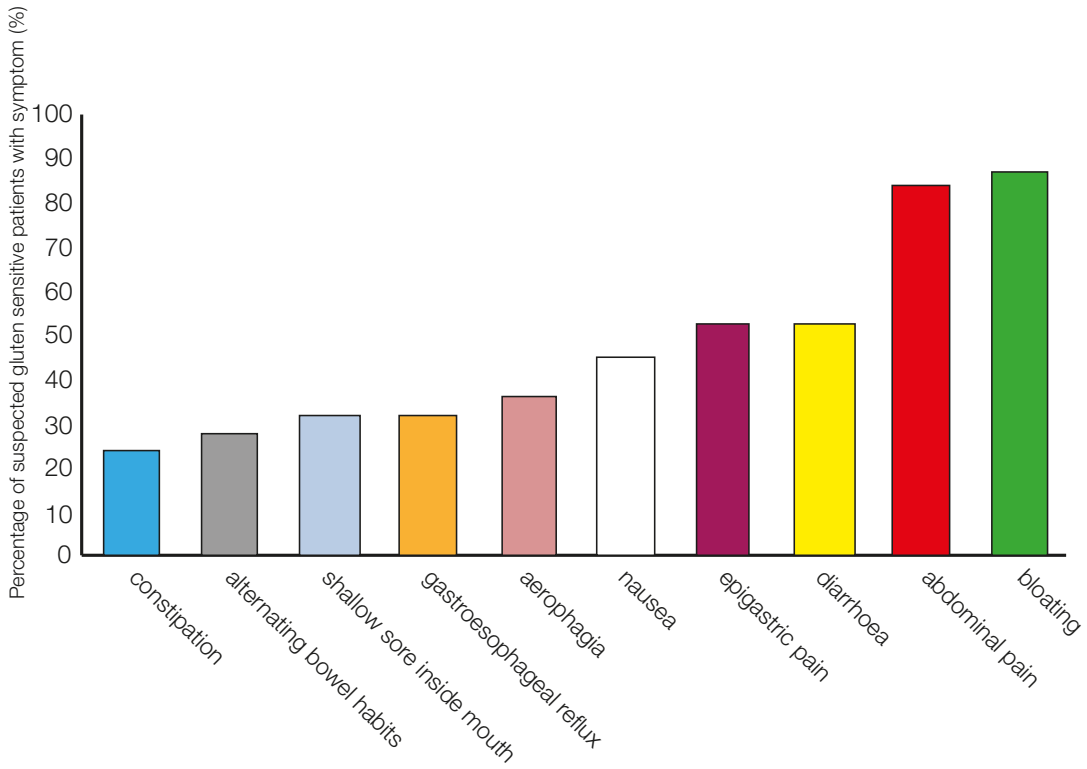
(4 marks)

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(b) Describe why an individual's tolerance to chemicals in foods is likely to be higher when on holidays.

(2 marks)

2. Refer to the graph below to answer the following questions.



The graph above represents the percentage of suspected non-coeliac gluten sensitivity patients that experienced a variety of gastrointestinal symptoms.

(a) State the percentage of patients that exhibited abdominal pain.

(1 mark)

(b) Describe why non-coeliac gluten sensitive patients might experience bloating.

(2 marks)

(c) Explain the difference between a non-coeliac gluten sensitive individual (gluten intolerance) and an individual that who has coeliac disease.

(4 marks)

(d) Explain why an individual with coeliac disease is more likely to experience malabsorption of vitamin B12.

(4 marks)

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(e) Approximately 1 in 70 Australians have coeliac disease but it is estimated that 80% of these individuals remain undiagnosed. Explain the possible complications for individuals who have coeliac disease but live everyday undiagnosed.

(2 marks)

3. Individuals diagnosed with coeliac disease have to take extra care with their food selection and preparation techniques.

   (a) Name **three** different foods that an individual with coeliac disease should avoid.

   (3 marks)

   (b) Explain why households with a coeliac sufferer may need to have separate butter and condiment containers such as peanut butter and jam.

   (3 marks)

4. Explain **how** lactose intolerance differs to coeliac disease.

   (4 marks)

5. Name **two** different foods that lactose intolerant individuals should avoid.

   (2 marks)

6. Explain **two** symptoms associated with lactose intolerance.

   (4 marks)

7. (a) State the most likely mineral deficiency lactose intolerant individuals are at higher risk of developing.

   (1 mark)

   (b) Name the condition that could develop if an individual does not consume enough of the mineral answered in part (a).

   (1 mark)

   (c) Name **three** foods that a lactose intolerant individual could consume to obtain the mineral answered in part (a).

   (3 marks)

E Extension question

Research **and** explain what cow's milk protein intolerance is and how it differs to lactose intolerance.

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3.3 The microbiome

Nutrition Understanding

The human **microbiome** is the collection of microorganisms such as bacteria, fungi, protozoans and viruses that inhabit the body. It is estimated that there are 100 trillion microorganisms living on or within the body. In fact, current research estimates there are approximately the same number of microbial cells on or within a human as there are human cells. Every individual has a unique community of microorganisms with some studies suggesting that only 10% to 20% of the bacteria an individual has is shared with others.

Recent research is highlighting the important role our unique microbiome has on our health. This is because we have a **symbiotic relationship** with most of the microorganisms that live on or within us. Most of these relationships are mutualistic, where we provide them with a home and nutrition, and they benefit us in various ways such as extracting energy and vitamins from our food for us to absorb. However, humans can experience health issues if the wrong type(s) of species are introduced or if the balance of populations is disrupted.

The human microbiome is possibly the most **diverse ecosystem** on earth. Each area of our body is a different 'habitat' that has its own unique community of microorganisms, which develop and change throughout our lives. The species in these habitats are very specific, for example, there are certain bacteria that will only be found on the front of your teeth and not the back (and vice versa). See Figure 3.3.1 which shows the percentages of some 'divisions' of bacteria at different habitats of the body.

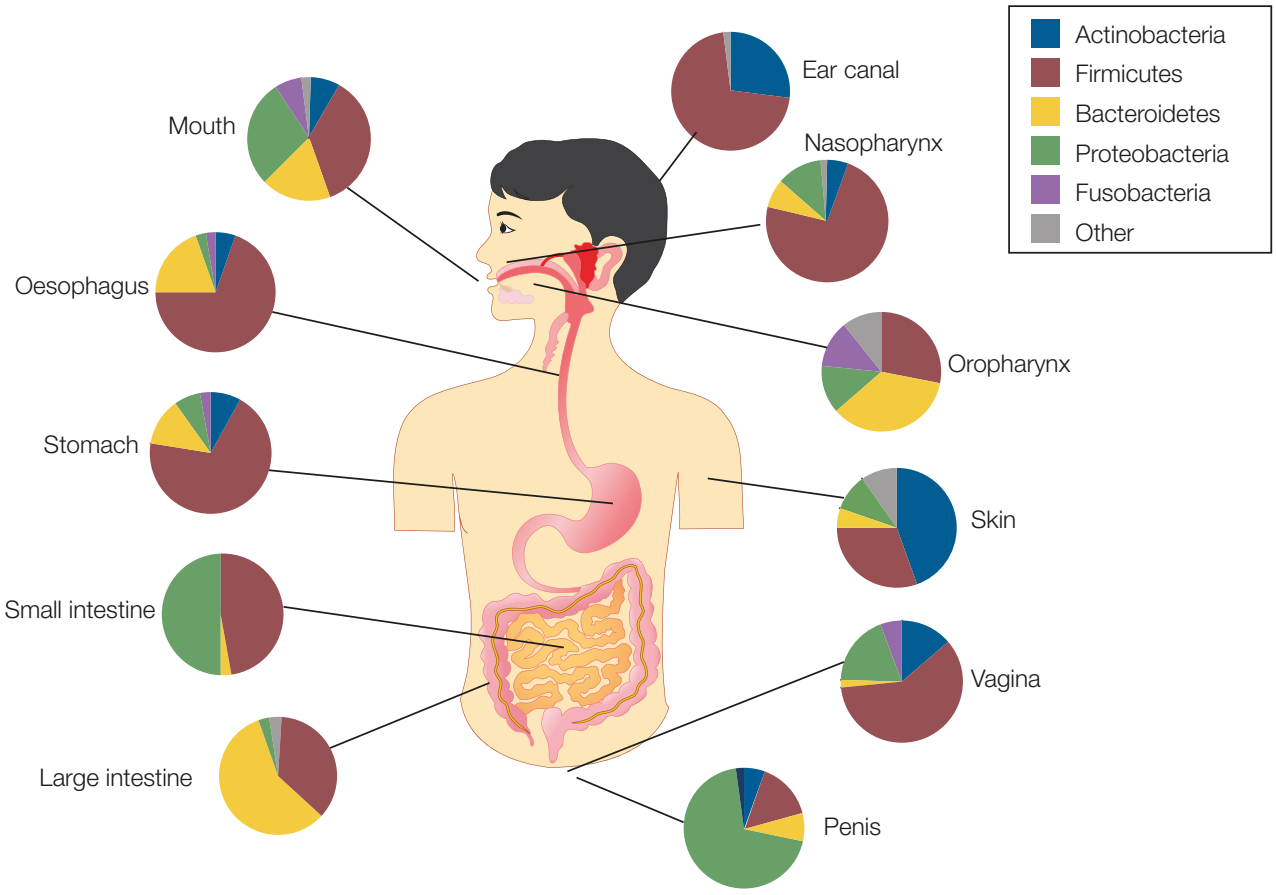


Figure 3.3.1: The general compositions of bacterial communities at various sites on or within the body.

Helpful online resources

FuseSchool - Global Education: Bacteria in Digestion

https://www.youtube.com/watch?v=Fe5wHw3pnmY

© Essentials Education

The gut microbiome

Although there are trillions of microorganisms on and within our bodies, the majority of them live in our **gastrointestinal tract**. Collectively, the gut microbiome weighs about 1.5kg. It is currently estimated that there are up to 1,000 different species of microorganisms within our guts. Only a small percentage of these species reside in the stomach because of its acidic nature. Many more species reside in the small intestine but most of them live in the large intestine. The majority of the gut microbiome is made up of **bacteria**. There are currently 55 recognised 'divisions' of bacteria, of which eight have been found residing in the guts to date. Three of these bacterial divisions are common in the gut. *Bacteroidetes* and *Firmicutes* make up two thirds of the microbes in the guts. The third common division is *Proteobacteria*.

It is now known that the more **diverse** an individual's microbiome is, the less likely they are to develop adverse health outcomes. One reason for this is that the **more diverse** an individual's microbiome is, the **more resilient** it is. A resilient microbiome can recover more easily from disturbances, such as **infections and antibiotics**. This concept is also seen elsewhere in nature, such as stable ecosystems throughout the world. Each species in an ecosystem has a specific role(s) and removing one species can start a chain reaction of adverse effects and destabilise it. Healthy ecosystems with a large biodiversity exhibit greater resilience to the removal of a species than ecosystems with reduced biodiversity. This is because there is a greater number of species available to fill the role(s) of the missing species.

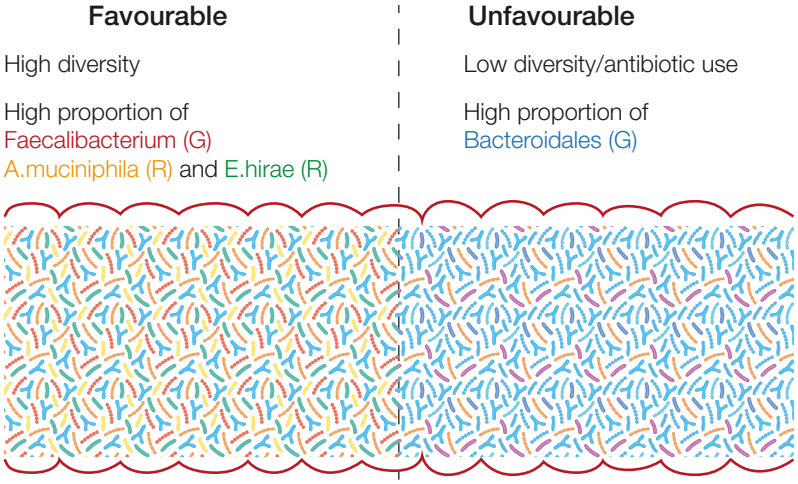


Figure 3.3.2: A microbiome with high diversity is generally associated with more favourable health outcomes than a microbiome with low diversity.

Benefits of the gut microbiome

Bacteria in the intestines increase energy availability from our food by breaking down carbohydrates we cannot digest, extracting energy. The bacteria use some of this energy but the remainder is made available to us. In fact, the bacteria in our guts can produce up to 30% of our daily energy. They do this by breaking down carbohydrates that we cannot digest, such as fibre and resistant starch. *Bacteroides thetaiotaomicron* is one species of bacteria that lives in our guts and it has over 460 different enzymes that can extract energy from carbohydrates. That is approximately 360 more enzymes involved for carbohydrate digestion than our bodies possess. These additional enzymes allow the bacteria to digest fibre and extract energy and other nutrients from it. As every individual's microbiome is unique, the amount of nutrients extracted from the carbohydrates we cannot digest varies from person to person. A microbiome that can extract more energy from indigestible carbohydrates could increase the risk of the host being overweight/obese. However, all of us rely on our microbiome to extract the energy required for our daily needs.

Gut bacteria also release **short chain fatty acids (SCFAs)** as a result of fermenting our dietary fibre. Short chain fatty acids, such as butyrate, nourish our intestinal lining and **protect against inflammation** of the gut. Ultimately, this also protects us against **intestinal cancer**. Additionally, bacteria also **release vitamins** from our food increasing their bioavailability. **An important vitamin produced by the microbiome is vitamin K**. Infants have severely underdeveloped microbiomes and cannot synthesise vitamin K efficiently. As a result, they are given a vitamin K supplement injection to last until the microbiome develops and they can become more self sufficient at producing it. Some additional vitamins produced by bacteria for us are vitamin C, B1, B2, B5, B6, B7, B9 & B12; however, these are generally not produced in amounts large enough for our body to rely on. Furthermore, as each individual's microbiome is unique, not everyone's microbiome can produce all of these vitamins to the same degree.

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Helpful online resources

Kurzgesagt: How Bacteria Rule Over Your Body – The Microbiome

https://www.youtube.com/watch?v=VzPD009qTN4

Ted-Ed: You are your microbes – Jessica Green and Karen Guillemin

https://www.youtube.com/watch?v=1X8p0vhsWRE

Microbiome development

There are many factors that can affect the development of the gut microbiome and it starts before we are even born. Initially, it was thought that the uterus was sterile (no microorganisms) and we were not exposed to microorganisms until the birthing process. However, new evidence now suggests that the microbiome starts to form in the amniotic fluid. Once we are born, we are exposed to millions of different microbes and the different environmental factors we are exposed to help determine the makeup of our unique microbiomes and increases diversity (see Figure 3.3.3).

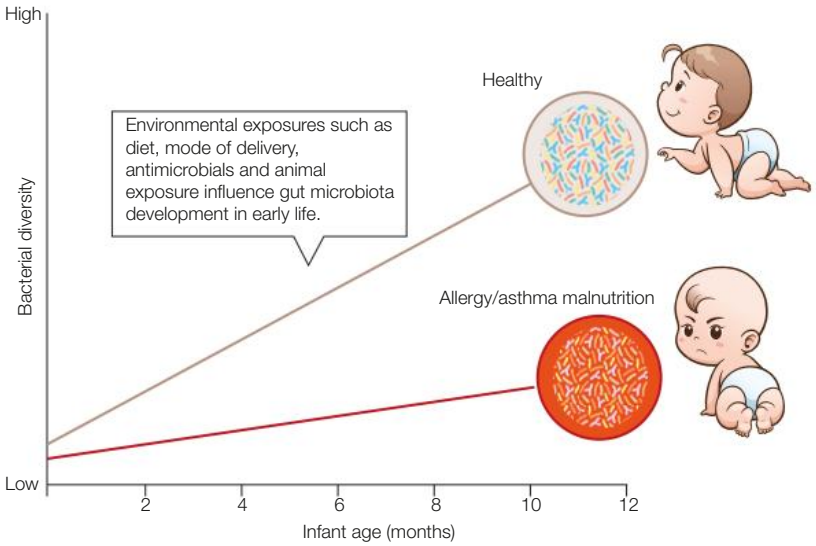


Figure 3.3.3: The environmental factors infants are exposed to contribute to the development of their microbiome and can determine its health and diversity.

Type of birth

The initial microbes that form our microbiome are derived from our **mother**. As mentioned previously, new evidence suggests this starts in the amniotic sac. Subsequently, the birthing process itself affects the microbiome. There are two types of birth, **vaginally** and by **caesarean section** (C-section). When a baby is born vaginally it passes through the birth canal and is covered in microbes that reside there. However, babies born by C-section are not exposed to the species in the birth canal and are instead exposed to a different set of species, such as those that live on the skin. Furthermore, where the baby is born can influence the microbiome development. Babies born at home are exposed to different species than those born in hospital.

Many studies have shown that babies born vaginally have a **more diverse microbiome** than those born through C-section, as the latter miss out on the initial inoculation that would normally occur passing through the vaginal canal. As a result, babies born through C-section are generally **slower** at developing their microbiome. It generally takes up to **two years** for a healthy microbiome to form but it may take longer for babies born by C-section.

As babies born by C-section tend to have a lower diversity of microorganisms, they are associated with a higher risk of developing health issues in the long term (for example, allergies, asthma and obesity later in life). One study at New York University compared the weight of 35 mice born vaginally to the weight of 34 mice born by C-section. The mice were weighed 15 weeks after birth and the results showed that the mice born by C-section were 33%

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heavier. The scientists conducting the study concluded that humans born by C-section are 1.3 times more likely to be obese than those born via vaginal birth. However, further studies need to be performed to confirm this because the results could be influenced by other factors. For example, the results could be influenced by a greater number of larger babies and mothers requiring C-sections. It is important to note that **C-sections are an important medical procedure** and that many mothers and their children would not be here without it. In fact, the physical size of human heads (as a species) is increasing and one reason is because of C-sections. In the past, infants with big heads that could not fit through the vaginal canal would not survive, and in many cases, the mother would not either. C-sections allow both the mother and baby to survive and reduces unnecessary suffering.

Some parents are now choosing to perform **vaginal seeding** on their children when born via C-section. This involves smearing the infant in vaginal fluid to expose them to the microorganisms after birth. However, further studies need to be performed into the advantages and disadvantages of vaginal seeding. One such concern is that this could increase the risk of infection for the newborn.

Our microbiome is not fully determined at birth. As we grow up, we are exposed to different bacteria from our environment through diet, the people we're exposed to, the city we live in, exposure to pets, infections and medication consumed. All of these different exposures will influence our microbiome.

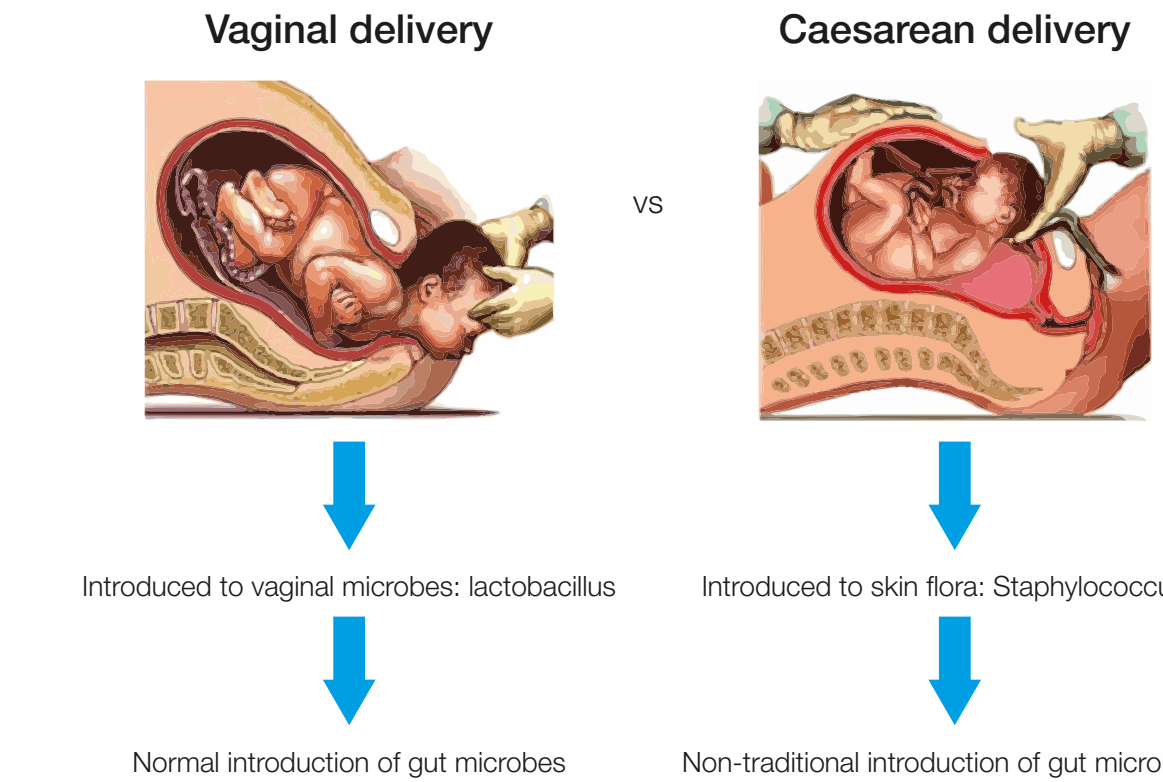


Figure 3.3.4: The type of birth can influence the development of the microbiome due to exposure to different microorganisms.

Diet

Environmental factors such as our **diet** also influence our gut microbiome. The nutritional choices parents make for their infant have a significant effect on their developing microbiome. One major choice is whether or not to **breastfeed**. Breastmilk provides microorganisms directly and provides specific sugars (oligosaccharides) for specific bacteria, such as bifidobacteria, in the gut to feed on. Babies can also get microbes from the mother's skin when they suck on the breast. Infants who are formula-fed have distinctively different microbiomes to those who are breastfed. One study in the US showed that infants who were breastfed had a greater diversity of microorganisms and were more capable of fighting off infection.

It is important to note that it is not always possible or practical for a mother to breastfeed her child and in such circumstances feeding the baby formula is appropriate. Some mothers have difficulty producing milk and some infants have trouble latching on. Mothers may also choose not to breastfeed for a variety of reasons and that choice should be respected. **The most important thing is to ensure the baby is receiving sufficient nutrition** (through either breastmilk, formula or a combination of both) and putting on the appropriate amount of weight to support development.

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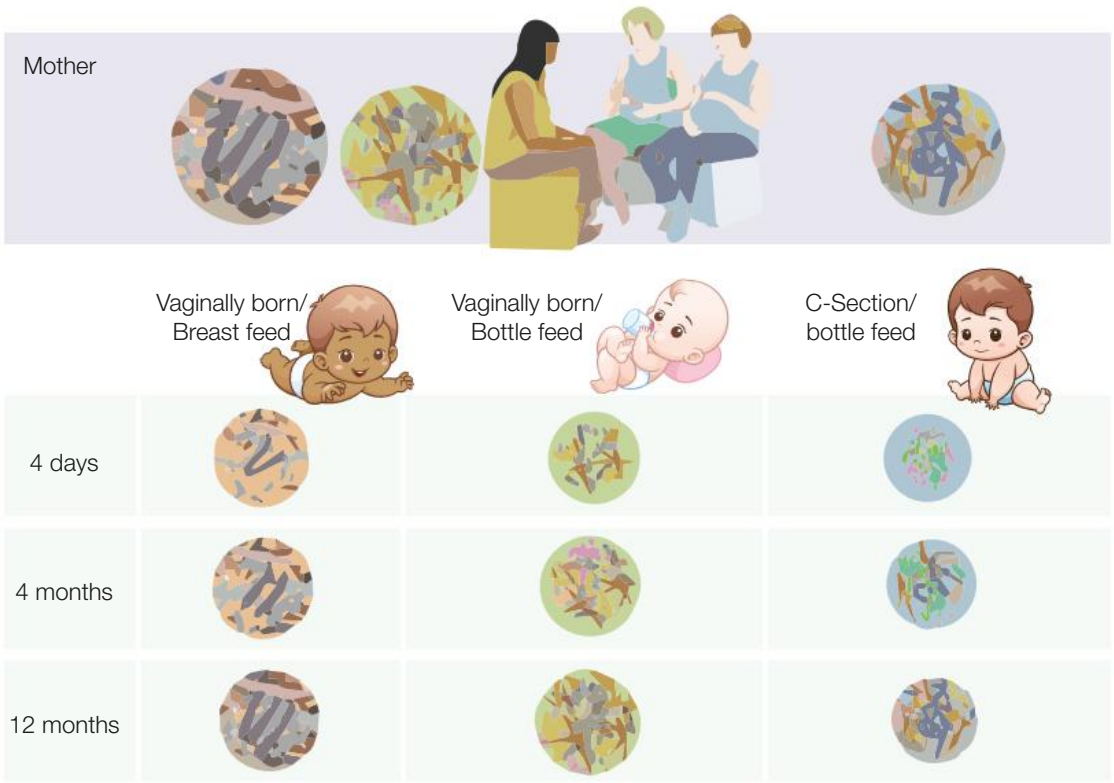


Figure 3.3.5: The way a baby is fed can influence its microbiome development and diversity of bacteria.

Our diet after we finish breastfeeding and begin to consume solid food continues to influence our microbiome development. The food we eat contains microorganisms on and within it. For example, leafy spinach can have 800 species living *inside* the plant. This means they cannot be washed off and when eaten they can contribute to the microbiome. **Prebiotics** and **probiotics** have also been shown to increase the microbiome diversity (see Figure 3.3.6). **Prebiotics**, also known as 'gut fertiliser', are non-living, indigestible carbohydrates (by humans) that gut bacteria feed on, promoting growth of that colony. Some examples of prebiotics are fibre, resistant starch and breastmilk (see Figure 3.3.7 for some more examples). Prebiotics are naturally occurring in many foods, such as fruits, vegetables, legumes, wheat products, herbs, spices, nuts and seeds. **Probiotics** are foods that contain living 'good' bacteria and yeast cultures that can make their way into our gut and are beneficial to the host. Probiotics can help digest food, produce vitamins and help restore the balance of good bacteria versus bad bacteria in our guts, especially after diarrhoea or antibiotics. Some examples of probiotics are yoghurt, kombucha, sauerkraut and kimchi (see Figure 3.3.7). Yoghurt contains good bacteria called lactobacillus that produce vitamins and minerals, prevent diarrhoea and can improve symptoms of irritable bowel syndrome.

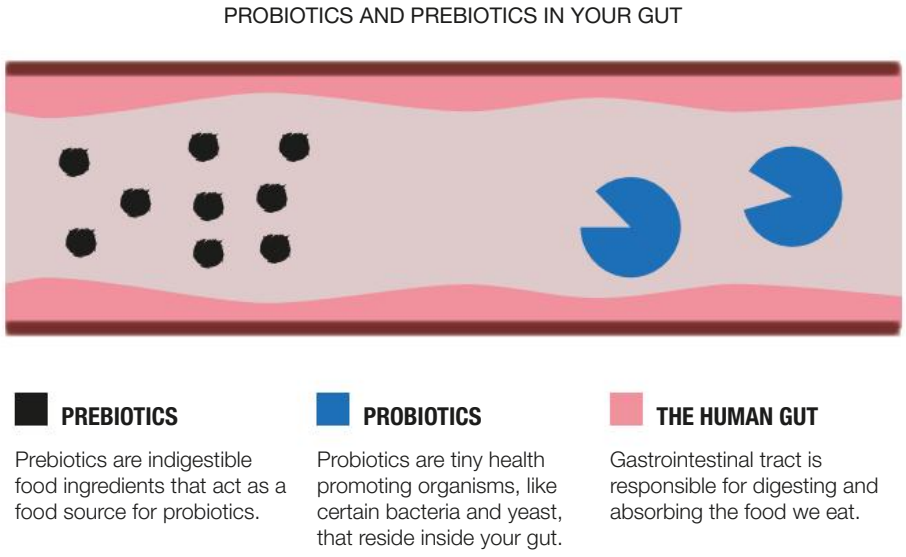


Figure 3.3.6: The difference between probiotics and prebiotics.

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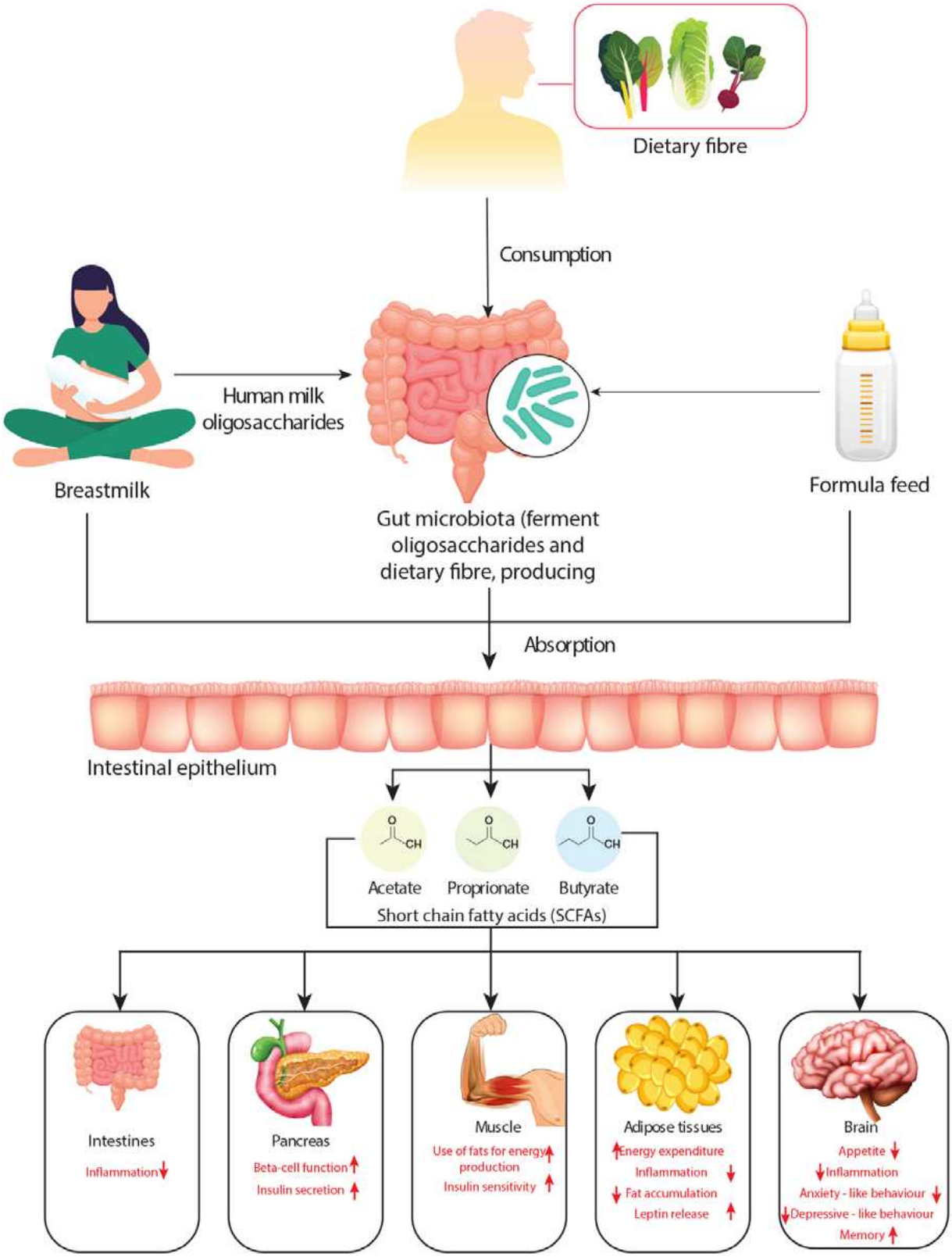


Figure 3.3.7: The gut microbiome ferments oligosaccharides and dietary fibre to produce short chain fatty acids (SCFAs). The three major types of SCFAs are acetate, proprionate and butyrate, which play multiple roles within the body including reducing inflammation (and disorders associated with it), anti-obesity roles (e.g. decreasing fat accumulation) and anti-diabetic roles (e.g. increasing insulin sensitivity). Please note that the arrows pointing upwards indicate an increase, and arrows pointing downwards indicate a decrease.

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PROBIOTIC-RICH FOODS



DAIRY SOURCES

- Yoghurt
- Kefir
- Buttermilk
- Creme fraiche
- Lassi, a drink made from yoghurt and water
- Aged cheeses, such as bleu, Gouda and cheddar

FRUIT AND VEGETABLE SOURCES



- Brined pickles
- Tangy chutneys
- Brined olives
- Sauerkraut and its ethnic variations — kimchi (Korean), tsukemono (Japanese), choucroute (French)
- Sauerruben (fermented sour turnips)
- Pickled beets

SOYBEAN SOURCES



- Miso
- Tempeh
- Natto
- Soy sauce
- Tamari

GRAIN SOURCES

- Traditional sourdough breads

NONDAIRY BEVERAGES

- Kombucha

PREBIOTIC-RICH FOODS

VEGETABLES



- Tomatoes
- Artichokes
- Onions
- Chicory
- Greens (especially dandelion greens)
- Asparagus
- Garlic
- Leeks

FRUIT



- Berries
- Bananas

WHOLE GRAINS



- Oatmeal
- Barley
- Flaxseeds
- Wheat

LEGUMES



- Lentils
- Kidney beans
- Chickpeas
- Navy beans
- White beans
- Black beans

Figure 3.3.8: Some examples of probiotics and prebiotics.

Helpful online resources

Osmosis from Elsevier: Prebiotics & probiotics

https://www.youtube.com/watch?v=0z47wLZ4-O4

Ted-Ed: How the food you eat affects your gut–Shilpa Ravella

https://www.youtube.com/watch?v=1sISguPDlhY

Did you know?

A recent study showed that microbiome diversity decreased for immigrants to America from Southeast Asia. This change occurred within months of moving due to a change in diet. In Southeast Asia, a high fibre diet was generally consumed but in America, their diet changed to one that is higher in sugar, fats and protein. Moving to America was associated with a 15% decrease in microbiome diversity and a six fold increase in obesity. Those individuals who became obese also lost a further 10% of microbiome diversity. This study does not directly link the decrease in microbiome diversity to obesity but separate studies have linked changes in gut microbiome to obesity.

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Medications

Some common medications can affect the gut microbiome. Recent research has shown that at least 18 common medications can affect the microbiome. The gut microbiome has up to 1,000 different bacterial species. Most of the bacterial species living on or within us are 'good' bacteria that perform important functions for us but sometimes we can contract pathogenic bacterial infections. These infections are commonly treated with **antibiotics**. Antibiotics **kill bacteria**. They do not kill other microorganisms like fungi, protozoa or viruses. Generally, broad-spectrum antibiotics are used as they kill a wide range of bacterial species. This can treat the infection so we are no longer ill but it can also kill the 'good' bacteria in our guts, causing a microbial shift. This means that the microbiome no longer has the correct kinds of species and the right proportions. Taking antibiotics, especially chronically, has been linked to broad health issues, including nutrient deficiencies and greater exposure to pathogenic disease. Furthermore, the use of antibiotics in premature infants has been linked to altering the microbiome and a higher mortality rate. Some other medications that can affect the microbiome are:

- Metformin, a drug used to treat type 2 diabetes, is associated with a higher percentage of potentially harmful *E. coli* bacteria.
- SSRI antidepressants have been linked with increased populations of potentially harmful *Eubacterium ramulus*.
- Oral steroids have been linked with increased methanogenic bacteria which are associated with obesity.

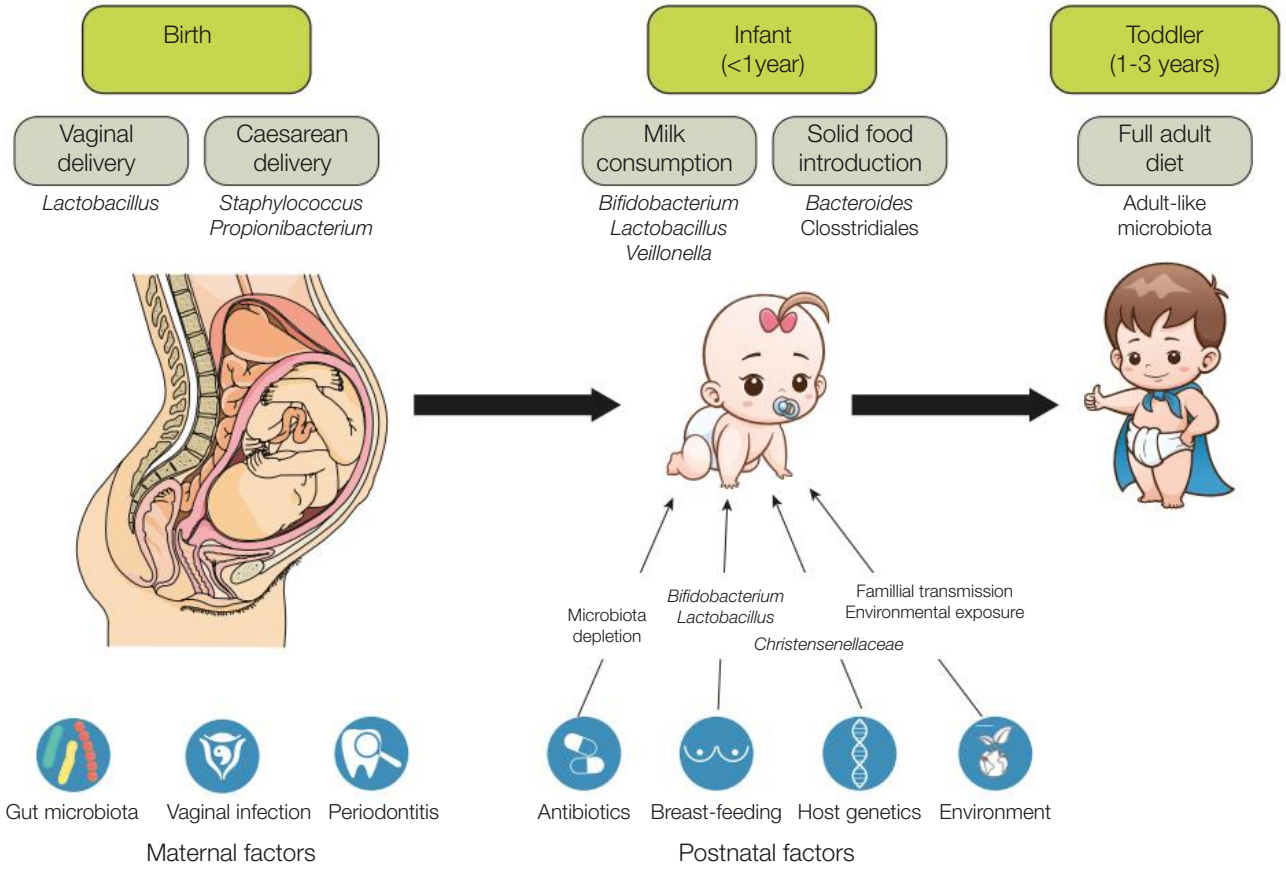


Figure 3.3.8: A summary of environmental factors that can influence the development of an individual's microbiome.

Did you know?

Triclosan is an antimicrobial chemical that is used in more than 2,000 consumer products, including toothpaste, hand soaps and body wash. Research has shown that this chemical can alter the gut microbiome causing inflammation and increase the risk of certain diseases developing, such as colitis and colon cancer. Mice exposed to the chemical in their diet at similar levels to those found in human blood exhibited inflammation and a decreased microbiome diversity. Specifically, the 'good' bifidobacterial population was decreased. Further research is required on the effects of triclosan on humans especially because it is currently near impossible to avoid this chemical in our daily lives.

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Microbiome dysbiosis

A healthy and balanced microbiome is also known as a **eubiotic** microbiome.

Eubiosis is associated with a high diversity of microorganisms and abundance of microbes within these populations. When the microbiome becomes unbalanced, indicated by a marked loss of microbial diversity, it is known is **dysbiotic**. A wide range of factors can cause shifts in the composition of the microbiome, such as poor diets that are high in processed foods, chronic stress, lack of sleep and some medications.

Dysbiosis disrupts the normal functioning of the microbiome and can cause harmful effects, such as contributing to the development of diseases. There are many health complications and diseases that dysbiosis has been implicated in, including:

Intestinal infections	Obesity
Gut inflammation	Crohn's disease
Diarrhoea/constipation	Type 2 diabetes
Allergies	Cancer
Lactose intolerance	Multiple sclerosis
Cognitive decline	Autism
Depression	Parkinson's disease
Inflammatory bowel disease	Alzheimer's disease

Did you know?

Recent research indicates that altering the gut microbiome of children with autism may reduce the severity of symptoms in some cases. Autism is a neurological disorder that is associated with impaired social and communicative skills, motor control and sensory challenges. However, approximately 50% of cases are also associated with gut disorders. Researchers at Arizona State University performed a faecal transplant into 18 children with autism who also had gut problems, shifting the composition of their microbiome. The children were treated for 10 weeks with follow up appointments for a further eight weeks. The results showed that there was an 80% reduction in gastrointestinal problems and the children showed substantial improvement in the autism diagnostic tests. The researchers followed up with the children two years later and found that the beneficial microbes remained in their microbiome and the diversity had also increased. They also discovered that two years later there was still a 58% reduction in gut problems and a 47% reduction in severity of autism spectrum disorder traits. This highlights that faecal transplants could be a potential treatment for autism in the future. It is important to note that autism is a complex condition and this does not mean that the gut microbiome causes autism but rather suggests it may be a contributing factor.

Dysbiosis treatments

The microbiome is very complicated because every individual has a unique microbiome making it hard to study. Scientists have been able to develop some treatments for certain dysbiosis conditions, such as a faecal transplant for a clostridium difficile infection. However, it is unlikely that there will be one single treatment that will allow all individuals to have a healthy microbiome.

Scientists have been researching possible treatments that block the toxins released by certain bacteria and genetically engineering bacteria (probiotics) that fight off the 'bad' microbes in the gut. If developed for public use, both of these treatments would alleviate the need for using broad spectrum antibiotics which kill both good and bad bacteria, thereby reducing the diversity of microbiomes. However, significant research still needs to be conducted.

Faecal microbiota transplants

A faecal microbiota transplant (FMT) is a process that involves the transfer of faeces from one patient into the intestines of another patient (see Figure 3.3.9). This process is currently used to treat Clostridium difficile (C. diff) infections. These infections normally overtake the microbiome following antibiotic prescriptions especially after being admitted to hospital. Antibiotics kill both good and bad bacteria in the intestines and disrupt the microbiome balance. This can give an opportunity for Clostridium difficile to grow and multiply due to less competition. A Clostridium difficile infection causes severe diarrhoea, which can result in severe dehydration and even death if not treated. These infections are usually treated with a prolonged course of antibiotics, but there are many cases where it does not work. This is becoming more common due to the rise of antibiotic resistance. A current

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technique is to transfer a 'healthy' faecal sample with a diverse range of good bacteria to the infected patient to effectively 'reset' their microbiome. The good bacteria in the healthy donor faecal sample outcompete the Clostridium difficile bacteria and restore a balanced microbiome. After a faecal transplant the patient generally ends up with a microbiome that is similar to the donors. This can resolve the infection and save lives but there are also some concerns with the process.

Firstly, what if the faecal sample contains antibiotic resistant bacteria? These bacteria could be passed on to the patient and this could lead to certain resistant infections in the future. Furthermore, the microbiome is very complex and there is a lot we don't know about it. There is concern that transplanting a microbiome from one donor to another can also transfer the issues and predisposed conditions associated with the donor's microbiome. For example, a woman in the United States of America received a faecal microbiota transplant from an overweight donor and became obese within 16 months. There was little change to her diet or exercise plan. She was 32 years old and went from weighing 61kg (with a BMI of 26) before the transplant, to 75kg with a BMI of 33, 16 months after the transplant. Three years after the faecal microbiota transplant, the woman was 80kgs with an obese BMI of 34.5. This suggests that the transferred healthy gut microbes from the donor extracted more energy from food than the patient's original microbiome. However, a limitation of this study is that the microbiome before the transplant was not sequenced so it cannot be compared to the current microbiome to determine the differences.

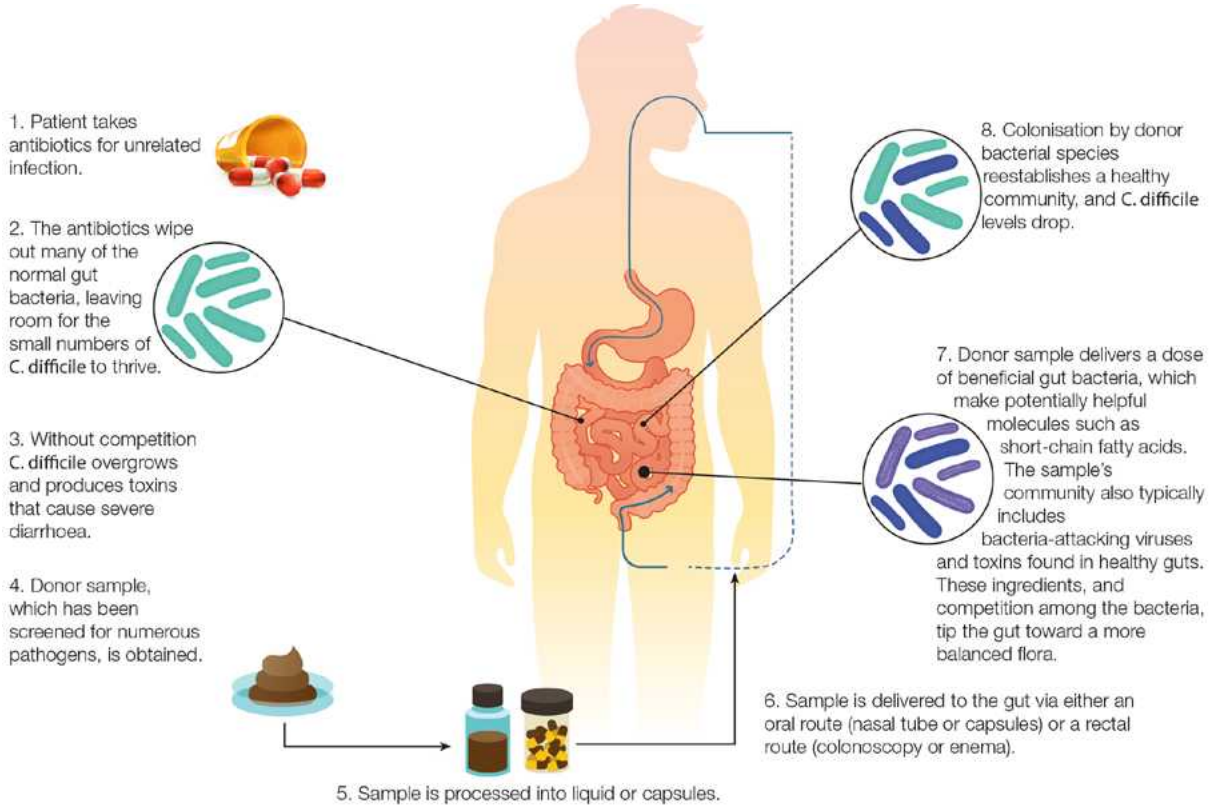


Figure 3.3.9: A summary of how a faecal transplant can treat recurring Clostridium difficile infections.

Helpful online resources

TED-Ed: The surprising secret to a healthier gut - Kathryn M. Stephenson and David L. Suskind

https://www.youtube.com/watch?v=ryGpw660ehc

Minute Earth – Poop Transplants!

https://www.youtube.com/watch?v=Dim7YXYlRm0

John Hopkins Medicine: Faecal Microbial Transplantation: A Treatment for Clostridium Difficile

https://www.youtube.com/watch?v=-nDPjGAGEak

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Treatment for obesity

Scientists have discovered a link between the gut microbiome and obesity. One study confirming this link involved comparing 'normal' mice with 'microbe free' mice. Microbe free mice are delivered through caesarean section, are housed in sterile conditions and are fed microbe free food The experiment concluded that the 'regular' mice that contained gut microbes ate 29% less rodent food but their body composition had 42% more fat than the 'microbe free' mice. The 'microbe free' mice were unable to extract the same amount of energy from their food because they lacked the microbes to help them do so. The gut bacteria in humans helps extract up to 30% of daily energy.

Further research on human microbiomes determined that our gut microbes adjust their population size based on the food we eat. In a separate study, 12 obese and five lean volunteers' microbiomes were examined. It was found that the microbiome of the obese subjects had 90% less *Bacteroidetes* and 20% more *Firmicutes* bacteria than the lean participants. Following a year on a low energy diet, the obese subjects lost 25% of their body weight and there was also a shift in the composition of their microbiomes. There was an increase in *Firmicutes* and a decrease in *Bacteroidetes*.

Scientists are now trying to develop a potential faecal microbiota transplant to treat obesity. They have discovered that performing faecal transplants from an obese twin into 'microbe free' mice causes **greater fat gain** than from a lean twin when fed the same diet (see Figure 3.3.10). In a separate study, a faecal transplant from a skinny person into an obese person, resulted in the obese person having a more diverse microbiome and **increased sensitivity to insulin.** This suggests that a faecal microbiota transplant could be a treatment option for type 2 diabetes and/or obesity in the future.

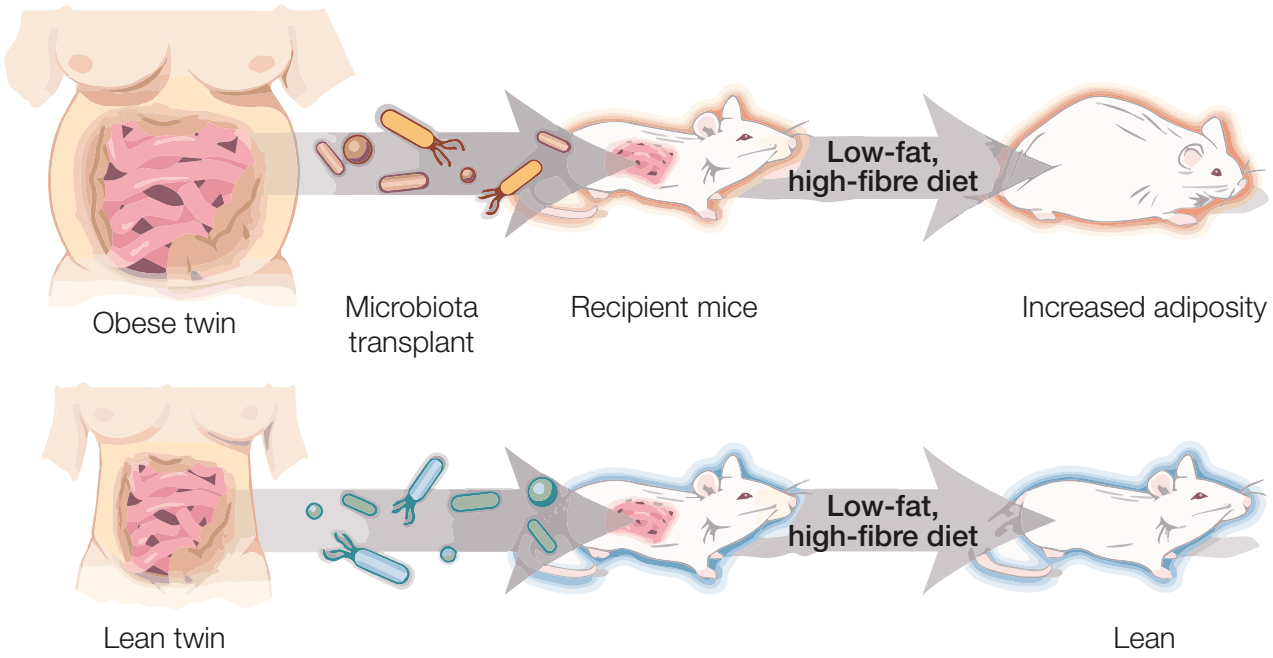


Figure 3.3.10: The transplantation of microbiota from an obese twin into 'microbe free' mice causes increased fat gain when compared to a lean twin.

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Science as a Human Endeavour 8

Genetically engineered probiotics

Probiotics are very popular and are attractive alternatives for treating some intestinal disorders. However, scientists are currently experimenting with genetically engineering probiotics to increase their effectiveness as treatments for intestinal disorders. Scientists at Northwestern University have genetically engineered *Lactobacillus acidophilus*, which is a common bacterium found in yoghurt. Normal *Lactobacillus acidophilus* triggers the production of beneficial molecules that regulate the immune system. However, they also produce an enzyme that increases inflammation. Inflammation is associated with many diseases including Crohn's disease and ulcerative colitis. Therefore, scientists deleted the gene that codes for this enzyme and fed genetically engineered probiotics to the mice with ulcerative colitis. This treatment prevented the symptoms associated with colitis, such as bloody diarrhoea and weight loss, and reduced inflammation of the gut lining by 90% in comparison to mice fed 'normal' *Lactobacillus acidophilus*. However, the microbiome is very complex and researchers are unsure if the probiotic alters the diversity and alleviates symptoms temporarily or if the effects are longer lasting. It is also unclear how much of a role the microbiome plays in all intestinal disorders.

Questions

1. Explain two **limitations** of genetically engineered probiotics.

(4 marks)

2. Explain two possible **applications** of genetically engineered probiotics.

(4 marks)

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Factors affecting microbiome diversity

It is not yet clear what constitutes a healthy gut microbiome but it is clear that a diverse microbiome is associated with a lower risk of developing many diseases. A healthy variety of gut bacteria is more able to adapt to the broad range of foods we consume, whilst maintaining its important functions, such as preventing inflammation. The current advice to maintain a healthy gut microbiome is to eat healthy, exercise regularly, get enough sleep, avoid stress, only take antibiotics when needed and do not drink too much alcohol.

A healthy diet constitutes a diverse range of foods, especially prebiotics. The greater the range of healthy foods consumed the more 'food' there will be for the various microorganisms in the guts. This increases the chance of establishing and maintaining a diverse microbiome. Conversely, research has linked the modern Western diet, which is high in processed foods that are rich in saturated fat and sugar and low in fibre, with a less diverse microbiome. Refer to Table 3.3.1 below, for a list of some sources that increase and decrease microbiome diversity.

Table 3.3.1: Some examples of sources that can increase and decrease gut microbiome diversity.

Sources that increase microbiome diversity	Sources that decrease microbiome diversity
Fruits	Whole milk
Vegetables	Soft drinks
Pasta and potatoes (resistant starch)	Processed foods
Nuts/seeds	Fried foods
Herbs/spices	Artificial sweeteners
Tea/coffee	High-mercury fish
Dark chocolate	Dried fruit and fruit juices (high in sugar).
Red wine (in small amounts)	
Fermented foods (probiotics), such as kimchi, kombucha and sauerkraut	
Other probiotics, such as yoghurt and Yakult.	

CS Possible case study 2

A 30 year old single male called Andrew is experiencing inflammatory gut issues, Andrew lives by himself, trains and plays football three times a week and works long hours. Due to his busy lifestyle, Andrew eats a lot of convenient meals, including junk food, pre-packaged meals and coffee. Andrew also likes to drink a few beers socially on the weekends. Design a diet and make some lifestyle recommendations that Andrew could implement to reduce symptoms associated with inflammation.

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3.3 Review questions

1. Define the gut microbiome.

(1 marks)

2. Describe why the stomach has less diversity of microbes compared to the intestines.

(2 marks)

3. Explain why the diversity of the microbiome is important for good health.

(4 marks)

4. State whether the following statements are true or false **and** explain why.

   (a) The microbiome starts forming from birth when the baby is exposed to bacteria in the vaginal birth canal.

(2 marks)

   (b) Breastfed babies are more likely to have a more diverse microbiome than bottle-fed babies.

(2 marks)

   (c) Prebiotics are foods that contain live bacterial cultures.

(2 marks)

   (d) Being born through the vaginal birth canal increases risk of disease later in life.

(2 marks)

5. Describe how antibiotics at a young age could increase the risk of disease later in life.

(3 marks)

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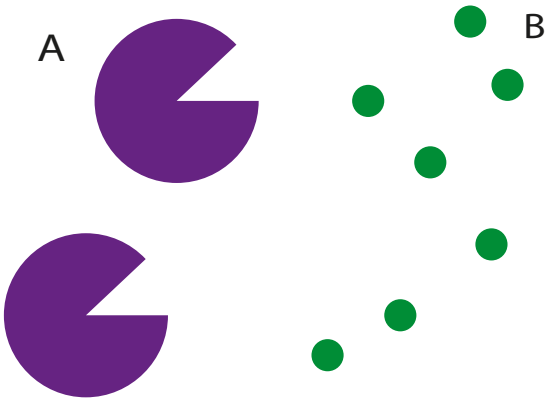
6. Bifodobacteria are a type of good bacteria that digest fibre, producing short chain fatty acids. Explain the benefit of short chain fatty acids for humans.

(4 marks)

7. Explain **two** environmental factors that could increase the diversity of a child's microbiome after being born.

(4 marks)

8. Refer to the diagram below to answer the following questions:



(a) Identify which of molecules A and B is the prebiotic and which is the probiotic.

A:

B: *(2 marks)*

(b) Name **two** examples of prebiotics and describe how they increase microbial diversity.

(3 marks)

(c) Identify whether yoghurt is a prebiotic or probiotic **and** describe how it can contribute to a healthy microbiome.

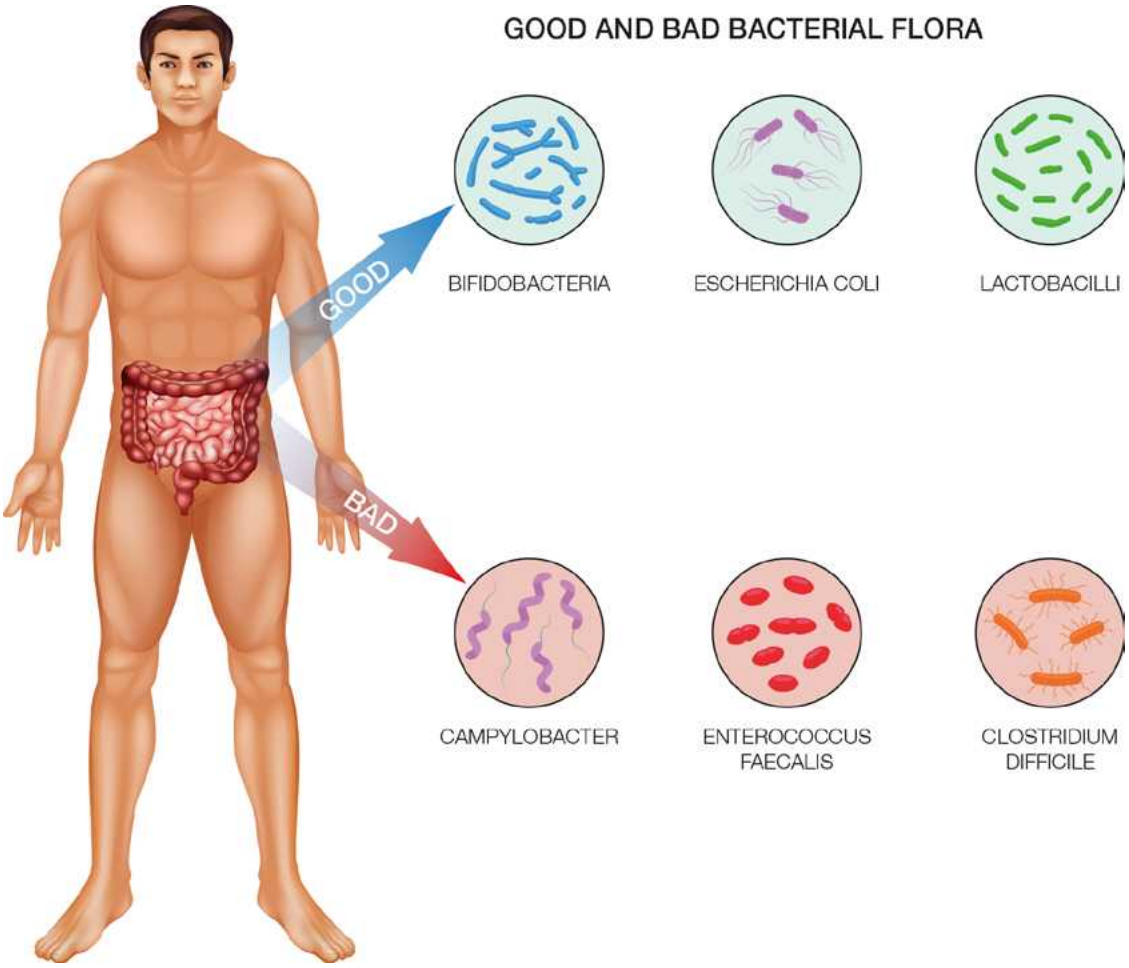
(3 marks)

9. Describe the type of diet associated with a low diversity microbiome.

(1 mark)

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10. Refer to the diagram below to answer the following questions.



(a) Our microbiome increases energy available to us by digesting hard to process carbohydrates, such as fibre. State **two** other molecules that beneficial bacteria such as *E.coli* and *Lactobacilli* produce for us to absorb.

(2 marks)

(b) *Camplyobacter* is a pathogenic bacterial species that can cause infection through ingestion of contaminated resulting in dysbiosis. Describe what dysbiosis is.

(2 marks)

(c) State **two** possible causes of dysbiosis of the gut microbiome, other than infections.

(2 marks)

(d) *Clostridium difficile* can also cause dysbiosis. Some of these infections can be resistant to being treated by antibiotics. Explain a contemporary treatment for resistant *Clostridium difficile* infections.

(4 marks)

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11. State if the following statements are true or false **and** explain why.

    (a) Antibiotics should never be consumed due to the negative effects on the microbiome.

(3 marks)

    (b) Faecal transplants have no negative side effects.

(2 marks)

    (c) Faecal transplants could result in a treatment for weight loss.

(2 marks)

12. A healthy variety of gut bacteria is more able to adapt to the broad range of foods we consume, whilst maintaining their important functions (such as preventing inflammation).

    (a) State **two** lifestyle factors that can increase diversity of the gut microbiome.

(2 marks)

    (b) State **two** foods that could increase the diversity of the gut microbiome.

(2 marks)

E Extension question

Research **and** explain the link between the microbiome and Parkinson's disease.

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3.4 The digestive system, microbiome and the brain

Nutrition Understanding

It should be no surprise that there is communication between our guts and brain given the food we eat supplies the brain with the energy needed to perform our daily functions. In fact, our gut is often referred to as our 'second brain.' There are multiple ways that the gut and brain communicate with each other and recent research has also determined that the microbiome has a role in this communication. Gut dysbiosis has been linked with cognitive decline and implicated in many neurological disorders, including anxiety, depression, autism and Parkinson's disease. Scientists are now exploring possible treatments for these conditions by targeting the gut microbiome.

The microbiome-gut-brain axis

In the gut, there is a 'second brain' called the **enteric nervous system** (ENS) that oversees the function of the gastrointestinal tract and can act independently of the brain and spinal cord. The ENS is made up of more than 500 million neurons spread over the entire digestive tract. It is directly connected to the central nervous system via the **vagus nerve**. The ENS has 0.5% of the number of neurons the brain has but it makes a respectable 40 neurotransmitters when compared to the brain's 100 neurotransmitters. Neurotransmitters are chemicals released by nerves to transmit an impulse to another nerve (see Figure 3.4.1). Incredibly, the **ENS makes 95% of the neurotransmitter serotonin**, which is the hormone that affects mood and is associated with 'feeling good'. By contrast, the brain only makes 5% of serotonin. Furthermore, the **ENS makes 50% of the neurotransmitter dopamine**, which is associated with the pleasure and the reward system. The brain makes the remaining 50% of dopamine.

The gut and brain functions are intertwined and are essential to each other (see Figure 3.4.2). Additionally, studies in mice have shown that brain development is abnormal when there is no microbiome present. There are multiple ways the microbiome, gut and brain communicate with each other (see Figure 3.4.3), some of which are:

1. The gastrointestinal tract can communicate directly with the hypothalamus in the brain, which is responsible for regulating emotions, via the vagus nerve. This can activate the hypothalamic-pituitary-adrenal (HPA) axis which involves both nervous and hormonal communication.
2. Bacteria in the gut can release metabolites, such as short chain fatty acids, that can alter activity of the cells in the blood-brain barrier and its permeability.
3. Bacteria in the gut can also release chemicals that stimulate intestinal cells to release hormones that can travel to the brain and communicate with it.
4. Gut microbes can interact with the immune system cells stimulating them to produce chemicals called **cytokines** that can communicate with the brain and influence its physiology.
5. Gut microbes can also play a role in the metabolism of an amino acid called tryptophan, which is the precursor to serotonin neurotransmitter. If the bacteria that are involved in this process are low in number due to disturbances, less serotonin is produced.
6. Other neurotransmitters, such as gamma aminobutyric acid (GABA) and brain derived neurotrophic factor (BDNF), are also produced by bacterial species in the gut. GABA is the main inhibitory neurotransmitter in the brain and BDNF is important for higher-order thinking, memory and learning.

1. AN IMPULSE ARRIVES AT THE END OF THE PRESYNAPTIC NEURONE
2. VESICLES MOVE TOWARDS, AND FUSE WITH, THE PRESYNAPTIC MEMBRANE. THIS RELEASES NEUROTRANSMITTERS INTO THE SYNAPTIC CLEFT.
3. THE NEUROTRANSMITTERS DIFFUSE ACROSS THE SYNAPTIC CLEFT (DOWN A CONCENTRATION GRADIENT)
4. NEUROTRANSMITTERS ATTACH TO RECEPTORS ON THE POSTSYNAPTIC MEMBRANE.
5. THIS TRIGGERS AN IMPULSE WHICH TRAVELS ALONG THE POSTSYNAPTIC NEURONE.
6. THE NEUROTRANSMITTERS ARE RECYCLED OR DESTROYED ONCE AN IMPULSE IS SENT.

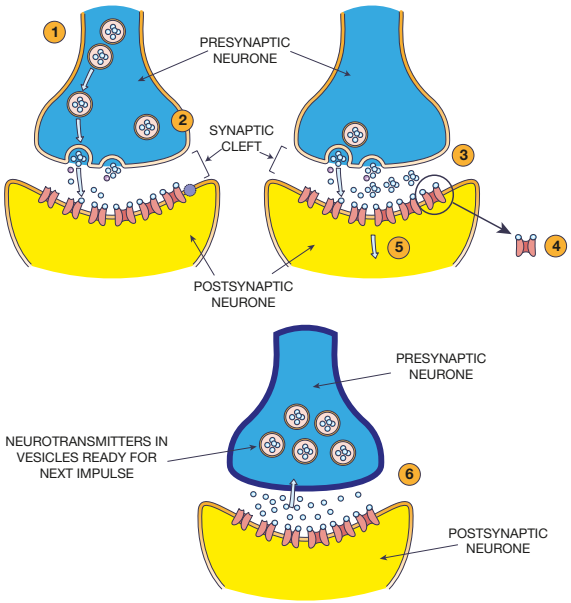


Figure 3.4.1: A summary of the steps involved in a synapse between two nerves. A synapse requires neurotransmitters to cross the synaptic cleft to pass on the message to the next nerve. Some examples of neurotransmitters are serotonin and dopamine.

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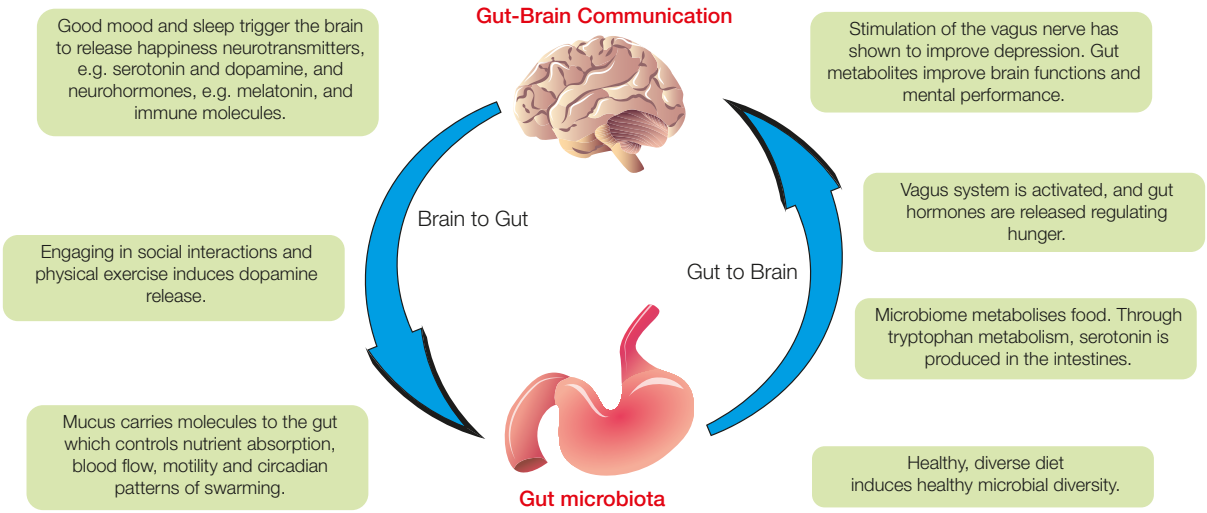


Figure 3.4.2: Some examples of the intertwined functions of the gut-brain axis.

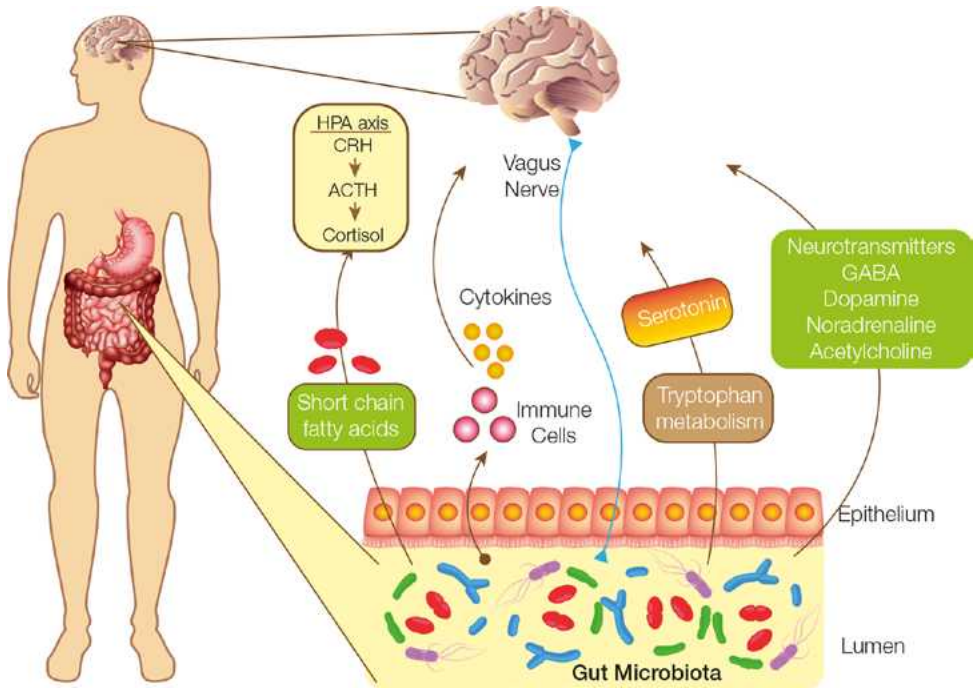


Figure 3.4.3: Some of the methods that the gut microbiome, gut and brain communicate with each other.

Food addiction

The bacteria in our intestines are able to produce chemicals that communicate with our brain. Some of these bacteria feed on fibre from fruit and vegetables and others feed on sweet food and fatty food. When an individual eats junk food they are also providing the 'junk food loving' bacteria in their guts with nutrients they require to grow. This results in increased growth and division of 'junk food loving' bacteria and additional signals to the brain to eat more junk food. This can result in cravings to eat junk food and, when eaten, the population of 'junk food eating bacteria' increases again, restarting the cycle (known as a positive feedback loop). This **positive feedback loop** increases the cravings we have for particular junk foods and can be hard to fight off as it is **self-reinforcing**. This can be a contributing factor to obesity. However, the cycle can be broken by eating a more nutrient dense diet. These foods feed our 'good' bacteria and fuel their growth and division. When their population increases, they communicate to our brain to eat more fibre rich foods and, through the same process, it is self-reinforcing and we are more likely to crave fibre rich foods, such as fruit and vegetables. As a result, the population of 'junk food loving bacteria' decreases, as there is less food for them to feed on, thereby reducing the signals to the brain and subsequent cravings for junk food.

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Helpful online resources

SciShow: Why Our Brains Love Junk Food

https://www.youtube.com/watch?v=ZMsW2oXors8

Ted-Ed: How the food you eat affects your brain–Mia Nacamulli

https://www.youtube.com/watch?v=xyQY8a-ng6g

Microbiome and mental health

It is common knowledge that our brain can affect our gut. When we are anxious our stomach can feel uneasy and we may experience diarrhoea. Conversely, when feeling depressed we may experience constipation if we are less active. A reduction in movement by the body and, in turn, the guts, can cause constipation. It is now becoming clearer that the gut can affect the brain and may be linked to **anxiety** and **depression**. There is an increasing amount of evidence suggesting that our lifestyle can affect our microbiome, which can influence our mood and behaviour and mental health (see Figure 3.4.4).

The microbiome produces and influences the production of a wide variety of different chemicals, such as neurotransmitters and cytokines, which are able to affect the brain. An **imbalance in the microbiome** could therefore lead to an **imbalance in neurotransmitter and cytokine production** and this could alter nervous communication and lead to anxiety or depression. We know that gut dysbiosis can lead to **inflammation** of the brain and this is associated with cognitive decline and other brain disorders (see Figure 3.5.5). It is now also becoming clearer that dysbiosis may disrupt neurotransmitter production and contribute to anxiety and depression. As mentioned above, the ENS produces 95% of serotonin, a neurotransmitter that influences mood and is associated with '**feeling good**.' Changes in the diversity of species in the gut can therefore affect the amount of serotonin produced and this affects the brain. This is significant because many of the drugs used to treat depression target the serotonin pathways in the brain. Research has also demonstrated that if gut bacteria are transplanted from a depressed human into a non-depressed mouse, the mouse will start showing symptoms and behaviours of depression.

Multiple studies have shown that **stress** can affect the diversity of the gut microbiome but until recently it was unclear if this worked both ways and whether gut dysbiosis could cause stress. It is now clear that there is a connection between the microbiome, stress and changes in brain chemistry. There is also an established link between chronic stress and increased risk of developing anxiety and depression; therefore, scientists are researching links between the gut microbiome, stress and depression with the hope of developing new treatments or therapies. One study on mice determined that 'microbiome free' mice, which are mice that have had their microbiome wiped out with antibiotics, produced less of the neurotransmitter BDNF in the regions of the brain that react to stress. Reduced BDNF has been linked to reduced brain activity and depression.

Currently, most studies have been performed on mice and it cannot be assumed that the results are directly comparable to humans; however, some human studies have been performed. One particular study examined whether changing the microbiome could alter anxiety symptoms in humans. In this study, treating anxiety with both prebiotics and probiotics was examined. It was found that treating anxiety with **prebiotics (changing diet) was more effective than treating with probiotics (live cultures)** with an 86% efficacy in intervention. It is clear that the microbiome influences the brain but the mechanisms behind how the prebiotics and probiotics are influencing the gut microbiome and brain are currently unclear. It was concluded that prebiotics were more effective than probiotics because they provided food for a wider range of bacteria thereby increasing diversity, whereas probiotics may have been competing with each other to establish themselves in the ecosystem.

Currently, the direct link between the microbiome and depression in unknown but there is growing psychiatric evidence that **inflammation** increases the risk of development of disorders such as depression, cognitive decline and post-traumatic stress disorder (PTSD). It is also unclear how the use of **antibiotics** may affect mental health and cognition given they can kill bacteria and cause a shift in the composition of the microbiome, causing dysbiosis. Whilst there is not enough evidence at present to recommend exactly which foods to eat and which foods to avoid in order to treat depression through diet, studies do suggest that eating a healthy **diet rich in fibre** can reduce the risk of anxiety and depression.

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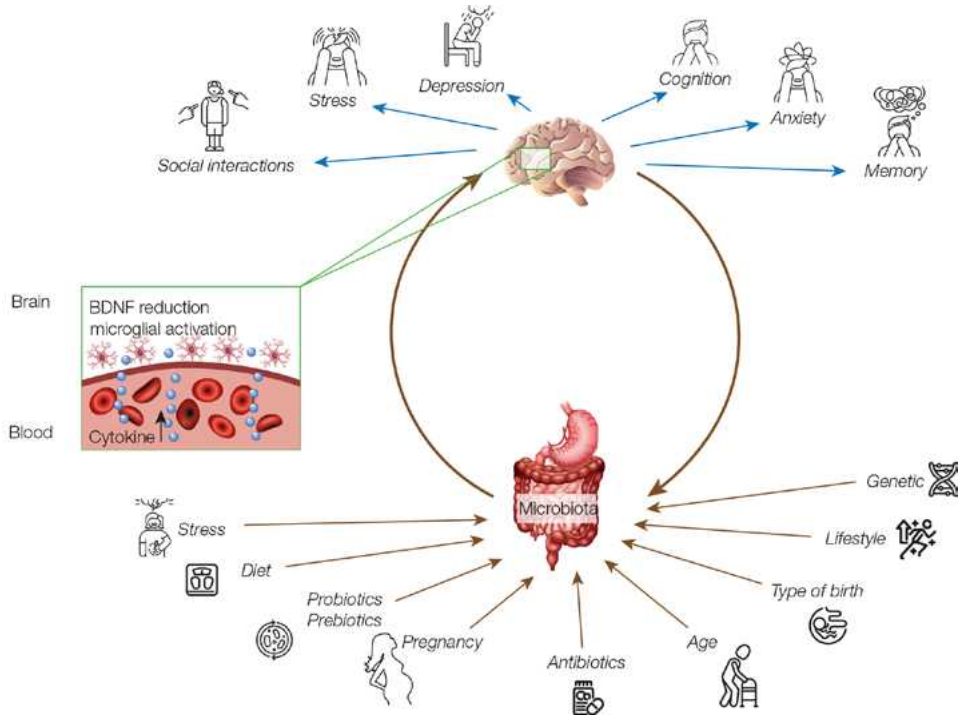


Figure 3.4.4: Some lifestyle factors that can affect the composition of the gut microbiome and some of the mental health conditions an altered microbiome has been linked to.

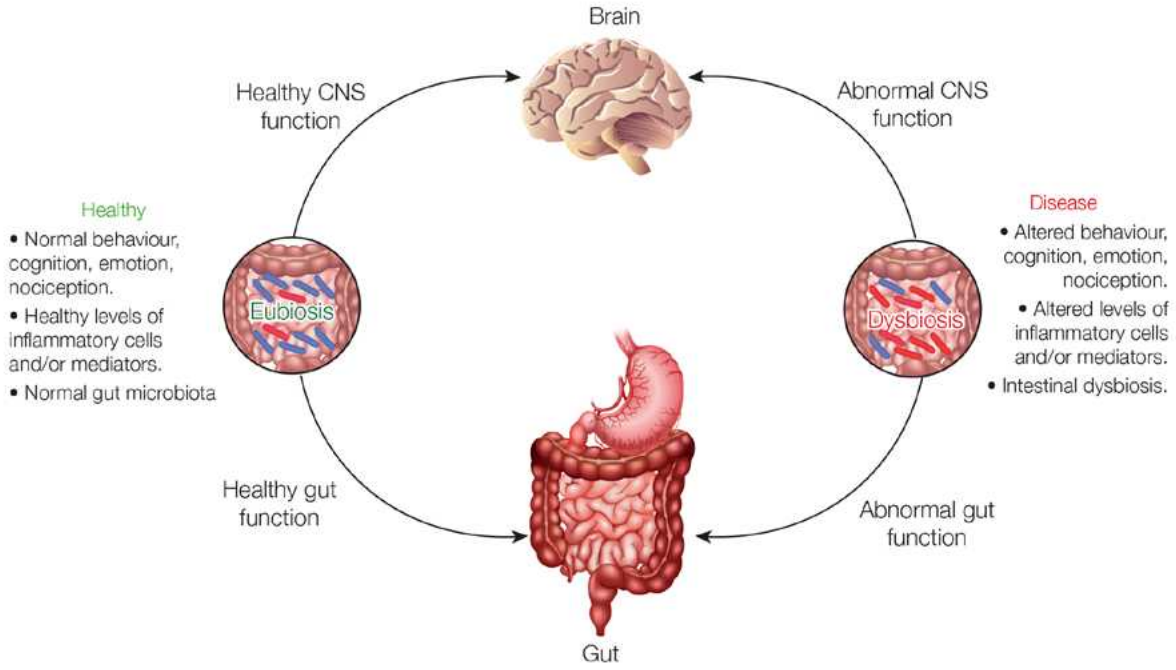


Figure 3.4.5: A summary of how dysbiosis can cause inflammation in the brain and lead to mental health issues.

Did you know?

An interesting study on mice established that our microbiome could affect our personality. At McMaster University, two groups of mice were bred for their behavioural characteristics. One group was bred to be introverts and the other to be extroverts. Samples of both groups' microbiome were collected and then wiped out using antibiotics. The microbiome of the introverted mice was transplanted into the extroverted mice and vice versa. This resulted in the extroverted mice exhibiting shy and timid behaviour (becoming more introverted) and the introverted mice exhibiting more sociable and bold behaviour (becoming more extroverted).

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Helpful online resources

Big Think: How To Conquer Depression Through Diet | Dr. Drew Ramsey

https://www.youtube.com/watch?v=na1gn5bHRCY

Mind-altering microbes: how the microbiome affects brain and behavior: Elaine Hsiao at TEDxCaltech

https://www.youtube.com/watch?v=FWT_BLVOASI

3.4 Review questions

1. Explain how our microbiome can increase food cravings for junk food.

(4 marks)

2. Describe **two** ways that the gastrointestinal tract can communicate with the brain.

(2 marks)

3. Describe **two** ways that a disruption in the microbiome could lead to anxiety or depression.

(4 marks)

4. Describe the type of diet that could reduce the risk of anxiety and depression in individuals.

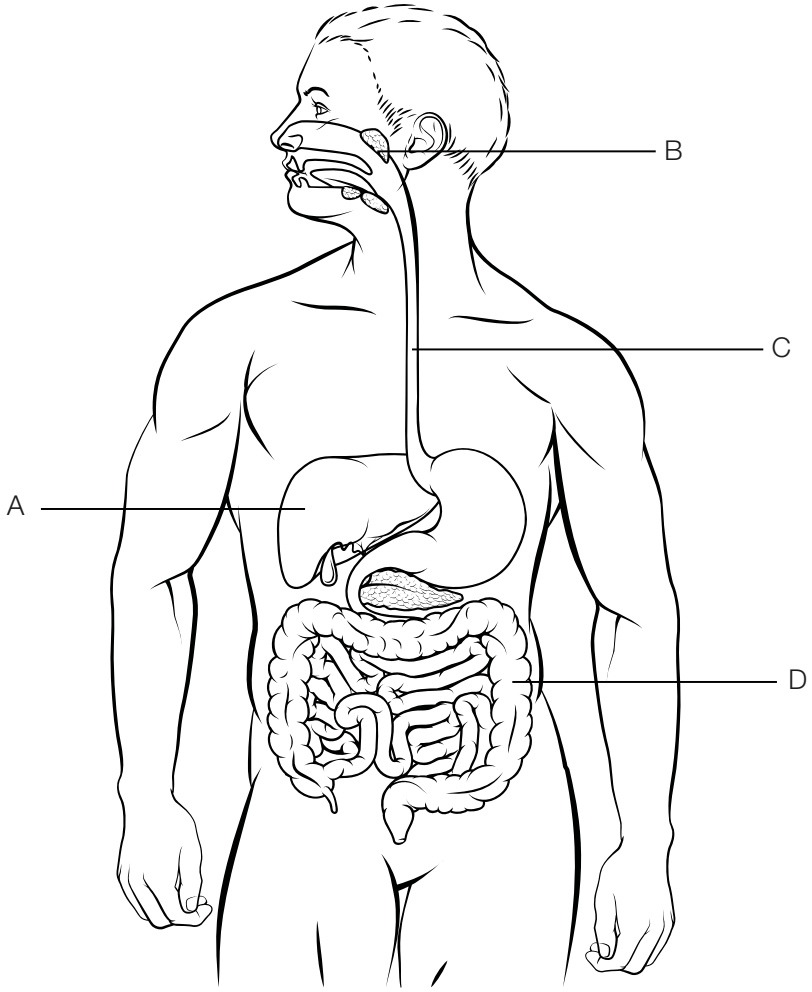
(2 marks)

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Topic 3 Review Test

1. The gastrointestinal tract is a group of organs that work together to convert food into nutrients the human body can use to make energy, to grow, and to repair itself.

   Refer to the following diagram, which shows the human digestive system:



   (a) On the diagram above, identify the name of the structures A, B, C & D. *(4 marks)*

   (b) When food moves to the lower part of the stomach it is mixed into a semi-fluid substance called chyme.

   (i) Describe how the entry and exit of food to and from the stomach is controlled.

(2 marks)

   (ii) Describe the process of mechanical digestion in the stomach.

(2 marks)

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(c) Gastric juice, which is a mixture of mucus, hydrochloric acid and digestive enzymes, is secreted into the stomach.

(i) State **two** functions of hydrochloric acid in the stomach.

(1)

(2)

(2 marks)

(ii) Describe the chemical digestion of lipids.

(2 marks)

(iii) Identify the organ of the digestive system where the majority of fermentation of fibre by bacteria occurs.

(1 marks)

(iv) Explain how a diet consisting of low fibre and a high amount of junk food can result in craving more junk food.

(4 marks)

Food intolerances can make maintaining a diet following the Australian Dietary Guidelines (ADG), difficult.

(d) Name **one** malabsorption syndrome.

(1 mark)

Use the malabsorption syndrome you have selected in (d) to answer questions (e) and (f) below.

(e) Describe a symptom of the identified malabsorption syndrome.

(2 marks)

(f) Name **two** foods that someone with this malabsorption syndrome must avoid in their diet.

(2 marks)

2. *α-amylase is an enzyme found in saliva that acts upon the polysaccharide starch. An experiment was carried out in order to investigate the effect of acidity, as measured in pH units, on the rate of reaction of α-amylase. The greater the rate of reaction of α-amylase , the greater the digestion of starch. A number of test tubes were set up, each containing the same amount of starch and the enzyme α-amylase but each at a different pH value. The tubes were incubated at 37ºC and after 30 minutes the relative activity of the enzyme in each of the tubes was measured. The results were as follows:*

Test Tube Number	pH of Contents	Relative activity of α-amylase
1	4.5	7
2	5.0	45
3	5.5	71
4	6.0	84
5	6.5	73
6	7.0	40
7	7.5	7

(a) Graph the relative activity of α-amylase against pH on the grid below.

(5 marks)

(b) Identify the optimum pH for α-amylase activity based on the results from this experiment.

(1 mark)

(c) State the independent variable for this experiment.

(1 mark)

(d) State **one** factor controlled in this experiment.

(1 mark)

(e) α-amylase is an enzyme found in saliva. Explain why the relative activity of α-amylase would be reduced after swallowing.

(2 marks)

3. Current studies suggest that we each have up to 1,000 different species of bacteria living in our intestines.

(a) Explain why it is important for there to be many different species of bacteria in our intestines.

(2 marks)

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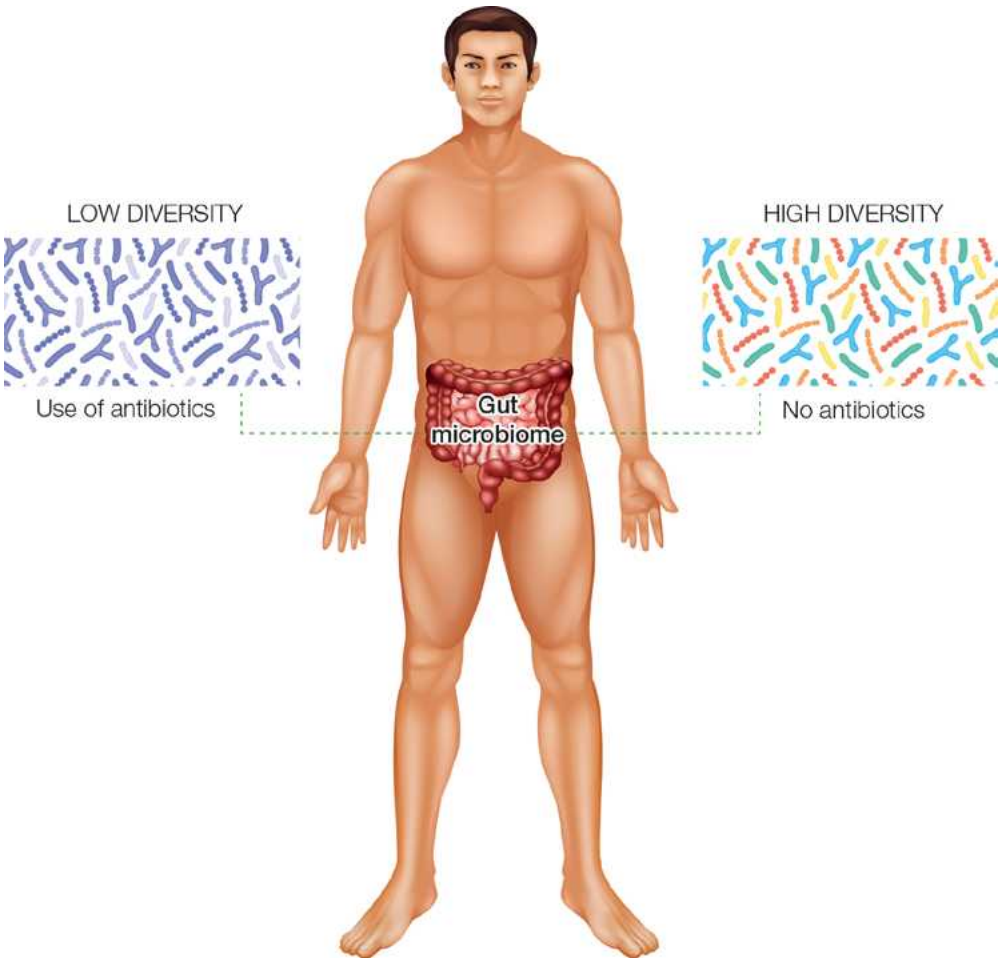
(b) Explain how eating prebiotics can help maintain a diverse microbiome.

(2 marks)

(c) Name **one** probiotic food source.

(1 mark)

Refer to the diagram below to answer question 3(d):



(d) Explain how antibiotics can change our microbiome diversity **and** a possible consequence of using antibiotics for humans.

(4 marks)

(e) Some people can contract a Clostridium difficile infection in the intestines following a course of antibiotics because this species recovers very quickly and can divide quicker than our good bacteria. This infection causes severe diarrhoea and can lead to dehydration and death. For cases that do not respond to further antibiotics, a faecal transplant may be performed.

Explain what a faecal transplant is and how it works.

(2 marks)

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(f) Identify **and** explain **one** possible side effect of a faecal transplant.

(3 marks)

(g) There is an increasing amount of evidence suggesting that our microbiome can influence our mood and behaviour.

Describe **one** way that the gut can communicate with the brain.

(2 marks)

(h) Describe what type of diet could reduce the risk of anxiety and depression **and** explain how it can do this.

(3 marks)

4. Recent studies suggest that weight gain could be contagious. The increase in cases of obesity has correlated with significant changes in human gut microbiomes. Research has now discovered a mechanism linking our gut microbiome to the amount of fat stored in our bodies. The researchers discovered a molecule produced by the gut microbiome called delta-valerobetaine. This molecule is not present in microbiome-free mice (which is induced through antibiotic treatments). Delta-valerobetaine decreases levels of another molecule called carnitine, which transports fats to the mitochondria of cells to be used as energy. Therefore, high levels of delta-valerobetaine increases weight gain. The same study could not be repeated on humans, but the researchers obtained blood samples from approximately 200 human subject and measured the concentration of delta-valerobetaine. The subject considered overweight and obese had a 40% higher blood concentration than subjects who didn't classify as overweight or obese.

(a) Identify **one** possible reason why recent research suggests weight gain could be contagious.

(1 mark)

Use your understanding of science as a human endeavour to answer the following questions.

(b) Discuss **two** reasons why the study performed was limited to using microbiome-free mice and could not be repeated using human subjects.

(4 marks)

(c) Discuss how this new scientific knowledge could be applied to treating obesity.

(4 marks)

Total: ____/60

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Topic 4

Food marketing & nutritional guidelines concepts



Concept: Health promotion and emerging trends

4.1 The psychology of food marketing

4.2 Australian dietary guidelines

4.3 Indigenous Australians: food changes from the traditional to the contemporary

4.4 Nutrition in the life cycle

4.5 Health promotion for specific community groups

Topic 4 Review Test

4.1 The psychology of food marketing

Nutrition Understanding

Most companies promote their products through advertising, including via social media, television, radio, the internet and traditional print media (e.g. newspapers and magazines). Advertising practices have evolved and online advertising is becoming more common as it better enables businesses to target specific audiences. The evolution of online advertising, combined with more traditional methods, means that consumers are being exposed to more advertising than ever before. Digital marketing experts estimate that the average person is exposed to around 4,000 to 10,000 adverts every day. Advertising can influence consumer choices and businesses are therefore required to comply with advertising laws. All Australian businesses (including online businesses) must comply with the Australian Consumer Law (ACL), which is part of the *Competition and Consumer Act 2020*. The ACL protects Australian consumers and ensures fair trading.

There are many marketing strategies that businesses use to expand their consumer base and influence consumers to purchase their product(s). These strategies are ultimately used to increase sales. Some marketing strategies that are used to influence consumer choices include targeted marketing to children, marketing via social media, the use of competitions and celebrity endorsements.

Food marketing to children

It is important to have sufficient controls regarding food marketing to children, particularly advertising relating to unhealthy foods, as children are very receptive to marketing and more easily influenced by advertising than adults. Currently, there is not a uniform policy set by Federal government to control targeted advertising to children in Australia. Advertising targeted at children is currently regulated by a mix of standards and codes, which is quite complex. This means that businesses can often find gaps in the current legislation to promote their product to children. For example, certain restrictions that limit advertising to children currently apply to free to air television but not paid television. In addition, businesses often make adverts that are primarily aimed at children but assert that the advert is targeting adults by evoking a sense of nostalgia for childhood. Many food businesses target their advertising to the peak times and shows that children watch television, such as Saturday morning cartoons. The repetitive nature of advertising can imprint brands in children's minds and once these brand preferences have been established it is very hard to reverse. In fact, **brand loyalty can start as early as two years old**. Once children are attached to a brand, they often pressure their parents to purchase the brand. For example, a young child having a tantrum at a supermarket can influence their parent to purchase the product to reduce the commotion in public. Advertising to children is so effective that children who are exposed to alcohol adverts and can recognise alcohol brands and slogans are more likely to consume alcohol when they are of legal age.

There is strong evidence that television advertising affects the food and drink preferences of children (2–11 years old). Most of the food and drink advertisements that children are exposed to promote products that are high in saturated fat, sugar and salt. This is an issue because childhood obesity is a serious public health issue. **The behaviours that children develop typically follow them into adulthood**. This means that obese children tend to stay obese in adulthood and are more susceptible to dietary disorders, such as type two diabetes and cardiovascular disease.



Figure 4.1.1: Television advertising to children can affect their food choices for the rest of their life.

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The use of competitions and social media as a marketing tool

Many companies use competitions as a marketing strategy to attract customers to purchase their product(s). Competitions offer consumers an incentive to purchase products and can influence choices. For example, when picking between two similar products that are similarly priced, a competition associated with one product can sway a consumer's choice over another. Competitions allow companies to increase their brand awareness, broaden their reach to more consumers, engage audiences and generate sales. Competitions can also be used effectively in conjunction with social media and phone applications due to their accessibility. When conducted through social media, it also allows companies to boost their followers with 'likes' and by requiring friends to be referred to win (refer to Figure 4.1.2). Social media advertising and competitions can also allow businesses to collect user content, including email addresses, which can be used to provide additional promotional material. **Social media competitions often target adolescents** because they are regular and competent users. Competitions and social media can expose consumers to more advertising and can influence product purchasing, sometimes without any/little realisation by the consumer of the effect it is having on them.



Figure 4.1.2: Competitions run through social media can require consumers to like a page, refer a friend or compete another challenge, such as supply a comment or upload a photo to win a prize.

Celebrity endorsements

Some food companies use celebrities in their advertising campaigns to influence the public and boost sales of their product(s). Celebrity endorsement can increase awareness and add credibility to a food product. This can influence consumer choice because these variables are important when making decisions and consumers tend to be more sympathetic to food products that are promoted by celebrities they admire. Celebrity endorsements also benefit the celebrity. The celebrity is remunerated and provided a platform to reach a wider audience. This is particularly important for emerging celebrities. However, the celebrity endorsement of take away food has been criticised and is often blamed for the increase in childhood obesity cases. There are many factors contributing to childhood obesity and celebrity endorsements are only one of these several factors.

Did you know?

The products at supermarkets are deliberately positioned to influence our purchasing. There has been significant research conducted into supermarket psychology and how to increase consumer spending. Some of these positions are obvious, such as the chocolates and chewing gum at the checkouts; however, others are less obvious. Some additional examples are:

- Flowers are placed at the entrance of supermarkets to provide a pleasant scent to put consumers in a good mood.
- Essential items like milk and bread are placed at the back of the supermarket to ensure consumers walk past many other products to reach the essentials, thereby increasing the likeliness of them purchasing something else.
- Cereals targeted at children are often placed on the lower shelves so the bright colours and mascots attract children who can reach them, pick them up and take them to their parent's trolley.
- Many sale items are stocked at the end of aisles (known as endcaps) to entice consumers who are dropping in for a few items to purchase items in aisles that they wouldn't otherwise enter.



Science as a Human Endeavour 9

The use of artificial intelligence to influence consumer shopping

Please watch the following video about artificial intelligence (AI) and the future of shopping and answer the following SHE questions:

Helpful online resources

Insider Tech: How AI Can Elevate the Consumer Shopping Experience

https://m.youtube.com/watch?v=fKX5igoT0yI

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Science as a Human Endeavour 9

Questions

1. Discuss how kitchens that could restock themselves could **influence** society.

(4 marks)

2. Explain how supermarket chains need to **communicate and collaborate** with other businesses to provide targeted discounts to their consumers.

(4 marks)

4.1 Review questions

1. It is predicted that childhood and adolescent (ages 5 – 19) obesity worldwide will increase from approximately 158 million in 2020 to 254 million in 2030. Explain how banning junk food advertising to children worldwide could reduce the projected figure.

(4 marks)

2. Describe why the amount of advertisements the average person is exposed to daily has increased in the last 20 years.

(2 marks)

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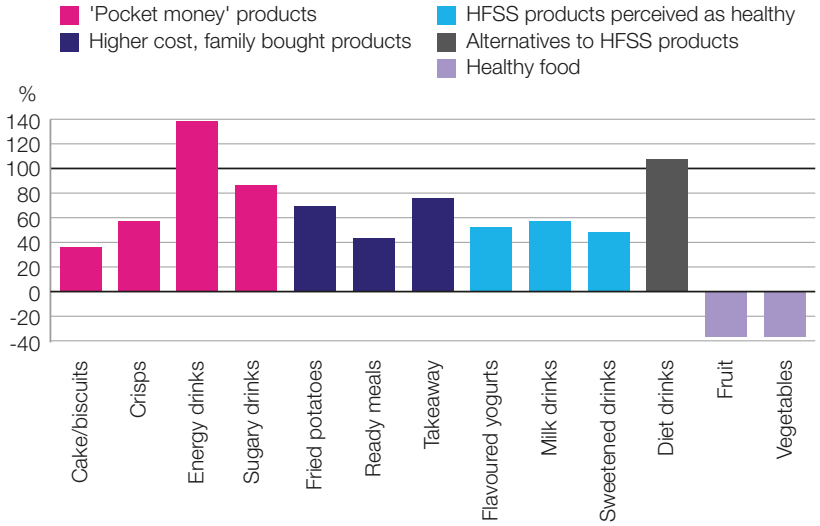
3. (a) Describe why adolescents are more likely to be affected by advertising through social media.

(1 mark)

(b) Describe how a business could increase their reach to more consumers using social media.

(2 marks)

4. Refer to the following graph showing the effect of exposure to junk food marketing through traditional or on-demand television shows on the risk of consuming products high in fat, sugar or salt ('HFSS'):



(a) Using data from the graph, identify the listed HFSS product for which television marketing had the greatest risk of increasing its consumption.

(2 marks)

(b) Describe why the overconsumption of energy drinks can be unhealthy.

(2 marks)

(c) Describe why flavoured yoghurts could be perceived as healthy but could actually be classified as a HFSS product.

(2 marks)

(d) Some takeaway foods and takeaway food services are endorsed by celebrities. Describe how this could influence adolescent food choices.

(2 marks)

E Extension question

Research **and** explain the types of food advertising used to target the elderly. Comment on the ethical nature of advertising to the elderly.

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4.2 Australian Dietary Guidelines

Nutrition Understanding

The Australian Dietary Guidelines (ADGs) are a set of five guidelines that are based on extensive scientific research to provide recommendations to the public on how to live a healthier life. It is important for all individuals to consume the right amount of essential nutrients and the right types of foods to reduce their risk of developing undernutrition and overnutrition disorders, such as obesity, hypertension, diverticular disease and cardiovascular disease (see Topic 2: Dietary disorders). The guidelines provide information on how to make healthy food choices and reduce the risk of developing these chronic health disorders.

Did you know?

According to the 'Australian Health Survey: Consumption of Food Groups from the Australian Dietary Guidelines, 2011-12,' approximately 96% of Australian's do not consume the minimum recommended number of serves of vegetables regularly. It also estimated that less than 1% of children consume their recommended number of serves regularly.

The Australian Dietary Guidelines

Guideline 1

To achieve and maintain a healthy weight, be physically active and choose amounts of nutritious food and drinks to meet your energy needs.

- Children and adolescents should eat sufficient nutritious foods to grow and develop normally. They should be physically active every day and their growth should be checked regularly.
- Older people should eat nutritious foods and keep physically active to help maintain muscle strength and a healthy weight.

Guideline 2

Enjoy a wide variety of nutritious foods from these five groups every day:

- Plenty of vegetables, including different types and colours, and legumes/beans
- Fruit
- Grain (cereal) foods, mostly wholegrain and/or high cereal fibre varieties, such as breads, cereals, rice, pasta, noodles, polenta, couscous, oats, quinoa and barley
- Lean meats and poultry, fish, eggs, tofu, nuts and seeds, and legumes/beans
- Milk, yoghurt, cheese and/or their alternatives, mostly reduced fat (reduced fat milks are not suitable for children under the age of 2 years)
- And drink plenty of water.

Guideline 3

Limit intake of foods containing saturated fat, added salt, added sugars and alcohol.

(a) Limit intake of foods high in saturated fat such as many biscuits, cakes, pastries, pies, processed meats, commercial burgers, pizza, fried foods, potato chips, crisps and other savoury snacks.

- Replace high fat foods which contain predominantly saturated fats such as butter, cream, cooking margarine, coconut and palm oil with foods which contain predominantly polyunsaturated and monounsaturated fats such as oils, spreads, nut butters/pastes and avocado.
- Low fat diets are not suitable for children under the age of 2 years.

(b) Limit intake of foods and drinks containing added salt.

- Read labels to choose lower sodium options among similar foods.
- Do not add salt to foods in cooking or at the table.

(c) Limit intake of foods and drinks containing added sugars such as confectionery, sugar-sweetened soft drinks and cordials, fruit drinks, vitamin waters, energy and sports drinks.

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(d) If you choose to drink alcohol, limit intake. For women who are pregnant, planning a pregnancy or breastfeeding, not drinking alcohol is the safest option.

Guideline 4

Encourage, support and promote breastfeeding.

Guideline 5

Care for your food; prepare and store it safely.

The Australian Guide to Healthy Eating

The Australian Guide to Healthy Eating (AGHE) is a national food selection guide for Australians to complement the Australian Dietary Guidelines, in particular, Guideline 2 which is "Enjoy a wide variety of nutritious foods from these five groups every day." The AGHE is a resource that has been developed to increase **nutritional literacy** of the public so that they can improve their eating habits to maintain their health and reduce their risk of contracting dietary disorders. The AGHE groups similar foods together based on the **nutrients they supply** and presents them on a 'plate' (see Figure 4.2.1). It also provides information about the **various types** of foods within each group and the recommended servings of these foods you should eat daily. The amount of each food group recommended is depicted by the **size of the portions on the 'plate.'** However, the recommended amounts of the food groups differ with gender and stages in the life cycle (see Figure 4.2.2 for some examples). The five food groups of the AGHE are:

1. Vegetables and legumes/beans
2. Fruit
3. Grain (cereal) foods (mostly wholegrain)
4. Lean meats, poultry, fish, eggs, tofu, nuts and seeds, and legumes/beans
5. Milk, yoghurt, cheese and/or alternatives (mostly reduced fat).



Figure 4.2.1: The Australian Guide to Healthy Eating (AGHE).

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SAMPLE DAILY FOOD PATTERNS FOR CHILDREN AND ADOLESCENTS

Recommended average daily number of serves from each of the Five Food Groups*							Additional serves for more active, taller or older children and adolescents
	Age	Vegetables and legumes/ beans	Fruit	Grain (cereal) foods, mostly wholegrain and/or high fibre cereal varieties	Lean meats and poultry, fish, eggs, tofu, nuts and seeds, and legumes/beans	Milk, yoghurt, cheese and/or alternatives, mostly reduced fat	Approx. number of additional serves from the Five Food Groups or unsaturated spreads and oils or discretionary choices
Boys	2-3	2½	1	4	1	1½	0-1
	4-8	4½	1½	4	1½	2	0-2½
	9-11	5	2	5	2½	2½	0-3
	12-13	5½	2	6	2½	3½	0-3
	14-18	5½	2	7	2½	3½	0-5
Girls	2-3	2½	1	4	1	1½	0-1
	4-8	4½	1½	4	1½	1½	0-1
	9-11	5	2	4	2½	3	0-3
	12-13	5	2	5	2½	3½	0-2½
	14-18	5	2	7	2½	3½	0-2½
Pregnant		5	2	8	3½	3½	0-3
Breastfeeding		5½	2	9	2½	4	0-3

* *Includes an allowance for unsaturated spreads or oils and nuts or seeds: ½ serve [4–5g] per day for children 2–3 years of age, 1 serve [7–10g] per day for children 3–12 years of age, 1½ serves [11–15g] per day for children 12–13 years of age, and 2 serves [14–20g] per day for adolescents 14–18 years of age and for pregnant and breastfeeding girls.*

Figure 4.2.2: The recommended servings of the five food groups for children, adolescents, pregnant women and breastfeeding women.

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Vegetables and legumes/beans

Vegetables and legumes/beans are nutrient dense foods that provide high levels of **fibre**, vitamins, minerals and phytonutrients. There is strong evidence that consuming the recommended serves of vegetables can prevent or delay the onset of some dietary disorders, such as cardiovascular disease and diverticular disease (see Figure 4.2.3 for examples of serving sizes). A **variety** of foods from this group should be consumed to provide a range of micronutrients and phytochemicals.

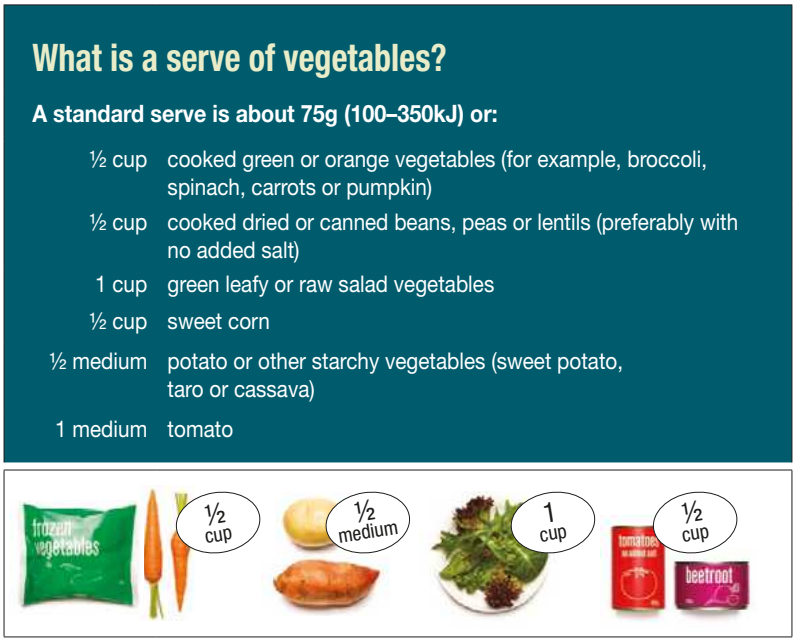


Figure 4.2.3: Examples of a serve of vegetables and legumes/beans.

Fruit

A **variety** of fruits should also be consumed to increase the variety of nutrients consumed, such as vitamins, minerals and phytonutrients. Fruits provide more natural sugars than vegetables and therefore less serves of fruits should be consumed than vegetables (see Figure 4.2.4 for examples of serving sizes). Fruit juice is not a suitable regular alternative to eating the whole fruit because it is high in sugar and **lacks the fibre that the whole fruit provides**. Fruit juice is also less filling than eating whole fruits.

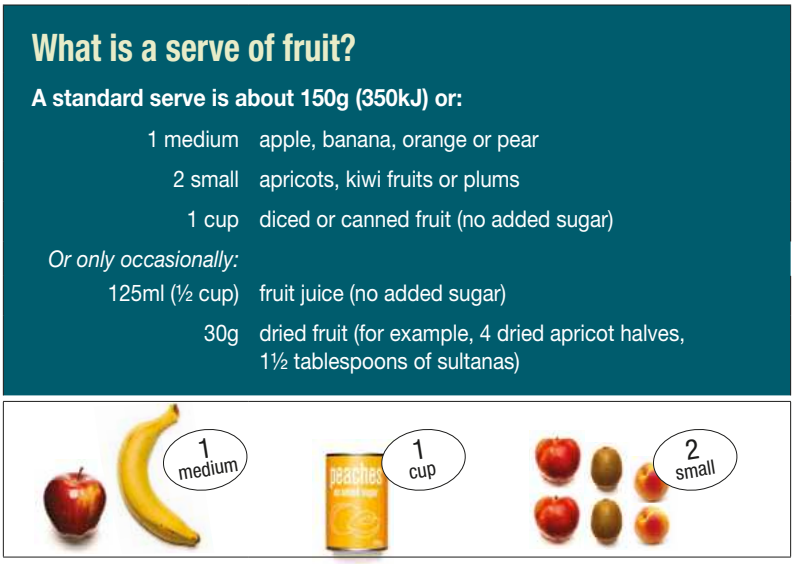
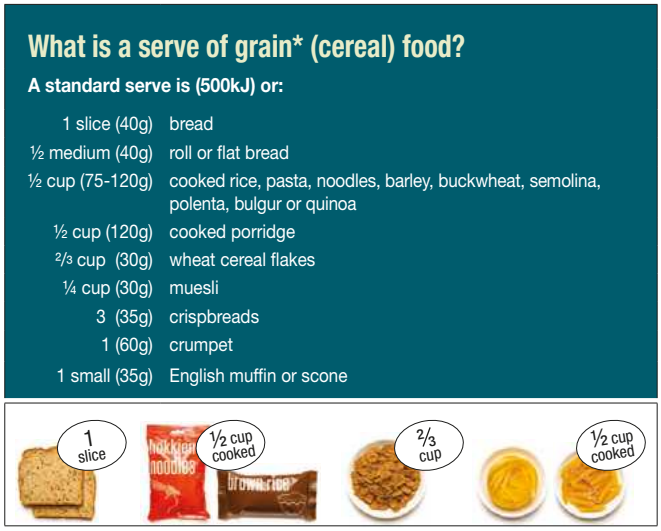


Figure 4.2.4: Examples of a serve of fruit.

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Grain (cereal) foods, mostly wholegrain and/or high cereal fibre varieties

The key message for this food group is that **at least two thirds of the serves of grains should be wholegrain** and not refined grains. Wholegrain foods contain all three layers of the grains, so they include the beneficial fibre, micronutrients and phytonutrients found in the outer layers of grains. Refined foods, such as white flour and the products it is used to make, have had the outer two layers of the grains removed, and with it, the important nutrients mentioned above. Choosing wholegrains over refined grains supplies individuals with more fibre, which reduces the risk of diverticular disease. High fibre counts also slow down digestion, reducing the risk of significant blood sugar spikes and the associated risk of weight gain and type 2 diabetes. Wholegrains also supply us with **complex carbohydrates**, which are important for the supply of energy. Examples of grain food serves can be viewed in Figure 4.2.5.

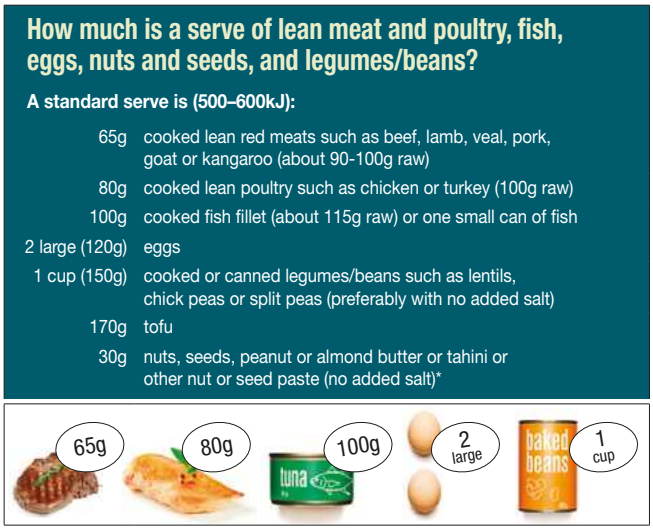


*Grain (cereal) foods, mostly wholegrain and/or high cereal fibre varieties

Figure 4.2.5: Examples of a serve of grain (cereal) foods, mostly wholegrain and/or high cereal fibre varieties.

Lean meat and poultry, fish, eggs, tofu, nuts and seeds and legumes/beans

The lean meats food group supplies **protein, essential fats** and important micronutrients, such as **iron**, zinc and **vitamin B12**. Vitamin B12 is only found in animal products and the iron and zinc in animal products are absorbed more easily than the forms found in plant-based products. Nuts and legumes are also included in this group because they provide many of the nutrients that lean meats supply, which is important for vegans and vegetarians to understand and include in their diet. Some examples of serving sizes for this food group are outlined in Figure 4.2.6.



*Only to be used occasionally as a substitute for other foods in the group

Figure 4.2.6: Examples of a serve of lean meat and poultry, fish, eggs, tofu, nuts and seeds and legumes/beans.

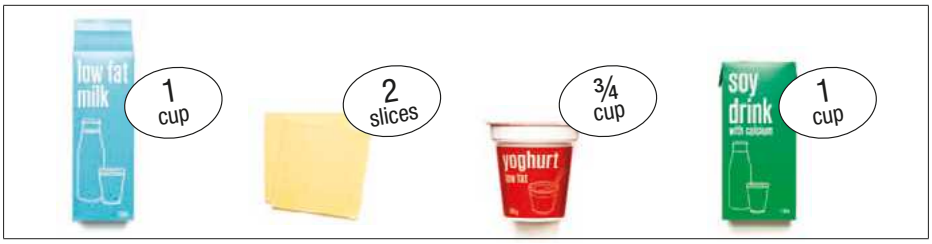
Milk, yoghurt, cheese and/or their alternatives (mostly reduced fat)

Milk and milk products, such as cheese and yoghurt provide consumers with protein and micronutrients. One important micronutrient provided by this food group is **calcium**, which is important for the development and maintenance of strong bones and teeth. Where possible, **reduced fat** milk and milk products should be consumed to reduce saturated fat consumption and energy intake. However, reduced fat milks are not suitable for children under the age of two years. Some individuals may be intolerant to lactose, which is a simple sugar found in milk and many milk products. Lactose intolerant individuals need to make **suitable alternative choices** to ensure they meet their recommended calcium intake. Some examples of milk, milk products and their alternatives are provided in Figure 4.2.7.

How much is a serve of milk*, yoghurt*, cheese* and/or alternatives?

A standard serve is (500–600kJ):

1 cup (250ml)	fresh, UHT long life, reconstituted powdered milk or buttermilk
½ cup (120ml)	evaporated milk
2 slices (40g)	or 4 x 3 x 2cm cube (40g) of hard cheese, such as cheddar
½ cup (120g)	ricotta cheese
¾ cup (200g)	yoghurt
1 cup (250ml)	soy, rice or other cereal drink with at least 100mg of added calcium per 100ml



The following foods contain about the same amount of calcium as a serve of milk, yoghurt or cheese:

100g	almonds with skin
60g	sardines, canned in water
½ cup (100g)	canned pink salmon with bones
100g	firm tofu (check the label as calcium levels vary)

**Choose mostly reduced fat*

Figure 4.2.7: Examples of a serve of milk, yoghurt, cheese and/or their alternatives (mostly reduced fat).

Helpful online resources

Edith Cowan University: Facts about the Australian Guide to Healthy Eating (AGHE)–Refresh.ED

https://www.youtube.com/watch?v=7rgl5q-XnKg

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Foods to limit: Discretionary food and drink choices

There are some foods that cannot be grouped into the Five Food Groups of the Australian Guide to Healthy Eating because they are highly processed and **energy dense**. These foods are not an essential part of the diet and are termed '**discretionary food and drink choices**.' Discretionary foods and drinks are often high in saturated fat, sugar, salt and/or alcohol and the overconsumption of these products can lead to weight gain and dietary disorders, such as obesity, type 2 diabetes, cardiovascular disease and some types of cancer (see Figure 4.2.8 for some examples of discretionary foods and drinks and their serving sizes).

What is a serve of discretionary choices?

A serve of Discretionary choices provides about 500-600 kilojoule:

2 scoops (75g)	ice-cream
2 slices (50-60g)	processed meats, salami or mettwurst
1½ thick or 2 thin (50-70g)	regular sausages
½ snack-size packet (30g)	salty crackers or crisps
2-3 (35g)	sweet plain biscuits
1 (40g)	doughnut
1 slice (40g)	plain cake/small cake-type muffin
5-6 (40g)	sugar confectionary/small lollies
1 tblsp (60g)	jam or honey
½ bar (25g)	chocolate
2 tblsp (40g)	cream
1 tblsp (20g)	butter
1 can (375ml)	soft drink (sugar-sweetened)
¼ pie or pastie (60g)	commercial meat pie or pastie (individual size)
12 (60g)	fried hot chips
200ml	wine (2 standard drinks; but note this is often 1 glass for many Australian wines)
60ml	spirits (2 standard drinks)
600ml	light beer (1½ standard drinks)
400ml	standard beer (1½ standard drinks)



Figure 4.2.8: Examples of a serve of various discretionary food and drink choices.

Helpful online resources

More information on the Australian Dietary Guidelines and the Australian Guide to Healthy Eating can be found at:

https://www.eatforhealth.gov.au/guidelines

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4.2 Review questions

1. Describe the difference between the Australian Dietary Guidelines and the Australian Guide to Healthy Eating.

(2 marks)

2. (a) State Guideline 5 of the Australian Dietary Guidelines.

(1 mark)

(b) Describe why this guideline is important to follow for pregnant women and the immunocompromised.

(2 marks)

3. Refer to the healthy living pyramid below and the Australian Guide to Healthy Eating (AGHE) on page 222 to answer the following questions:



(a) Identify **two** nutritional similarities shared by the Healthy Living Pyramid and The Australian Guide to Healthy Eating (AGHE).

(1)

(1 mark)

(2)

(1 mark)

(b) State **two** ways in which the healthy living pyramid differs from The Australian Guide to Healthy Eating.

(1)

(1 mark)

(2)

(1 mark)

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(c) Identify the food group of the AGHE that has the highest recommended number of serves.

(1 mark)

(d) Identify the drink that is recommended by both the AGHE and healthy living pyramid.

(1 mark)

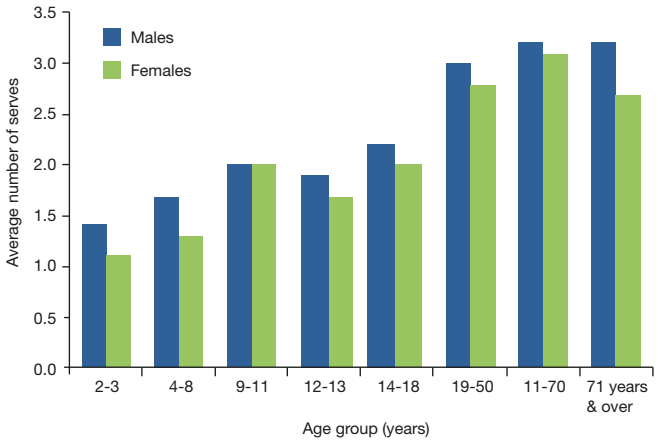
(e) Describe why fruit juice is not a suitable regular replacement for fruit.

(2 marks)

(f) There are some foods and drinks that are not supplied in the healthy food pyramid and AGHE. State the name given to these products and describe why they should not be consumed as part of a regular diet.

(3 marks)

Refer to the following graph, which shows the average serves of vegetables and legumes/beans consumed by Australian males and females aged two and over.



(g) With reference to the graph, state the average number of serves of vegetables and legumes/beans by males and females aged 14 to 18.

(2 marks)

(h) With reference to the graph and Figure 4.2.2, determine how many extra serves of vegetables and legumes/beans the average male and female aged 14 to 18 needs to consume to meet their recommended requirements.

(2 marks)

E Extension question

Evaluate your current diet to identify if there are any food groups that you are not consuming enough serves of. Estimate how many serves of each food group you would average each day over a week and compare these numbers with the recommended servings for your age group in Figure 4.2.2.

4.3 Indigenous Australians: food changes from traditional to contemporary

Nutrition Understanding

Traditional indigenous food

Aboriginal Australians are the traditional owners of the Australian lands and have survived on the food it has provided, often referred to as '**bush tucker**,' for thousands of years. The Aboriginal Australians' diet was varied and balanced because food sources would vary based on the **changing seasons** and their movement patterns.

The Aboriginal Australians were **hunter-gatherers** and consumed a variety of available animal and plant-based sources. They hunted animals such as kangaroo, emu, fish, possum, birds and lizards. Insects (such as grubs), berries, vegetables, a variety of edible roots, wattle seeds and eggs of young birds were also gathered daily.

In the Adelaide region, plant-based foods were important for Aboriginal sustenance year-round. It is reported that a variety of edible roots were a staple of the Aboriginal diet, especially in winter. In contrast, *mirnu* (wattle gum) was a significant source of nutrition for Aboriginals of the Adelaide region during summer. The main source of *mirnu (*edible gum) was golden wattle (*Acacia Pycnantha)* which was roasted in the fire. Animal-based products were favoured however, when available. To ensure availability of animals, Aboriginal Australians used to burn off withered grass every year to ensure the growth of new grasses to attract native animals to their hunting grounds. This would allow the males to hunt *paru* (meat) whilst the women gathered *mai* (vegetable food).



Figure 4.3.1: Gum nodules 'mirnu' form on the trunk of Golden wattle (Acacia pycnantha) and this was a principal part of the Aboriginal Australians' diet. The gum was also used as currency to trade with other Aboriginal groups.

In addition, Aboriginal Australians also consumed **bush bread**. Bush bread was generally made by females within the tribe who would grind local seeds, such as wattle seeds, into a flour. A small amount of water was then added to form dough, which was then heated over coals until cooked and ready to serve to the tribe. Bush bread was high in protein and carbohydrate, contributing to a well-balanced diet.

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Figure 4.3.2: Bush bread is a traditional Aboriginal food that has been made for thousands of years.

Contemporary indigenous food

Aboriginal Australian's diet has changed significantly since Europeans colonised Australia. Traditional foods are still strongly linked to Aboriginal culture, identity and country, and still remain an important component of the contemporary Aboriginal diet. Some examples of contemporary Indigenous foods are:

- Kangaroo and emu salami
- Kangaroo mince
- Green ant cheese
- Bush tomato chutney
- Kakadu plum jam
- Lillypilly jam
- Wattle seed pasta
- Saltbush dukkah.

Risk of type 2 diabetes

There is no evidence that Aboriginal Australians had type 2 diabetes living their traditional lifestyle; however, they are now almost three to four times more likely than non-Indigenous Australians to develop type 2 diabetes

Prior to European settlement, Aboriginal Australians were very healthy, with an active lifestyle and balanced diet. Their diet was nutrient dense and was high in protein, fibre, polyunsaturated fats and complex carbohydrates. Following colonisation however, the nutrient dense diet has generally been replaced by a more energy dense Westernised diet, which is high in sugars, fats and salt.

Aboriginal Australians evolved to survive the scarcity of food but now that many Aboriginals are following a more Westernised diet, they are at higher risk of developing type 2 diabetes. Their efficient metabolism pre-disposes them to developing type 2 diabetes if they live an unhealthy lifestyle.

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CS Possible case study 3

Assess the nutritional needs of an Indigenous 19 year-old female and suggest some meals that incorporate traditional and contemporary Aboriginal foods. As part of your investigation, you should also assess the risk of developing type 2 diabetes and make some dietary and lifestyle suggestions.

Did you know?

Indigenous mulberries are much more nutritious than blueberries because they have not been selectively bred to be mass produced. When fruits are selectively bred, they are generally bred for their size, colour, flavour and number of fruit produced per plant. Nutrition is rarely considered. Studies conducted on indigenous mulberries confirm that they far exceed blueberries for nutrient density, including manganese and selenium. Selective breeding of crops combined with poor farming techniques like monoculture is leading to a decrease in nutrients in our food and is contributing to human deficiencies in certain nutrients.

Ex Possible excursion 2

'Something Wild' at the Adelaide Central Markets is an Indigenous-owned food and beverage company. They specialise in Indigenous foods, such as game meats, native greens, seasonal fruits, herbs and spices. Students can visit Something Wild to introduce them to Indigenous foods and culture. This excursion could be performed as part of the Design Practical (see Science Inquiry Skills 6) where students can ask staff questions about their products or to experience a native grazing plate, including tasting green ants. Contact: alice@somethingwild.com.au for more information.

4.3 Review questions

1. Describe the term 'bush tucker'.

(1 mark)

2. Describe **two** reasons why traditional Aboriginal Australians' diets varied.

(2 marks)

3. Suggest why Aboriginal tribes traditionally placed more value on the men's food supply than women's food supply.

(2 marks)

4. Suggest why Aboriginal women generally supplied more food to their tribes than the men.

(2 marks)

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5. Refer to the following diagram and the Australian Guide to Healthy Eating (AGHE) on page 222 to answer the following questions:



(a) Identify **two** nutritional similarities shared by the Aboriginal and Torres Strait Islander Guide to Healthy Eating and The Australian Guide to Healthy Eating (AGHE).

(1)

(1 mark)

(2)

(1 mark)

(b) State **two** ways in which the Aboriginal and Torres Strait Islander Guide to Healthy Eating differs from The Australian Guide to Healthy Eating.

(1)

(1 mark)

(2)

(1 mark)

E Extension Question

Research the nutritional differences between the Kakadu plum and conventional red plums. Which option is more nutrient dense and why?

4.4 Nutrition in the life cycle

Nutrition Understanding

Everyone requires the same **essential nutrients** to maintain vital bodily processes and health but the amount of specific nutrients required differ as we progress through life from an infant to an elderly person. For example, children require a greater intake of carbohydrates to supply the increased energy requirements, relative to their body size, to facilitate their cognitive development and physical growth. In comparison, the elderly require less energy than children, relative to their body size, because they are generally less active and have likely lost muscle mass.

The human diet can also be influenced by social, emotional and psychological issues throughout life. Children can be influenced by advertising; adolescents can be influenced by social media and peer pressure; and adults' choices can be influenced by many life changing events, such as moving out of home or having children. There are many external pressures that can influence nutritional choices. The nutritional choices individuals make throughout their lives influence their health and wellbeing, now and in the future.

Infancy (0 to 1 year)

Infancy is the period of growth from birth to the end of the first year of life. This stage of life is the **fastest growing period** of the life cycle and many physiological changes occur. During this period an infants' weight generally triples and their height increases by approximately 50%. Paediatricians and parents can use **growth charts to track an infant's growth** to ensure that their infant is tracking normally, and if not, this could be a warning of malnourishment or another medical problem. If there is insufficient growth, an infant could have a condition called **failure to thrive**. During infancy, the brain is developing rapidly and by the end of 12 months, infants have generally developed the ability to hold their head up, voice themselves and walk. This rapid growth and development requires adequate nutrition throughout the first year of life.

The World Health Organisation (WHO) recommends exclusive breastfeeding for the first six months of a baby's life because it supplies the baby with all the nutrients it requires. Breastfeeding has the added benefit of providing the infant with **antibodies** protecting them from pathogens that the mother has been exposed to. Not all mothers are able to breastfeed for six months or choose not to. In this case, baby formula should be used to feed the baby. The formula must be made up accurately to ensure the baby is supplied with the correct ratio of powder to water so the baby can remain **hydrated** and to prevent organ complications. For example, incorrectly prepared formula that is too concentrated can provide excess protein, which can increase the strain on the baby's kidneys. The **formula should also be made with sterilised water and bottles to prevent contamination** and the baby from getting sick. If possible, a formula with added **omega-3 fatty acid (DHA)** is optimal because it is important for brain development. Breastmilk naturally supplies omega-3 fatty acids.

Infants should be introduced to **solid foods** between four and six months. The timing depends on the development of the baby, such as its ability to hold its own head up, and should be timed in accordance with the advice from the infant's general practitioner (GP) or paediatrician. Infants receive an approximate four months' supply of iron from their mother in the third trimester of pregnancy and the introduction of **solid foods helps supply infants with iron** ongoing. Solid foods should be introduced individually to identify any possible allergies or intolerances an infant may have. Infants should not be fed solids before the age of four months because infants have not yet developed the ability to digest foods properly and this can cause complications such as undernutrition, choking and sometimes death. The early introduction of solids has also been linked to a greater risk of developing allergies and dietary disorders, such as obesity, diabetes and cardiovascular disease in the future.



Figure 4.4.1: Infancy is the fastest growing period and requires adequate nutrition for physical and mental development.

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Childhood (1 to 12 years)

The growth and motor development during childhood slows down in comparison to the significant growth period of infancy. However, children **experience significant cognitive and socioemotional changes** during this period. It is important for children to have positive interactions with their parents and others, such as reading aloud, singing, dancing and playtime to help with their development. In fact, research has shown that a lack of positive interaction during childhood can lead to a gap in language as early as 18 months. These positive interactions progressively change as children get older and move through their pre-school years into junior school. As children age, their brain develops and there are a number of 'sensitive periods' for the development of various social and emotional skills (see Figure 4.4.2). A lack of stimulation during these 'sensitive periods' can inhibit the maximum development of these skills. Children also learn to crawl, stand, walk, run and develop coordinated use of their limbs during this period. Energy needs are therefore very high, and they continue to increase with age due to increased activity, growth and repair of body tissue. This continued growth and development also requires increased amounts of protein, vitamins and minerals. Ideally children should be accumulating stores of nutrients in preparation for the rapid growth spurt in adolescence.

Healthy food and nutrition play an important role in the development of intellectual, social and emotional skills. During childhood, the diet progressively shifts from breastfeeding or formula feeding to a diet of solid foods and water. Children should be exposed to a wide variety of foods, including fruits, vegetables, grains, meats and fish. **Healthy eating habits should be established during childhood** and products with added salt and excess sugar should be avoided. Children generally take their eating and nutritional cues from their parents. Parents should therefore be good role models and display healthy eating habits in front of their children, who often mimic their parents' behaviours. Poor eating habits developed during childhood can lead to weight gain and these habits can follow through to adolescence and adulthood and lead to obesity. Children's food and lifestyle choices can also be influenced by their peers and the environment they are exposed to. The World Health Organisation (WHO) recommends that children younger than two should not be exposed to sedentary electronic screen time and children between the ages of two and four should not have more than one hour per day. **Excessive exposure to electronic devices early in life** has been linked to delayed language development and can lead to unhealthy lifestyle choices. In addition, screen time can expose children to unhealthy food advertising, which can impact their food choices.

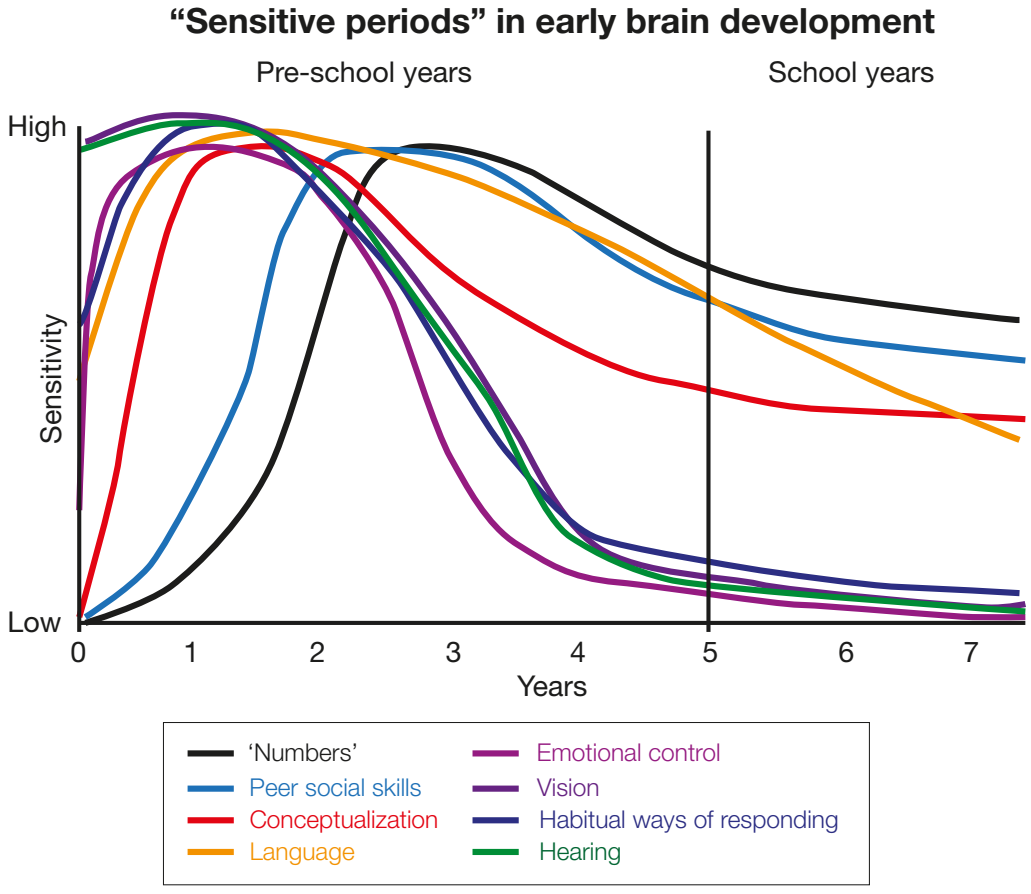


Figure 4.4.2: It is important for children to be stimulated during childhood to support their brain development, especially through the sensitive periods.

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Adolescence (13 to 17 years)

Puberty occurs during adolescence, which is a period of growth and development of a child into a sexually mature adult. Puberty is a period of rapid growth, second only to infancy, which requires increased energy and nutrients. During this **growth spurt**, muscles grow, and bones increase in length to their final adult size, resulting in an increased height (see Figure 4.4.3). This requires extra protein, iron and calcium. Extra protein is also required for the increased blood volume and the continued development of the primary sex organs. Females start menstruating during puberty and both males and females develop their secondary sexual characteristics. These characteristics include the development of breasts, the widening of hips, the storage of essential fat, and pubic hair growth in girls; and the production of sperm, deepening of the voice, and growth of facial, pubic and body hair in boys.

Adolescents have **greater control over their accessibility to food** and therefore, their food choices. During adolescence, teenagers may start their first job and start to earn their own money, allowing them to purchase their own food. This lifestyle change can also result in eating away from home more often. Food choices during this growth period are important to ensure enough essential nutrients are being consumed. **A lack of nutritional literacy and cooking skills** can be problematic and lead to poor food choices. For example, a lack of calcium and protein during this growth spurt can contribute to an individual not reaching their potential maximum height and peak bone mass. Many adolescents dislike the flavour of salads and boiled/steamed vegetables and may have parents that lack the nutritional and cooking knowledge to hide vegetables in meals. This can lead to a reduced intake of essential vitamins, minerals and fibre during this period. Adolescent food choices can be influenced by a range of additional factors including peer pressure, advertising, social media and body image.

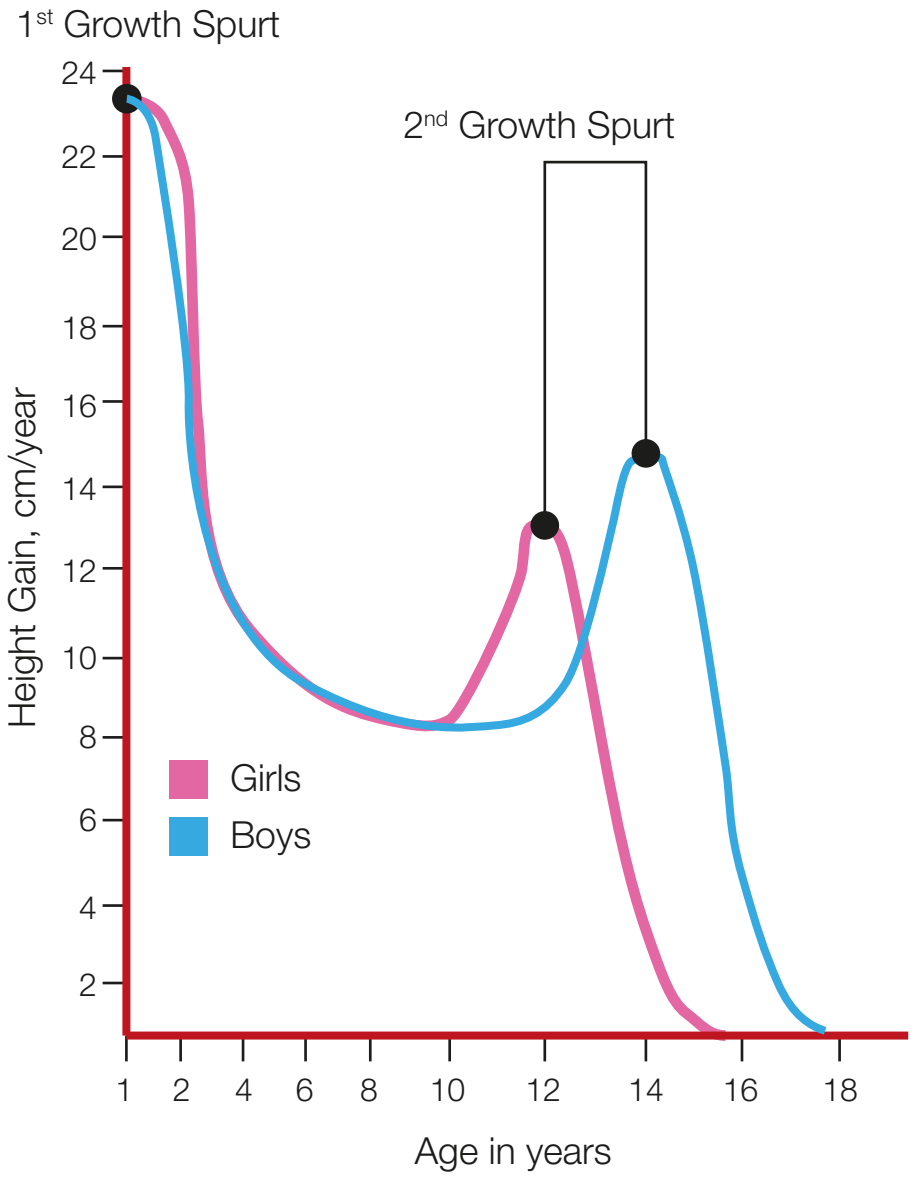


Figure 4.4.3: Adolescents experience a second growth spurt but females generally experience it earlier than males.

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Adulthood (18 to 65 years)

During adulthood, **growth is complete** and body systems have fully matured. This stage of life is when individuals reach their physical peak, including their maximum cardiac output and peak bone mass. However, in the **late thirties and early forties adults' physical functioning declines**. This is when individuals can notice changes, such as wounds taking longer to heal, visual decline, a reduction in endurance and aching joints. Physical signs of aging also start to appear, such as the development of wrinkles and hair starting to grey. Many women also experience pregnancy, childbirth, and lactation during adulthood. In later adulthood, women also experience menopause.

Adults experience many life changing events, such as moving out of home, starting a career, getting married and having children. These events can be very **stressful** at times and this can influence diet and lifestyle choices. People react differently to stress but many people find some comfort in eating energy dense discretionary foods. These foods can often be high in saturated fat, salt, sugar and/or alcohol. Chronic stress and the consumption of energy dense foods can contribute to weight gain during adulthood. In addition, the physical activity levels of many adults decrease, further contributing to weight gain. **Many adults are time poor** and find it hard to balance their competing interests, such as family, work and social commitments. This can make it hard to fit in an exercise routine as well. However, physical activity and good nutritional choices are important during this stage of life cycle to maintain good health and fitness, and to prevent the development of chronic dietary disorders. It is not too late to start implementing healthy lifestyle choices during adulthood. Doing so may still reduce the risk of developing chronic dietary disorders.



Figure 4.4.4: It can hard balancing work, family and home life during adulthood. The reduced available time combined with internal and external stressors can contribute to poor nutrition choices.

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Pregnancy and lactation

Author's Note: The nutritional requirements during pregnancy and lactation are comprehensively covered in Topic 6: Nutrition and food safety during pregnancy and lactation. The information presented below is a snapshot of the nutritional requirements during pregnancy and lactation. Please review Topic 6 for more information.

From conception, the foetus uses nutrients consumed by the mother and is fully dependent on her. The mother's body naturally prioritises the foetus and provides it with the nutrients it requires at the expense of her own health. This means that the mother needs to consume extra nutrients and any malnutrition in the mother's diet will also cause the same malnutrition in the growing foetus. During pregnancy, the woman's body experiences some drastic changes that require extra nutrients including:

- The mother's blood volume increases 1½ times its normal volume to carry the extra nutrients to the foetus and extra tissues
- The placenta forms
- The uterus and supporting muscles increase in size
- The breasts enlarge in preparation for lactation.

All of these changes **require extra energy**; however, there is a misconception that pregnant women can 'eat for two.' This is not true and it can result in excessive weight gain. In fact, in the first trimester, there is no additional energy intake required. Energy requirements do pick up after the first semester, with an extra 1,400kJ required in the second trimester, an extra 1,900kJ required in the third trimester, and an extra 2,000kJ required during lactation. Carbohydrates are the primary energy source and it is recommended that the increased energy is provided by **increasing grain servings**. The servings of **lean meats, fish, and alternatives also increase** to provide extra protein, essential fats and micronutrients, such as iron, iodine and vitamin B12. The extra protein is required for the growth of the baby and the biological changes in the mother's body, such as the development of the placenta. **Essential fatty acids**, such as DHA, are vitally important for the **brain and retina**, which is important in the development of cognitive and visual function. There are many increased micronutrients required during pregnancy and lactation but consuming the recommended intake of folate is very important. **Folate** is important in the early stages of pregnancy to prevent **neural tube birth defects**, such as spina bifida. There is also growing research that a lack of folic acid during early pregnancy can also lead to congenital birth defects such as **cleft lip** and **cleft palate.** In general, pregnant and lactating women need to eat some additional serves of certain food groups but overall, they require more **nutrient dense** foods.

During pregnancy, **extra water is needed** to provide a sufficient amount to the developing foetus, for the **increased blood supply** and to provide the fluid for the growing **amniotic sac.** The amniotic sac is a fluid filled sac that has many functions, including protecting the foetus in the womb by cushioning it from impacts and keeping the foetus warm. The fluid in the amniotic sac is constantly being replaced, which requires additional water intake daily. Additional water is also needed to make **breast milk** during lactation. Water accounts for approximately 87% of breast milk, which is provided to the infant during breastfeeding. In the first six months after birth, mothers produce 0.8L of breast milk per day on average.

The World Health Organisation (WHO) recommends exclusive breastfeeding for the first six months of a baby's life. The WHO recommends breastfeeding over formula feeding because it is clean and safe, **provides all the nutritional requirements** infants need, and **contains antibodies** to boost the immune system and defend against infectious diseases. When a baby is born, its immune system is not fully developed, and it cannot fully defend itself. The infant acquires its protection against disease from the antibodies in breastmilk, which confer resistance to pathogens the mothers have previously been exposed to.

It is important to note that **smoking and alcohol** are strongly advised against during pregnancy and lactation. Smoking can increase the risk of respiratory distress, low birth weight and failure to thrive in infants, while alcohol can increase the risk of premature birth, stillbirth, miscarriage, birth defects and foetal alcohol spectrum disorder (FASD).

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Menopause

Menopause is the stage of a woman's life where her final period occurs, and the woman no longer ovulates. This stage of life signifies the end of a woman's fertility and in most cases occurs between the ages of 45 and 55. The cessation of ovulation also results in a **significant reduction in the production of the hormones oestrogen and progesterone** (see Figure 4.4.5). This significant change in hormone levels results in physiological changes and some consequences for women's health including more fat being stored in the abdominal area.

Oestrogen plays an essential role in building and maintaining bone density in females. The significant drop in oestrogen levels during menopause results in **accelerated bone loss**. This can result in approximately 10% loss of bone mass in the first five years after menopause and increase the risk of breaking bones and developing **osteoporosis** (see Figure 2.8.4). Oestrogen also increases the 'good' high density lipoprotein (HDL) cholesterol providing a 'protective' effect against cardiovascular disease (CVD). HDL cholesterol lowers the 'bad' low density lipoprotein (LDL) cholesterol by transporting excess cholesterol from the cells and blood back to the liver for processing. This reduces the risk of cholesterols building up against the artery walls and atherosclerosis and the diseases associated with it developing (refer to Topic 2: Dietary disorders for more information). As there is a significant decrease in oestrogen levels during menopause, **LDL levels increase in post-menopausal women and so does their risk of CVD**.

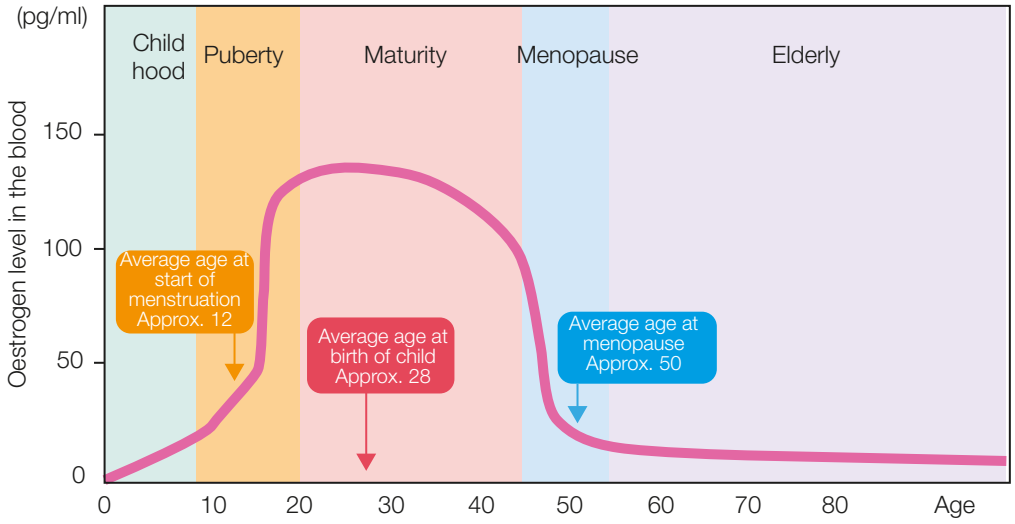


Figure 4.4.5: The average blood oestrogen levels of a woman through the life cycle.

Elderly years (65 years and over)

The **highest risk of malnutrition** occurs during the elderly years of the life cycle. After hitting peak fitness during early adulthood, muscle mass and bone density generally start to decrease. This can lead to serious complications later in life where the accumulated loss of muscle and bone density can reduce the mobility of the elderly. The elderly are also **more likely to fall** due to weakened muscles, and have an increased risk of **bone fractures** if they do fall, as their bone density is decreased. In addition, the decrease in muscle results in a reduction in the elderly's basal metabolic rate and therefore appetite. This can make it hard for the elderly to maintain a balanced diet because they may not eat enough food to provide sufficient nutrients. For example, the weakening of muscles surrounding the jaw can make it more **difficult for the elderly to chew**. The elderly can start to avoid consuming foods that are difficult to chew as a result, including meats and fibrous vegetables. This can result in decreased protein, iron and fibre intakes. A deficiency in protein can affect many bodily functions including the ability to heal wounds and the immune system defending the body against invading pathogens. A lack of fibre can increase the risk of constipation and diverticular disease in the elderly. However, the decreased physical activity and basal metabolic rate can result in weight gain in some elderly individuals who continue to eat more food than required. This can put increased pressure on joints and increase the risk of developing overnutrition disorders such as cardiovascular disease and type 2 diabetes.

The elderly often face some serious health challenges including overnutrition disorders, cancer and **dementia**. Dementia is a collective term used to describe the decline in functioning of the brain including the symptoms such as forgetfulness, impaired thinking and communication, and delusions. The elderly with dementia can suffer from memory issues associated with shopping, preparing and cooking food. They may even forget to eat altogether. Some elderly with dementia are good at hiding their memory loss. In circumstances like this, the elderly may require extra care and assistance from family, nurses and in some cases, nursing homes.

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During this stage of the life cycle, it is more common for individuals to **lose their life partners**. Losing a loved one is very hard, and individuals can become depressed as a result. This can reduce the motivation to cook and can take time to adjust to cooking for one person. In some cases, there can also be a loss of nutritional and cooking knowledge with the loss of a partner. Both of these situations can lead to poor nutritional choices and diets for the remaining partner.

It is important for the elderly to remain active to maintain their basal metabolic rate and bone density, and to continue to eat a healthy nutrient dense diet. It is a good idea for the elderly to participate in **physical activities that can increase their balance** such as tai chi, yoga and Pilates. However, the physical activity and nutritional choices made earlier in life can contribute to the health outcomes of individuals later in life.



Figure 4.4.6: Keeping fit and making good nutrition choices earlier in life can delay dietary disorders that normally affect the elderly.

CS Possible case study 4

An 11 year-old adolescent girl named Ella is starting puberty. Ella is very health conscious and wants to ensure that her diet meets her nutritional needs during this growth period. She is very proactive and decided to seek advice from a dietician. As her dietician, evaluate her nutritional needs as an adolescent girl and make some diet and lifestyle recommendations.

4.4 Review questions

1. (a) Name the life cycle stage with the fastest growing period.

(1 mark)

(b) Name the life cycle stage with the second fastest growing period.

(1 mark)

2. Describe why the elderly require less energy than children, relative to their body size.

(2 marks)

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3. Explain why infants should be introduced to solids between four and six months of age.

(2 marks)

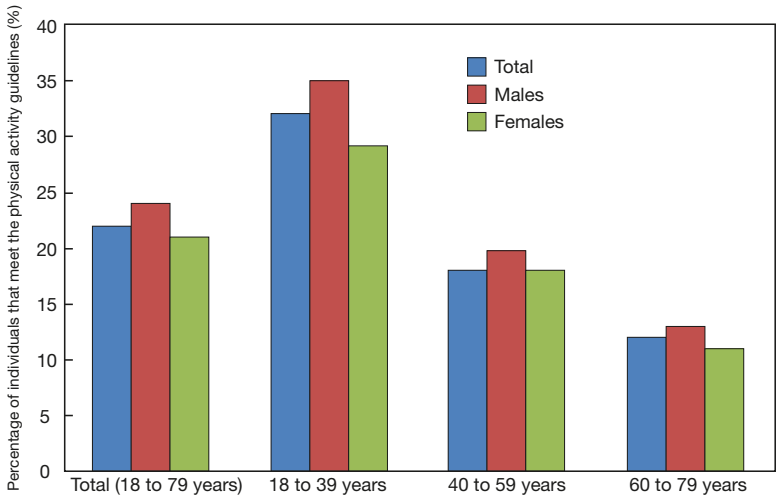
4. (a) Explain why an adolescents' protein requirements increase.

(2 marks)

(b) Describe **two** factors that can negatively affect adolescents' food choices.

(2 marks)

5. Refer to the following graph which shows the proportion of adults and elderly individuals aged 18 to 79 that meet the physical activity guidelines by age group and gender:



(a) Describe the general pattern of individuals meeting the exercise guidelines from 18 to 79 years old.

(1 mark)

(b) Using data, identify whether more males or females meet the recommended exercise guidelines.

(2 marks)

(c) The exercise guidelines advise to complete 150 minutes of moderate to vigorous activity per week.

(i) Describe **two** logical reasons why adults may not be able to achieve this amount of exercise.

(2 marks)

(ii) Describe **two** logical reasons why the elderly may not be able to achieve this amount of exercise.

(2 marks)

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6. (a) Name the stage of a woman's life that signifies the end of her fertility.

(1 mark)

(b) Describe how menopause can result in accelerated bone loss.

(2 marks)

(c) Explain how menopause can increase the risk of females developing cardiovascular disease.

(3 marks)

7. (a) Water requirements increase during pregnancy and lactation. State three reasons why water requirements increase.

(3 marks)

(b) Describe **two** benefits of breastfeeding for the baby.

(2 marks)

(c) Describe **two** benefits of breastfeeding for the mother.

(3 marks)

E Extension question

Research **and** discuss the effects of teaching children and adolescents both cooking skills and nutritional knowledge, and form an opinion as to whether both subjects should be taught to all students through primary and middle school.

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4.5 Health promotion for specific community groups

Nutrition Understanding

There are many different types of health promotions that target specific community groups. Many of these are funded by governments. By promoting healthy diet and lifestyle, the education of specific groups in the community is increased. If the health promotions are implemented, the likeliness of developing dietary disorders can be reduced and individuals' quality of life improved. This is advantageous for governments who fund health promotions because by reducing cases of dietary disorders, the strain on the health system is also decreased. Some examples of health promotions are:

- Go for 2&5®
- Measure Up
- Rite Bite.

Go for 2&5

The Go for 2&5 campaign was launched in 2005 and its aim was to promote awareness of eating two fruits and five vegetables every day. Approximately 95% of Australians do not consume the recommended daily vegetable servings, which provide us with valuable fibre and micronutrients. Those that do consume the recommended servings have less chance of developing dietary related disorders.

This health promotion was aimed at children over five years of age and parents to set good behaviour patterns and ensure that their children also consumed the recommended servings. The health promotion also gives suggestions to demonstrate how people can add more vegetables to their diet such as adding vegetables to their favourite meals (see Figure 4.5.1).

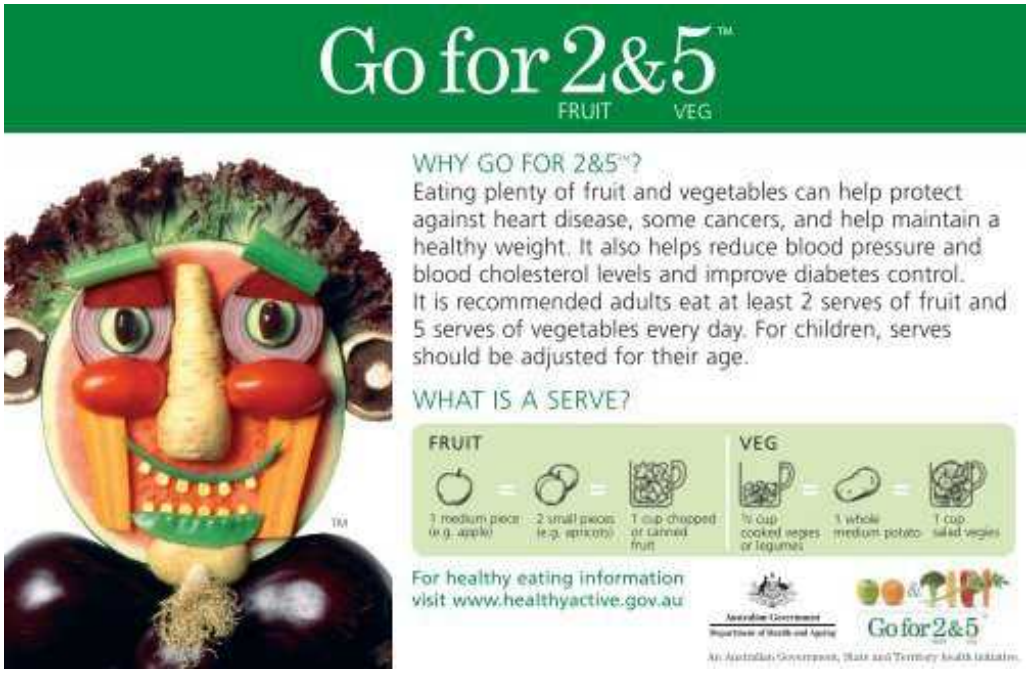


Figure 4.5.1: The Go for 2&5 health promotion is defined by the man made from vegetables.

Measure Up

Measure Up is a health promotion campaign that is specific for adults, especially those who already have a large waist circumference. A large waist circumference is linked to increased risk of developing diet and lifestyle disorders. As males store more of their fat around their abdomen, this campaign aimed to increase the awareness of males more than females (who have less risk as they store more essential fat than males). This health promotion encourages adults to measure their waist circumference and prevent it from increasing by exercising more and choosing healthier food options.

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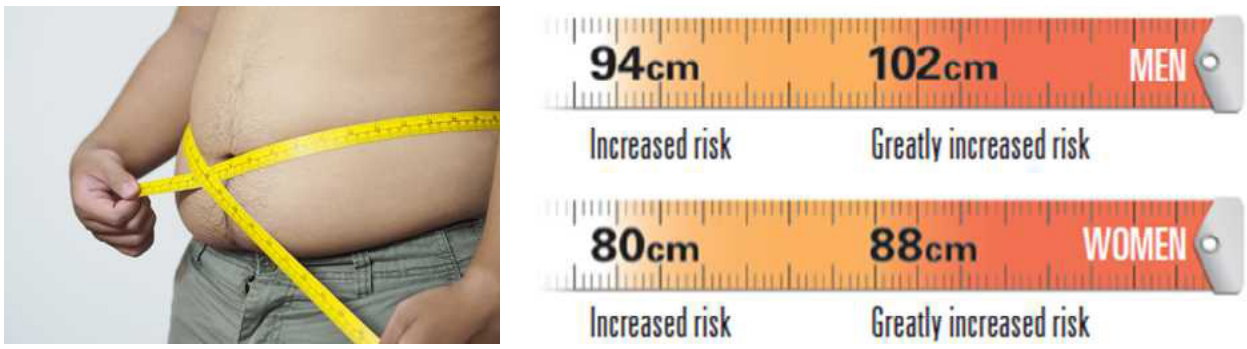


Figure 4.5.2:The Measure Up campaign promotes awareness of waist circumference and associated risk of developing diet related disorders. Males and females are at a greater risk of dietary disorders if their waist measurements are in the ranges highlighted in the respective tape measures.

Rite Bite (Traffic Light)

The Rite Bite health promotion is also known as the 'traffic lights' system and is a South Australian initiative in government schools and preschools. Rite Bite promotes healthy eating to children in an easy to understand visual 'traffic light' system. Foods in the GREEN group cover all the food groups of the AGHE and should cover the majority of the diet. Foods in the AMBER group have some added fat, sugar and salt and children are encouraged to reduce the quantity of foods in this group. The RED category is known as the 'occasional' category and these energy dense foods are unhealthy. Foods in this category are banned from being sold at government school and preschool canteens; however, they are allowed to sell them twice a term for special occasions. This is an important health promotion for children as unhealthy habits developed in childhood can follow through to adulthood and increase risk of developing diet related disorders.



Figure 4.5.3: Some examples of foods for the three 'traffic lights' of the right bite health promotion.

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4.5 Review questions

1. Discuss **one** reason why the Australian Government has invested numerous resources in healthy eating campaigns such as Measure Up and Go for 2&5 ®.

(2 marks)

2. The Measure Up campaign is 'for all Australians and aims to provide them with the tools and understanding to make healthy lifestyle choices' (www.measureup.gov.au).

   Two particular groups are targeted by the campaign: adults 25 to 50 years old who have children, and adults 45 to 60 years old. Suggest why each of these two groups of people is targeted by the campaign.

   (a) Adults 25 to 50 years old with children.

(2 marks)

   (b) Adults 45 to 60 years old.

(2 marks)

3. Most school canteens use the Right Bite policy to classify food and drink according to its nutritional value. Many fruit juices are considered red-category drinks.

Right Bite food and drink spectrum

RED	These foods and drinks are banned from sale in SA school canteens and preschools … They: • lack adequate nutritional value • are high in saturated fat and/or sugar and/or salt • can contribute to excess energy (kilojoules or calories)

Source: Adapted from DECD 2015, 'Right Bite food and drink spectrum', *Right Bite, easy guide to healthy food and drink supply for South Australian schools and preschools*, Department for Education and Child Development, viewed 23 April 2018, education.sa.gov.au

   (a) (i) Identify **one** diet-related disorder associated with high energy intake for children.

(1 mark)

   (ii) Explain how overconsumption of fruit juices may increase the risk of this disorder.

(2 marks)

   (b) Discuss the importance of healthy eating initiatives, like Right Bite, for children aged 5–12 years.

(2 marks)

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Topic 4 Review Test

1. The Go for 2&5® campaign is a nutritional educational aid that encourages people to eat two servings of fruit and five servings of vegetables every day (www.gofor2and5.com.au).

   (a) You have been asked to conduct an investigation to assess the impact of the Go for 2&5® campaign in helping people to improve their diet, lifestyle, and health.

   Write a suitable question of inquiry for the investigation.

   (2 marks)

   (b) Outline **three** procedural steps that could be undertaken to explore the question identified in (a) for the investigation.

   (1)

   (2)

   (3) *(3 marks)*

   (c) State **two** factors that need to be held constant to ensure the reliability of the data collected during the investigation.

   (1)

   (2) *(2 marks)*

   (d) State **one** possible error (either random or systematic) that could occur during the investigation.

   (1 mark)

   (e) People from three different age groups were interviewed in a survey to determine their level of understanding about the Go for 2&5® campaign. The results of this survey are shown in the following table:

	Level of Understanding	
Age Group (years)	*Poor*	*Good*
11–20	2	15
21–30	6	7
31–40	5	2

   (i) On the grid below, construct a graph to represent the data in the table above.

   (5 marks)

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(ii) Using data, write a conclusion about the level of understanding of the age groups surveyed.

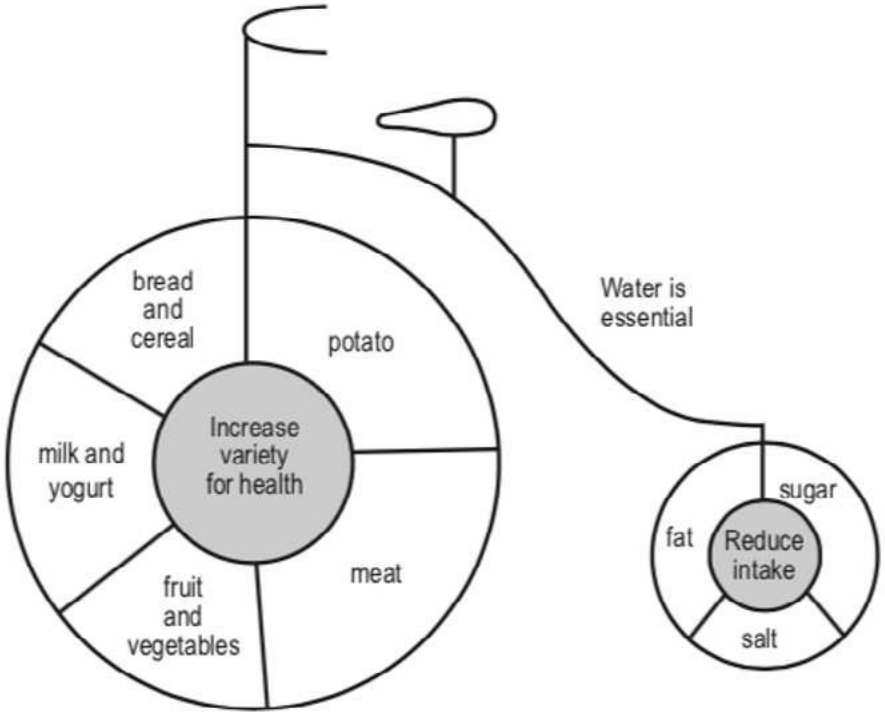
(2 marks)

(iii) Using data, suggest **one** improvement (other than increasing the number of people surveyed) that would increase the reliability of the data from this survey, if it were to be repeated.

(2 marks)

Please refer to the Australian Guide to Healthy Eating (AGHE) on page 222 to help answer questions 2 and 3.

2. Refer to the following diagram, which shows the Food Wheels System selection guide:



Source: Adapted from D. Carey, G. Perraton, & K. Weston, *People, Food & Growth*, Units 3 & 4, Rigby Heinemann, Port Melbourne (Vic.), 1994, p. 58

(a) Compare the food selection guide above with the Australian Guide to Healthy Eating.

State **two** similarities between the guides.

(i)

(ii)

(2 marks)

(b) State **two** reasons why the Food Wheels System would ***not*** be recommended by Australian nutritionists and explain your answers.

(i) Reason:

Explanation:

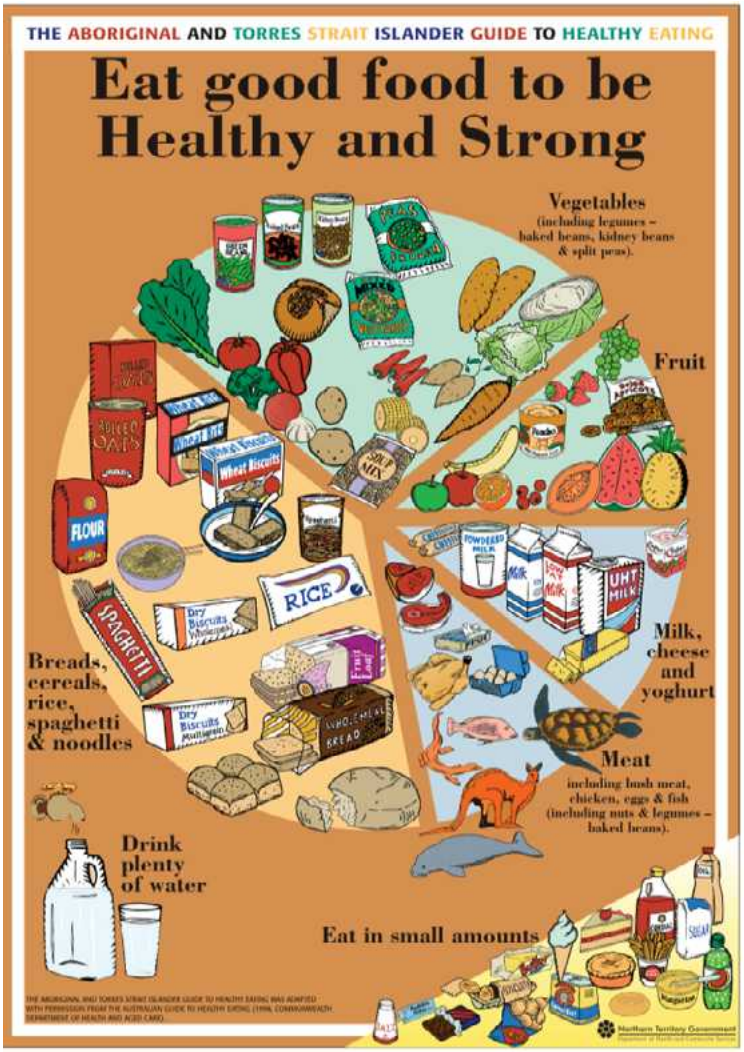
(2 marks)

(ii) Reason:

Explanation:

(2 marks)

3. Refer to the following food selection guide, which remote Aboriginal and Torres Strait Islander communities could use to improve their diet, lifestyle, and health:



Source: Northern Territory Government Department of Health and Community Services website, http://digitallibrary.health.nt.gov.au

(a) Identify **two nutritional similarities** between the Aboriginal and Torres Strait Islander Guide to Healthy Eating shown above and the Australian Guide to Healthy Eating.

(1)

(2)

(2 marks)

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(b) Describe **two** ways in which the foods in the Aboriginal and Torres Strait Islander Guide to Healthy Eating **differ** from those in the Australian Guide to Healthy Eating.

(1)

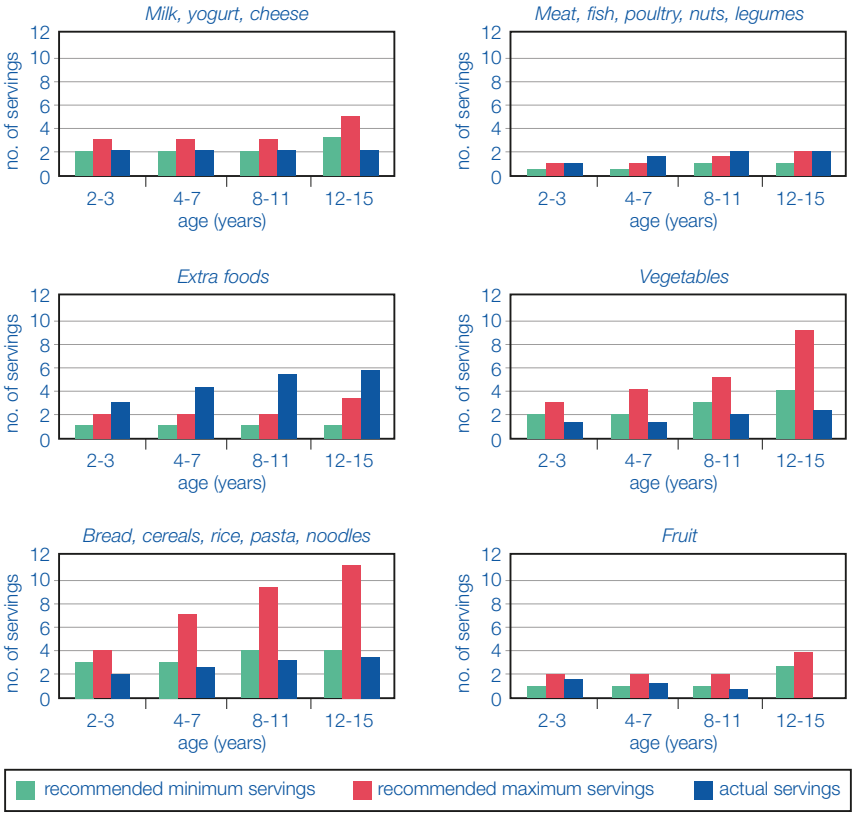
(2)

(2 marks)

(c) Describe how the changing seasons could impact traditional Aboriginal Australians food sources.

(2 marks)

4. Refer to the following six graphs of food groups, which show the actual food intake of the children who were surveyed, by age group, compared with the recommended number of servings per day:



(a) From the graphs above, identify **two** areas of concern for the food intake of the 4–7 age group and explain why each area is of concern.

(i) Area of concern:

Explanation:

(2 marks)

(ii) Area of concern:

Explanation:

(2 marks)

(b) Choose **one** of the food groups shown on the graphs. With reference to **one** nutrient provided by this group, explain the importance of including these foods in the diet of a 12–15 year old.

Food group:

Nutrient:

Explanation:

(3 marks)

(c) Explain how the targeted advertising to children of foods likely to be categorised by the group 'Extra foods' in the graph, can increase their chance of obesity.

(3 marks)

5. The recommended daily intake (RDI) of vegetables and legumes/beans for 2–3 year-old children is 2.5 serves per day.

(a) Data from the Australian Health Survey in 2011–12 showed that less than 1% of children aged 2–3 years are consuming the RDI of vegetables and legumes/beans (ABS 2016).

(i) Identify **one** media campaign and explain how it helps families ensure that children consume their RDI of vegetables and legumes/beans.

(2 marks)

(ii) Explain how social interaction can influence the nutritional health and wellbeing of children aged 2–3 years old. Provide an example to support your answer.

(2 marks)

(b) The second guideline from the *Australian Dietary Guidelines* recommends that Australians consume 'a wide variety of nutritious foods from [the] five food groups every day'.

(i) Explain the importance of this dietary guideline.

(2 marks)

(ii) State **one** other guideline from the *Australian Dietary Guidelines*.

(1 mark)

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6. A study found that pregnant women who follow a vegan diet may not have an adequate intake of folic acid (folate).

   (a) State **one** risk to a pregnant woman and *one* risk to a developing foetus if the pregnant woman is deficient in folic acid.

   Risk to woman:

   Risk to foetus:

   (2 marks)

   (b) Suggest **one** suitable food that would provide a pregnant vegan woman with folic acid.

   (1 mark)

   (c) Breast-fed infants who are over the age of 6 months and whose mothers are vegan are at risk of developing other micronutrient deficiencies.

   (i) Name **one** micronutrient in which the infant could be deficient.

   (1 mark)

   (ii) Name **one** food that the mother could consume to reduce the infant's risk of developing a deficiency in the micronutrient that you named in part (c)(i).

   (1 mark)

7. Eleanor is a 75 year-old, recently widowed woman who has a limited income. She lives alone and does not have any family nearby. Eleanor is slightly underweight and has severe osteoporosis, which limits her mobility.

   Identify **three** barriers to Eleanor meeting her nutritional needs **and** describe a strategy that will assist her to overcome each of these barriers.

   (a) (i) Barrier:

   (1 mark)

   (ii) Strategy:

   (1 mark)

   (b) (i) Barrier:

   (1 mark)

   (ii) Strategy:

   (1 mark)

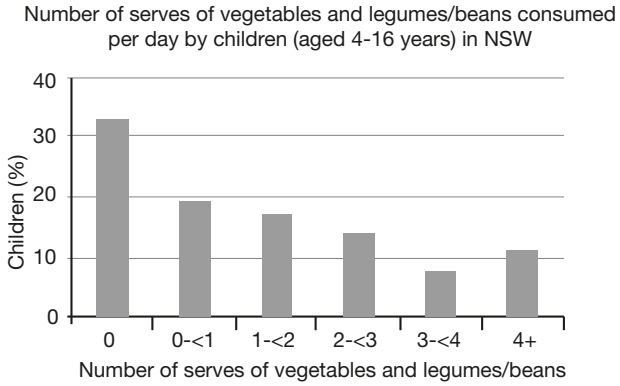
   (c) (i) Barrier:

   (1 mark)

   (ii) Strategy:

   (1 mark)

8. Refer to the following graph and table:



Australian Dietary Guidelines recommended number of serves per day

	Age (years)	*Vegetables and legumes/beans (serves per day)*
Boys	4-18	4½-5½
Girls	4-18	4½-5

(a) Using data from the graph and table above, comment on the number of serves of vegetables and legumes/beans consumed by children in NSW compared with the number of serves recommended by the *Australian Dietary Guidelines* (NHMRC 2013).

(2 marks)

(b) Suggest why the *Australian Dietary Guidelines* recommends more serves of vegetables and legumes/beans per day for boys than for girls.

(2 marks)

(c) The *Australian Dietary Guidelines* recommends that people eat plenty of vegetables of different types and colours each day.

Provide **two** reasons for this recommendation. Give examples to support your answer.

(4 marks)

Total: /65

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Topic 5 Food trends



Concept: Health promotion and emerging trends

5.1 Fad foods and diets

5.2 Future foods

5.3 Paddock to plate

5.1 Fad foods and diets

Nutrition Understanding

There are many marketing ploys that consumers encounter every day. Many of these are gimmicks that companies use to try to distinguish themselves from their competitors to increase sales. Fad foods are one example of the numerous marketing strategies used to attract consumers. The term '**fad foods**' is generally used to describe foods that claim health or weight loss benefits without solid science behind them to support those claims. There are many fad foods that claim to have advantages over others but they may not be telling the whole truth. These fad foods come and go over time. Some recent examples include Kombucha, cold pressed juice, coconut oil and gluten free products. A Canadian artist recently shone light on just how susceptible consumers can be to fad foods and unsubstantiated claims of health benefits. The artist sold **hot dog water** at a festival in Canada for CAD$27 a bottle, claiming it was **gluten free** and compatible with the **ketogenic diet**. The hot dog water was simply a hot dog sausage floating in a bottle of water. Unbelievably, the artist sold enough hot dog water to derive a profit of CAD$1,500. This highlights how little some people question the health claims of fad foods prior to purchasing them.

In addition, many individuals are looking to lose weight and try **fad diets** to help achieve this. A fad diet is one which promises weight loss, is often hard to stick to long term and is generally not supported by scientific research. Fad diets are usually energy restrictive and can involve cutting out one or more of the food groups of the Australian Guide to Healthy Eating (AGHE) (see Topic 4: Food marketing and nutritional guidelines concepts for more information on the AGHE). This can result in the individual missing out on vital nutrients provided by that food group and can also lead to yo-yo dieting due to the energy restrictive nature of the diets (see Topic 2: Dietary disorders for more information on yo-yo dieting). Certain celebrities are often used to endorse fad diets even when they do not possess the appropriate qualifications to be providing advice on health matters. A few examples of recent fad diets are the ketogenic diet, the paleo diet and intermittent fasting diet.

Helpful online resources

Ted-Ed: How to spot a fad diet – Mia Nacamulli

https://www.youtube.com/watch?v=8V15Z-yyiVg&t=23s

AsapSCIENCE: Which Diets Actually Work?

https://www.youtube.com/watch?v=YPl0naO6GR0

Kombucha

Kombucha is a fermented beverage made from black or green tea. To make kombucha, sugar and a culture of bacteria and yeast are added to the tea and fermented for one to two weeks. As a result, acetic acid is produced, giving the drink its sour vinegary taste. Fermented foods like kombucha contain healthy bacteria known as probiotics (see Topic 3: Digestion, malabsorption and the microbiome for more information on probiotics and the microbiome). It has been known for some time that **probiotics** colonise the gut, increasing the number of healthy bacteria inhabiting the gut and outcompeting harmful microorganisms. However, more recent research suggests that **prebiotics** are more effective at sustaining a healthy gut microbiome than probiotics. This is because prebiotics provide food for the healthy bacteria already colonising the gut, which results in them multiplying and outcompeting harmful microorganisms. Although kombucha does have established health benefits due the fact it is a probiotic, it is important to note that many kombucha varieties found in supermarkets and delicatessens have fruit juice added to them. This gives them a sweeter flavour, which is more appealing to people who do not like the sour flavour. As a consequence, these flavoured kombucha drinks contain added sugar and can contain up to 3.8g per 100mL. This means a 600mL bottle of kombucha can contain up to 22.8g of sugar. Many people focus on the health claims of kombucha and are unaware of the sugar they are consuming when drinking it. It is well established that excess consumption of sugary drinks supplies excess energy to the body and can increase the risk of obesity, type 2 diabetes and cardiovascular disease. However, despite its added sugar, kombucha generally contains less sugar than soft drinks and can be a suitable lower sugar alternative to soft drinks.

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Cold pressed juice

Another recent fad food is cold pressed juice. Many people claim that cold pressed juice is healthier than normal juice. Cold pressed juice is made by pressing fruits and/or vegetables to extract their juice, in comparison to normal juice that is extracted using rotating blades. The reason cold pressed juice is claimed to be healthier is because it does not use centrifugal fast spinning blades that produce heat and expose the fruit and vegetables to oxygen while juicing. Heat and oxygen can destroy some nutrients in juice, such as vitamin C (see Topic 8: Food processing for more information on the effect of food processing on nutrients). Theoretically, cold pressed juice may contain more nutrients than normal juice but little research has been conducted to confirm these claims in practice and, as a consequence, there is little evidence to support this. The nutrients in cold pressed juices will also depend on the quality and freshness of the fruits and vegetables used to make it. Sometimes it can take weeks for produce to make its way from farms to the supermarket, where it is purchased by individuals to make cold pressed juice. This is important because fruits and vegetables naturally start degrading from the moment they are harvested, gradually reducing their nutrient content. One benefit of cold pressed juices is they often include vegetables, in comparison to normal juice that generally only comprises of fruit. The inclusion of vegetables can provide a greater variety of nutrients. In addition, normal juices can contain added sugars and can be more diluted than cold pressed juice. However, it should be noted that drinking any juice is less filling and nutritious than eating the whole fruit or vegetable because juice does not include the skin and flesh, which provides nutritious fibre and other nutrients. In addition, juice contains the excess sugar from multiple pieces of fruit and/or vegetables, so consuming whole fruits or vegetables also provides less sugar.



Figure 5.1.1: An example of cold pressed juice.

Coconut oil

Coconut oil is the latest cooking fad and many people claim it is healthier than other cooking oils. This is due to an effective marketing of coconut oil in western society. However, according to the American Heart Association, coconut oil is as unhealthy as butter. This is because coconut oil is comprised of approximately **92% saturated fat**. Saturated fats are generally referred to as 'bad' fats because they increase blood lipids, including 'bad' LDL cholesterol. A diet high in saturated fats can increase the **risk of cardiovascular disease** by increasing the chance of cholesterol build up in the blood vessels. Saturated fats also take longer for the body to break down and contribute to **obesity**.



Figure 5.1.2: Coconut oil mostly consists of saturated fat.

Gluten free products

Gluten is a protein, which is found in wheat, rye, barley and oats. Some examples of food products containing gluten include breads, pasta, pastries, biscuits, cakes and cereals. Some people have coeliac disease which means their body's immune system reacts abnormally to the presence of gluten and attacks the lining of the gut. This can result in malabsorption of nutrients and long-term damage. There are also some people who are intolerant to gluten. When someone with gluten intolerance consumes gluten, they might exhibit some short-term symptoms, such as bloating and abdominal pain. Because these are common symptoms for a variety of intolerances which many people naturally experience; an increasing number of individuals are self-diagnosing themselves as gluten intolerant. This has resulted in a trend whereby many people are unnecessarily avoiding gluten in their diet. In addition, many individuals have heard the 'benefits' of eating gluten free through word of mouth and have decided to avoid gluten without any medical or health basis. Due to this trend, food companies have increased their gluten free range to profit from the movement. However, gluten free products generally replace the gluten with sugar, making the product's taste more appealing. As a result, gluten free products generally contain more sugar than their gluten containing equivalents. An increased sugar intake can provide excess energy and can increase the risk of obesity, type 2 diabetes and cardiovascular disease. For more information on coeliac disease and gluten intolerance, see Topic 3: Digestion, malabsorption and the microbiome. It is important to note that gluten free products are a necessary range at the supermarket for those with coeliac disease and diagnosed gluten intolerance.



Figure 5.1.3: The Coeliac Australia Endorsement Program logo can be found on gluten free products that have met the tests for no detectable gluten.

Did you know?

Food companies are taking advantage of the knowledge gaps some consumers have and advertising their products with absent ingredients. A prime example of this is gluten free products. Some companies are deliberately preying on consumers' concern for products containing gluten by advertising their product as gluten free even if the product would not normally contain gluten. This strategy is very misleading and takes advantage of consumers who are willing to pay premium prices for items that are gluten free. For example, you can now buy 'gluten free water.' As gluten is a protein found in wheat, rye, barley and oats, there is no way that water naturally contains any gluten. This highlights the lengths some companies will go to sell their product and the lack of knowledge among consumers.

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Ketogenic diet

The ketogenic diet, or keto diet for short, is a diet that is high in fat and low in carbohydrates. This type of diet aims to put individuals into a metabolic state called ketosis where the liver converts fats into **ketones**. The body naturally enters a state of ketosis when there is a lack of carbohydrate supply during times of fasting or starvation and becomes more efficient at using fats to supply the body with energy. The ability to enter a state of ketosis when there is insufficient carbohydrate intake is especially important for the brain. The brain primarily relies on glucose for its energy source but can use ketones as an alternate source when blood glucose levels are low. As a ketogenic diet is low in carbohydrates, there is generally not enough glucose to maintain the activity of the brain, so the body enters a state of ketosis to supplement the brain with ketones to use as an energy source.

Following a ketogenic diet properly involves cutting out almost all carbohydrates, which affects multiple food groups of the Australian Guide to Healthy Eating (AGHE) (see Topic 4: Food marketing and nutritional guidelines concepts for more information on the AGHE). Grains, fruits and vegetables are three food groups that are high in carbohydrates but they also contain a range of important nutrients, including fibre, vitamins and minerals. The ketogenic diet can therefore result in nutritional deficiencies and their associated diseases. A key example of this is the lack of fibre in the diet, which could lead to increased cholesterol levels, constipation and diverticular disease (see Topic 2: Dietary disorders for more information). For many people, the ketogenic diet is not sustainable because carbohydrate intake is so restrictive that many people find it hard to maintain. In addition, a ketogenic diet can negatively impact exercise (especially intense exercise) due to the lack of carbohydrates in the diet that would normally be used as an immediate energy source.

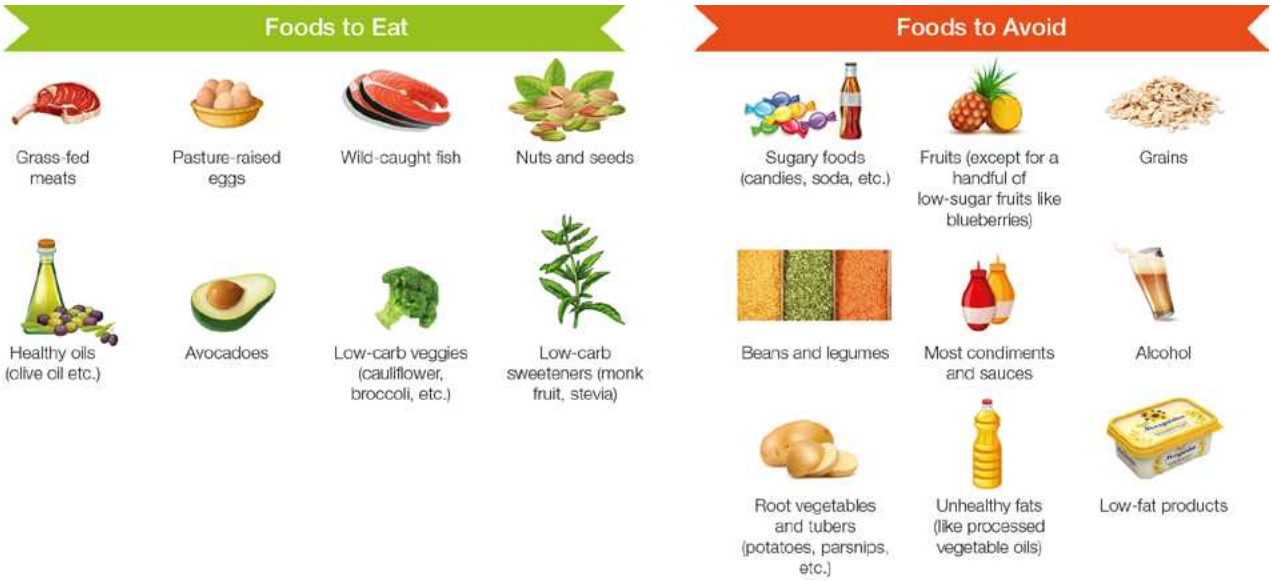


Figure 5.1.4: Some examples of foods that can be eaten and are avoided as part of the ketogenic diet.

Helpful online resources

PictureFit: The Ketogenic Diet Explained in Under 5 Minutes. Low Carb = Best Weight Loss Diet?

https://www.youtube.com/watch?v=AOJxfh0b3o8

Vox: The ketogenic diet, explained

https://www.youtube.com/watch?v=xgtLKeCkCiw

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Paleo diet

The Paleolithic (paleo) diet, also known as the caveman or hunter/gatherer diet, is a diet that aims to reproduce how ancient humans ate. Some believe that our ancestors naturally evolved to eat foods that we were able to hunt or gather approximately 10,000 years ago and we should continue to eat those same foods today. The concept behind this diet is that modern agricultural and commercial food techniques render many of our foods 'unnatural' and that humans are not genetically adapted to eat them. For this reason, the paleo diet prioritises whole foods such as vegetables, nuts and wild meats over processed foods. However, the paleo diet excludes whole grains and legumes as they are associated with modern agricultural practices. This means a whole food group of the Australian Guide to Healthy Eating (AGHE) is cut out of the diet (see Topic 4: Food marketing and nutritional guidelines concepts for more information on the AGHE). This food group is important to supply individuals with energy from carbohydrates and a range of nutrients such as fibre, vitamins and minerals. The paleo diet is essentially a low carbohydrate and low processed foods diet. Eating a reduced amount of processed foods is a positive because it cuts out unhealthy energy dense foods, which have been shown to increase the risk of obesity, diabetes and cardiovascular disease. However, excluding all carbohydrates, including grains and legumes, is not healthy.

Not all populations that lived during the paleolithic period consumed the same amount and types of foods. These populations generally consumed what was available in their land so they could survive. For example, the Paleolithic Inuit populations that inhabited Alaska had a diet that consisted entirely of animals (fish). Trying to recreate the diet of our Paleolithic ancestors is somewhat unrealistic. Over centuries, humans have selectively bred almost all the fresh produce we eat today to maximise the size, sweetness, appeal and to increase yield. In addition, our genomes have also adapted to our changing diet. For example, our ability to digest starch has evolved over time so that more energy can be extracted from the carbohydrates we consume. This is a selective advantage and highlights that cutting out healthy carbohydrates such as whole grains and legumes is not necessary.

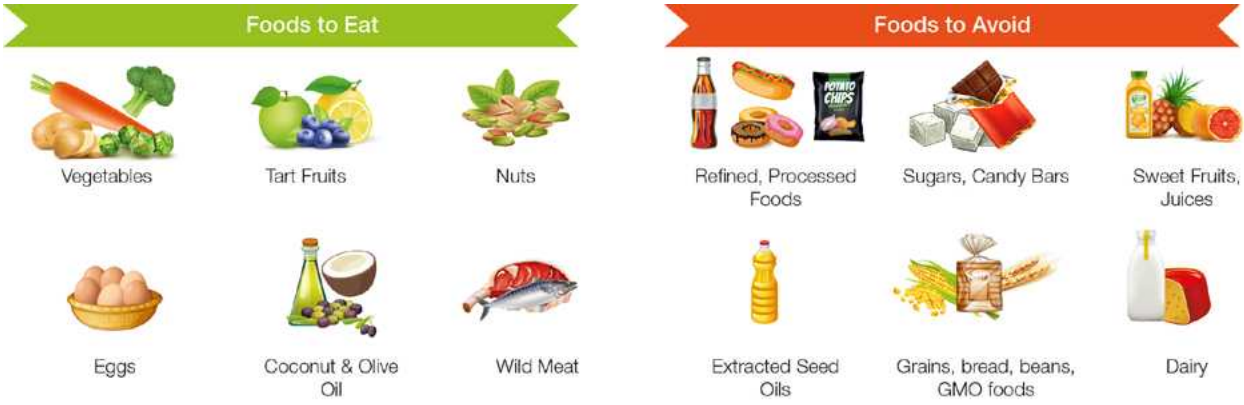


Figure 5.1.5: Some examples of foods that can be eaten and are avoided as part of the paleo diet.

Helpful online resources

PictureFit: Paleo Diet Explained–The Good and The Bad

https://www.youtube.com/watch?v=rBLsChvPiMY

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Intermittent fasting

Intermittent fasting is not a conventional diet as it does not restrict the types of foods you can and cannot eat. Intermittent fasting focuses on the timing of your eating pattern which rotates between periods of eating and fasting. There are two common intermittent fasting diets: the 16:8 method and the 5:2 method. The 16:8 method involves fasting for a 16 hour period and eating all meals within the remaining 8 hours every day of the week. The 5:2 method involves eating normally for 5 days and 'fasting' for two non-consecutive days within a week. The two 'fasting' days in the 5:2 method are either fasting days or reduced energy intake days. On these two days people can consume up to 2,500kJ (the average daily energy intake for an adult is 8,700kJ). Both intermittent fasting diets involve reduced energy consumption across the fasting periods. Supporters of intermittent fasting diets assert that the diet is appropriate because our ancestors did not eat three meals and snacks every day, as food was not as readily available. Some research has demonstrated that intermittent fasting can be effective for weight loss but there are also many people that cannot cope with the fasting and cannot maintain its restrictive nature. Some research has also shown that intermittent fasting could reduce blood pressure, cholesterol levels, insulin sensitivity and increase life expectancy. However, as intermittent fasting involves calorie restriction, this could make it harder to maintain weight loss long term. This is because fasting is generally associated with losing muscle and bone mass as well as fat mass. If muscle is lost, this can result in a decreased basal metabolic rate and if the individual returns to their normal diet it can result in weight gain due to the decreased energy requirements of the body. Intermittent fasting also relies on individuals eating healthily during the non-fasting periods. Despite some of its benefits, intermittent fasting should be treated with caution as it may lead to other unhealthy eating habits associated with restricted food intake.

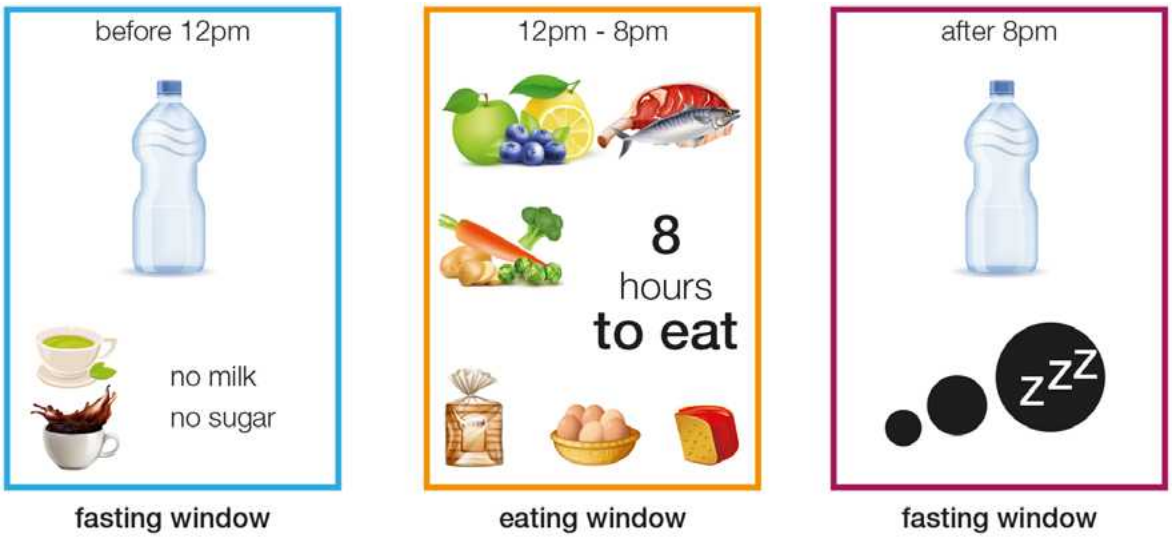


Figure 5.1.6: An example of the time periods associated with the16:8 intermittent fasting diet method.

Helpful online resources

Intermittent Fasting Explained – Will It Help You Lose Weight?

https://www.youtube.com/watch?v=aqdWCf0aMIw

CS Possible case study 5

An individual is following a particular fad diet (choose fad diet). Analyse their current nutritional intake and compare the results with the Australian Guide to Healthy Eating (AGHE) recommendations. Identify any nutrient(s) the individual following the chosen diet is likely to be deficient in and make some recommendations for the individual to achieve greater health outcomes.

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Science as a Human Endeavour 10

Nutrigenomics

Nutrigenomics is the study of how the variations of genes associated with the metabolism of food affect human health and increase the risk of developing diet related diseases. Due to advances in genetic sequencing, scientists have been able to map some of the genes that are associated with diet related diseases and that play a role in the metabolism of macronutrients. Nutrigenomics seeks to clarify how different chemicals in foods interact with specific genes and aims to understand how individuals can reduce their risk of developing dietary diseases such as obesity and type 2 diabetes. There is already evidence that the type of food we eat can play a role in activating specific genes within cells, increasing the risk of developing health conditions. An example of this is how high GI diets increase the expression of the adiponectin gene, which is involved in the regulation of blood glucose levels and fatty acid breakdown. This can result in reduced insulin sensitivity and type 2 diabetes.

As there is not a one fit diet for everyone, nutrigenomics has the potential to develop personalised diet plans for individuals to maximise results based on their DNA. There are already companies offering personalised diets through DNA analysis. These companies develop individual nutritional profiles providing genetically linked information on:

- Food reactions, such as intolerances and allergies
- Food behaviours, such as cravings and ability to feel full
- Nutritional needs, such as which vitamins and minerals need optimising
- Metabolic health factors, such as how your diet affects your cholesterol and blood glucose levels
- An individual diet type, which includes the ideal ratio of macronutrients and nutrients to avoid.

In addition, these nutritional profiles often address personalised exercise routines to help individuals maximise outputs from workouts to help lose weight. For example, whether the individual is genetically predisposed to respond better to endurance or interval-based training.

However, there is not yet enough evidence to guarantee that genetically matched diets alone are effective for weight loss. Research has already shown that variations in genes can impact the metabolism, absorption and excretion of nutrients and their associated waste products; however, there are many other factors that can also affect weight gain/loss, such as social, emotional and economic factors. It is therefore unclear exactly how much influence genetics has alone. There are also many genes associated with the metabolism of food and the interactions between them and the chemicals in our food. Developing a clear understanding of these topics can be difficult due to complexity.

In the future, nutrigenomics could offer more accurate personalised diet, exercise and lifestyle plans to assist individuals with weight loss and preventing or delaying the onset of dietary diseases. This information could be useful to help individuals make proactive healthy decisions but having the information does not guarantee that individuals will implement the recommendations. More time is needed for nutrigenomics to develop and determine if it will be a sustainable diet and lifestyle option for individuals.

Questions

1. Discuss two possible **applications** of nutrigenomics.

(4 marks)

2. Discuss two **limitations** of nutrigenomics.

(4 marks)

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5.1 Review questions

1. (a) State **one** possible health benefit of kombucha.

(1 mark)

(b) Describe **one** health concern of drinking too much kombucha.

(2 marks)

2. (a) Describe why cold pressed juice is said to be more nutritious than normal juice.

(2 marks)

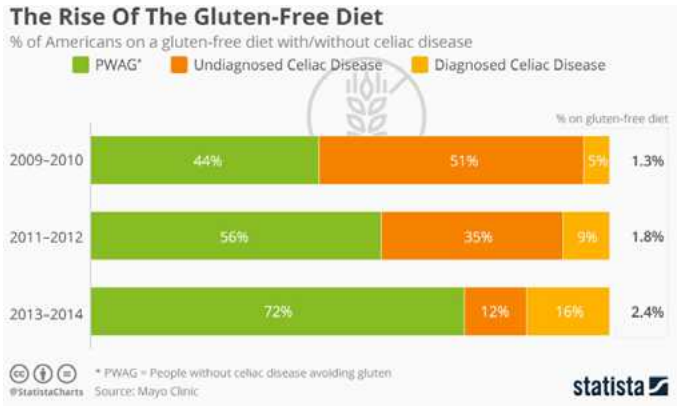
(b) Describe why eating fruits and vegetables is healthier than drinking cold pressed juice.

(2 marks)

3. Explain how the ongoing consumption of coconut oil could increase an individual's risk of developing cardiovascular disease.

(3 marks)

4. Refer to the following graph which shows the percentage breakdown of Americans following a gluten-free diet with and without coeliac disease.



Source: https://www.statista.com/chart/7639/the-rise-of-the-gluten-free-diet/

(a) State **two** examples of foods that contain gluten.

(2 marks)

(b) Using data, describe the percentage of people without coeliac disease avoiding gluten (PWAG) from 2009 to 2014.

(2 marks)

(c) Describe why people without coeliac disease may be avoiding gluten.

(1 mark)

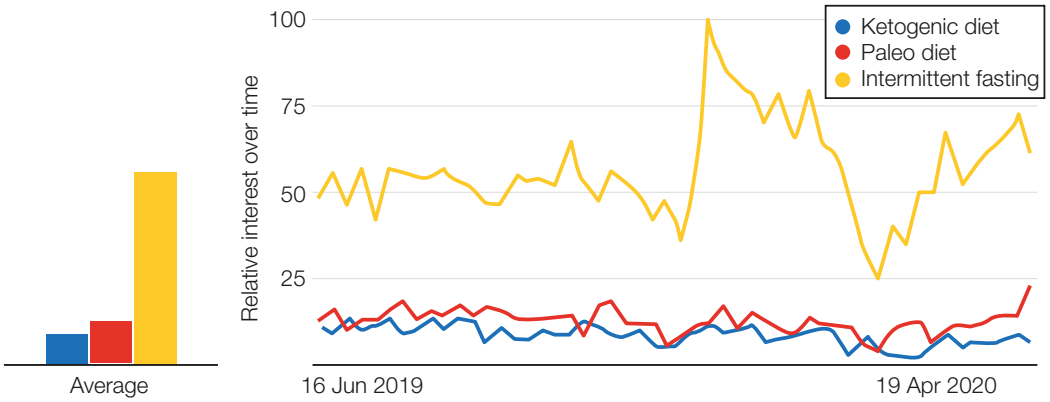
(d) The percentage of people diagnosed with coeliac disease has increased from 5% in 2009/10 to 16% in 2013/14. Describe **one** likely reason for the increase in diagnosis.

(1 mark)

(e) Describe how people with coeliac disease could benefit from the trending gluten free diet.

(2 marks)

5. Refer to the following graph that shows the relative interest of Google searches for different fad diets from 16 June 2019 to 19 April 2020.



(a) Using data, describe which of the three fad diets has developed the most interest from Australians for the time period shown.

(2 marks)

(b) Using data, describe which diet has developed the least interest from Australians for the time period shown.

(2 marks)

(c) Describe why the ketogenic diet excludes carbohydrates.

(2 marks)

(d) Identify the food group that the paleo diet excludes.

(1 mark)

(e) Explain **two** reasons why the paleo diet cannot be replicated authentically today.

(4 marks)

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5.2 Future foods

Nutrition Understanding

As of 1 July 2020, the human population currently stands at an estimated 7.8 billion with an annual growth rate of approximately 81 million. The human population is currently projected to reach 9 billion by 2037, 10 billion by 2057 and 11.2 billion by 2100. The growth of human population has not been gradual. Most of the growth has been concentrated in a huge exponential increase in the last 500 years, which has put enormous strain on the earth's natural resources, such as fresh water and fertile land. These **resources are finite** and are being used at a much faster rate than they can be replaced.

In order to meet growing agricultural demands, large areas of land and forests have been cleared. As a result, many animal habitats have been destroyed, reducing biodiversity and increasing soil erosion. A lack of education in efficient farming practices (such as crop rotation, intercropping and wind barriers) has further contributed to excessive land clearances, especially in developing countries. This is because soil erosion causes the crop yields to decrease after a couple of years and, without knowledge of alternative methods, more land is cleared to gain access to fertile soils. In addition, modern lifestyle and industrial practices are releasing and producing toxins, wastes and other pollutants at a much faster rate than they are being broken down, which is polluting the environment and contributing to climate change. As a consequence, crop yields are decreasing, resulting in less food for the growing population, which further adds to food production issues.

A part of the solution to feeding the growing population is growing more food, but the productivity of the land in some areas of the world is decreasing. The United Nations estimates that food production needs to increase by 70% by 2050 to meet the demands of the growing population. This has resulted in food futurologists rethinking possible options and scientists looking into alternative food options that are more environmentally friendly and sustainable. Some of these options are insects, algae, lab grown meat and genetically modified organisms. It is important to note that humans are also wasting a lot of food that could be used to help feed the growing population (see Topic 7: Water and sustainable food supply for more information).

Helpful online resources

Astrolabe: Future Food | The Menu of 2030

https://www.youtube.com/watch?v=mnoCy0j7DNs

Insects

Entomophagy, the consumption of insects, may become a sustainable and nutritious food source in the future for more people. Approximately two billion people currently consume insects as part of their diet and there are an estimated 1,900 edible insects on earth. However, as insects are part of the animal kingdom, **insects are not a suitable alternative source of protein for vegans**. Insects are a great source of protein, fats, vitamins and minerals. Insects such as crickets and locusts are **high in protein,** with protein content comparable to beef, whereas others such as mealworm and black soldier flies are high in dietary fats. In fact, mealworms contain approximately the same amount of omega-3 and omega-6 essential fatty acids as fish and more than beef does (per gram). Some insects also contain more minerals than beef, such as locusts and mopane caterpillars, which contain more iron per gram than beef.

Insects can be eaten individually but many people may find eating insects unappealing and hard to palate. To make them more palatable, insects can be **processed** into a range of food products, such as grinding them down and using them in burger patties and sausages or using cricket flour to make pasta.

There are also **environmental benefits** associated with farming insects over livestock farming. The farming of insects **requires less land and water** and generates significantly less greenhouse gases. Insects are also more efficient than animals at converting their feed into body mass. For example, crickets convert two kilograms of feed into one kilogram of edible meat, whereas cattle require eight kilograms of feed to produce one kilogram of meat. Furthermore, only 40% of a cow can be consumed as edible meat, whereas 80% of a cricket can be consumed. If more humans ate a greater amount of insects than conventional meats, this would significantly reduce the strain on finite resources.



Figure 5.2.1: Deep fried insects could become a more common meal option in the future.

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Algae

Algae are a diverse group of photosynthetic organisms that could be the next generation of farming and an **alternative protein source**. There are thousands of different types of algae, each with their different tastes, which highlights the potential of using algae in a variety of products. Some more commonly known examples are chlorella, which consists of about 50% protein and spirulina, which consists of about 60% protein. Both chlorella and spirulina are also **complete proteins,** which means they contain all essential amino acids. They also contain many vitamins, minerals and essential fatty acids. This makes them a great alternative source for direct human consumption and could help combat malnutrition in the developing world, especially as the population increases. Also, unlike crickets, algae are not animals and **are a suitable protein alternative for vegans**.

Algae can be harvested in open or closed systems. An open system involves algae being grown in ponds that are exposed to environmental elements. A closed system involves the use of photobioreactors that are purposely built to maximise production inside a factory. In both systems the algae are provided water, sunlight, carbon dioxide and fertiliser to maximise their growth. Both of these systems can be set up on arid land that is not suitable for traditional crop farming and approximately only 10% of the land size is required. Algae also grows ten times faster than traditional crops and does not require freshwater, instead saltwater is used. It is estimated that 70% of the world's fresh water is used to grow crops and livestock, so growing algae is more environmentally friendly. In addition, approximately 80% of the water used to farm algae can be recycled.

Like insects, algae does not have to be consumed alone. Instead, it can be processed with other ingredients to make algae-based food products. Some examples of this are algae crackers, algae hummus dips, algae based soft drinks, and dried algae oat milk and chia seed puddings.



Figure 5.2.2: One example of how the algae spirulina is currently being incorporated into food is green smoothies. This one consists of spirulina powder, spinach and blueberries.

Helpful online resources

CNN Business: Is algae the food of the future? | Mission Ahead

https://www.youtube.com/watch?v=tAdrNQNP8ew

Clean meat

Clean meat is meat that is produced from culturing cells instead of slaughtering animals. It was previously known as **cultured meat** or **lab grown meat**, but the marketing of this product has been changed to clean meat because some consumers were being deterred by the thought of lab grown meat. Growing clean meat firstly requires obtaining a sample of the desired animal's muscle stem cells. The stem cells are then supplied with the nutrients they need to grow and divide, such as glucose, amino acids, water and oxygen. This allows the cells to multiply quickly and form muscle fibres that result in a product similar to mince beef, which is then moulded into products such as hamburger patties. There are many companies developing clean meat and it is not just hamburger patties they are developing. Lab grown chicken nuggets, fish croquettes and pork sausages have all been developed too.

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These products are safe to eat because they are replicated meat from a sample taken directly from the animal and according to taste testers, they taste very similar to the real thing. However, clean meat companies are still working on **upscaling the production** of their clean meat to factory-sized commercial production.

The first lab grown meat was produced in 2013 but its production cost was US$325,000. Scientists have managed to refine the process and the new developments have resulted in significant price decreases. A lab grown beef hamburger patty now costs less than US$10. Currently, there is no clean meat company that has released a commercial product but at this rate it shouldn't be long before clean meat makes its way into restaurants and supermarkets. In fact, it is expected that high end restaurants will add clean meat to their menus in the next couple of years. This is because the clean meat is still rather expensive but as its price reduces it will offer another **protein alternative** that is more **environmentally friendly** than eating meat from livestock.

As the population grows, there will be a higher demand for meat, and if this demand is met with clean meat the strain on the environment can be reduced. Animal farming requires a lot of land and this has resulted in a significant amount of deforestation for agriculture use. A substantial percentage of the Amazon rainforest has already been cleared for animal farming. As a consequence, there are fewer trees absorbing atmospheric carbon dioxide, which also contributes to global warming. It is estimated that clean meat production will use approximately 99% less land, resulting in significantly less deforestation. Animal farming also requires a lot more freshwater than the production of clean meat. According to People for the Ethical Treatment of Animals (PETA), clean meat production uses 90% less water than traditional animal farming. In addition, PETA supports the development of clean meat because no animals are harmed and slaughtered in the process. Clean meat has the potential to save the killing of billions of animals every year. It may also be an **alternative protein option for vegans.** Many vegans choose not to eat animals due to the unethical treatment and slaughter of animals but if no animals are harmed, clean meat could be a viable option.



Figure 5.2.3: An example of clean meat that is then processed into a hamburger patty.
Source: https://www.abc.net.au/news/rural/2019-07-30/australia-joins-lab-grown-meat-industry/11360506

Helpful online resources

Evan Fraser: Feeding 9 Billion Video 10: The Future Of Meat

https://www.youtube.com/watch?v=pgtmDAU34rQ

Mosa Meat: How is cultivated meat (a.k.a. cultured meat) made exactly?

https://www.youtube.com/watch?v=kG4EO-P93Dk

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Science as a Human Endeavour 11

Lab grown steaks

Researchers have been able to create lab grown meat that they can process into products like hamburger patties and sausages; however, the next challenge is to make cuts of meat such as steaks and chicken breasts. This is much more complex because cuts of meat consist of more than just muscle cells. They consist of blood vessels and other connective tissues too. To produce cuts of meat, complex scaffolding is required to support the various types of cell growth to replicate the cut of meat. This is very complex and a lot more research is required before we will be eating lab grown steaks at home. Watch the following video for more information about some challenges that lab grown meat is facing and its potential effect on society.

Helpful online resources

Seeker: This Breakthrough in Lab-Grown Meat Could Make it Look Like Real Flesh

https://www.youtube.com/watch?v=1lUuDi_s_Zo

Questions

1. Discuss two **limitations** associated with culturing lab grown steaks.

(4 marks)

2. Discuss how the development of lab grown steaks could **influence** society.

(4 marks)

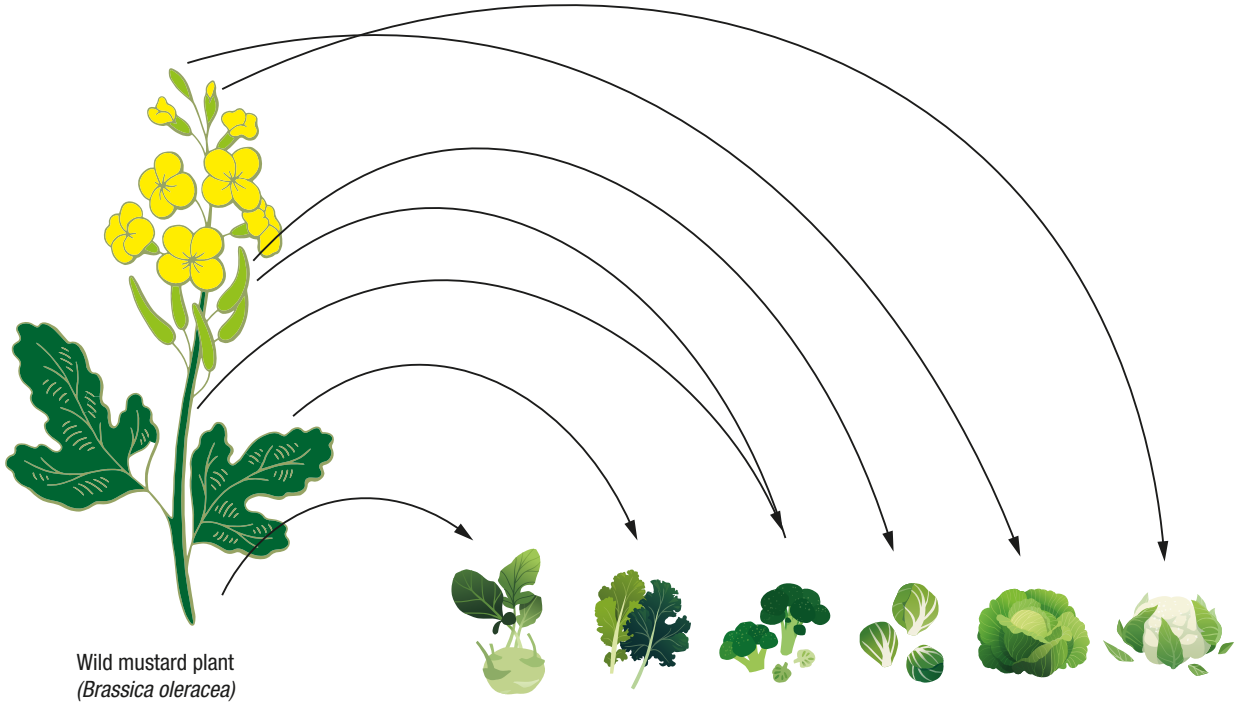
3. Discuss how society has **influenced** the development of lab grown steaks.

(2 marks)

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Genetically modified food

Humans have been altering the genomes of plants and animals for many years. We have selectively bred species for desired traits such as bigger and juicier fruits, seedless watermelons and leaner animals. One could argue that none of the produce we eat is 'organic' and 'natural' due to humans' interference. A prime example of this is the selective breeding of the wild mustard plant. Many of the leafy greens we eat today were created by selectively breeding the wild mustard plant for different traits. This gave rise to vegetables such as broccoli, cauliflower, cabbage and kale (see Figure 5.2.4). It is because of humans that these new varieties exist.



Wild mustard plant
(Brassica oleracea)

Strain	Kohlrabi	Kale	Broccoli	Brussels sprouts	Cabbage	Cauliflower
Modified trait	Stem	Leaves	Flower buds and stem	Lateral leaf buds	Terminal leaf bud	Flower buds

Figure 5.2.4: Some of the leafy greens that resulted from the selective breeding of the wild mustard plant by humans.

Did you know?

Israeli scientists have selectively bred chickens without feathers. Chickens have a high metabolism and they are often mass produced in tight spaces. As a result, chickens are prone to overheating, especially in the humidity of some Asian climates. Also, the chickens' feathers do not need to be plucked, saving time when preparing them for market.

Genetic engineering allows greater precision and control over the genetic changes to organisms in comparison to selective breeding. Genetic engineering allows scientists to transfer specific genes from one species to another, providing the target organism with the new desired trait(s). For example, an antifreeze gene from a deep-sea fish can be transferred into a tomato plant to reduce the loss of tomatoes damaged by frost. This is a very specific trait that is transferred and it is possible because all organisms contain the same genetic code: DNA. The potential is endless and genetically modified organisms (GMOs) can help with optimising agricultural performance and increasing food security for the growing population. Some examples of genetically modified organisms are discussed in more detail below.

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Golden rice and bananas

The World Health Organisation (WHO) estimates that between 250,000 and 500,000 children go blind every year due to **vitamin A deficiency (VAD)**. Of the children that go blind, approximately 50% of them will die. It is estimated that up to 2.5 million people die worldwide due to VAD. The majority of VAD occurs in developing countries with little access to fresh wholefoods. **In Asia, rice is the staple food**. Scientists have been able to genetically modify rice so the provitamin A is expressed in the rice grains instead of just the leaves. This version of rice has been called 'golden rice' due to the yellow colour of the rice grain resulting from the presence of provitamin A. Golden rice was developed in 1999/2000 and the first field trial occurred in 2004. This genetically modified rice has the potential to save millions of lives each year, yet countries have been slow in passing legislation for farmers to grow it. There are multiple reasons for this slow uptake, including how genetically modified crops could affect their current trade agreements. However, the Philippines is the first country to legalise the farming of golden rice to help address their country's cases of vitamin A deficiency. **In Africa, bananas are the staple food** rather than rice. Scientists have also been able to genetically modify bananas to include provitamin A. Scientists have also had some success with biofortifying rice with iron and zinc (see Science as a Human Endeavour 5 in Topic 1: Fundamentals of Nutrition for more information).



Figure 5.2.5: A comparison of the golden rice grain and white rice grain

Helpful online resources

International Rice Research Institute: The Road to Golden Rice

https://www.youtube.com/watch?v=L05d0_tkR_s

Fast growing salmon

Atlantic salmon do not grow all year round. They only grow when environmental conditions are favourable. For example, when the water temperature gets very low during winter and food sources are scarcer, their growth hormone gene is turned off and they stop growing. Scientists have introduced two genes into Atlantic salmon, one from Chinook salmon and another from ocean pout, which has allowed the growth hormone gene in Atlantic salmon to remain switched on all year round. As a result, the genetically modified (GM) Atlantic salmon **grow twice as fast** as wild Atlantic salmon. This means that farmed GM Atlantic salmon can be grown in two years compared to four years. By halving the amount of time Atlantic salmon takes to grow, twice as much farmed Atlantic GM salmon can be produced and supplied to the growing population. In addition, 25% less feed is required to grow GM Atlantic salmon, further reducing the strain on resources. Fast growing GM salmon is the first genetically modified animal that has been approved for sale and is currently approved for sale in the United States of America and Canada. At the time of writing, GM Atlantic salmon is yet to be approved for sale in Australia.

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Disease resistant crops

You may have tried banana flavoured lollies before and thought that the flavour is quite different to the bananas you buy at the supermarket. This is because the flavour is based on a banana called the Gros Michel that became virtually extinct in the 1950s. The Gros Michel crop became virtually extinct because the crops were susceptible to a fungus that caused Panama disease. Because the crops were genetically identical, the fungus could infect all Gros Michel crops and eventually the crop was wiped out in the banana industry. The bananas that you buy at the supermarket today are called Cavendish bananas and this crop was initially resistant to Panama disease. However, the fungus has evolved and is now also able to infect the Cavendish banana crop. Just like the Gros Michel, the Cavendish crops are genetically identical, which means the disease can infect all Cavendish crops. The disease is spreading to many countries throughout the world, so it is possible that the Cavendish banana could also become extinct. A possible solution to save the Cavendish banana from extinction is genetically modifying it to become immune to the new strain of Panama disease. Researchers in Australia have been successful in modifying the Cavendish banana to protect it from Panama disease. They did this by inserting two genes into the plant, one of which was a gene from a wild banana plant that confers resistance to the disease. This research could save the Cavendish banana from extinction and keep the banana industry alive. In addition, further research could be conducted to genetically modify the Gros Michel to be resistant to both strains of Panama disease and bring about the return of the Gros Michel to the supermarket. This is only one example of genetically modifying crops against disease. There are many more diseases attacking our crops, such as the PVY virus that infects potatoes and can reduce crop yields by up to 70%. GM potatoes that are resistant to the PVY virus have been developed and approved for use in Argentina. Genetically modified crops can save some crops from extinction and increase yields of others by providing immunity to certain diseases.

For more examples of GMOs, such as pesticide resistant crops, herbicide resistant crops and nitrogen fixing crops, please see Topic 7.3: Sustainable food futures.

3D food printing

3D food printing has the potential to revolutionise the food industry in the future. It is possible that 3D food printers could become a staple household appliance just like microwaves are today. Imagine being at home and you are craving some chocolate but you do not have any in the cupboard. Instead of having to go to the supermarket, you could use your 3D food printer to download a recipe and print yourself a chocolate bar at home. Ultimately, researchers would like to develop the technology to 3D print meals at home that are cooked to the ideal temperature when printed. The technology has not developed this far yet but if it does, cooking dinner could be as simple as selecting a recipe from the internet and inserting the respective food cartridges into the 3D food printer. This would save time preparing food, cooking and cleaning up in the kitchen. In today's busy world, many people do not cook enough healthy meals because they are too busy or tired. 3D food printers could change this and increase the health outcomes of individuals and families. In addition, the food cartridges could be made using food waste that are thrown away because they do not meet the tight restrictions of the supermarkets (see Topic 7: Water and Sustainable Food Supply for more information on food wastage).

Most 3D food printers currently on the market work by depositing layers of food on top of each other in a programmed pattern; however, this still requires processing the ingredients and manually preloading foods into nozzles prior to selecting the program. If the food being printed consists of different types of foods then the different ingredients have to be loaded into multiple nozzles. For example, to print a Margherita pizza, the dough base has to be loaded into one nozzle, the tomato paste in another and the cheese in a third nozzle. The pizza program is then selected and the 3D printer will then print the layers according to the pre-set program. This is still very labour intensive as the ingredients have to be prepared in the nozzles and the final product is printed raw and still needs to be cooked. In addition, if the ingredients are not made to the right consistency, they will not be able to fit through the nozzle and be printed. 3D food printing at home is not a reliable option just yet but it still does have current applications. Some high-end restaurants have incorporated food printers into their kitchen to print foods into patterns that are not easily created by humans, to increase the appeal of their foods. For example, 3D printing butter onto a plate in an elaborate pattern to serve with bread as starters. In addition, some nursing homes are using 3D food printers to print food purées into more appetising meals. The elderly can find chewing difficult and this can lead to under eating and malnutrition. By pureeing food, the elderly are more likely to consume the meal and reduce cases of malnutrition, however it may be visually appealing. Making food more appealing is a great application of 3D food printers and they could be used to make insects and algae more appealing in the future.

There is still a lot of research and development required for 3D printers to become mainstream. There are many limitations that still need to be overcome, one of which is upscaling to become commercial, however, the nutritional advantages gained from this technology could change society forever. It is possible that 3D food printers could be used to customise meals for individuals' macronutrient and micronutrient requirements whilst cutting out the use of additives. This could reduce the prevalence of overnutrition and undernutrition diseases. It is also possible that 3D food printers could be used in space shuttles to provide nutritious meals to astronauts. This could allow deeper space exploration.

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Helpful online resources

Origin of Foods: Is 3D Printed Food the Future?

https://www.youtube.com/watch?v=2kCjSq_I-0s

Science as a Human Endeavour 12

3D printed food

Use the information in the 3D food printing section above and the following videos on the development of 3D food printing to answer the following questions:

Helpful online resources

FT Rethink: Dinner is printed: is 3D technology the future of food?

https://www.youtube.com/watch?v=B0Ty6wgM8KE

CAN Insider: 3D Food Printing Desserts To Hospital Meals

https://www.youtube.com/watch?v=Bv03C58sSR4

Questions

1. Discuss two possible **applications** of 3D food printers.

(4 marks)

2. Explain how the **development** of 3D food printers could change the way we eat and prepare food.

(4 marks)

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5.2 Review questions

1. Describe why food production needs to increase in the future.

(1 mark)

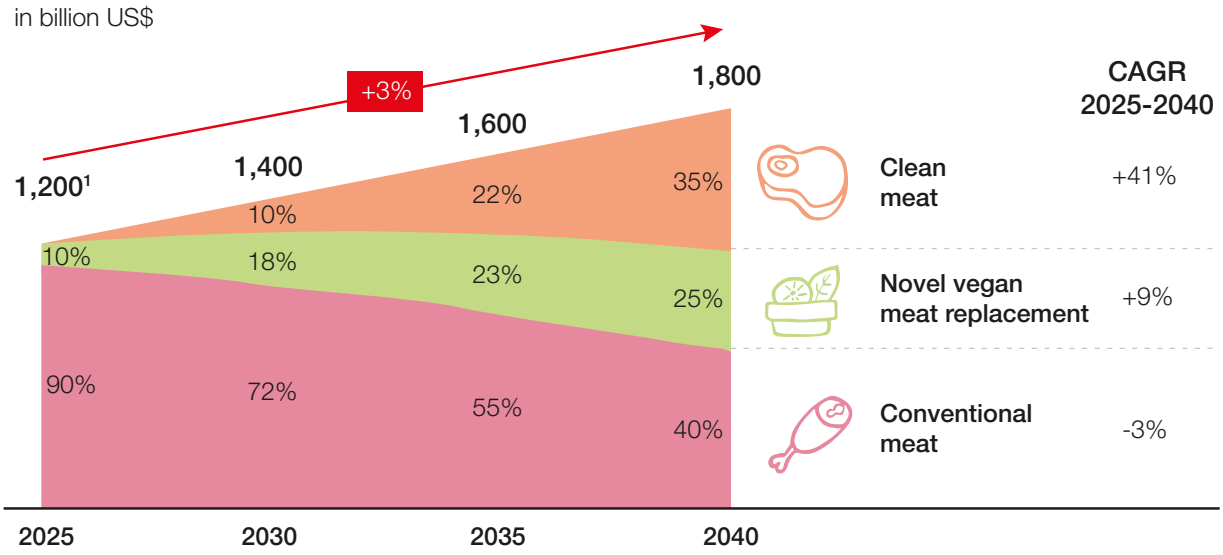
2. Using an example, explain why insects are considered to be a nutritious alternative food source of the future.

(4 marks)

3. Describe why algae might be a more appropriate alternative food source for vegans instead of insects.

(3 marks)

4. Refer to the following graph below that represents the estimated global meat consumption by 2040 (in billion $US). The graph also allows for a predicted 3% increase in demand.



(a) Describe how clean meat is produced.

(2 marks)

(b) Describe why a 3% increase has been factored into the calculations.

(1 mark)

(c) Using data, describe the predicted trend of the consumption of conventional meat.

(2 marks)

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(d) The consumption of clean meat is predicted to increase to 35% of the market share by 2040. Explain **two** reasons why the consumption of clean meat could increase.

(4 marks)

5. (a) Describe what a genetically modified organism is.

(2 marks)

(b) Explain how genetically modified golden rice could reduce the number of vitamin A deficiency cases and associated deaths.

(4 marks)

(c) Explain how genetically modified fast-growing salmon could help feed the growing population.

(4 marks)

6. Describe **one** current application of 3D food printers.

(2 marks)

E Extension question

Research **and** discuss how genetic engineering could increase productivity of crops in areas experiencing drought.

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5.3 Harvest to plate

Nutrition Understanding

Recently, there has been a national movement known as **harvest to plate** whereby consumers are seeking more information about the supply chain of the foods they eat. Australian consumers increasingly want to know where their food comes from, how it was processed and how far it has travelled. This information allows consumers to choose fresh ingredients that are locally grown and support local farmers. Consumers may also choose their ingredients or meals based on the premise of sustainably sourced foods. By purchasing foods directly from farmers, consumers can be assured that their food is locally made, has minimal processing and reduced transport miles. Because there is a growing harvest to plate consumer base, more farmers are starting to sell their produce directly to consumers. This gives farmers more control over where their food is going whilst making more profit at the same time. Selling direct from farmers to consumers is still a relatively niche market but with the rise in digital literacy and more people doing their shopping online, there is greater ability to connect farmers directly with consumers.

Because the harvest to plate movement has gained a lot of traction, many restaurants have also adapted to the consumer trend and incorporated harvest to plate as part of their business model. This involves partnering with local businesses and identifying where their food has come from on their menus. Some restaurants have even started their own herb and vegetable gardens, growing their produce on site and using it in the meals they serve. An excellent example of this is the Chef's Garden at Serafino Restaurant in the McLaren Vale, where locally grown produce is used as part of their contemporary menu (see Figure 5.3.1). As consumers become more conscientious about the food they eat, businesses are forced to adapt to appeal to these consumers and support local businesses.

The harvest to plate movement highlights the importance of transparency in the food supply chain. Consumers want to know more information about where their food has come from and how it was processed. This emphasises the need for traceability of food from harvest to plate. Food safety Australia New Zealand (FSANZ) has developed the primary production and processing (PPP) standards in conjunction with government agencies, industry stakeholders and consumers. The PPP standards were developed to improve the food safety outcomes and **traceability of foods from harvest to plate**. There are also new technologies being developed, such as TruTag's advanced anti-counterfeit technology that allows foods to be tagged with a unique edible microscopic scannable tag. The microscopic tags are invisible to the naked eye, are almost impossible to replicate and have unique identifiable codes that can be detected by a device using a complementary iPhone or Android application. Blockchain technology stores all applicable data from harvest to plate within the microscopic tag. This allows consumers to scan their foods using their device to determine if the item they are about to purchase is legitimate and locally sourced. This increases consumer confidence as they can also view the entire processing history of the food they are about to purchase. Understanding food supply chains can also help prevent **food fraud** and the **contamination** issues associated with this. For more information, please see Topic 8: Food processing and Science as a Human Endeavour 17.



Figure 5.3.1: Serafino Restaurant in the McLaren Vale, South Australia, uses fruits, vegetables and native herbs that are grown on-site as part of their contemporary menu.

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Did you know?

There is an application for iPhones and Android called 'From Paddock to Plate'. This application provides a variety of recipes and connects consumers with farmers to purchase the ingredients directly from the 'paddock'. This allows consumers to ensure that their food purchase is locally sourced and minimally processed. It also guarantees that their purchase is supporting local farmers. More information is available on the From Paddock to Plate website using the link below:

Helpful online resources

The From Paddock to Plate website

https://www.frompaddocktoplate.com.au/app/

5.3 Review questions

1. State **three** reasons that there is a growing harvest to plate consumer trend.

(3 marks)

2. Outline **two** benefits of the harvest to plate movement for farmers.

(2 marks)

3. Suggest **two** complications that farmers might have with connecting their product directly with consumers.

(2 marks)

4. Describe why many restaurants have incorporated the harvest to plate movement as part of their business model.

(2 marks)

5. Discuss how TruTag's anti-counterfeit technology can increase traceability of food from harvest to plate.

(4 marks)

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Topic 6

Nutrition and food safety during pregnancy and lactation



Concepts: Health promotion and emerging trends & Sustainable food systems

6.1 Introduction

6.2 Nutrition during preconception

6.3 Food group recommendations for pregnancy and lactation

6.4 Nutrition during pregnancy and lactation

6.5 Food contamination & safety

Topic 6 Review Test

6.1 Introduction

Nutrition Understanding

A balanced diet that includes a variety of nutritious foods is important to support the growth & development of a baby. A balanced diet is, however, equally important for the health of the mother during and following pregnancy. This is because a woman's body naturally prioritises the nutritional requirements of a developing baby over her own, even at the detriment of the mother. If a mother has an insufficient nutritional intake during pregnancy or lactation due to a poor or insufficient diet, her body's nutritional stores may be depleted, potentially raising the risk of some conditions or diseases.



Figure 6.1.1: A healthy baby relies on its mother to eat healthy and nutritious food to support its development.

A balanced and nutritious diet is also important because malnutrition during **critical growth periods of pregnancy** can increase the risk of the baby developing chronic diseases later in life (see Figure 6.1.2). Malnutrition can lead to lower birth weight and this has been associated with an increased risk of developing type 2 diabetes and cardiovascular disease later in life. For example, malnutrition during the development of the pancreas can significantly decrease the presence of beta cells that are critical for insulin production. When this occurs, there are not enough beta cells developed during the early stages of critical growth to support the amount of food eaten later in life when individuals are more likely to overindulge (i.e. the body cannot make enough insulin to support the amount of carbohydrates eaten and type 2 diabetes develops).

A mother's diet can also influence gene expression in the baby as it is developing. This means that what a mother eats can determine what proteins her child's cells will make and this can influence the future risk of diseases for an infant. For example, a particular study on mice has shown that the supplementation of both folate and vitamin B12 during pregnancy can cause changes in gene expression (epigenetic changes) in cells of the developing baby that reduce the risk of developing diet related diseases such as obesity, cardiovascular disease and type 2 diabetes. This study was only completed on mice and it is not yet determined if it has the same effect on humans; however, this does highlight that diet not only provides nutrients for the developing baby's growth but can also result in changes to the DNA, which can increase or decrease their risk of chronic disease in the future.

Helpful online resources

LIVE IT: Importance of Nutrition During Pregnancy

https://www.youtube.com/watch?v=FpG9OCD5G1g

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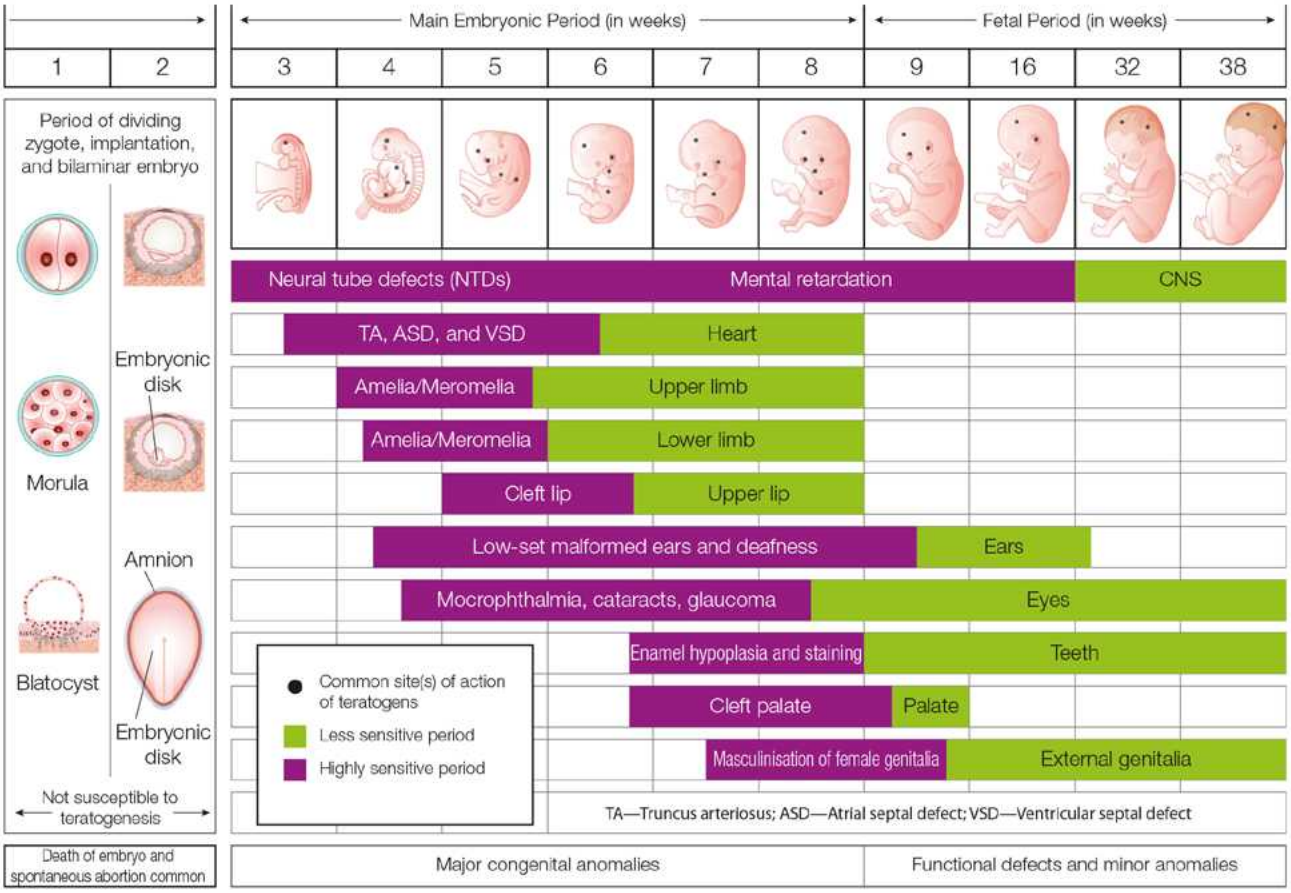


Figure 6.1.2: Some examples of critical growth periods during pregnancy.

6.1 Review questions

1. Explain **two** reasons why consuming a nutritious diet during pregnancy is important.

(4 marks)

2. Explain how malnutrition during critical growth periods of the foetus can increase the risk of the individual developing chronic disease(s) later in life. Use one example to support your answer.

(4 marks)

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6.2 Nutrition during preconception

Nutrition Understanding

A mother's diet prior to conception is very important to maintain health and ensure her **nutrient stores are full**. This is especially important between pregnancies. The World Health Organisation currently recommends that females **wait approximately 18 months between giving birth and becoming pregnant again**. A woman's nutrient stores may become depleted with pregnancies less than 12-18 months apart, even if she consumes the recommended nutrients in ample amounts during and after her pregnancy. Depleted nutrient stores may affect the mother's health in a negative way. Furthermore, if the mother's nutrient stores remain depleted during the subsequent pregnancy, the risk of growth and development complications in the resulting infant are increased. It is also **important for males to have a healthy diet** prior to conception because diet can affect the **quality of sperm** and the likeliness of conception.



Figure 6.2.1: Nutrition prior to becoming pregnant is very important for the development of the foetus.

Folate (Vitamin B9)

Folate is found naturally in our foods but there is also a **synthetic form called folic acid,** which is used in supplements and to **fortify foods,** such as grain products. Most people eat grain products (like bread and pasta) so fortifying these foods with folic acid is an effective way to reach the majority of the population. The synthetic form of folate also has up to double the bioavailability (amount absorbed by the body to use) than the natural form. Vegetables, legumes and fruits are good sources of folate, whereas animal products generally are not. It is also important to note that up to half of the folate in foods can be destroyed through poor storage (exposure to oxygen) and heat when cooking.

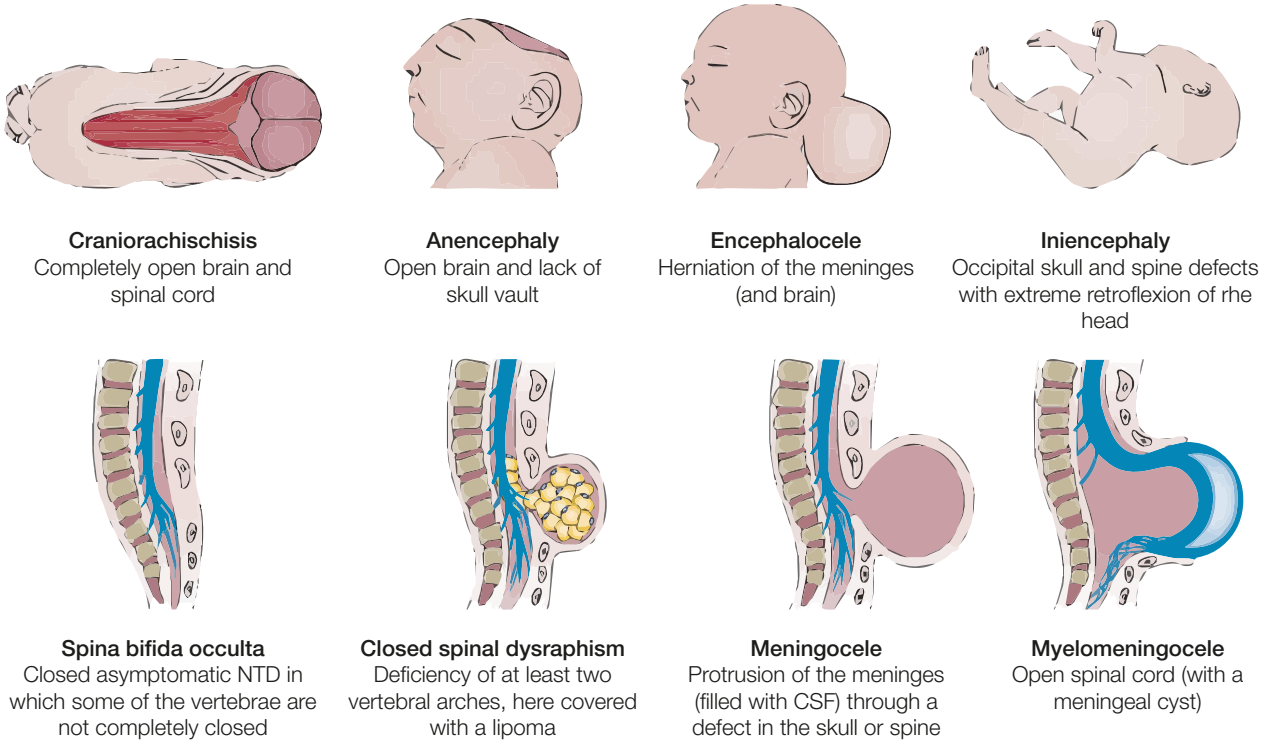
Why is folate important?

Folate is essential for the **synthesis of DNA**. The synthesis of DNA is required to make new cells for growth, repair, replacement and reproduction. When a sperm and egg fuse through reproduction, a zygote is formed. This is followed by **rapid cell division to form an embryo** and further cell division into a foetus. Without folate, DNA synthesis cannot occur, resulting in DNA damage and the abortion of cell division. This can lead to development issues in the infant. It is therefore important for the mother to have sufficient folate reserves prior to falling pregnant. A pregnancy test generally will not show a positive result until approximately two weeks after conception. During early pregnancy, the foetus (including the **neural tube**, which later develops into the **brain** and **spinal cord)** grows rapidly. A lack of folate during the development of a foetus can result in a range of **neural tube birth defects** (see Figure 6.2.2). In the first four to six weeks, the neural tube closes and fuses but a lack of folate can increase the chances of an incomplete fusion and can result in neural tube defects such as **spina bifida**.

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Therefore, it is important for mothers to consume extra folate prior to pregnancy to ensure their folate stores are sufficient to supply the necessary folate for the DNA synthesis of the early embryo and foetus, which may be occurring even before the mother knows she is pregnant.

Folate is also very important for the production of red blood cells, of which approximately two million are replaced every second. A lack of folate can result in **folate deficient anaemia** in the mother and can lead to low energy production due to restricted delivery of oxygen to cells. Extra energy is needed for the growth and development of the foetus.



Craniorachischisis
Completely open brain and spinal cord

Anencephaly
Open brain and lack of skull vault

Encephalocele
Herniation of the meninges (and brain)

Iniencephaly
Occipital skull and spine defects with extreme retroflexion of rhe head

Spina bifida occulta
Closed asymptomatic NTD in which some of the vertebrae are not completely closed

Closed spinal dysraphism
Deficiency of at least two vertebral arches, here covered with a lipoma

Meningocele
Protrusion of the meninges (filled with CSF) through a defect in the skull or spine

Myelomeningocele
Open spinal cord (with a meningeal cyst)

Figure 6.2.2: Some examples of neural tube defects that can be caused by a deficiency of folate prior to and during the early stages of pregnancy.

Did you know?

Sometimes complications can occur during early pregnancy. One complication is an ectopic pregnancy. An ectopic pregnancy occurs when a fertilised egg implants itself outside of the uterus (usually in the fallopian tube) and continues to divide. Unfortunately, an embryo that implants outside of the uterus is unviable. Once diagnosed (through scans) the ectopic pregnancy needs to be ended for the safety of the mother. If an ectopic pregnancy in the fallopian tube is not treated and the embryo continues to develop, the fallopian tube may rupture (split open), causing life threatening internal bleeding in the mother. There are two ways of treating an ectopic pregnancy: surgery and medication. If the ectopic pregnancy is diagnosed at an early stage, a medication called methotrexate may be administered to stop the embryo from developing. If the ectopic pregnancy is diagnosed at a more advanced stage, or if the mother does not want or is unable to have methotrexate, surgery can be performed to remove the pregnancy sac from the fallopian tube. There are various reasons why a woman may prefer one treatment to the other. Surgery is a more invasive treatment and can result in the loss or use of the fallopian tube, however, the woman can ordinarily start trying to conceive again at her next cycle. Methotrexate is a less invasive treatment but will require the woman to delay future conception. Methotrexate targets rapidly dividing cells preventing them from absorbing folate by inhibiting an enzyme in the folate pathway and preventing DNA synthesis and cell division. As the embryo is rapidly dividing, it is targeted by the methotrexate, preventing cell division and preventing the development of the embryo. The pregnancy tissue is then absorbed into the woman's body. A further consequence of the methotrexate treatment, however, is the **depletion of the mother's folate stores**. A woman who is treated for an ectopic pregnancy using methotrexate is therefore advised not to conceive for a minimum period after receiving their final dose of methotrexate so that her body can replenish its folate stores. If the mother were to conceive again prior to the end of the minimum period, there would be a serious risk of severe neural tube defects and developmental problems in the resulting foetus.

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Supplementation and recommendations

To reduce the risk of neural tube birth defects in babies, the National Health and Medical Research Council (NHMRC) recommends that women consume an extra 400 micrograms of folic acid a day for **at least one month before conception**, and for the **first three months of pregnancy**. This is in addition to eating a healthy diet rich in folate. Furthermore, folate is essential for men and folic acid supplementation may also improve sperm development. One study has shown that supplementation with 700 micrograms of folate lowered sperm abnormalities by approximately 20%.

In Australia, it is a legal requirement for wheat flour used in breadmaking to be **fortified** with folic acid. This is because most people eat bread regularly and this ensures almost everyone consumes folic acid. This is especially important for **unplanned pregnancies** because the neural tube defects generally occur prior to the mother becoming aware that she is pregnant. There is approximately 120µg of folic acid in 100g of fortified bread (three slices). It is important to note that **organic bread is not fortified with folic acid** (and is exempt from the legal requirement to do so). In Australia, some cereals and juices are also fortified with folic acid.

Folate's bioavailability, the amount absorbed by the body from food, is much higher in its synthetic form (folic acid) than its natural form (folate). Folic acid in fortified foods and supplements can have up to 100% absorption on an empty stomach and up to 85% when taken with food. By comparison, when natural folate from food is consumed, absorption can be as low as 50%.



Figure 6.2.3: Prenatal vitamins are recommended at least one month prior to preconception to build folate stores and prevent neural tube defects.

Food sources and folate content

Without folate **supplementation** it is hard to meet the folate requirements for an adult, let alone the requirements in pregnancy and lactation. For this reason, supplementation is always recommended during pregnancy and often during lactation. Some food sources that contain folate are leafy green vegetables, fruits, wholegrain breads and cereals, legumes, nuts and yeast extracts (e.g. Vegemite). Some specific examples are represented in the table below:

Table 6.2.1: Some examples of folate sources.

Food	Serving Size	Folate Content (µg)	Food	Serving Size	Folate Content (µg)
	15g	100		½ a raw avocado	82
	1 cup (177g)	131		1 medium banana	23.6
	1 cup (30g)	58.2		5g	100

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6.2 Review questions

1. Explain why it is recommended by the World Health Organisation that mothers leave 18 months between pregnancies.

(2 marks)

2. Explain why folate is important for growth.

(2 marks)

3. An ectopic pregnancy can be treated with a drug called methotrexate, which prevents folate absorption in cells and stops rapidly dividing cells and the development of the unviable embryo. It is not recommended for mothers to try and conceive for a minimum period after methotrexate treatment.

   Explain the possible effects for the foetus if the mother does conceive too soon after methotrexate treatment.

(3 marks)

4. In Australia, it is mandated that all bread produced, except organic bread, be fortified with folic acid.

   (a) State **one** group in society that this fortification is targeting.

(1 mark)

   (b) Describe why bread was chosen for folic acid fortification.

(1 mark)

   (c) Explain why folic acid fortification is important for unplanned pregnancies.

(5 marks)

   (d) Name **two** good sources of folate.

(2 marks)

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6.3 Food group recommendations for pregnancy and lactation

Nutrition Understanding

Introduction

The Australian Guide to Healthy Eating (AGHE) is a national food selection guide for Australians to complement Guideline 2 of the Australian Dietary Guidelines, which is "enjoy a wide variety of nutritious foods from these five groups every day." The AGHE groups similar foods together based on the nutrients they supply (see Figure 6.3.1). It also provides information about the various types of foods within each group and the amounts of these foods you should eat daily (see Topic 4: Food Marketing and Nutritional Guidelines Concepts for more information on the AGHE). However, the recommended amounts of some of the groups change for women who are pregnant or who are lactating. Unfortunately, there is a misconception that pregnant women can 'eat for two' but this is not true and can result in excessive weight gain. In general, pregnant and lactating women need to eat some additional serves of certain food groups but overall, they require more **nutrient dense** foods. The five food groups of the AGHE are:

1. Vegetables and legumes/beans
2. Fruit
3. Grain (cereal) foods (mostly wholegrain)
4. Lean meats, poultry, fish, eggs, tofu, nuts and seeds, and legumes/beans
5. Milk, yoghurt, cheese and/or alternatives (mostly reduced fat).

Recommended nutritional changes during pregnancy

During pregnancy there are two main food groups that have increased requirements (see Table 6.3.1):

- The servings of **grains** increase to provide the **extra energy** required during the second and third trimesters.
- The servings of **lean meats, fish, and alternatives** increases to provide the **extra protein and micronutrients,** such as iron, iodine and vitamin B12.

Table 6.3.1: The recommended servings of food groups for women and the serving increase during pregnancy (highlighted).

Food Group	Woman <18 years old	Woman 19-50 years old	Pregnancy <18 years old	Pregnancy 19-50 years old
Vegetables & legumes	5	5	5	5
Fruit	2	2	2	2
Grain (cereal) foods (mostly wholegrain)	7	6	8	8.5
Lean meat & alternatives	2.5	2.5	3.5	3.5
Milk/cheese & alternatives	3.5	2.5	3.5	2.5

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Figure 6.3.1: The Australian Guide to Healthy Eating 2013.

Did you know?

The types of foods the mother eats during pregnancy could shape the food preferences of her child later in life. Developing foetuses are surrounded by amniotic fluid and their taste buds develop at approximately 13 to 15 weeks. The foetus swallows small amounts of the amniotic fluid each day and this is sometimes referred to as its 'first food.' The amniotic fluid contains a complex mix of chemicals that provide taste and smell. This evolutionary process allows babies to develop their flavour awareness months before being born. Scientists have shown that the amniotic fluid reflects the mothers' diet by extracting samples of amniotic fluid from mothers 45 minutes after eating specific foods, such as garlic, mint, aniseed and carrot. Participants in the study were required to smell the amniotic samples and determine what it smelt like. The participants were clearly able to correctly identify the smell of the amniotic fluid samples. Studies have also shown that foetuses will increase the amount of amniotic fluid swallowed when it is sweet and less when it is bitter. This highlights how the mother's diet during pregnancy could shape a child's food choices in the future, especially as scientists have determined that food memories are formed prior to birth. This means that a mother who eats a lot of Brussels sprouts during pregnancy is more likely to have a child who likes Brussels sprouts. Interestingly, one particular study required pregnant women to drink 300mL of carrot juice for a few days during the last three weeks of pregnancy. The babies who had tasted carrot in utero ate more carrot during weaning than babies who were not exposed to carrot juice in the amniotic sac.

Recommended nutritional changes during lactation

Two food groups have an increase in the recommended servings during lactation for mothers over the age of 18; with three food groups having an increase for mothers under 18 years of age (see Table 6.3.2):

- The servings of **vegetables and legumes** increase to provide the **extra energy and micronutrients,** such as iron, iodine and folate.
- The servings of **grains** increase to provide the **extra energy** required during this time.
- The servings of **dairy products** increase for females **under the age of 18** to provide **calcium** for the development of a teenager's bones as well as the baby.

More energy is required by the mother during lactation than pregnancy.

Table 6.3.2: The recommended servings of food groups for women and the serving increase when lactating (highlighted).

Food Group	Woman <18 years old	Woman 19-50 years old	Breastfeeding <18 years old	Breastfeeding 19-50 years old
Vegetables & legumes	5	5	5.5	7.5
Fruit	2	2	2	2
Grain (cereal) foods (mostly wholegrain)	7	6	9	9
Lean meat & alternatives	2.5	2.5	2.5	2.5
Milk/cheese & alternatives	3.5	2.5	4	2.5

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6.3 Review questions

1. State if the following statements are true or false and explain why.

   (a) During pregnancy, the servings of grain foods increase to supply energy for the development of breast milk.

   (2 marks)

   (b) During the first trimester of pregnancy, the nutrient requirements of the mother increase.

   (2 marks)

   (c) During lactation, the servings of dairy products stay the same for females under the age of 18.

   (2 marks)

   (d) During lactation, the fruit and vegetable servings increase to provide extra lipids for cellular use.

   (2 marks)

Refer to Tables 6.3.1 and 6.3.2 on pages 282 and 284 to answer question 2.

2. Use data to compare **and** explain the amount of serves of grains for a female aged 18 during pregnancy and during lactation.

   (3 marks)

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6.4 Nutrition during pregnancy and lactation

Nutrition Understanding

From conception, the foetus uses nutrients consumed by the mother and is fully dependent on her. The mother's body naturally prioritises the foetus and provides it with the nutrients it requires at the expense of her own health. This means that the mother needs to consume extra nutrients (see Figure 6.4.1) and any malnutrition in the mother's diet will also cause the same malnutrition in the growing foetus. During pregnancy the woman's body experiences some drastic changes that require extra nutrients, including:

- The mother's blood volume increases 1½ times its normal volume to carry the extra nutrients to the foetus and extra tissues
- The placenta forms
- The uterus and supporting muscles increase in size
- The breasts enlarge in preparation for lactation.

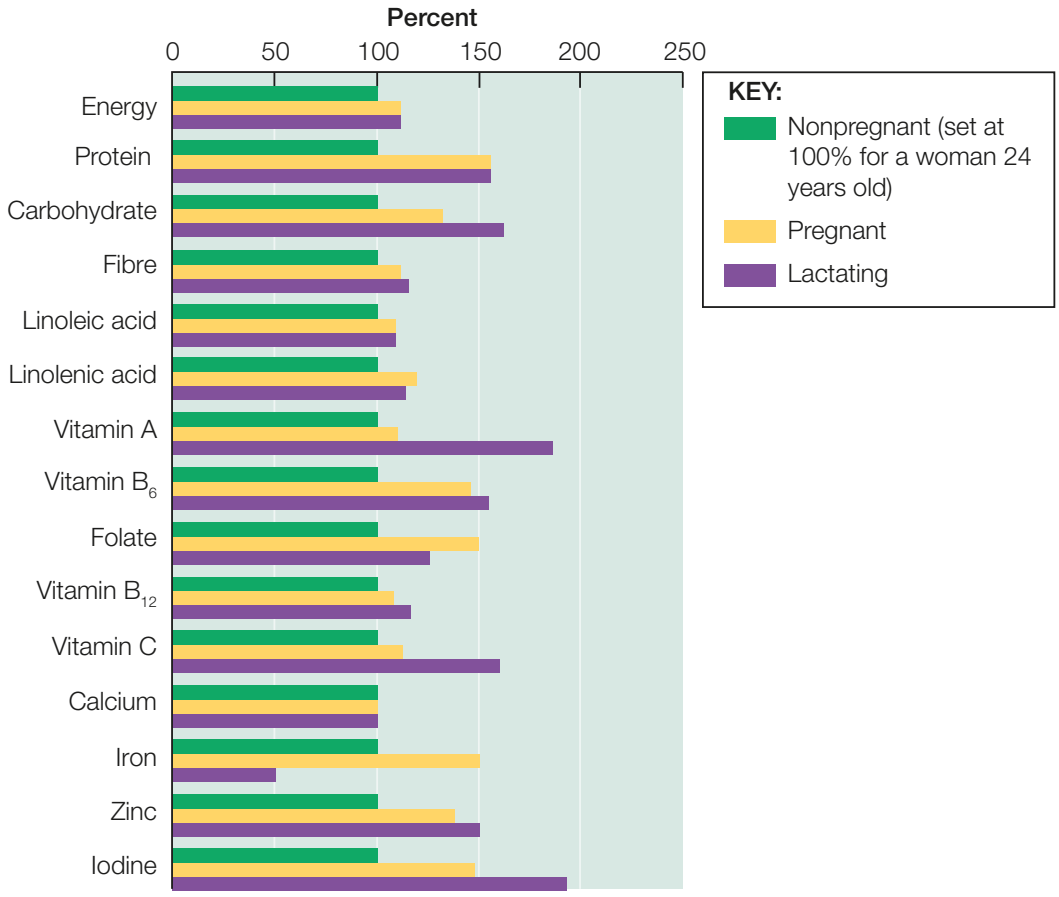


Figure 6.4.1: A comparison of selected nutrient recommendations for non-pregnant, pregnant and lactating women.

Helpful online resources

SciShow: How Pregnancy Is Like Growing an Alien Inside You

https://www.youtube.com/watch?v=OwrjBiW3suM

SciShow: 3 Weird Things That Happen When You're Pregnant

https://www.youtube.com/watch?v=NY209Le027I

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Energy and carbohydrates

As mentioned previously, there is a misconception that pregnant women can eat for two; however, this can lead to an excess energy intake and contribute to excessive weight gain, especially in the first trimester. **Carbohydrates** are the **primary energy source** and it is recommended that the increased energy is provided by increasing grain servings.

It might surprise some that there is actually **no increased energy requirement during the first trimester**; however, there is an increased requirement of micronutrients**.** This means that it is important that the mother is not consuming 'empty carbohydrates' regularly and consumes more nutrient dense foods. 'Empty carbohydrates' are foods that contain carbohydrates but no or little micronutrients; for example, sweets and soft drinks. **Extra energy is needed during the second and third trimesters and lactation** as the basal metabolic rate (BMR) increases in the mother (see Table 6.4.1 for the increased energy requirements during pregnancy and lactation).

It is essential that the mother consumes enough carbohydrates to fuel the growing brain of the foetus. If the mother does not consume enough carbohydrates, the protein consumed will be converted into glucose to supply the foetal brain with energy and this could result in a deficiency of protein needed for foetal growth. Furthermore, women who exercise a lot during pregnancy and lactation need to ensure that the increased needs of both pregnancy and exercise are accounted for. Lactating mothers require extra carbohydrates to provide the lactose in breast milk for the infant.

Table 6.4.1: The increased energy requirements during the three trimesters of pregnancy and lactation.

Stage	Increased Energy (kJ) per day
First Trimester	0
Second Trimester	1,400
Third Trimester	1,900
Lactation	2,000

Gestational diabetes

During pregnancy some mothers can develop a condition called gestational diabetes because their body cannot produce enough insulin to support the carbohydrates being consumed. Between 2% and 10% of expectant mothers develop this condition, making it one of the most common health problems of pregnancy. Diabetes is complicated, but in a nutshell, it means someone has abnormally **high levels of sugar in their blood**. The digestive system breaks down most of the carbohydrates consumed into glucose. The glucose is absorbed into the bloodstream and insulin, which is a hormone made by the pancreas, communicates to the liver and muscle cells to absorb glucose from the blood. However, if the body's pancreas cannot produce enough insulin to support the body, or the liver and muscle cells don't respond to the insulin, the glucose remains in the blood and this can lead to other complications, such as high blood pressure, increased infection and damage to the internal lining of blood vessels.

As pregnancy progresses, the **placenta grows and releases an increased amount of hormones that block insulin**, increasing insulin resistance. This means that the mother's body cannot absorb all the glucose and it remains in the blood. This is a normal part of pregnancy and occurs because the developing foetus requires lots of glucose and increasing insulin resistance means there is more glucose available in the mothers blood for the foetus. For most pregnant women these changes do not cause concern, however, in some pregnant women, the pancreas cannot keep up with the increased insulin demand and their blood glucose levels rise too high, resulting in gestational diabetes. Most cases of gestational diabetes can be **managed with a change in diet** that restricts carbohydrate intake but sometimes women may require medication to manage the condition. Uncontrolled gestational diabetes can cause complications in the foetus. If the mother continues to consume too many carbohydrates, it puts pressure on the foetus' pancreas to increase insulin production and this results in the foetus storing additional weight (see Figure 6.4.2). Unmanaged gestational diabetes is associated with increased birth weight, increased likeliness of a caesarian section delivery (due to a large baby), premature birth and increased risk of the infant developing diabetes and/or obesity later in life.

Gestational diabetes is temporary and most women's response to carbohydrates returns to normal after the baby is born. However, if a woman experiences gestational diabetes, she is also more likely to experience it again in future pregnancies and to develop type 2 diabetes later in life. In fact, a woman diagnosed with gestational diabetes in pregnancy has a 1 in 2 chance of developing type 2 diabetes within ten years of giving birth.

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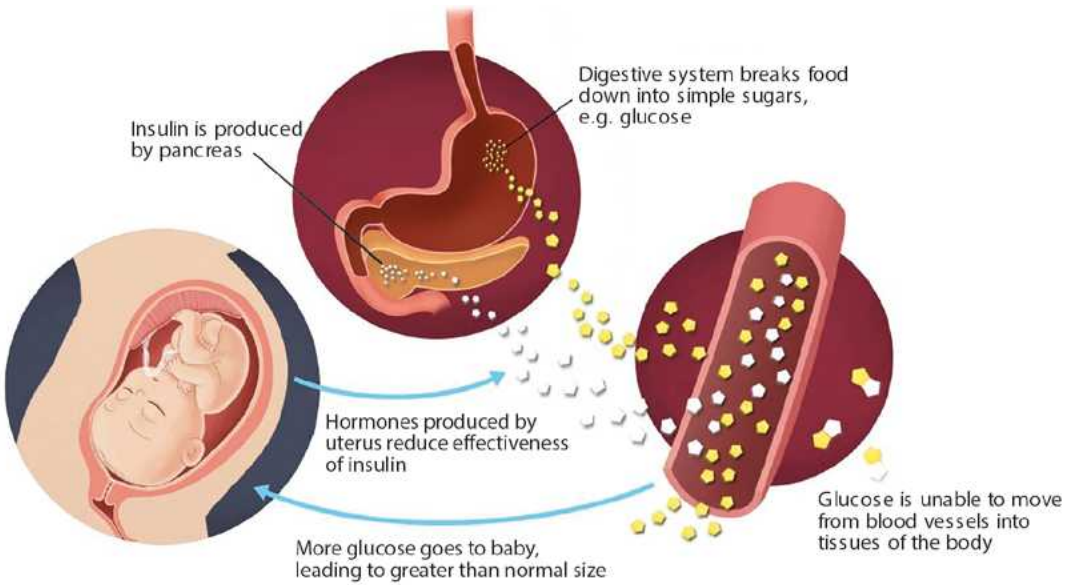


Figure 6.4.2: Gestational diabetes results in higher blood glucose levels and the baby taking in extra glucose resulting in an above average birth weight.

Helpful online resources

Medical Centric: Gestational Diabetes: Everything You Need to Know

https://www.youtube.com/watch?v=BMGDcnZexjY

CS Possible Case Study 6

Design an appropriate diet for a pregnant woman in her third trimester with gestational diabetes, whilst incorporating suitable food safety measures.

Protein

Proteins are long chains of amino acids that are broken down into their building blocks, amino acids, by the digestive system and transported to the body's cells to make proteins for **growth**. The mother's body supplies the amino acids to the foetus for the production of proteins associated with making new cells. Higher intakes of protein are also required for growth of the placenta, breasts, uterus and increased red blood cell production. It is not recommended to take protein supplements during pregnancy because too much protein can be harmful to foetal development. The following table highlights the increased protein requirements:

Table 6.4.2: The increased protein requirements during the three trimesters of pregnancy and lactation.

Stage	Increased Protein Required per day (g)	Total Protein Required per day (g)
First Trimester	0	46
Second Trimester	14	60
Third Trimester	14	60
Lactation	21	67

Recall that there are 20 different amino acids that make up proteins and nine of them are essential, meaning our body cannot make them and they have to be consumed. Animal products (except gelatin) contain all nine essential amino acids (EAAs). However, almost all plant-based proteins do not contain all nine EAAs. Some exceptions are soy and quinoa. Plant-based proteins therefore have **limiting essential amino acids.** This means that multiple types of plant-based proteins must be consumed to obtain all the EAAs. These are referred to as **complementary proteins.** This is especially important for **vegans and vegetarians** to understand and manage, especially throughout pregnancy. Some examples of complementary proteins can be seen in Table 6.4.3.

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Table 6.4.3: Examples of limiting amino acids and complementary foods.

Food	Limiting Amino Acid(s) in Food	Complementary Foods
Beans	Methionine	Grains (rice), nuts, seeds
Grains (rice)	Lysine, threonine	Legumes (peas, lentils, peanuts...)
Nuts and seeds	Lysine	Legumes (peas, lentils, peanuts...)
Vegetables	Methionine	Grains, nuts. seeds
Corn	Tryptophan, lysine	Legumes (peas, lentils, peanuts...)

Essential fats

Recall that there are two categories of essential fats: **omega-6 and omega-3**. One example of an omega-6 fatty acid is arachidonic acid (ARA) and this fatty acid is important for the development of the foetal brain and other vital organs. ARA is commonly found in meat and vegetable oils and most Australian women consume enough omega-6 fatty acids to meet the body's needs. One example of an omega-3 fatty acid is docosahexaenoic acid (DHA) and this fatty acid is **vitally important** for the **brain and retina**, which is important in the development of cognitive and visual function. Both ARA and DHA are important in cerebral, cardiovascular and immune functions and they play important roles in the prevention of chronic diseases. DHA is commonly found in fatty fish, such as salmon. During pregnancy, the consumption of fatty fish, such as salmon, is beneficial and encouraged but it should only be consumed within the recommended limits and quantities to ensure too much mercury is not consumed (the consumption of too much mercury during pregnancy is dangerous for a developing foetus – refer to Topic 8.2 – Food contamination, for more information).

Alpha-linolenic acid (ALA) is the primary member of the omega-3 family (see Figure 6.4.3). ALA can be found in chia seeds, flaxseeds and walnuts, among other sources. Our bodies are able to convert the omega-3 ALA into the other omega-3 fats, such as DHA and EPA but it is not very efficient at doing so (approximately 10% efficiency). DHA and EPA are better sourced from fatty fish, such as salmon, therefore **vegans** may find it harder to consume enough for them and their developing baby. Omega-3 fatty acids are naturally found in breast milk and are important for the visual and neurodevelopment of the baby, especially over the first 12 months. In some cases it may also be beneficial for a breastfeeding mother to take omega-3 supplements because DHA in the breast milk is dependent on the mother's diet but a medical professional should always be consulted before making this decision. The values in Table 6.4.4 are the fatty acid quantities recommended during pregnancy and lactation by the Australian Government National Health and Medical Research Council.

Table 6.4.4: The recommended essential fatty acids by the Australian Government National Health and Medical Research Council during pregnancy and lactation.

Stage	Omega-6 (g) per day	ALA (omega-3) (g) per day	DHA and EPA (omega-3) (mg) per day
Woman over 18	8	0.8	90
Pregnancy	10	1.0	115
Lactation	12	1.2	145

Types of Omega 3 fatty acids

ALA	EPA	DHA
(Alpha-linolenic acid)	**(eicosapentaenoic acid)**	**(docosahexaenoic acid)**
Health benefits are less than EPA and DHA	**Reduces inflammation**	**Improves nervous function**
Simplest form of Omega 3	Complex omega 3 with 5 double bonds	Complex omega 3 with 6 double bonds
Available in plant foods as well as animal foods	Mainly obtained from animal sources (fish oil) with few plant sources	Only obtained from animal sources (fish oil)
Flaxseeds, flaxseeds oil, pumpkin seeds, walnuts are rich sources of ALA.	Health benefits of EPA and DHA are superior to ALA.	Plant sources don't provide DHA.

Figure 6.4.3: A summary of the types of omega-3 fatty acids.

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Science as a Human Endeavour 13

Omega-3 Canola

As the omega-3 fatty acid DHA is only found in animal products, such as fatty fish, vegans are at a higher risk of being deficient in DHA. However, in the future this could be less of an issue. Scientists in Australia have had some success in genetically engineering canola crops to secrete DHA oil instead of canola oil. The crop is called Omega-3 Canola and it is the first genetically modified crop created entirely by Australian scientists. The Australian scientists have achieved it by using gene technology to insert specific genes from marine microalgae into canola crops. The crops could provide an alternative source to deep-sea fish in providing DHA for fish oil supplements. Food Standards Australia and New Zealand (FSANZ) have concluded that there are no public health or safety issues associated with Omega-3 Canola but they have not permitted its use for supplementation in formula products. This is not because of an identified safety concern but rather because of a lack of data to confirm safety.

Omega-3 Canola could be a suitable DHA option for vegans because no animals are harmed in its production. In fact, the seeds from one hectare of the Omega-3 Canola crop provide approximately the same amount of DHA as 10,000kg of wild fish. An application for Omega-3 Canola to be grown in Australia has been submitted to the Office of the Gene Technology Regulator, which has currently approved a field trial. Omega-3 Canola will be commercialised by a company called Nuseed Pty Ltd, which initially plans to release an aquaculture feed to supply to fish farmers. This is because fish rich in omega-3, like salmon, require a substantial amount of omega-3 in their diet and this is usually sourced from ocean stocks. Nuseed Pty Ltd also plans to release a human nutrition product in the future named Nutriterra.

Questions

1. Explain two **limitations** of Omega-3 Canola.

(4 marks)

2. Discuss how the approval to grow and harvest Omega-3 Canola in Australia could **influence** society.

(4 marks)

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Folate

Table 6.4.5: The increased folate requirements during pregnancy and lactation.

Stage	Folate per day (µg)
Woman over 18	400
Pregnancy	600
Lactation	500

As previously mentioned in Topic 6.2: Nutrition during preconception, folate is important in the early stages of pregnancy to prevent neural tube birth defects, such as spina bifida. However, **increased folate is important during all of pregnancy and lactation** because it is required for the synthesis of new DNA and cells. There is growing research that a lack of folic acid during early pregnancy can also lead to **congenital birth defects such as cleft lip and cleft palate** (see Figure 6.4.4). In fact, the risk of congenital birth defects is approximately four times higher if the mother does not consume the recommended amount of folate in the **first three months**. This is another reason why folic acid supplementation is recommended during the month prior to conception and throughout the first trimester. There is also some research suggesting folate taken before and during pregnancy can reduce the risk of neurodevelopmental issues, such as autism.

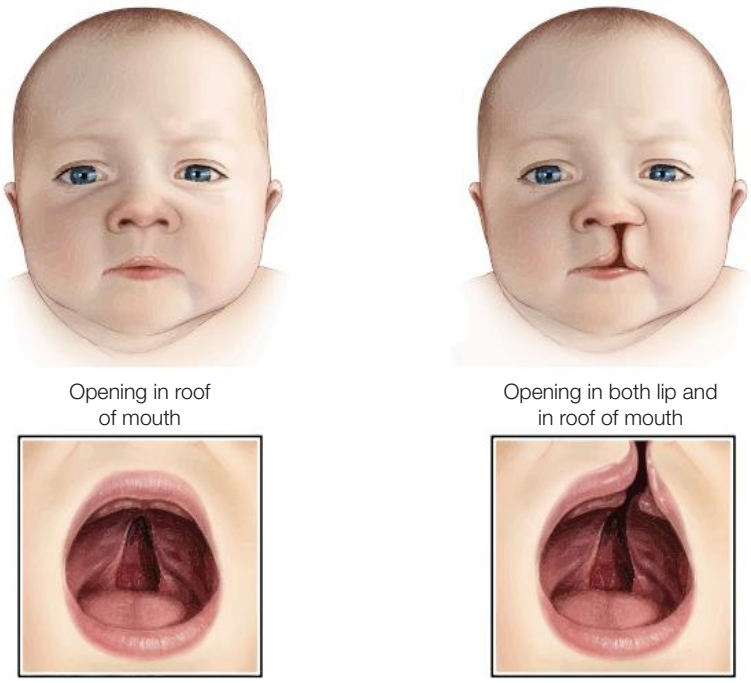


Figure 6.4.4: Folate deficiency during the first three months of pregnancy can contribute to cleft palate (left) and cleft lip (right).

Vitamin B12

Table 6.4.6: The increased vitamin B12 requirements during pregnancy and lactation.

Stage	Vitamin B12 per day (µg)
Woman over 18	2.4
Pregnancy	2.6
Lactation	2.8

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Vitamin B12 works together with folate in the **synthesis of DNA and RNA.** These two vitamins are dependent on each other to convert into their activated forms and help synthesise DNA and RNA that is essential for cell division associated with the growth of a developing foetus. Furthermore, vitamin B12 helps to maintain the myelin sheath surrounding nerve cells and **promotes normal nerve cell growth** (see Figure 6.4.5).

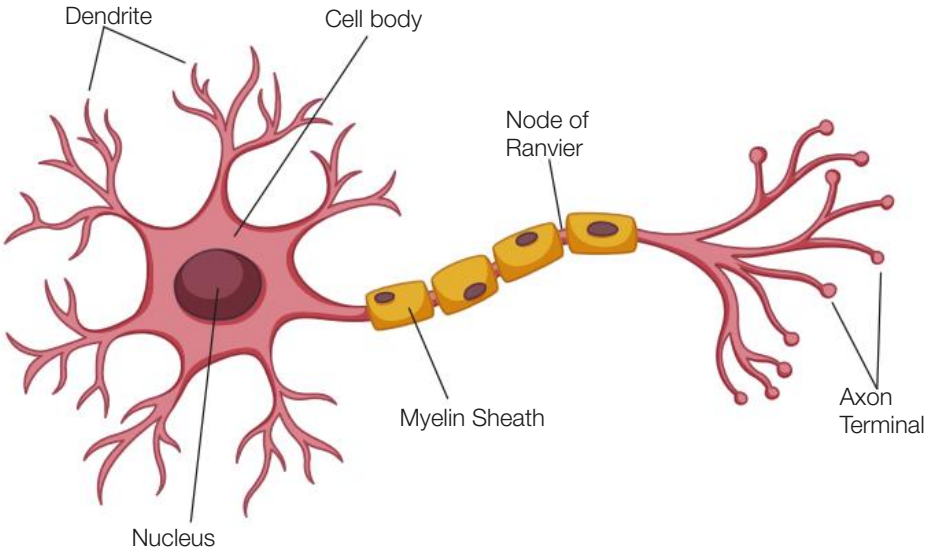


Figure 6.4.5: Vitamin B12 helps maintain the myelin sheath of nerve cells, promoting normal nerve cell growth.

Vitamin B12 is only found in **animal products,** such as meat, dairy and eggs. **Vegans** are highly likely to become deficient in vitamin B12 and also experience vitamin B12 deficient anaemia when pregnant because they are more likely to exhaust their stores of vitamin B12. This means **supplementation is required** for vegan mothers-to-be. It is important for vitamin B12 deficiency to be identified because it is essential for DNA synthesis and maintains healthy myelin sheaths, which protect nerve cells. If it is not identified and treated it can lead to devastating neurological symptoms, such as permanent nerve damage and paralysis. It can also result in **irreversible neurological damage to the developing baby.**

Vitamin B12 is constantly secreted in the bile, which is produced by the liver into the small intestine and reabsorbed. Because it is reabsorbed, vitamin B12 deficiency can take a long time to develop symptoms, potentially delaying diagnosis. Furthermore, symptoms are similar to those of folate deficiency, which can mask the symptoms of vitamin B12 deficiency or result in a misdiagnosis.

Iron

Table 6.4.7: Iron requirements during pregnancy and lactation.

Stage	Iron per day (mg)
Woman over 18	18
Pregnancy	27
Lactation	9

During pregnancy **iron requirements increase by 50%** to support the growing placenta, the increased blood volume and the developing foetus. Even though less iron is lost during pregnancy due to the lack of menstruation, most women do not have enough iron stores to last them through pregnancy and lactation. This is especially important for those whose diet is low in iron prior to conception. It is also important to note that the mother provides enough iron stores to the developing foetus during pregnancy so that when the baby is born, the **newborn has enough iron stores to last the first four to six months of its life.** After four to six months, newborns generally commence eating solids, enabling them to source iron from solid food. Even if the mother is low in iron, her body will prioritise the developing foetus and transfer iron stores to the baby at her detriment. The mother will also lose blood, and therefore iron stores, during the birth of the baby (regardless of whether birth is by vaginal delivery or caesarian section).

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Technically, only 1mg of iron is needed normally per day and 1.5mg during pregnancy per day; however, because **iron is not well absorbed by the human body**, a much greater amount of iron needs to be consumed to ensure the required amount is absorbed.

To support the increase in iron requirements, **iron absorption increases during pregnancy.** This is due to an increase in production of the protein transferrin that carries and absorbs iron. Iron supplementation may still be necessary for some women but this can lead to constipation in some, which pregnant women are already prone to. For this reason, supplementation is not generally recommended unless a woman is deficient, however, iron is often included in pregnancy multivitamins. Advice from a medical professional should always be sought prior to taking supplements.

Iron absorption can also depend on the type of food eaten. There are two forms of iron: **haem** and **non-haem** iron (see Figure 6.4.6). Haem iron is only found in animal meats, such as beef, pork, lamb and poultry. Animal meats also contain non-haem iron. However, plant-based products only contain non-haem iron. Haem iron is more readily absorbed by humans (approximately 25% absorption) than non-haem iron (approximately 17% absorption). The majority of iron we consume is non-haem iron. Because **vegan diets only contain non-haem iron**, vegans should be especially aware of foods that are high in iron and techniques that can promote iron absorption. One way to **increase non-haem iron absorption** is to consume the source of iron with **vitamin C.**

One of the greatest sources of iron is liver. This is because a lot of blood flows through the liver. However, liver should be avoided when pregnant because it is also rich in vitamin A, which is a fat-soluble vitamin that can be stored and generally builds up in the liver. Vitamin A is still necessary for vision development and immune functions in the developing foetus but **too much vitamin A can lead to serious birth defects.**

There are also some foods and drinks that can **reduce** the absorption of iron. Some examples are:

- Tea, coffee and other caffeinated drinks
- Soy products
- Calcium
- Eggs
- Fibre (cellulose)
- Phytic acid (e.g. from seeds/legumes)

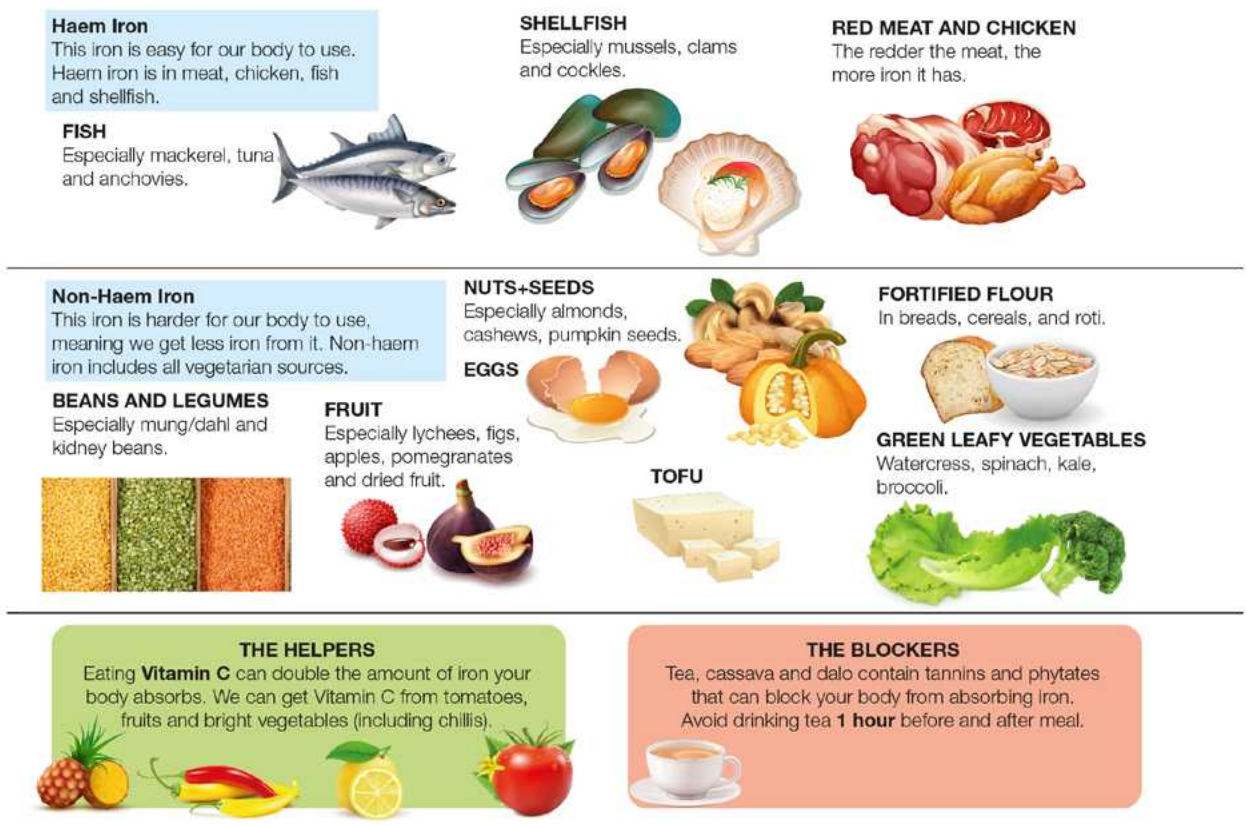


Figure 6.4.6: Some sources of haem and non-haem iron.

Anaemia

It is common for pregnant women to have mild anaemia during pregnancy but severe anaemia can result in complications. As pregnancy requires additional red blood cells to carry oxygen to the baby, **anaemia can delay the development of the foetus**. It can also result in the baby being **born prematurely**, resulting in a low birth weight. The baby could also be born with anaemia. **For more information on anaemia, refer to Topic 2.7 Anaemia on page 145**.

Calcium

Table 6.4.8: Calcium requirements during pregnancy and lactation.

Stage	Calcium per day (mg)
Woman over 18	1,000
Pregnancy	1,000
Lactation	1,000

Calcium is important for the **growth of healthy bones and teeth and regulating muscle contraction and relaxation, including heart muscle**. Under normal circumstances, only about 30% of the dietary calcium consumed is absorbed by the average adult. **Calcium requires vitamin D** to be absorbed across the intestines, in fact, calcium cannot be absorbed at all without some vitamin D. If enough vitamin D is not available, less than 30% of the calcium consumed is absorbed. As noted in Table 6.4.8 above, the amount of calcium recommended to be consumed by a woman per day does not increase during pregnancy or lactation. Although additional calcium is required to support the growth and development of a healthy baby, during pregnancy and lactation a woman's body becomes **more efficient at absorbing calcium from the diet.** During pregnancy and lactation, calcium absorption increases from 30% to approximately 50%.

It is important to note that there is no relationship between the mother's calcium intake and the quality of breast milk. A low intake of calcium will not affect the calcium content of the breast milk because the body will source calcium from the mother's calcium reserves if supply is insufficient. This may have long term adverse effects on the mothers' **bone density** and increase her risk of developing **osteoporosis** later in life (see Topic 2.8 Osteoporosis on page 150 for more information). Fortunately, during pregnancy and lactation the mother's body also becomes more efficient at replacing calcium stores in the bones to help minimise bone loss. It should be noted, a lack of vitamin D may affect the absorption of calcium by the mother or her infant (thereby resulting in a calcium deficiency), even though they consuming sufficient calcium.

Calcium deficiency can compromise normal bone formation as calcium is needed to form the hard structure of the bone. A calcium deficiency during pregnancy and lactation can contribute to the development of **rickets** in babies. . Rickets is a disease where the bones fail to develop properly because there is not enough calcium. This results in skeletal abnormalities such as bowed legs. The bone deformities generally start to appear before the age of 18 months. In breastfed infants, rickets is generally the result of a deficiency of vitamin D, which is required for the absorption of calcium. However, calcium deficiency can occur in infants who do not feed sufficiently or bottle-fed infants where the formula concentration is miscalculated consistently.

Some examples of good sources of calcium are:

- Dairy products, such as milk, cheese and yoghurt
- Sesame seeds and poppy seeds
- Almonds
- Sardines (with bones)
- Seaweed
- Tofu
- Dark green vegetables, such as broccoli, kale and bok choy
- Fortified milk alternatives, such as soy milk.

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Vitamin D

Table 6.4.9: Vitamin D requirements during pregnancy and lactation.

Stage	Vitamin D per day (µg)
Woman over 18	5
Pregnancy	5
Lactation	5

Vitamin D is equally important for strong bones as calcium. The main role of vitamin D is to control blood concentrations of calcium and phosphorus for **bone formation and maintenance**. Vitamin D increases the absorption of calcium in the small intestine and mobilises calcium from bones to increase concentration in the blood when required. Vitamin D can be sourced from the **diet** and through **sunlight exposure.** Exposure to sunlight for about **10 minutes per day** in Australia can provide most individuals with their recommended intake. Some foods that naturally contain vitamin D include seafood (including salmon, halibut, herring, tuna, Atlantic mackerel, oysters and shrimp), cheese and egg yolks. In Australia, it is mandated that **margarines are fortified with vitamin D** and it is optional for some other products to be fortified with vitamin D, including milk, juice, soymilk and dairy products. Vitamin D is also available as a **supplement.**

As vitamin D is important for calcium absorption, a deficiency in vitamin D also results in a **deficiency of calcium**. This can compromise normal bone formation as calcium is needed to form the hard structure of the bone. A deficiency of vitamin D during pregnancy and lactation can cause **rickets** in infants and increase the risk of reduced bone density and osteoporosis for the mother. Rickets is a disease where the bones fail to develop properly because there is not enough calcium absorption. This results in skeletal abnormalities such as bowed legs.

Did you know?

Rickets is a preventable bone disease that results from a lack of vitamin D and causes delayed growth and skeletal deformities. Even though Australia is a very sunny country, rickets cases in Australian children have been rising. It is estimated that 10% of babies are vitamin D deficient in Australia. This can develop from the mother during pregnancy but it can also continue into infancy because breast milk is not a good source of vitamin D. Doctors are concerned that vitamin D deficiency in infants is going undetected and are calling for a public health campaign. In the UK, there is clear advice for mothers to take vitamin D supplements during pregnancy and for infants to be supplemented for the first 12 months.

Iodine

Table 6.4.10: The increased iodine requirements during pregnancy and lactation.

Stage	Iodine per day (µg)
Woman over 18	150
Pregnancy	220
Lactation	270

Iodine is an essential trace mineral that the body needs to make a hormone in the thyroid called thyroxine (also known as T4). Thyroxine is an important hormone for the regulation of metabolism, thermoregulation (controlling body temperature) and growth. Thyroxine is released into the blood to communicate with cells to increase metabolism. This results in an increase in chemical reactions, such as aerobic respiration. When chemical reactions occur, heat is produced as a by-product, which helps keep our body warm. If there is a lack of iodine in the diet, a mother may not be able to produce enough thyroxine, resulting in a decreased metabolism, and insufficient energy available for daily processes or the development of the baby.

During pregnancy and lactation iodine requirements increase by 47% and 80%, respectively. Iodine is essential for the **development of the baby's brain and nervous system** and it is therefore important for mothers to meet the increased requirements during pregnancy and lactation. If the mother is deficient during pregnancy and

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lactation it can result in stunted growth, diminished intelligence and even retardation. Severe iodine deficiency during pregnancy can cause cretinism, which is an **irreversible mental and physical retardation**.

Recently, **mild iodine deficiency has re-emerged in Australia**. Some possible reasons for this are the decreased use of iodised salt in processed foods and cooking at home and restaurants, and less iodine in the soil due to non-sustainable farming techniques. Because mild iodine deficiency is a major public health issue, both Australia and New Zealand have implemented **mandated fortification of bread with iodised salt**. This means that all bread contains iodine except for organic bread, which is exempted from the mandate.

Some good sources of iodine are seafood, dairy products, eggs, fortified bread and iodised salt (see Figure 6.4.7). Australian's have sufficient access to these foods but iodine occurs at low levels in the Australian food supply and varies depending on season and processing practices. Because of this and the serious consequences of deficiency, iodine **supplementation** during pregnancy of 150 micrograms per day is recommended to ensure the baby's demands for growth are met.



Figure 6.4.7: Some examples of sources of iodine.

Zinc

Table 6.4.11: The increased zinc requirements during pregnancy and lactation.

Stage	Zinc per day (mg)
Woman over 18	8
Pregnancy	10
Lactation	11

Zinc is essential for normal growth and development of bones, the brain and many other parts of the body. Over 100 enzymes in the body require zinc, so **virtually all cells contain it**. Zinc is also essential for **DNA and RNA synthesis**. DNA synthesis is required to make new copies of the genetic code prior to a cell dividing into two new cells, so that each daughter cell has an identical copy of the DNA. RNA synthesis is needed for the production of structural and functional proteins within cells so that they can grow and perform their role(s) within the body. As a growing foetus involves rapid cell division, zinc is essential for cell development and growth. Zinc is also very important for **thyroid hormone function** and a zinc deficiency can result in decreased metabolism, thereby decreasing energy availability. As energy is required for cellular processes and cell growth and division, a zinc deficiency can delay/inhibit foetal development.

Zinc is widely available from a variety of foods making it possible for pregnant women to achieve their zinc requirements through diet alone (see Figure 6.4.8 for some examples of foods containing zinc). However, if zinc intakes are lower than recommended in pregnant women, the body is able to increase the amount of zinc absorbed from food. Zinc absorption naturally ranges from 15% to 40% based on the amount our body needs at any given time. Zinc is **more easily absorbed from animal sources**, such as red meat, fish and dairy, and to a lesser extent plant sources, including nuts, legumes and cereals. Supplementation of zinc is not recommended during pregnancy unless women are taking iron supplements because **iron can reduce the absorption and use of zinc**. Zinc is included in some pregnancy multi vitamins.

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Zinc is also essential for the **healthy development of sperm** and it is recommended that males take zinc supplements for **74 to 78 days prior to conception** because this is the time it takes for sperm production.

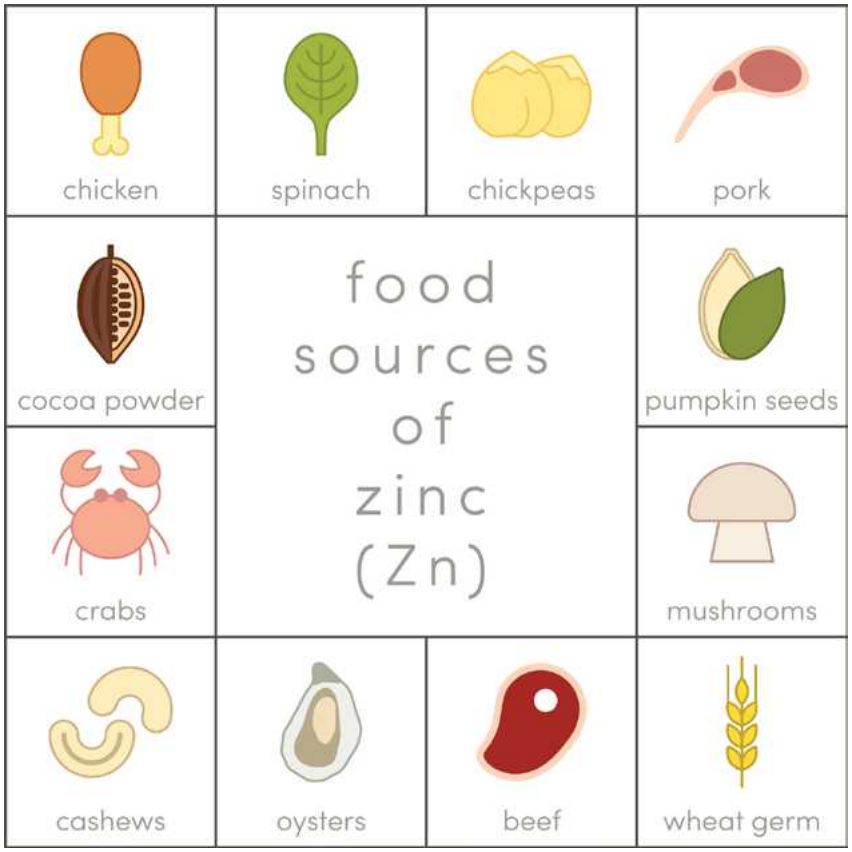


Figure 6.4.8: Some examples of food sources of zinc.

Vitamin E

Table 6.4.12: Vitamin E requirements during pregnancy and lactation.

Stage	Vitamin E per day (mg)
Woman over 18	7
Pregnancy	7
Lactation	11

The main role of vitamin E is its **antioxidant** role in protecting lipids. It is especially important in protecting polyunsaturated fats from oxidation by free radicals. Additionally, it **protects our cell membranes** and vitamin A from oxidation. By protecting vitamin A from being oxidised, vitamin A is able to perform its roles, including improving efficiency of the immune system and preventing infectious diseases. Vitamin E deficiency can lead to the destruction of red blood cells through the oxidation of polyunsaturated fats in their cell membranes. This effectively 'opens up' cells, releasing their contents. This is more likely to occur in infants, especially infants born prematurely. **Vitamin E stores are only provided to the baby by the mother in the last couple of weeks of pregnancy**. If the baby is born early a **vitamin E supplement** is required to prevent red blood cells from being destroyed.

Polyunsaturated fat sources, such as **plant oils**, are generally good sources of vitamin E; however, leafy green vegetables, egg yolks, salmon, nuts and seeds are also good sources of vitamin E. Vitamin E requirements are not increased during pregnancy but they are **increased for women who are breastfeeding** to account for the extra vitamin E provided to the baby in the breast milk. If a woman has given birth but the baby is formula fed and she is not lactating, then there are no increased requirements.

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Vitamin K

Table 6.4.13: Vitamin K requirements during pregnancy and lactation.

Stage	Vitamin K per day (µg)
Woman over 18	60
Pregnancy	60
Lactation	60

The **bacteria in our intestines ferments the fibre we eat producing vitamin K**; however, infants have a severely undeveloped microbiome, which takes approximately two years to establish (see Topic 3: Digestion, Malabsorption and the Microbiome for more information). This means that their body cannot make vitamin K efficiently. The primary function of vitamin K is to assist in **normal blood clotting**. When damage occurs to blood vessels and bleeding occurs, the blood needs to clot to prevent blood loss. If insufficient vitamin K is present and an injury occurs where the blood vessels are broken, it could lead to 'bleeding out', known as haemorrhaging. For this reason, a **vitamin K supplementation** injection is normally given to babies at birth to supply them with months' worth of vitamin K stores. If the parent chooses not to administer the vitamin K supplementation there is an increased risk of vitamin K deficiency bleeding (VKDB) occurring in the infant. VKDB can be very serious and lead to **bleeding into the brain** resulting in **brain damage** to the infant and potentially result in **death**.

The microbiome provides us with a lot of vitamin K but it can also be sourced through our diet. Vitamin K is commonly found in leafy green vegetables and liver. Currently, there is no data that suggests increased vitamin K requirements during pregnancy or lactation.

Water

Table 6.4.14: The increased water requirements during pregnancy and lactation.

Stage	Water per day (L)
Woman over 18	2.1
Pregnancy	2.3
Lactation	2.6

Water is an **essential nutrient** that is more important for the body than any other. This is because it is needed for many different processes and provides the environment for many reactions. Without water, we can only survive a few days, whereas we can survive a deficiency of any other nutrient for months or even years. Our bodies are made up of roughly 60% water. This means that a 70kg person contains roughly 41kgs of water.

A person's **body composition** influences how much water makes up the individual. The water proportion is generally less in females, the elderly and those who are obese. This is generally due to lower amount of lean body tissue. Water makes up approximately 75% of the weight of lean muscle tissue and roughly 25% of fat tissue.

During pregnancy, extra water is needed to provide a sufficient amount to the **developing foetus**, for the **increased blood supply** and to provide the fluid for the growing **amniotic sac** (see Figure 6.4.12). The amniotic sac is a fluid filled sac that has many functions, including protecting the foetus in the womb by cushioning it from impacts and keeping the foetus warm. The fluid in the amniotic sac is constantly being replaced, which requires additional water intake daily. Additional water is also needed to make **breast milk** during lactation. Water accounts for approximately 87% of breast milk, which is provided to the infant during breastfeeding. In the first six months after birth, mothers produce 0.8L of breast milk per day on average.

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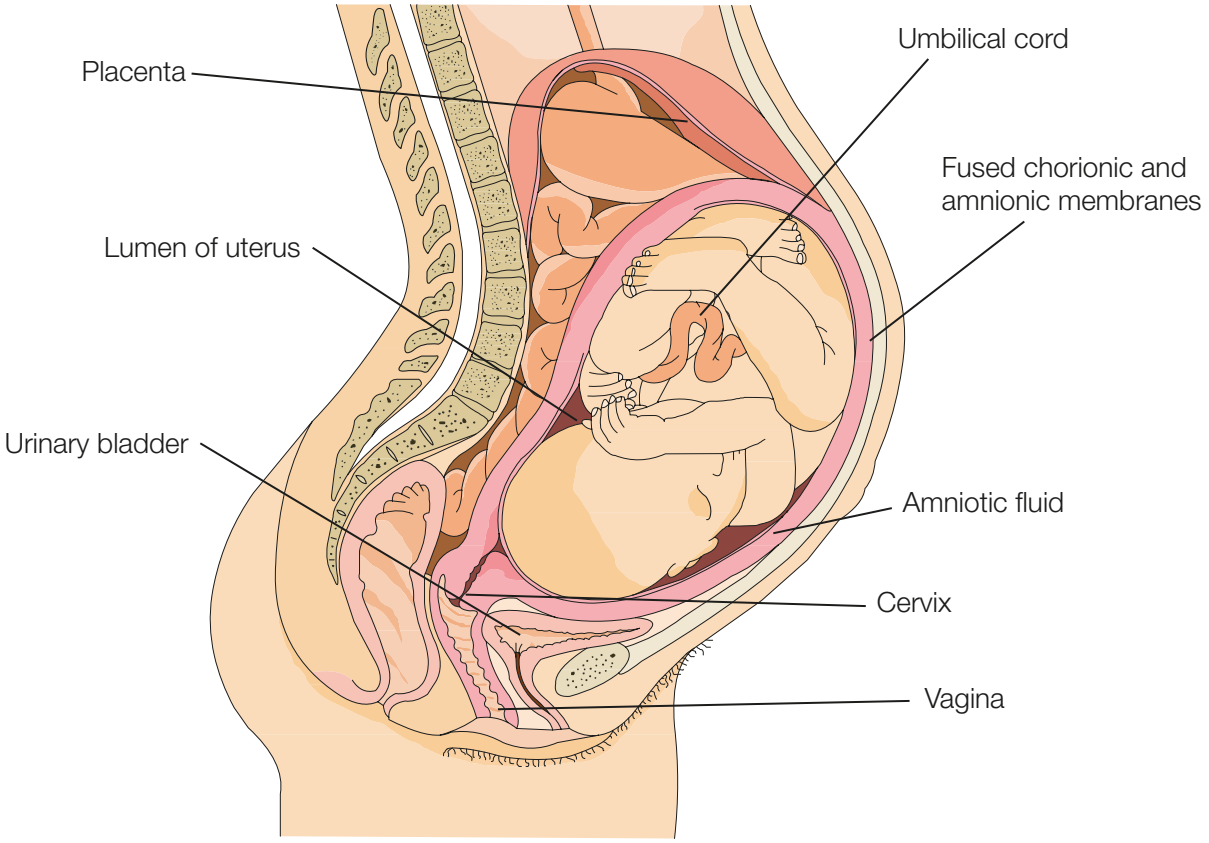


Figure 6.4.12: The amniotic fluid is mainly comprised of water and protects the foetus from impacts by cushioning bumps.

Caffeine



Figure 6.4.13: Coffee contains caffeine that can cross the placenta.

Caffeine is a chemical that is found in foods and drinks such as coffee, tea, cola, chocolate and energy drinks. Under normal circumstances, a maximum of 400mg is recommended per day for individuals aged 18 and over. However, during pregnancy and breastfeeding a maximum of 200mg is recommended per day (see Table 6.4.15 for quantities of caffeine in various drinks). This is because it takes the mother longer to breakdown caffeine during pregnancy and **caffeine can cross the placenta**. During lactation, caffeine can be present in the breastmilk and infants cannot process it as quickly as adults. There is also a possible risk of complications to the foetus if excess caffeine is consumed.

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Caffeine is a stimulant that acts on the nervous system and can cause a rise in heart rate and blood pressure. These two functions need to be maintained at healthy levels during pregnancy, especially considering blood pressure naturally increases during pregnancy. Caffeine can also **interfere with iron and calcium absorption**, reducing the bioavailability of these minerals for the mother and baby.

There does not appear to be a link between caffeine and birth defects, but one study has linked excess caffeine consumption with lower birth weights, which is associated with both short and long-term health issues. There is also a possibility that excess consumption could increase the risk of miscarriage. Therefore, it is safest to limit caffeine intake to the recommended amounts. **Caffeine can also pass into the breast milk** and to the baby so it should also be limited while breastfeeding. Furthermore, when trying to conceive, high levels of caffeine may affect both sperm and egg development making it more difficult to become pregnant.

Table 6.4.15: The average amount of caffeine in various beverages.

Beverage	Serving Size	Amount of Caffeine (mg)
Espresso	50mL	145
Mountain Dew	600mL	91
Nespresso capsules (except Kazaar)	1 capsule	55–65
Brewed black tea	250mL	55
Brewed green tea	250mL	25
Lipton Lemon Iced Tea	500mL	21
Instant coffee	250mL (1 teaspoon)	80
Diet Pepsi	600mL	115
Coke	600mL	55
Red Bull	250mL	80

Alcohol

For women who are planning a pregnancy, are pregnant or breastfeeding it is recommended not to drink any alcohol as **no alcohol is the safest option**. Alcohol crosses the placenta to the baby, who has a very limited ability to process the alcohol and this **can cause drastic effects on the development of the foetus**. In 2023, scientists determined that even drinking 12g of alcohol (which is one standard drink) per week during pregnancy, is linked to permanent changes in the developing child's facial features and likely their cognitive development too. Drinking alcohol during pregnancy can increase the risk of:

- Premature birth
- Stillbirth
- Miscarriage
- Birth defects
- Foetal alcohol spectrum disorder (which causes learning and behavioural difficulties and physical impairments).

Alcohol consumption while breastfeeding **can contaminate the breast milk** given to an infant. In fact, the blood alcohol level of the mother's blood is very similar to the concentration of alcohol in the breast milk. If significant amounts of alcohol are consumed by a breastfeeding mother, the infant can experience weakness, drowsiness, decreased growth, altered sleep patterns and delayed developmental milestones. It can also cause decreased milk supply for the mother, making it harder to produce sufficient milk for her growing baby.

Additionally, studies have also shown that males' quality of sperm can be significantly reduced by regular alcohol consumption, making it harder to conceive and increasing the risk of intellectual and physical developmental problems for the resulting child. It is therefore **recommended that males do not drink alcohol for three months** prior to conceiving.

Lactation

The World Health Organisation (WHO) recommends exclusive breastfeeding for the first six months of a baby's life. However, approximately two thirds of infants worldwide do not meet this criterion. The WHO promotes breastfeeding and is working towards the goal of 50% of children being exclusively breastfed for the first six months of life by 2025. They recommend breastfeeding over formula feeding because it is clean and safe, provides all the nutritional

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requirements infants need, and contains antibodies to boost the immune system and defend against infectious diseases. Furthermore, breastfed children can have a lower risk of developing obesity and diabetes later in life and have shown to perform better on intelligence tests. The WHO predicts that over 800,000 children's lives could be saved if they were breastfed optimally during the first two years of life.

Before breast milk is produced, the mother produces a milky fluid called **colostrum**. Colostrum is produced in small amounts, which reflects the small size of a newborn baby's stomach. Even though only a small amount of colostrum is produced it is packed with nutrients and immune cells. Colostrum contains an estimated 1 to 5 million white blood cells per millilitre, which is 100 times more concentrated than the mother's blood. This helps the baby defend itself against foreign pathogens, as its own **immune system is still undeveloped**. Colostrum is also easy for the baby to digest and helps it pass its first stool known as meconium. Colostrum is 10 times higher in vitamin A concentration than mature breast milk and contains greater amounts of zinc and vitamin E, which are required for skin and eye development.



Figure 6.4.14: Breastfeeding provides babies with all their nutritional requirements, passive immunity and can be more convenient than having to sterilise bottles for formula feeding.

Following colostrum production, the mother produces transitional milk within one to three days after giving birth, with mature milk coming in at around day 10 to 14. Mature milk has **all the nutritional requirements** the baby needs for its growth and development and changes according to the baby's developmental needs. For example, after the first year of feeding, the fat content of breast milk increases to reflect the increased energy requirements of the baby. Interestingly, the fat content of breast milk changes during feeds too. At the start of a feed, breast milk is generally 1% fat but this increases to up to 5% fat at the end of the feed. This is because fat is filling, and this helps control the baby's appetite and provide extra energy as the baby grows and feeds more.

Breast milk also contains **hormones** that can influence the baby's development, for example, by triggering developmental milestones. Some of the hormones that breast milk contains are melatonin, which helps the baby's circadian rhythm develop; thyroxine, which helps with controlling metabolism; leptin, which assists in controlling hunger; **endorphins,** which help with **pain** and settling the baby when crying; and **oxytocin**, which relaxes the baby by decreasing heart rate and blood pressure and has a physiological role in **bonding** the mother and baby. The production of oxytocin during breastfeeding has also been shown to decrease the risk of cardiovascular disease for both the mother and baby.

Breast milk is also important for the **development of a healthy gut microbiome.** Microorganisms, such as bacteria, are transferred through the breast milk and through contact with the skin into the baby. These bacteria help maintain a stable environment in the gut, reducing **inflammation** and diseases associated with inflammation, and helping to develop the immune system. Breast milk provides over 150 different types of oligosaccharides (sugars) that are food for different healthy microorganisms in the gut. By providing these sugars, these healthy populations are able to grow, reducing the ability for disease-causing species to thrive (see Topic 3: Digestion, malabsorption and the microbiome for more information). In addition, the mother's body is able to **detect the presence of disease-causing pathogens from the baby's saliva** when it comes into contact with the nipple. Upon detection, an immune response is activated in the mother's body, which produces specific antibodies for the pathogen invading the baby's body. These specific antibodies are then supplied to the baby through the breast milk, allowing the baby to fight off the disease even though its immune system is compromised due to lack of development.

During and after World War II, **formula feeding** became more popular due to more women having to work while their partners were away at war. Formula makers advertised their product as a replacement for breastfeeding and a **more convenient option for busy lifestyles**. This resulted in a significant drop in breastfeeding at the time. Breastfeeding has since increased in the developed world, largely because of the advice of the WHO and other medical advisory boards but this has caused a reduction in profits for formula makers. Consequently, formula makers started advertising their products in developing countries. These advertisements generally use pictures of healthy, chubby Caucasian babies, leading mother's to believe that formula is preferable over breast milk. This unethical and profit driven advertising has targeted poor members of the developing world and resulted in a decrease in breastfeeding worldwide. The use of formula in developing countries is significantly less safe than developed countries due to lack of safe water supply and inability to sterilise the feeding equipment. Contamination

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of formula by diarrhoea-causing pathogens results in dehydration and is the **leading cause of death of infants in developing countries**. These deaths could be prevented by breastfeeding, as unlike formula feeding, breastfeeding does not require the use of potentially contaminated water or sterilisation of feeding equipment.

Mothers also benefit from breastfeeding. In addition to the positive feedback loop resulting in greater oxytocin release and **bonding with the baby**, there are some short and long-term health benefits for the mother. Initially, breastfeeding can help speed up the retraction of the uterus and help to lose excess weight gained during pregnancy. Mothers who do not breastfeed also have an increased risk of breast and ovarian cancer, cardiovascular disease, obesity and type 2 diabetes, amongst other conditions, compared to those who do breastfeed.

There are many reasons a mother may choose not to breastfeed and it is not always possible or practical for a mother to breastfeed her child. Some mothers have difficulty producing breast milk and some infants have trouble latching on or the latching can be too painful for the mother. Others may find it very hard to maintain breastfeeding, as they need to feed the baby every few hours upon demand. This can be very energy draining and tiring, especially combined with the lack of sleep associated with raising infants and/or returning to work. Mothers may also choose not to breastfeed for a variety of reasons and that choice should be respected. In such circumstances, it is appropriate to feed the child formula.

As much as breastfeeding is recommended by the WHO and midwives as preferable to formula feeding, it is most important that the baby is not lacking nutrients. If breastfeeding is not working for a mother it can be very stressful for her and her baby, and formula may be required to ensure the baby is receiving sufficient nutrients and energy. Good quality formula is necessary and sometimes lifesaving when breast milk is not available for whatever reason. **The most important thing is to ensure the baby is receiving sufficient nutrition (through either breast milk, formula or a combination of both)** and putting on the appropriate amount of weight to support development. Parents should make a decision on whether to breastfeed or formula feed their baby based on their individual circumstances and needs in consultation with their medical advisers.

Did you know?

Babies are not born with an innate sense of time. This is generally learnt over time through exposure to sunlight during the day and darkness at night, and possibly breast milk. Human breast milk may help babies set their circadian rhythm and 'tell the time.' The composition of breast milk differs throughout the day. In the morning, breast milk is more energising and contains three times the amount of the hormone cortisol than evening milk. Cortisol is a stress hormone that also promotes alertness and has a role in waking us up and keeping us awake. In contrast, melatonin, which is a hormone that promotes sleep and digestion, is high in night milk and almost not present in day milk. Day milk has also been found to be higher in antibodies and white blood cells. Even though scientists know that these hormones and immune components are passed through the breast milk to babies, it is not clear what all of this means for an infants' health and development of circadian rhythm. If breast milk does help in setting an infant's circadian rhythm, expressing milk could interrupt this process and even upset digestion and development too. If morning milk is expressed with its high levels of cortisol and very low levels of melatonin, and fed to a baby at night, what affect does this have on the infant and its ability to 'tell time' through the breast milk? This 'mistimed' delivery of milk to the infant could delay its circadian rhythm development. This variation in feeding pattern throughout society could also help explain why some babies develop good routines and settle more easily than other babies. If parents are concerned about this, they can label the expressed milk with the time it was expressed before storing it in the fridge, only then feeding it to their baby at the appropriate time of day to maintain consistent physiological communication of time.

Helpful online resources

SciShow: 5 Reasons Breastfeeding is Awesome

https://www.youtube.com/watch?v=mm_Gs4uyQ_U

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Science as a Human Endeavour 14

Artificial wombs

Researchers have successfully grown lambs in an artificial womb. The researchers sealed eight lambs that were in the late stages of gestation in sterile bags that were filled with an electrolyte solution to replicate the amniotic fluid of the womb. The lambs' umbilical cords were attached to a gas exchange machine that was external to the bag. The lambs' heart pumped blood through the umbilical cord to the gas exchange machine to maintain a supply of oxygen. The scientists were successful in growing the lambs in the artificial womb where their lungs and brain matured. The initial purpose of this research was to investigate the ability to use artificial wombs for babies born extremely prematurely, so they can continue to develop and improve their survival and health outcomes. Additionally, as this technology develops further, scientists hope to extend IVF to growing babies in artificial wombs from conception. This would alleviate the concern for any chemical contamination through food and alcohol. Scientists could also supply the developing foetus with the optimal nutrient supply at certain developmental stages, eliminating the concern of inadequate nutrition during pregnancy.

Questions

1. Discuss **three** possible **applications** of the development of artificial wombs to society.

(6 marks))

2. Discuss **three limitations** of artificial womb technology today or in the future.

(6 marks)

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6.4 Review questions

1. (i) Identify the temporary disorder that can occur in mothers that can cause an imbalance of her blood glucose levels.

(1 mark)

(ii) Explain the possible effects the disorder identified in (i) could this have on the resulting baby if left unmanaged.

(2 marks)

2. Explain why is it important for a pregnant mother to ensure she consumes enough energy in the form of carbohydrates.

(2 marks)

3. Explain why an increased amount of protein is needed during pregnancy and lactation.

(2 marks)

4. Explain why vegans need to be especially aware of their protein intake during pregnancy and lactation.

(3 marks)

5. Identify **two** examples of complementary proteins that a vegan pregnant woman could eat to ensure she was consuming all essential amino acids.

(2 marks)

6. Describe why it is important for a mother to consume adequate essential fats during pregnancy and lactation, with regards to the developing baby.

(2 marks)

7. Explain why vegans need to plan their meals carefully to ensure they consume enough omega-3 fats.

(3 marks)

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8. Folic acid supplementation is recommended for at least one month prior to conception and throughout the first trimester as a minimum. One reason for this recommendation is to reduce the risk of neural tube defects. State **one** important reason for folic acid supplementation during the first trimester.

(1 mark)

9. Identify the most likely micronutrient a pregnant woman who has coeliac disease and identifies as vegan might need supplementation with **and** explain why.

(3 marks)

10. Describe the consequence of inadequate vitamin B12 for the neurodevelopment of an infant.

(2 marks)

11. State **three** reasons why iron requirements increase by 50% during pregnancy.

(3 marks)

12. Explain why it is recommended to start babies eating solids between 4 to 6 months.

(3 marks)

13. Pregnant women are at higher risk of developing anaemia. Describe the possible consequences for the baby if the mother has severe anaemia during pregnancy.

(2 marks)

14. Explain why the recommended dietary intake (RDI) for calcium stays the same during pregnancy even though more calcium is required for foetal development.

(2 marks)

15. State **two** possible consequences that a mother who does not consume enough calcium during pregnancy and lactation is at higher risk of developing.

(2 marks)

16. State **two** sources of vitamin D.

(2 marks)

17. Describe **two** reasons why margarine is a good choice for vitamin D fortification.

(2 marks)

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18. (i) Identify the disorder that a 9 month old breastfeeding baby could develop due to inadequate vitamin D in the breastfeeding mother.

(1 mark)

(ii) Describe the impacts of the disorder identified in (i) above for the baby.

(2 marks)

19. Mild iodine deficiency has re-emerged in Australia.

(i) State **one** likely reason for this mild iodine deficiency re-emergence.

(1 mark)

(ii) Describe **one** strategy that the Australian government has implemented to help address the re-emergence of mild iodine deficiency.

(2 marks)

20. State **two** sources of iodine.

(2 marks)

21. Explain why the mandated fortification of bread with iodised salt is important for unplanned pregnancies and the developing infant.

(4 marks)

22. Describe **two** reasons why zinc is essential for the developing foetus.

(2 marks)

23. Some babies can be born prematurely (before the general 9 months have elapsed). Explain why an infant who was born prematurely might need vitamin E supplementation.

(2 marks)

24. Explain why an infant requires vitamin K supplementation after birth.

(3 marks)

25. Water requirements increase during pregnancy and lactation. State **three** reasons why water requirements increase.

(3 marks)

26. Describe **two** benefits of breastfeeding for the baby.

(2 marks)

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27. Describe **two** benefits of breastfeeding for the mother.

(2 marks)

28. Pregnant women also have to take care with their consumption of certain other chemicals in foods and drinks.

(a) Identify the maximum recommendation of caffeine a pregnant or lactating woman should consume per day.

(1 mark)

(b) Describe **one** possible reason a pregnant woman could be recommended to reduce her intake of caffeine.

(2 marks)

(c) It is recommended that no alcohol during pregnancy is the safest option. State **three** possible consequences for the foetus of alcohol consumption during pregnancy.

(3 marks)

(d) Explain **one** reason why the consumption of alcohol during lactation can inhibit the growth and development of an infant who is purely breastfed.

(2 marks)

E Extension question

Research **and** discuss the importance of choline in the development of a foetus.

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6.5 Food contamination

Nutrition Understanding

Author's note: The concepts of food contamination and safety are relevant to both Topic 6: Nutrition and food safety during pregnancy and lactation, and Topic 8: Food processing.

To prevent duplication, the content and questions for food contamination is covered in Topic 8.2. There is a strong focus on food safety during pregnancy embedded throughout this chapter.

It is highly recommended that food contamination and safety is covered when addressing nutrition and pregnancy. This is because these concepts are often poorly understood, and there can be severe consequences for those who do not follow the recommended safety guidelines. Subsequently, the Topic 6 Review Test also contains questions on food contamination.

Please refer to Topic 8.2: Food contamination on pages 357 to 374 for this information.

CS Possible case study 7

A 22-year-old woman named Madeleine just found out she is pregnant and needs to assess her current diet. Madeleine weighs 65kg with a healthy body fat percentage of 24%. She exercises 3 times a week and consumes alcohol socially on the weekends. Madeleine works in an office job and generally consumes three coffees a day from the company's automatic coffee machine. Her office is located in the city and she often purchases premade salads and sandwiches for lunch.

Evaluate Madeleine's current diet and lifestyle choices and make some recommendations to address her current needs in terms of both nutrition and food safety. Justify why these choices have been made using evidence.

Ex Possible excursion 3

Sprout Cooking School in Thebarton, Adelaide, can tailor a session for school groups on the topic of 'Nutrition and Food Safety During Pregnancy and Lactation' run by qualified dieticians. The session is followed by a demonstration and hands-on recipe modification session, which students can use as practice for their summative experiment. If schools do not have cooking facilities available, this session can also be tailored to run the summative experiment.

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Topic 6 Review Test

1. A woman has recently been diagnosed as pregnant. A general day's food intake for this individual is outlined below. She has a moderate activity level and acceptable weight range.

Breakfast:	Tea, white one sugar 4 pieces white toast, margarine and vegemite
Mid-Morning	Coffee, white one sugar 1 lamington cake
Lunch	Coffee, white one sugar 1 fritz & sauce sandwich made with white bread 1 apple
Pre-dinner	1 light beer
Evening Meal	Chicken curry and white rice Broccoli and cauliflower 2 light beers

Assume this is a fairly typical food pattern for this individual.

Suggest **three** modifications this person should make to their diet and explain why.

Modification 1:

Modification 2:

Modification 3:

(6 marks)

2. *Refer to the following table, which shows the recommended daily intakes (RDI) for a selection of nutrients at stages of the human life cycle:*

Nutrient	Infants (7-12 months)	Children (4-7 years)	Adolescent Girls (12-25 years)	Adolescent Boys (12-15 years)	Women (35-54 years)	Women (pregnant)	Men
protein (g)	1.6 per kg	18-24	44-55	42-60	45	51	55
iron (mg)	9.0	6.0-8.0	10.0-13.0	10.0-13.0	12.0-16.0	22.0-36.0	5.0-7.0
calcium (mg)	550	800	1000	1200	800	1200	800
sodium (mg)	320-580	460-1730	920-2300	920-2300	920-2300	920-2300	920-2300

(a) State the RDI for protein for a pregnant woman. *(1 mark)*

(b) Outline **two** reasons why it is particularly important for the diet of pregnant women to include protein.

Reason 1:

Reason 2:

(2 marks)

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(c) (i) With reference to the table, state the RDI for calcium for a pregnant woman.

(1 mark)

(ii) Outline **two** reasons why it is particularly important for the diet of pregnant women to include calcium.

Reason 1:

Reason 2:

(2 marks)

3. A pregnant woman requires 1,900kJ more energy per day during the third trimester.

(a) Describe why a pregnant woman requires more energy during the third trimester.

(2 marks)

(b) What type of macronutrient should the mother increase in her diet to address the increased energy requirements and what is a good example of a source of this macronutrient?

(2 marks)

(c) Explain a possible consequence to the foetus is the mother does not consume enough of this macronutrient.

(2 marks)

4. A study found that pregnant women who follow a vegan diet may not have an adequate intake of folate.

(a) State **one** risk to a pregnant woman and **one** risk to a developing foetus if the pregnant woman is deficient in folate.

Risk to woman:

Risk to foetus:

(2 marks)

(b) Suggest **one** suitable food that would provide a pregnant vegan woman with folate.

(1 mark)

(c) Breastfed infants who are over the age of six months and whose mothers are vegans are at greater risk of developing micronutrient deficiencies.

(i) Name **one** micronutrient of which the breastfed infant of a vegan mother is more likely be deficient in than breastfed infants whose mothers consume animal and plant-based foods.

(1 mark)

(ii) Name **one** food that the vegan mother could consume to reduce the infant's risk of developing a deficiency in the micronutrient that you named in part (c)(i).

(1 mark)

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5. Food Standards Australia New Zealand (FSANZ) is a bi-national government agency that develops and administers the *Australia New Zealand Food Standards Code*.

   (a) FSANZ mandates the addition of 2–3 milligrams of folic acid (the synthetic form of vitamin B9) per kilogram of wheat flour used in bread products (except in organic bread) in Australia.

   State the target group of this mandate and explain why the addition of folic acid was considered necessary.

   (i) Target group: *(1 mark)*

   (ii) Explanation:

   (2 marks)

   (b) State **one** other micronutrient that is mandated to be fortified in bread.

   (1 mark)

   (c) Explain why the micronutrient identified in (b) is important for the development of the foetus.

   (2 marks)

6. Pregnant women are temporarily at higher risk of contracting food poisoning.

   (a) (i) Explain why women have a higher chance of contracting food poisoning during pregnancy.

   (2 marks)

   (ii) State **two** possible consequences to the developing baby if a mother contracts food poisoning during pregnancy.

   (2 marks)

   (b) A salmonella infection is a bacterial infection that affects the gastrointestinal tract.

   (i) Identify **one** typical source of salmonella bacteria.

   (1 mark)

   (ii) Describe how salmonella poisoning could cause pregnant women to become dehydrated.

   (2 marks)

   (iii) Explain the possible consequences of dehydration associated with salmonella food poisoning for pregnant women and their developing baby.

   (2 marks)

   Another type of bacteria that can cause food poisoning is listeria. Listeria generally contaminate fruits and vegetables that are grown in the ground.

   (c) (i) State **one** reason why listeria generally contaminate fruits and vegetables grown in the ground.

   (1 mark)

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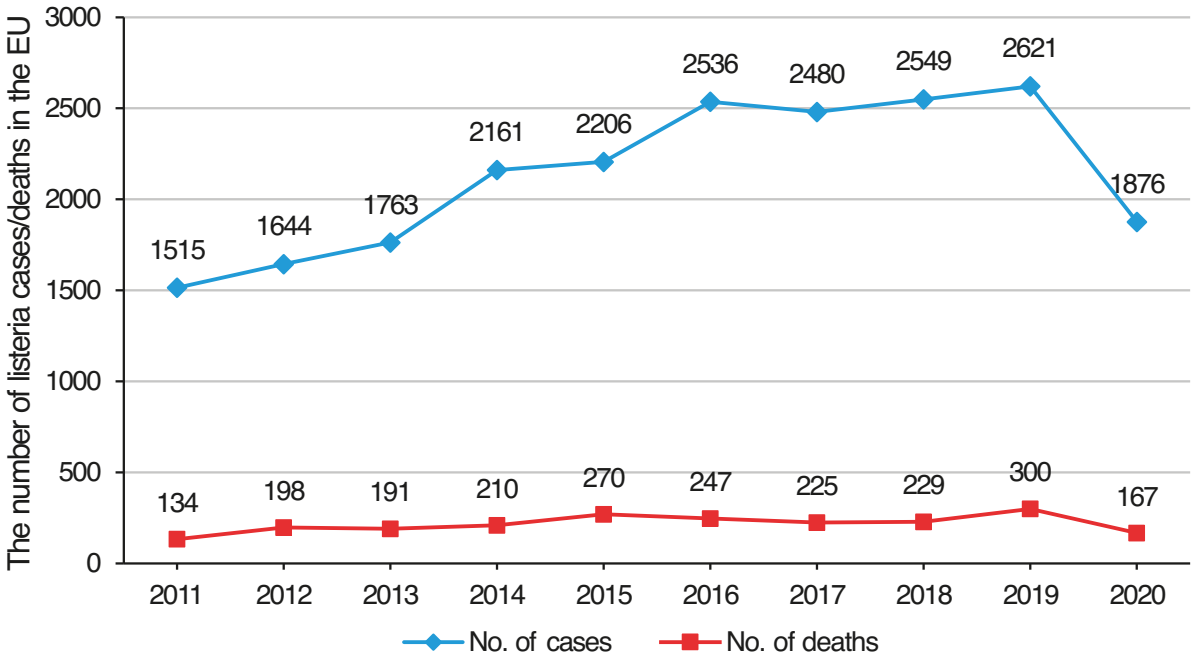
(ii) Explain why **processed** rockmelon is a high-risk food for listeria contamination.

(2 marks)

(iii) With regards to food poisoning, explain why pregnant women are advised to check the ingredients of sauces such as aioli and mayonnaise when ordering take-away food, or from a restaurant.

(2 marks)

Refer to the graph below, which shows the number of listeria cases and deaths in the European Union (EU) countries, between 2011 and 2020 to answer part (d).



(d) (i) Using data, describe the general pattern of listeria cases between 2011 and 2020 in the EU.

(2 marks)

(ii) Suggest **one** likely reason for the general pattern of listeria cases between 2011 and 2020 in the EU.

(2 marks)

(iii) Identify the **two** mistakes in the graph.

(2 marks)

7. Pregnant women are generally recommended to eat multiple serves of seafood a week. However, they are also recommended to be selective with the types of seafood consumed, as methylmercury can bioaccumulate in fish.

(a) State the type of contamination the bioaccumulation of methylmercury in fish is.

(1 mark)

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(b) Describe why it is still important for women to consume certain seafood, such as tuna and salmon during pregnancy.

(2 marks)

(c) Explain the possible consequences of a pregnant woman eating too much higher-order seafood on the development of the baby.

(4 marks)

Alcohol is another chemical that pregnant women need to be aware of when consuming foods and beverages.

(d) Explain why consuming no alcohol during pregnancy is the safest option.

(4 marks)

Total: /60

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Topic 7

Water and sustainable food supply



Concept: Sustainable food systems

7.1 Water quality and health
7.2 Famine
7.3 Sustainable food futures
7.4 Waste management
7.5 Foodbank and Ozharvest
Topic 7 Review Test

7.1 Water quality and health

Nutrition Understanding

Water is an **essential nutrient** and it is arguably the most important nutrient. This is because our bodies require more water per day than any other nutrient and we can **only survive days without water.** Our bodies are made up of approximately 60% water; therefore, the average 70kg person contains roughly 41kgs of water. Every day we lose water through urine, sweating, breathing and our faeces. The water that is lost must be replaced otherwise **dehydration** occurs. The symptoms of dehydration can become progressively more severe, progressing from weakness, exhaustion and delirium to death.

The average person generally consumes two litres of water per day but most people actually use an estimated 3,000 litres daily. The water used in households to clean dishes and ourselves only makes up a small fraction of this 3,000 litres. The vast majority of our water usage goes into **agriculture** that supplies the food we eat (see Figure 7.1.1) food supplied to communities.

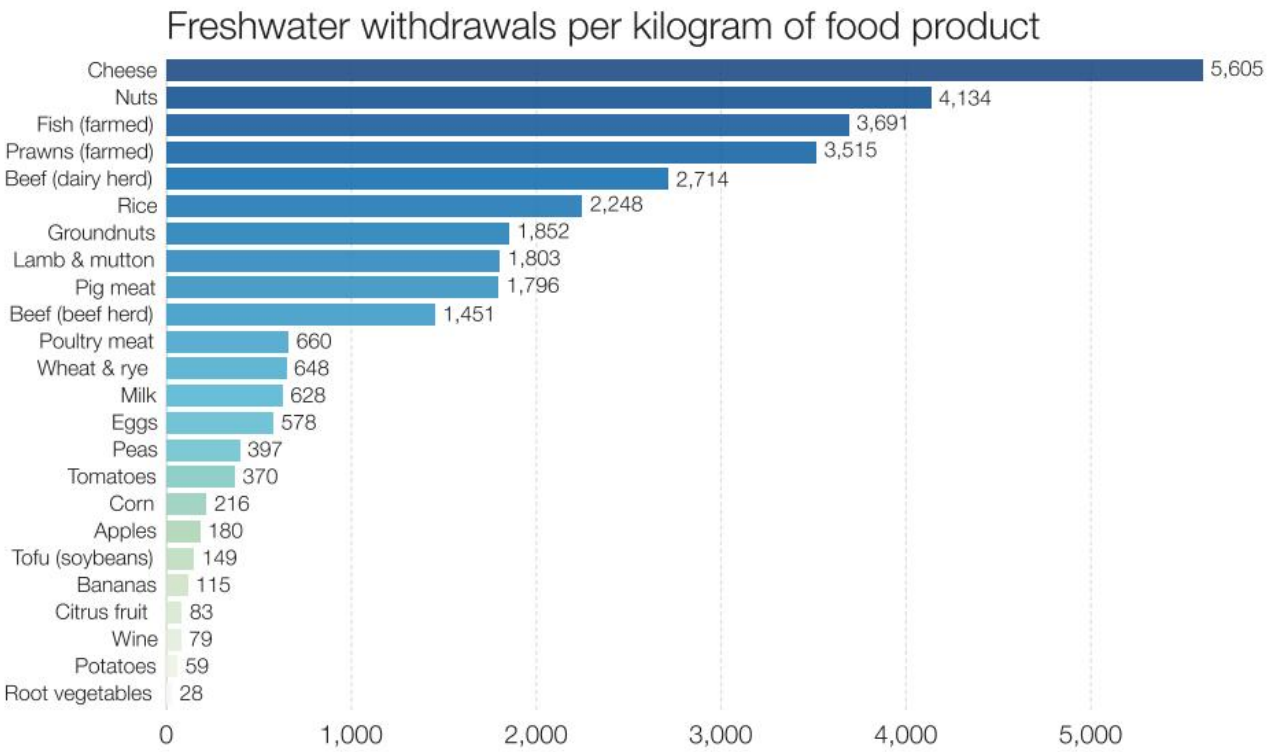


Figure 7.1.1: The fresh water footprint of various foods (measured in litres per kilogram of food product).

Helpful online resources

TED-Ed: Are we running out of clean water?–Balsher Singh Sidhu

https://www.youtube.com/watch?v=OCzYdNSJF-k&t=7s

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Water security

The human population is increasing and is currently projected to reach 11.2 billion by 2100 according to the United Nations (UN). The UN also estimates that food production needs to increase by 70% by 2050 to meet the demands of the growing population. However, there is a limited supply of water to meet our agriculture and livestock farming needs. Of all the water on earth, only 2.5% of it is actually freshwater and only 1% of this freshwater is easily accessible (with most of it trapped in glaciers). The global water demand is projected to increase by over 50% between 2000 and 2050 and the majority of this demand will be driven by agriculture. Approximately 70% of global freshwater is used by irrigation in agriculture, therefore **water security** is also the key to **food security**.

As there is a limited supply of freshwater and 70% of freshwater is used in agriculture, we need to become more efficient with our water use and produce more food from each litre of water used. Currently, many farmers **irrigate** their land inefficiently and a significant amount of water is wasted (see Figure 7.1.2). This can be due to **evaporation and over watering** leading to runoff. An example of this is farmers that mist spray their crops, which loses an estimated 30% of the water to evaporation. A more efficient delivery method would be to **install drip lines** that deliver water to the crop more efficiently and result in less evaporation while maintaining or increasing yields. Furthermore, as food requires significant amounts of water to grow, reducing **food waste** is important to help ensure water and food security in the future (see 7.4 Waste management for more detail).



Figure 7.1.2: A boom irrigator that sprays water into the air to water crops can be an inefficient delivery system due to the evaporation of water.

As there is a limited supply of water, governments are exploring new ways of securing a sustainable fresh water supply. One example is the construction and operation of **desalination plants**. Desalination plants produce freshwater by removing dissolved salts from seawater through reverse osmosis (see Figure 7.1.3). The resultant water is tested to ensure that it passes strict drinking water guidelines. Desalination plants are a good option for coastal countries, especially those that regularly experience drought. They can increase production of freshwater to be stored for future use with little risk of contamination.



Figure 7.1.3: The interior of a desalination plant showing the equipment used to produce freshwater from seawater though the process of reverse osmosis.

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Another sustainable way of securing freshwater is **recycling water**. Water can be reclaimed from wastewater (sewerage), greywater from households (water from hand basins, showers, washing machines, etc.) and stormwater. South Australia has multiple **wastewater treatment plants** that treat wastewater with physical, chemical and biological processes to remove contaminants and produce **treated wastewater**. This recycled water is purified and can be reused. Currently, recycled water is not used for drinking water in South Australia; however, this could change in the future if freshwater supplies become scarcer. Treated wastewater may become an essential water supply to ensure water security in the future, and to supply households and farms with a reliable source of freshwater.

Treated wastewater can currently be used in South Australia for:

- watering lawns and gardens including fruit trees, vegetables, and flowers
- flushing toilets
- washing cars
- filling water features and ornamental ponds (with no fish)
- washing pets
- operating evaporative coolers and air conditioners.

Helpful online resources

Would You Drink Water Made from Sewage?

https://www.youtube.com/watch?v=YocDQ9OqeuA

TED-Ed: How the water you flush becomes the water you drink - Francis de los Reyes

https://www.youtube.com/watch?v=SYia4zqcE4g

Did you know?

In 2018, Cape Town in South Africa almost became the first major city in the world to completely run out of water. Cape Town came within 90 days of "Day Zero", which is a reference to the day that the city would be forced to turn off the water supply to its citizens. Cape Town had experienced a number of years of drought prior to this occurrence but experts also blamed climate change, increased urbanisation and poor city management. In managing the situation, the city's mayor introduced water restrictions and a 'drought charge' that was used to fund the construction of new desalination plants. The strict water restrictions coupled with some eventual rain helped Cape Town avoid "Day Zero" but they are still at risk of future water shortages.

Ex Possible excursion 4

SA Water's education program, The Well, offers a range of excursions for secondary students including tours of water and wastewater treatment plants, local reservoirs and the Adelaide Desalination Plant in Lonsdale. Incursions are also offered, and can be booked online by teachers where there is opportunity for presentations to be tailored to a teacher's course design and delivered by experts from within SA Water. For regional and remote schools, virtual presentations and tours of local SA Water sites can be organised by contacting The Well. SA Water also offer a 'Young innovators and entrepreneurs program', which is a problem-based learning project that allows students to be resourceful, creative and to think critically while providing answers to real-world problems. To keep an eye out for new resources, or for more information on The Well education program, please visit the SA Water website and click on the 'Education and community' tab.

Helpful online resources

email: thewell@sawater.com.au

https://www.sawater.com.au

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Water borne disease and sanitation

Water borne diseases are illnesses caused by ingesting pathogenic microorganisms in contaminated water that is untreated, or through direct contact with faeces. According to the World Health Organisation (WHO), water borne diseases are the leading cause of death in the world, causing more than 3.4 million deaths annually, the vast majority of which are children. Most of these deaths occur in **developing countries** where water supplies may be contaminated by raw sewerage. Most of these deaths are preventable through access to clean water, and safe sanitation and hygiene practices.

In developing countries, it is common for urban wastewater to be inadequately managed due to lack of infrastructure and policy. In some developing countries, 90% of all wastewater is discharged directly into rivers, lakes and other bodies of water. This contaminates the drinking water supply with **faeces** and ingestion of this water may lead to the transmission of water borne diseases, such as cholera and typhoid (see Table 7.1.1). In addition, if the contaminated water is used in agriculture, **disease could be transmitted through the consumption of the resultant contaminated crops**. If the contaminated water is used in livestock farming, the livestock could also perish, limiting food production.

Helpful online resources

TED-Ed: When is water safe to drink? – Mia Nacamulli

https://www.youtube.com/watch?v=G244Q4AGJ7U

Waterborne diseases and associated symptoms

Table 7.1.1: A list of water borne diseases and some examples of associated symptoms.

Water borne disease	Symptoms
Cholera	Diarrhoea, dehydration, nausea, vomiting and leg cramps.
Typhoid	Fever, fatigue, tiredness, abdominal pains, loss of appetite, headache, constipation or diarrhoea.
Hepatitis A	Abdominal pain, yellow eyes, loss of appetite, fatigue and dark urine.
Polio virus	Fever, malaise, tiredness, muscle stiffness, vomit, headache.
Dysentery (e.g. shigella)	Diarrhoea, fever, cramps and blood in mucous or diarrhoea.
Giardia	Abdominal cramps, bloating, flatulence, nausea, diarrhoea and dehydration.

Water sanitation and hygiene

Water borne diseases can be prevented through a number of different water collection and sanitation techniques. Some examples are:

- Using water from a water pump in the community to collect sanitised water for the family.
- Boiling water to kill pathogens and sanitise it.
- Using previously boiled water to cook, clean and prepare food.
- Using boiled water to prepare formula bottles for infants.
- Washing hands properly (this can be an issue in areas where there is a lack of water supply and people prioritise drinking over handwashing).
- Separating bathing and washing from drinking sources of water.
- Using available materials to make a water filter and filter water with it.
- The quality of water catchment could be improved by preventing contamination from faeces and fencing waterways to restrict access to animals.

Helpful online resources

Michael Pritchard How to make filthy water drinkable

https://www.youtube.com/watch?v=rXepkIWPhFQ

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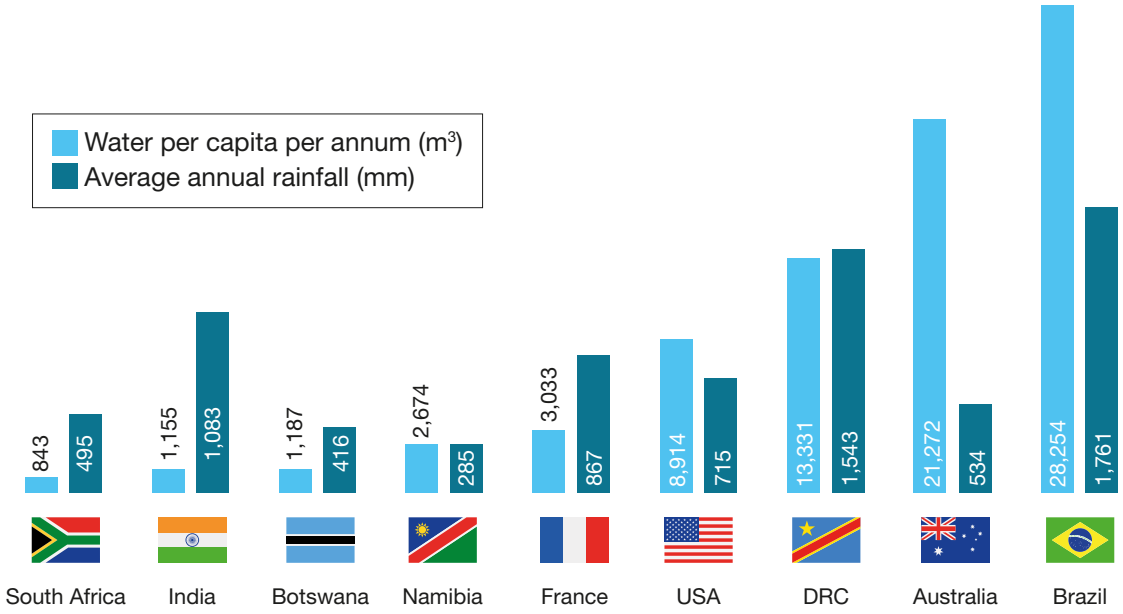
How waterborne diseases can affect livelihood

Contracting a waterborne disease can have a significant impact on an individual, their family and the wider community. Some examples are listed below:

- The infected individual may be unable to work for the short term and earn money to pay for food and other necessities.
- Some cases can result in death (especially due to dehydration) and this can affect household income and the ability to pay for food and other necessities ongoing. The loss of life can also indirectly negatively affect the community, as those who have passed away can no longer contribute to the community through work, skills, culture, etc.
- Some pathogens can remain present in the faeces for days after being infected and can infect other family members. Shed faeces may also end up in the environment, infecting other members of the community.
- Children infected are unable to attend school and this can negatively affect their educational outcomes and community engagement.
- Diarrhoea can result in malabsorption issues and lead to secondary malnutrition diseases such as anaemia.
- Each water borne infection adds further strain on medical resources and further stretches the country's health system.

7.1 Review questions

1. Refer to the following graph below that shows the water availability per person per year in selected countries:



(a) Use data to compare the water per capita per annum and average annual rainfall between Australia and South Africa.

(2 marks)

(b) Suggest a logical reason for the difference in water per capita per annum between Australia and South Africa.

(1 mark)

(c) Desalination plants are an option for South Africa to increase their freshwater reserves and water per capita per annum. Describe how a desalination plant provides a supply of freshwater.

(2 marks)

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2. (a) Describe how food security is reliant on water security.

(2 marks)

(b) Describe an example of how water can be used inefficiently in agriculture.

(2 marks)

3. (a) Name **two** common water borne diseases.

(2 marks)

(b) State **two** symptoms for each of the two water borne diseases named in part (a).

(4 marks)

(c) Explain how contracting a water borne disease that results in diarrhoea could cause death in an infected person.

(2 marks)

(d) Describe **two** preventative methods that could be used to prevent water borne diseases.

(2 marks)

(e) Describe **two** ways contracting a waterborne disease can impact an individual and their family.

(2 marks)

4. According to a report conducted by the Institution of Mechanical Engineers (IME), an estimated 30-50% of all food produced is wasted before it reaches the consumer.

(a) Identify **two** possible ways that food could be wasted prior to reaching a consumer.

(2 marks)

The IME also reports that it takes 1608L of water to make 1kg of bread and 15,415L of water to make 1kg of beef.

(b) Explain why it takes more water to produce the equivalent amount of beef compared with bread.

(3 marks)

E Extension question

Research some basic materials that could be used to make a water filter in a developing country **and** explain how they contribute to the filtering process.

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7.2 Famine

Nutrition Understanding

It is estimated that 128 million people have died due to famines between 1860 and 2016. It is also estimated that 80 million people currently experience severe **food insecurity**.



Figure 7.2.1: An empty bowl symbolises the concept of hunger and famine.

Famine

Famine is an episode of **severe hunger due to inadequate food supply**. Famines can result in malnutrition, starvation, disease and even death. It is commonly believed that famines are caused by a lack of food production but it is often more complicated and can involve multiple factors. For example, a government's response or inability to respond to a natural disaster such as a drought could cause a famine. Some examples of environmental and political causes of famine are outlined in Table 7.2.1.

Table 7.2.1: Some examples of environmental and political causes of famine.

Environmental	Political
Natural disasters such as floods, droughts and earthquakes can wipe out crops and livestock.	**War** impacts food supply by destroying crops, livestock and food processing plants. Employees in food production, manufacture and distribution may also be killed. War can also prevent food distribution of food to and within a country.
Global warming and climate change can lead to increased temperatures, changing weather patterns and increased severity of weather. This can decrease yields.	**Poor governance** can result in famine. If a natural disaster or systemic disease is not properly addressed by a government, this can exacerbate food security issues. Money may be spent on military rather than food and water security. In addition, when first aid is sent, **corruption** can lead to an inappropriate or lack of distribution of food to citizens.
Food production requires a **reliable water supply**. If the water supply or quality is unreliable, so will the food supply. Water supply can also be affected by global warming.	Food **'dumping'** in developing countries can prevent developing countries from improving food security through local farming. When food is 'dumped' (through aid) it lowers local prices, making it uneconomic for local farmers to produce and sell their produce.
Decreased soil fertility due to natural disasters or poor farming practices can result in decreased yields.	The **lack of infrastructure** to transport, process and store food can result in food being wasted in developing countries.

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Malnutrition

There is a general misconception that **malnutrition** and **undernutrition** are interchangeable terms but this is not the case. Undernutrition is a form of malnutrition that results from a chronic or recurrent deficiency in one or more nutrients, whereas malnutrition encompasses all disorders related to both overnutrition and undernutrition. A common form of undernutrition, especially in developing countries, is **energy malnutrition**. This results from a deficiency in food consumption, generally due to its unavailability. Women are of particular risk to hunger and malnutrition in developing countries. In many cultures, women are seen as second-class citizens and can only eat what the men and boys have not eaten (i.e. the leftovers). Many women in developing countries marry young and have large families to ensure some children survive through to adulthood. The numerous pregnancies decrease women's iron and calcium stores and increase their risk of malnutrition. In addition, mothers who are undernourished generally give birth to infants that are underweight. Some examples of disorders associated with undernutrition are presented in Table 7.2.2:

Table 7.2.2: Examples of undernutrition disorders and the nutrient(s) generally associated with each.

Undernutrition Disorder	Description
Beri Beri	Beri Beri is the deficiency of **vitamin B1** (thiamine). Beri Beri is a severe deficiency of vitamin B and can cause weight loss, weakness, pain in the limbs, periods of irregular heartbeat and damage to the nervous system. In extreme cases, Beri Beri is associated with Wernicke-Korsakoff syndrome. This is more common in developing countries with a diet high in processed white rice as it only has a tenth of the vitamin B1 of brown rice. It is rare for cases to develop in Australia because it is **mandated that wheat flour be fortified** with vitamin B1.
Pellagra	Pellagra is the deficiency of **vitamin B3** (niacin) and is associated with '**the three D's': D**iarrhoea, **D**ermatitis and **D**ementia. Pellagra is most common in developing countries with a staple food of corn. This is because corn does not contain an absorbable form of vitamin B3.
Scurvy	**Vitamin C** is required to make collagen (which holds our cells together). A lack of vitamin C can cause certain tissues in our body to start to break down. This can result in bleeding gums, capillaries breaking down under the skin causing small bruises, wounds not healing, and in extreme cases can result in death.
Rickets	**Vitamin D** is important for calcium absorption, therefore a deficiency in vitamin D also results in a **deficiency of calcium**. This can compromise normal bone formation as calcium is needed to form the hard structure of the bone. A deficiency can cause **rickets** in children, adolescents not to reach peak bone mass, osteomalacia in adults and **osteoporosis** in the elderly. Rickets is a disease where the bones fail to develop properly because there is not enough calcium. This results in skeletal abnormalities such as bowed legs. Osteomalacia generally occurs in adults and is caused by reduced bone density resulting in soft bones. Osteoporosis is also a result of reduced bone density and is associated with a very curved spine and increased risk of bone breakages.
Anaemia	Anaemia is a disease that involves the deficiency in the number or quality of red blood cells. Red blood cells transport oxygen from the lungs to our body's cells so they can respire and produce **energy**. A reduced number or lack of quality red blood cells, therefore, results in the reduced transport of oxygen to cells and reduced energy availability. The production of red blood cells requires sufficient **protein, iron, folate and vitamin B12**.
Xerophthalmia (blindness)	**Vitamin A** is primarily stored in the liver and the average adult has enough to last for over a year; however, children are less developed and are more prone to vitamin A deficiency (VAD). This is a serious concern in developing countries where there is low availability of fresh whole foods. As vitamin A is important for eyesight, a lack of supply can cause total **blindness** (xerophthalmia). Vitamin A is also important for immune function and a **compromised immune system** increases susceptibility to infectious diseases, such as measles, pneumonia, malaria, HIV, Ebola virus, etc.
Kwashiorkor	Kwashiorkor (also called protein malnutrition) is a **protein deficiency** disorder with adequate energy intake. Kwashiorkor is more common in rural areas and regions experiencing famine. People with Kwashiorkor generally have an emaciated appearance all over their body, oedema (swelling) in the ankles and feet, a bulging stomach and an inability to put on weight.
Marasmus	Marasmus is severe malnutrition characterised by **energy and protein deficiency** due to deficiency in all three macronutrients. Marasmus typically occurs in children and it mainly occurs in regions experiencing poverty and food scarcity. The main symptoms of marasmus is being underweight, stomach shrinkage, dehydration and diarrhoea.

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Helpful online resources

Food and Agriculture Organization of the United Nations: State of Food Security and Nutrition in the World 2022

https://www.youtube.com/watch?v=9rkE-gAUhBk

Free Animated Education: What is Starvation and Malnutrition? What are Food Deficiency Diseases?

https://www.youtube.com/watch?v=VM5fGbCGthA

Evan Fraser - Feeding Nine Billion Video 6: Climate Change and Food Security

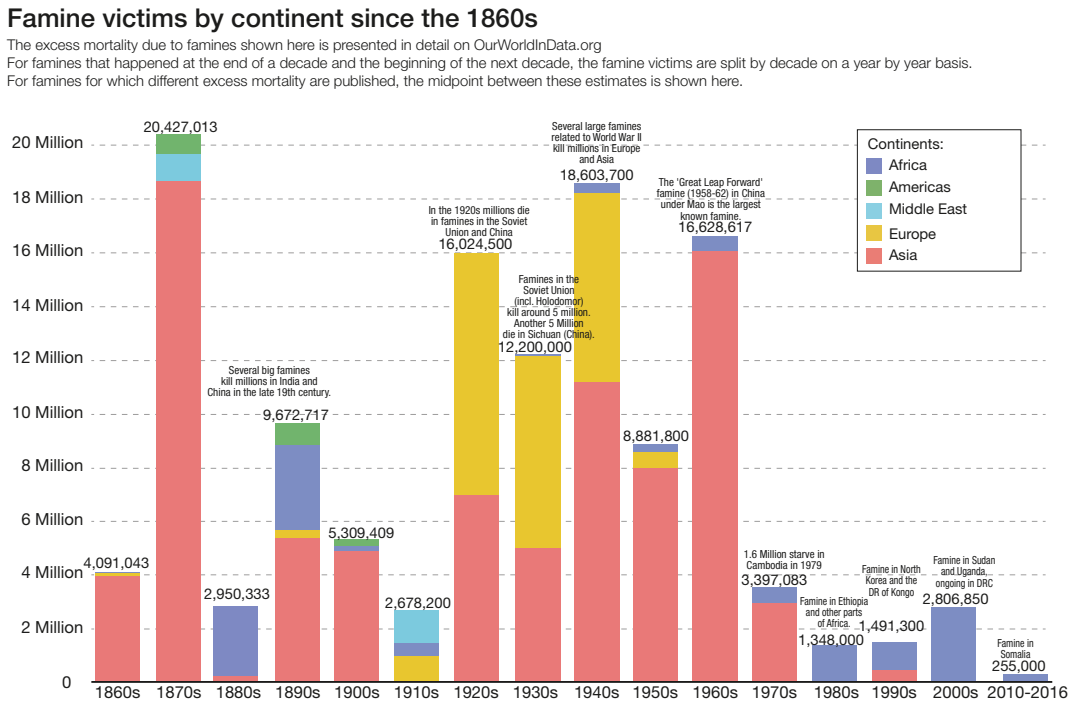
https://www.youtube.com/watch?v=cYq2elstFWQ

7.2 Review questions

1. Describe why famines are not simply caused by a lack of food production and give an example.

(2 marks)

2. Refer to the graph below, which shows the number of deaths caused by famines per continent between 1860 and 2016 to answer parts (a) to (c).



(a) Identify the continent that has experienced the most deaths caused by famine between 1860 and 2016.

(1 mark)

(b) Identify the continent that has experienced the most deaths caused by famine since the 1970s.

(1 mark)

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(c) Use the graph to calculate how many people died from famine in Europe between the years 1920 and 1949. Show your working out.

(2 marks)

(d) Describe **one** environmental and *one* political cause of famine.

(4 marks)

3. (a) Food insecurity can lead to malnutrition. Explain **two** reasons why women are generally at greater risk of malnutrition in some developing countries than men.

(4 marks)

(b) Women are also at greater risk of developing anaemia. Describe what anaemia is **and** identify the four key nutrients required to avoid developing anaemia.

(3 marks)

(c) Pellagra is an undernutrition disorder that is more common in developing countries. Identify the vitamin deficiency that causes pellagra.

(1 mark)

(d) State the **three** major symptoms of pellagra.

(3 marks)

(e) Corn is a staple food for citizens of Venda in South Africa. Corn can be eaten by itself, or processed into products such as bread, cornmeal and sweeteners. Describe why citizens of Venda could be at greater risk of developing pellagra.

(2 marks)

E Extension question

Research which countries are currently experiencing famine or are at risk of experiencing famine **and** identify the causes of each case of famine.

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7.3 Sustainable food futures

Nutrition Understanding

According to the United Nations (UN), the human population is currently projected to reach 9 billion by 2037, 10 billion by 2057 and 11.2 billion by 2100. The **growth of human population** has not been gradual. Most of the growth has been concentrated in a huge exponential increase in the last 500 years, which has put enormous strain on the earth's natural resources, such as fresh water and fertile land. These **resources are finite** and are being used at a much faster rate than they can be replaced.

In order to meet the growing agricultural demands, large areas of **land and forests have been cleared**. As a result, many habitats have been destroyed, **decreasing biodiversity**. Also, a lack of education in efficient farming processes has resulted in excessive land clearance, especially in developing countries. This is because the crop yields decrease after a couple of years due to **soil erosion**, so more land is cleared to gain access to more fertile soils, and in turn greater yields. In addition, toxins, wastes and other **pollutants** are being produced at a much faster rate than they are being broken down, which is polluting our environment. The increased resources required by the growing human population, combined with the increased land clearance and waste production are also contributing to global warming and climate change. This further impacts food production due to factors such increased evaporation of fresh water supplies, and increased frequency of natural disasters such as droughts, floods and cyclones. As a consequence, crop yields are decreasing in some locations, resulting in less food for the growing population, further adding to our food production issues. Additionally, overfishing our oceans is contributing to the endangerment and extinction of many fish species. Our modern fishing practices such as long lining and bottom trawling are also very inefficient resulting in a lot of by-catch that is wasted (see TED-Ed video link below for more information).

Consequently, more food has to be grown to feed the rapidly growing population. In fact, the United Nations estimates that food production needs to increase by 70% by 2050 to meet the demands of the growing population. Some possible farming approaches that could contribute to an **increase in productivity and reduce strain on the environment** are organic farming, genetically modified organisms (GMOs) and vertical farming.

Helpful online resources

FuseSchool - Global Education: Modern Agriculture and Fishing

https://www.youtube.com/watch?v=RZH5uh9oRgs

Cognito: Land Use - Deforestation & Peat Bogs

https://www.youtube.com/watch?v=SROoINlp4VY

Cognito: GCSE Biology - Global Warming & Climate Change #91

https://www.youtube.com/watch?v=lkqobb34oLI

Why Farming Is Broken (And Always Has Been)

https://youtu.be/UkMZJrbCRdQ

TED-Ed: Will the ocean ever run out of fish? - Ayana Elizabeth Johnson and Jennifer Jacquet

https://www.youtube.com/watch?v=WNdR808jMSA

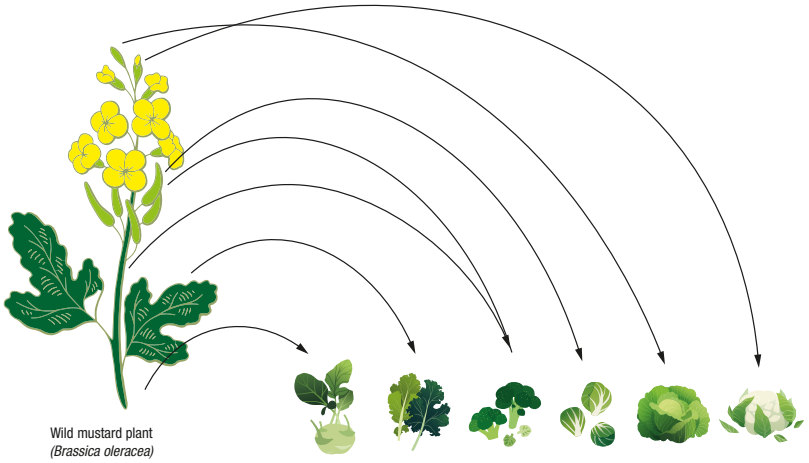
Evan Fraser: Feeding Nine Billion Video 1: Introducing Solutions to the Global Food Crisis by Dr. Evan Fraser

https://www.youtube.com/watch?v=raSHAqV8K9c

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Genetically modified organisms

Humans have been altering the genomes of plants and animals for many years. Humans have selectively bred species for desired traits such as bigger and juicier fruits, seedless watermelons and leaner animals. One could argue that none of the produce we eat is 'organic' and 'natural' due to humans' interference. A prime example of this is the **selective breeding of the wild mustard plant**. Many of the leafy greens we eat today were created by selectively breeding the wild mustard plant for different traits. This gave rise to vegetables such as broccoli, cauliflower, cabbage and kale (see Figure 7.3.1). It is because of humans that these new varieties exist.



Strain	Kohlrabi	Kale	Broccoli	Brussels sprouts	Cabbage	Cauliflower
Modified trait	Stem	Leaves	Flower buds and stem	Lateral leaf buds	Terminal leaf bud	Flower buds

Figure 7.3.1: Some of the leafy greens that resulted from the selective breeding of the wild mustard plant by humans.

Genetic engineering allows greater precision and control over the genetic changes to organisms in comparison to selective breeding. Genetic engineering allows scientists to transfer specific genes from one species to another, providing the target organism with the new desired trait(s). For example, scientists have experimented with transferring genes from deep-sea fish that enable antifreeze properties into tomato plants to reduce the loss of tomatoes damaged by frost. This is a very specific trait that is transferred and it is possible because all organisms contain the same genetic code: DNA. The potential is endless and genetically modified organisms (GMOs) can help with optimising agricultural performance and increasing food security for the growing population. Some examples of genetically modified organisms are discussed in more detail below.

Pest resistant crops

Crops can be genetically modified to be more resistant to attack from pests such as insects. Scientists can do this by introducing genes found in soil bacteria into the particular crop, for example corn. This enables the crop to produce a protein that is activated when eaten by certain target insects. This activated protein pierces holes in the insects' digestive system, causing it to leak and die of starvation. This means that the crop now has the ability to produce its own insecticide and protect itself from certain insects. This is beneficial for farmers and the growing population because it results in less crop damage from insects and a **higher yield**. It also reduces the chemical pollution of soils as farmers do not have to spray their crops with synthetic insecticides. The insecticide protein produced is **not toxic to humans** and other mammals because our digestive systems do not possess the complementary receptor to bind it. In fact, studies have shown that humans digest this insecticide protein into amino acids just like any other protein found in our food, such as meat, fish and tofu (see Figure 7.3.2).

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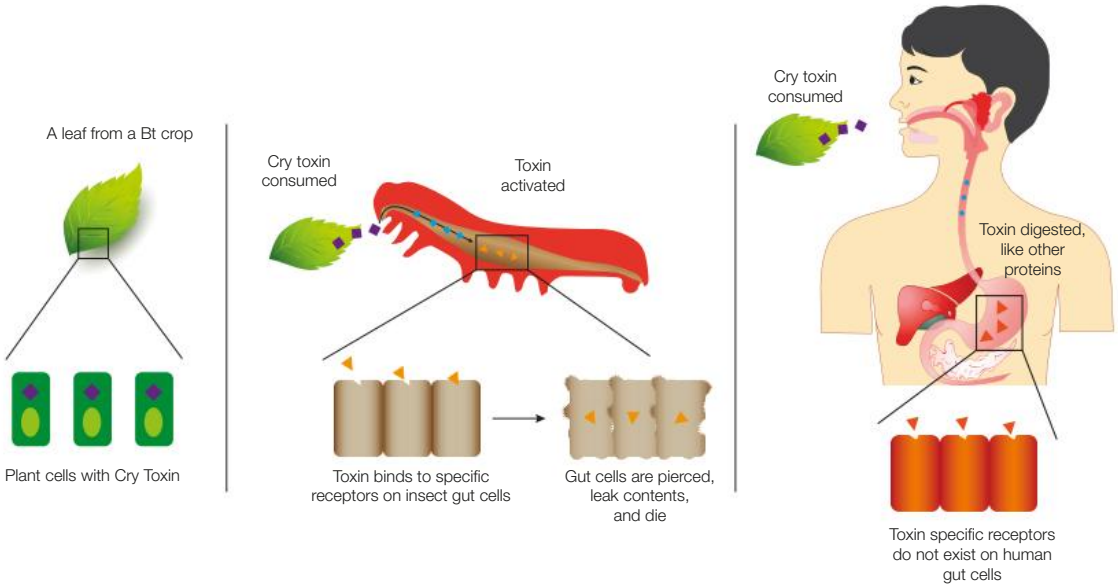


Figure 7.3.2: How the insecticide protein known as 'Cry', which is produced by genetically modified pest resistant crops, affects certain insects but not humans.

Herbicide resistant crops

Plants naturally compete with other plants for sunlight and nutrients. On farms, **crops compete with weeds for resources**. This competition can result in less nutrient availability for the crops and a lower yield overall. Therefore, many farmers use herbicides to eliminate weeds from their fields but crops are also susceptible to the herbicides. Scientists have been able to produce genetically modified crops that are resistant to herbicides, known as Roundup Ready crops (Roundup is a commonly known herbicide). This means that when the fields containing Roundup Ready crops are sprayed with the herbicide, **only the weeds are killed, and the crop is unaffected** (see Figure 7.3.3). This results in less competition for resources and the crop produces a higher yield. The increased yield is more profitable for the farmers but it also means that there is more food available for the growing population. Two examples are Roundup Ready soybean and Roundup Ready corn, which were introduced in the late 1990s.

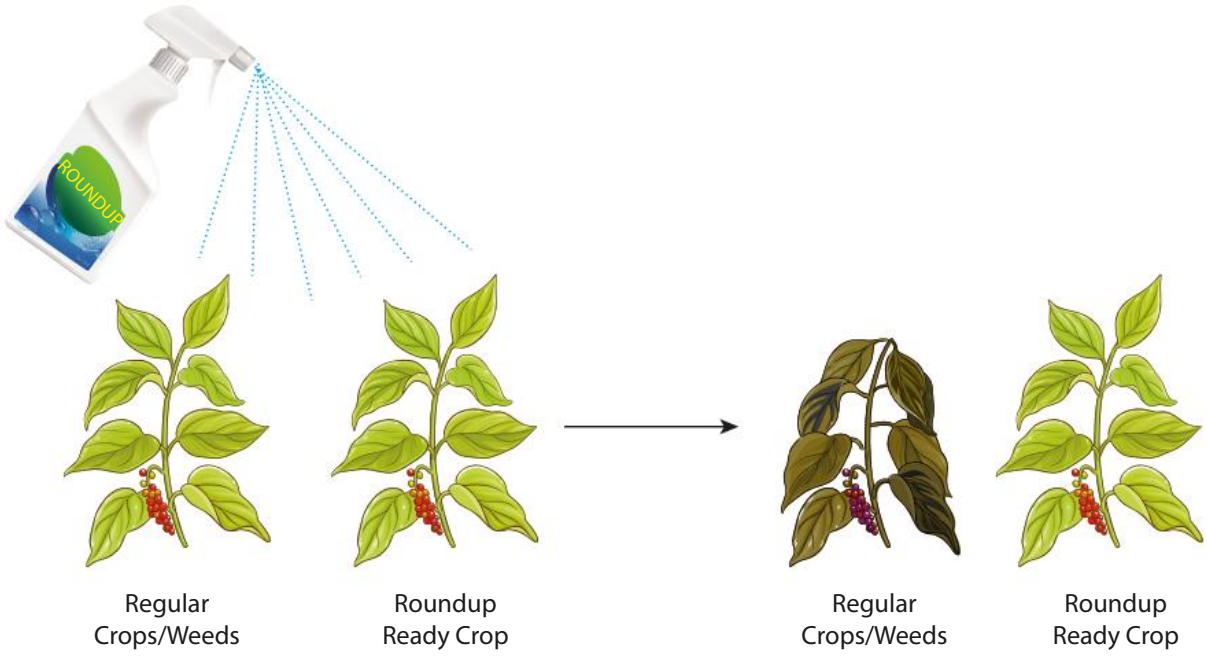


Figure 7.3.3: Roundup is a herbicide that contains a chemical toxic to standard plants and weeds. Roundup Ready crops have been genetically modified making them immune to Roundup whereas weeds are susceptible to it.

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Helpful online resources

FuseSchool - Global Education: GM Crops

https://www.youtube.com/watch?v=kZIYkYNpnP0

Nitrogen fixing crops

Nitrogen is an important component of the pigment chlorophyll in plants, which traps light for photosynthesis, and in amino acids, which are used to synthesise new proteins. Nitrogen, therefore, is an essential nutrient required for crops to produce a high yield. Farmer's often apply **fertilisers** (which contain a source of nitrogen) to their fields to increase available nutrients and produce a greater yield. Fertilisers can increase available nutrients to crops but they can also runoff into waterways leading to **eutrophication** and **algae blooms**. Please refer to Figure 7.3.4 for further explanation.

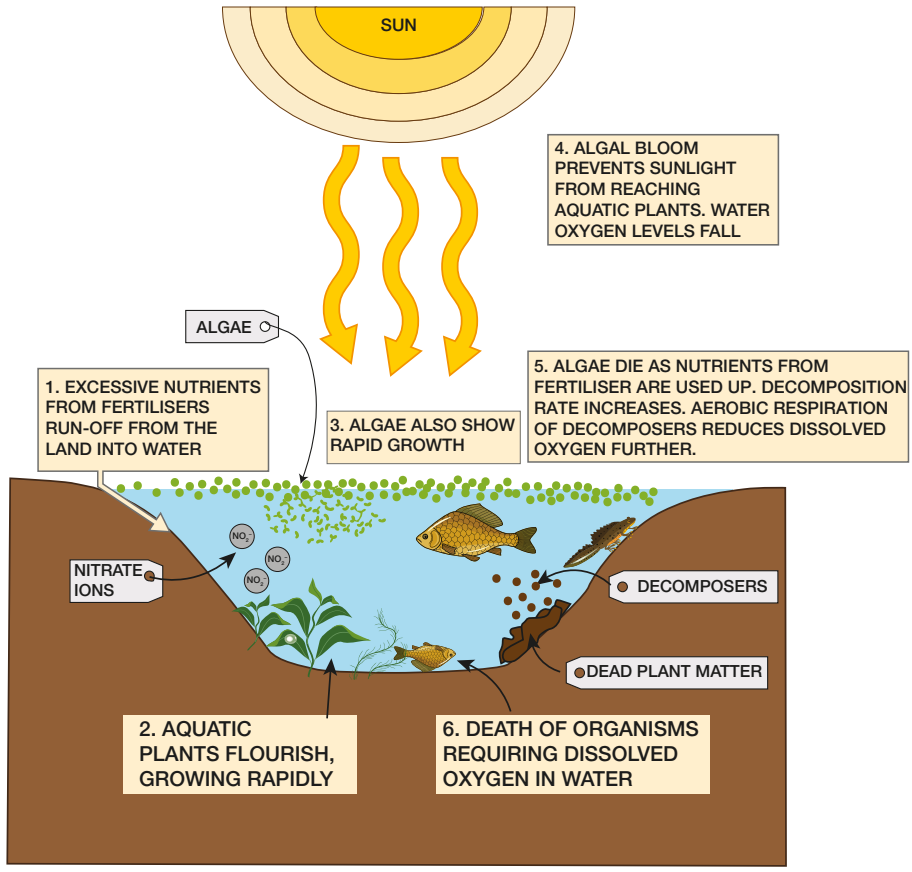


Figure 7.3.4: An explanation of how the excessive use of fertiliser can lead to algae blooms and loss of biodiversity in marine ecosystems.

Helpful online resources

FuseSchool - Global Education: What Are Fertilisers?

https://www.youtube.com/watch?v=jJSUN-r3ZXo

Oxford Mastering Biology: Animation E2, 1.1 Consequences of algal blooms

https://www.youtube.com/watch?v=JNoLNQ3ojE4

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There is abundant nitrogen in the atmosphere (N_2) but plants cannot use nitrogen in this form and require it in a useable form such as **ammonia** (NH_3). Some plants, such as legumes, are able to convert nitrogen gas from the atmosphere into ammonia (this is known as **nitrogen fixing**) but only a few types of plants can do this. Scientists are currently experimenting with transferring the genes associated with converting nitrogen gas into ammonia to crops other than legumes, so that they can directly make their own ammonia. If it is possible to introduce these genes to multiple staple crops, this could increase food production and reduce the use of synthetic fertilisers. Reducing the use of fertiliser would also benefit the environment by reducing its runoff and the risk of eutrophication and algae blooms.

For more examples of GMOs, such as golden rice and bananas, disease resistant crops and fast growing salmon, please see Topic 5.2: Future foods

Helpful online resources

Kurzgesagt: Are GMOs Good or Bad? Genetic Engineering & Our Food

https://www.youtube.com/watch?v=7TmcXYp8xu4

Evan Fraser: Feeding Nine Billion Video 2: Science, Technology and GMOs

https://www.youtube.com/watch?v=eFDyTz9K9i8

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Sex selection of egg laying chicks

In Australia, the egg farming industry produces approximately six billion eggs annually. This requires approximately 20 million hens to meet these demands. An ethical issue associated with egg farming is what happens to the male chicks that cannot lay eggs. Currently, the egg farming industry culls male chicks after they hatch. Fortunately, it is now possible to determine the sex of a chick prior to hatching due to recent developments in gene technology conducted by the CSIRO. This technology requires precision gene editing to add a biological marker to the sex chromosomes. This allows for egg farmers to determine the sex of pre-hatched eggs and as a result, only the female eggs can be hatched. As the male eggs are not hatched, there would be no need for the culling of newborn male chicks. In addition, the pre-hatched male eggs that are not required by the egg farming industry could be used in the vaccine industry that require fertilised chicken eggs to develop influenza vaccines.

Questions

1. Discuss how egg farmers need to **communicate and collaborate** with other parties to discontinue chick culling as part of their industry.

(4 marks)

2. Explain how the **application** of this technology could affect society.

(4 marks)

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Organic farming

Organic farming is an agricultural system that is designed to produce high yield crops and healthy animals with a sustainable approach that minimises the effect on the environment. Organic farms do not use **synthetic chemicals**, such as insecticides, herbicides, fertilisers, antibiotics and hormones. They also do not grow any genetically modified organisms. Instead of using synthetic fertilisers, organic farmers use 'natural products' such as animal manure, food scraps and industrial composting from the collection of household food scraps (green bins), to replenish the nutrients in the soil. They also practice **crop rotation** to maintain soil quality. Organic farmers also take a preventative insect control method as an alternative to using insecticides. This involves **intercropping** to discourage pests and **using natural predators** of pests, such as using ladybugs to control aphid populations on crops (see Figure 7.3.5). However, these methods do not always work, and organic farmers may have to resort to using natural pheromones to lure pests away from crops or natural insecticides to kill pests when necessary. Organic farms may also practice **mixed farming** as a measure to control weed populations and cycle nutrients back into the soil. Mixed farming involves raising animals and growing crops on the same farm. It is natural for weeds to grow on farms and some animals consume these weeds reducing/removing the need for organic farmers to use synthetic herbicides. Organic farming is very labour intensive however and **cannot produce the same high yields as conventional farming**. Therefore, it would not be sustainable for all farms to be organic. Some organic practices and additional positives and negatives of organic farming are discussed further below.



Figure 7.3.5: A ladybug eating an aphid.

Intercropping and crop rotation

In organic agriculture, techniques such as intercropping and crop rotation are used to maintain nutrients in soils. **Intercropping** is a farming technique used by organic farmers that plants two or more crops side by side (see Figure 7.3.6). There are multiple advantages to intercropping including:

- One crop can be used as a diversion for pests from another crop, known as a **cover crop**. For example, stinging nettle can be grown alongside broccoli. Stinging nettle grows taller and is less profitable than broccoli. Stinging nettle is used as a sacrificial crop to reduce loss of broccoli crop to pests and increase the yield of the more profitable broccoli. In addition, less organic pesticides need to be used to combat pests.
- Multiple crops can be grown to **hedge bets** during a farming season. If multiple crops are grown and one is wiped out by pests, then the farmer still has other crops that can be harvested and sold to market.
- Different crops require different nutrients in different amounts. This reduces the impact of growing one crop in the same soil repeatedly and increases yields.

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Figure 7.3.6: An example of intercropping.

Crop rotation is a farming technique that involves rotating different crops through farmable land. If only one crop dominates the farm such as wheat, specific nutrients may be depleted from the soil as the same nutrients are required by wheat each season, in the same amounts. This can result in decreased yields. By rotating crops, different nutrients are required by the alternate crops in different amounts. Legumes are popular crops that are rotated through because they are nitrogen fixing crops that replenish nitrogen stores in the soil. Legumes have a symbiotic relationship with a nitrogen-fixing bacteria (rhizobia) that can convert nitrogen (N_2) in the atmosphere to a useable form for plants ammonia (NH_3). This allows the crop to produce its own nitrogen and any excess remains in the soil for the next crop to use.

Helpful online resources

America's Heartland: What is crop rotation?

https://www.youtube.com/watch?v=O9YDlcKG4rA

Mixed farming

Mixed farming is an environmentally sustainable farming technique used on organic farms that involves a variety of crops and animals. There are multiple environmental and financial benefits to growing crops and raising livestock on the same farm. The mixture of crops and animals will differ from farm to farm and will depend on the needs of the farmer. One benefit of having animals on the farm is that certain animals will eat the weeds, such as sheep and geese. This can help farmers **combat weeds instead of using herbicides**. In addition, the by-products of each crop and animal assists in the production of the other. For example, the excrement from animals that roam the farm add nutrients, such as nitrogen and phosphorus, to the soil when they are decomposed. Whereas, the stalks of the crop can add to the feed for the animals, therefore reducing the need for specifically purchased fertilisers or feed.

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Positives and negatives of organic farming

Table 7.3.1: Some additional positives and negatives of organic farming.

Positives of organic farming	Negatives of organic farming
Uses organic fertilisers such as animal manure to improve soil health rather than relying on synthetic fertilisers, which can run off the land and contaminate rivers and streams resulting in eutrophication and algae blooms.	Organic farming does not use synthetic insecticides and herbicides to kill insects and weeds respectively. Instead they use approaches that are less efficient at doing so. They also do not use synthetic fertilisers, which provide more nutrients for crops to grow. Therefore, organic farming cannot produce the same high yields as conventional farming.
Farmers use organic systems to reduce insect infestation and for weed control, therefore avoiding the use of synthetic insecticides and herbicides that can impact native insect and bird populations.	Organic farming can be very time consuming and it is a labour-intensive job. For example, instead of spraying weeds with herbicides, more manual and physical control of weeds can be required.
Organic farmers are required to retain some native vegetation, which aids in maintaining biodiversity within the environment.	Organic fertilisers such as animal manure can still runoff into rivers and streams resulting in eutrophication and algae blooms.
Soil health is improved through practices such as crop rotation and intercropping with nitrogen fixing plants, therefore minimising soil erosion and soil salination.	Organic farmers must have a very strong understanding of the organic alternatives to synthetic chemicals such as fertilisers and insecticides. A lack of knowledge makes it more difficult to combat insects and weeds.
Organic farmers use natural predators such as ladybugs to combat aphid populations. It is estimated that a single ladybug can eat up to 50 aphids per day. This reduces the need for pesticides and the resultant contamination of air, soil and waterways.	Organic farming can still involve the use of natural insecticides and herbicides. Although these chemicals are not synthetic, they can still be harmful, and their use can mislead the public who may think that no chemicals were used on the organic produce they are purchasing.
No antibiotics are used in animal farming. Therefore, organic farming does not contribute to the rise in antibiotic resistant bacterial strains.	Organic produce costs more for the consumer than conventional produce. This is because organic farms produce a lower yield than conventional farming and prices are adjusted to reflect this.

Helpful online resources

FuseSchool - Global Education: What is Organic Farming?

https://www.youtube.com/watch?v=WhOrIUlrnPo

FuseSchool - Global Education: The Pros and Cons of Organic Farming

https://www.youtube.com/watch?v=QpkKW45cHaA

Kurzgesagt: Is Organic Really Better? Healthy Food or Trendy Scam?

https://www.youtube.com/watch?v=8PmM6SUn7Es&t=27s

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The Farm Robot

Scientists are currently developing a fully autonomous robot that can exterminate insects and weeds that is solar charged. Watch the following video for more information and answer the SHE questions below.

Helpful online resources

RIPPA The Farm Robot Exterminates Pests and Weeds

https://www.youtube.com/watch?v=XP7GoNKcTS4

Questions

1. Discuss the **development** of RIPPA the farm robot.

(4 marks)

2. Explain how the **application** of this technology could affect society.

(4 marks)

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Ex Possible excursion 5

The Food Forest is a certified organic farm and permaculture learning centre located near Gawler in South Australia. Over 160 fruits, vegetables, herbs, grains and nuts are grown and processed at the Food Forest. Wine and other fermented products are also produced.

The owners, Annemarie and Graham Brookman (who are both teachers), are passionate about sustainability and sharing their knowledge with schools, universities and the community to demonstrate how ordinary families can grow their own food at home in a sustainable way. Excursions involve a tour of the farm and explanation of practices such as intercropping, crop rotation, mixed farming, ethical animal management, sustainable use of water, passive-solar house design and domestic nutrient recycling.

Visits can be tailored to include topics like certified organic and GM-free growing, compost and soil management, food quality, value adding, distribution pathways and food miles, packaging and fair trade. Annemarie and Graham are experienced and engaging teachers who are happy to present short illustrated introductory talks in their learning centre to enhance the experience.

Helpful online resources

Visit the Food Forest website for more information and contact details:

https://www.foodforest.com.au

Vertical farming

Vertical farming is the indoor production of crops and involves stacking plants on top of each other using growing shelving (see Figure 7.3.7). This is a much more efficient use of space than conventional farming. Vertical farms are often established in old factories or buildings in urban areas and this **reduces the transport miles** (and associated carbon emissions) of the produce as it is grown in closer proximity to retailers. As the crops are grown indoors, there is little to no natural sunlight. This is a disadvantage because natural sunlight is free for conventional farming. Instead, rows of low energy LED lights are generally installed as a source of light for plants. Although these LED lights consume less energy than traditional light sources, they still require an energy input. Vertical farms generally try to reduce their carbon footprint and often opt for installing solar panels to supply energy to the building. The solar panels also provide energy to control the climate of the building. This allows for these crops to be grown all year round as they are not reliant on the weather. Vertical farming also involves the use of aeroponics which **can significantly reduce water usage** in comparison to traditional farming. This is very beneficial for drought prone countries such as Australia. Because vertical farms are a closed system and housed inside there is **no competition with weeds and insects**. Therefore, there is no need to use herbicides and insecticides, reducing their impact on the environment. Vertical farms are not suitable to grow all crops including rice and wheat. The main crops grown are leafy greens and tomatoes because they grow quickly and are profitable.



Figure 7.3.7: Vertical farms are often built in old factories or buildings in cities and are an efficient use of space given that the crops are grown on vertical shelving.

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Helpful online resources

What If We Built Vertical Farms?

https://www.youtube.com/watch?v=jeN2ynwny6A

This Farm of the Future Uses No Soil and 95% Less Water

https://www.youtube.com/watch?v=-_tvJtUHnmU

7.3 Review questions

1. Describe why food production needs to increase in the future.

(1 mark)

2. (a) Describe what a genetically modified organism is.

(2 marks)

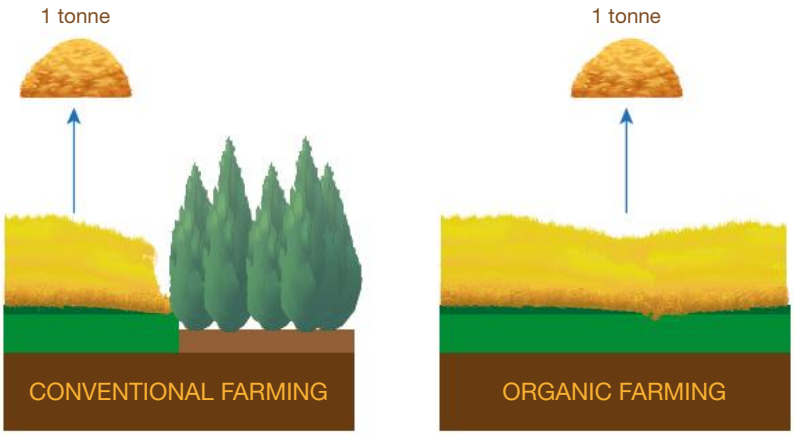
(b) Explain how genetically modified herbicide resistant soybean could increase the soybean yields.

(3 marks)

(c) Describe how genetically modified nitrogen fixing crops could reduce eutrophication and development of algae blooms.

(2 marks)

3. Refer to the following picture to answer Question 3(a) below:



(a) Explain why organic farming requires more land than conventional farming to produce the same 1 tonne of produce.

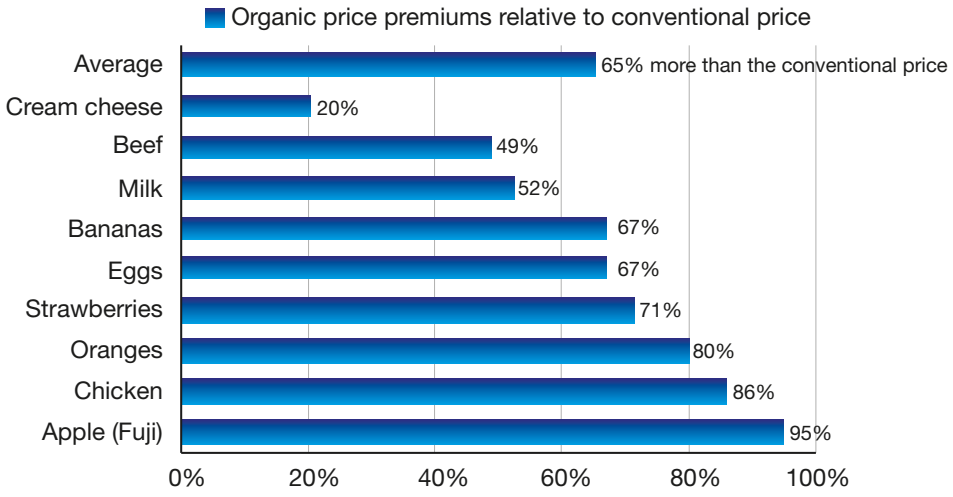
(4 marks)

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(b) Using a specific example, explain how intercropping can reduce the need for insecticides on organic farms.

(3 marks)

Refer to the following graph that shows the organic price premiums relative to conventional prices to answer the following question:



(c) Using data, explain why organic food is more expensive than conventionally grown food.

(3 marks)

(d) Describe **one** other negative aspect of organic farming.

(2 marks)

4. (a) Describe how vertical farms use space more efficiently than conventional farming.

(2 marks)

(b) Explain how vertical farms reduce 'food miles' **and** how this impacts global warming.

(3 marks)

E Extension question

Research **and** discuss how genetic engineering could be used to combat the current issues with cosmetic standards of fruit and vegetables and food wastage.

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7.4 Waste management

Nutrition Understanding

Australian's currently send approximately 40% of their waste to landfill. This is a stark difference to some European countries, such as Sweden, Germany, Netherlands and Switzerland that send less than 3% of their waste to landfill. Some countries like Switzerland do not even have any landfill sites. All of the waste that goes to landfill is a loss of valuable resources that humans have spent a lot of effort growing and mining, especially when the earth has a finite amount of resources. **Sending waste to landfill is not sustainable** long term because eventually earth's resources will run out. To maximise the life of our resources a **circular economy** approach must be implemented. A circular economy is an economic system that eliminates waste by retaining the value of resources through the continual use of resources. A circular economy also reduces the depletion of natural resources. In 2019, the Australian Government, in collaboration with state and territory governments, developed the *National Waste Policy Action Plan*. This policy applies the principles of a circular economy to better manage waste and protect our natural resources. The policy aims to recover 80% of resources from all waste streams and halve the amount of organic waste being sent to landfill by 2030. It also aims to phase out the use of problematic and unnecessary plastics by 2025 and significantly increase the use of recycled content.

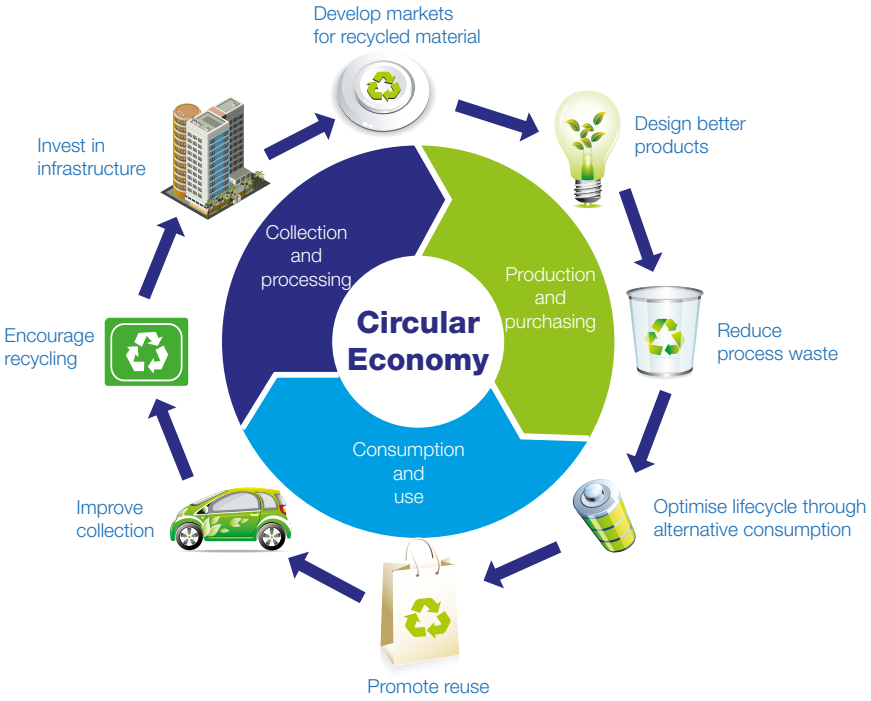


Figure 7.4.1: The principles of a circular economy with regards to waste management.

Helpful online resources

PostHarvest Technologies: Top Food Waste Statistics

https://www.youtube.com/watch?v=9s1rDcdhECA

Food waste and cosmetic standards

Food waste

Food wastage is a major issue worldwide. Approximately one third of all food produced is wasted. This equates to 1.3 billion tonnes of food that costs the global economy approximately $1 trillion annually. Furthermore, the **carbon emissions released from the decomposition of food waste** equates to approximately 8% of the total global gas emissions. Incredibly, if food waste was a country, it would rank third in the world behind USA and China. It is

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estimated that almost 800 million people are food insecure, yet if just one quarter of the food wasted was saved, it would be enough to feed 870 million people. This highlights that there is enough food being produced to feed the world's population but we need to be smarter about how we distribute, use and process food.

The Australian government estimates that food wastage costs the Australian economy $20 billion each year and that over five million tonnes of food end up in landfill, where it is decomposed emitting methane (a potent greenhouse gas). Furthermore, Australian consumers waste approximately 20% of the food they purchase. This equates to **one in five shopping bags** and an estimated $3,800 thrown away every year.



Figure 7.4.2: Large amounts of fresh food are thrown away by Australian's every day.

Did you know?

Throwing away one burger wastes the same amount of water as taking a 90-minute shower.

Cosmetic standards

Unfortunately, not all fruit and vegetables can be produced exactly the same and some are too big/small, and others have little bumps/lumps. This food is often referred to as '**ugly food**.' A significant source of food wastage is the **cosmetic standards** for fruits and vegetables set by supermarkets. Supermarkets set the cosmetic requirements for each individual fruit and vegetable based on the customer's idea of perfection. This means that any fruit or vegetable grown that does not meet the highly restrictive cosmetic standards, generally ends up as waste. Approximately 20 to 40% of Australian fruits and vegetables do not meet the supermarkets' cosmetic standards. This includes crooked carrots, undersized apples, curvy cucumbers and bananas that are too straight, too small or too big. All of these fruits and vegetables are edible and could be donated or processed into other food items.



Figure 7.4.3: Food that does not meet the cosmetic standards of supermarkets, also known as ugly food, generally does not make it into the food supply chain and is wasted.

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How food wastage can be reduced

Table 7.4.1: Some examples of how consumers and food producers, processors and retailers can reduce food wastage going to landfill.

Consumers	Food producers, processors & retailers
Plan ahead before going to the supermarket to ensure you only buy what is needed for the meals you are going to cook and perhaps plan how the leftovers will be used.	Food retailers can relax their cosmetic standards so that more food is acceptable and does not get wasted.
Sometimes the weekdays can get very busy and we can get very tired. Planned meals may not get cooked because of this and the ingredients can end up spoiling. One technique to address this is to use the weekends to cook up batches of food and freeze the separate portions.	Food processors can purchase the fruits and vegetables that did not meet the cosmetic standards and process it into food alternatives, such as cauliflower rice, apple pie, banana bread, carrot soup, etc.
Check the use by dates at the supermarket prior to purchasing foods and only buy what you can use before the food expires.	The ugly food from farms and leftover food from supermarkets could be donated to Foodbank or OzHarvest, who can redistribute it to charities to feed the food insecure.
If too much food is cooked, store the leftovers correctly and make sure they are eaten.	Food retailers can market and sell the 'ugly' fruit and vegetables cheaper than their perfect counterparts to entice consumers to purchase them.
Donate any food to Foodbank and OzHarvest that you will not be able to eat (this is a good idea prior to long holidays away from home).	Food producers could ensure that the fruits and vegetables are diverted from landfill and are composted to use as fertiliser for the next crop.

Did you know?

France became the first country to ban supermarkets from disposing of unsold food and made it mandatory to donate it to charities and food banks. Following its introduction in 2016, donations to food banks increased by an estimated 30% in 2017. This has resulted in food banks being able to provide for food insecure French citizens.

Helpful online resources

ClimateScience - Solve Climate Change: Food Waste: The Hidden Cost of the Food We Throw Out I ClimateScience #9

https://www.youtube.com/watch?v=ishA6kry8nc&t=125s

Cognito: GCSE Biology - How Human Waste Reduces Biodiversity - Explained #89

https://www.youtube.com/watch?v=0IUHnS-8kR4

Food expiration dates don't mean what you think - Carolyn Beans

https://www.youtube.com/watch?v=jDg8DQI7ZeQ

War on Waste Series 1 Episode 1

https://iview.abc.net.au/show/war-on-waste

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Waste sorting: Landfill, recycling and composting

In South Australia, there is a three-bin system. This system is comprised of:

- Landfill – blue or red bin (depending on your council area)
- Recycling – yellow bin
- Organic waste – green bin.

It is important that waste is disposed of in the correct bin (see Figure 7.4.4). There are many reasons for this, including **reducing the amount of valuable resources that end up in landfill**, reducing toxins leaching into groundwater, reducing the effect of plastic waste on biodiversity and recycling nutrients from organic waste into compost. It is also important that waste be disposed of in the correct bin from a processing point of view. An example of this is **soft plastics, which cannot be put in the recycling (yellow) bin** because they can get jammed in the automated sorting machines (see Figure 7.4.5 for more information). Furthermore, some food packaging can be placed in the organics (green) bin but they need to be compostable containers with no lining or additives, otherwise the compost produced could be contaminated. To correctly dispose of waste, reduce waste going to landfill and meet the goals of the Australian government's *National Waste Policy Action Plan*, **education** of the public on how to correctly dispose of their waste is essential.



Figure 7.4.4: The Which Bin campaign by the South Australian government is helping educate the public to correctly dispose of their household waste.



Figure 7.4.5: Soft plastics cannot be recycled in the yellow bins and must be collected separately and dropped off at the RedCycle bins commonly located at supermarkets. Some common soft plastics that can be recycled through RedCycle and some items that cannot are also presented.

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Did you know?

In 2020, the famous Nestle chocolate Kit Kat had its recognisable wrapper changed. The change in wrapper was in response to a damning study that revealed that even though 80% of Australians wanted to recycle, only 50% knew how to properly. It also revealed that 25% of Australians did not know they could recycle soft plastics like chocolate wrappers. The wrapper design is intended to raise awareness in Australia of how to recycle soft plastics through RecCycle bins at local supermarkets. More recently, Nestle has moved to wrapping Kit Kats and some other products in paper packaging. This move reduces the use of plastic packaging, which are synthesised from fossil fuels, and allows the paper packaging to be disposed of in the green compostable bins.



Landfill

There are two ways to dispose of solid waste. A dump and landfill. A **dump** is what most people think of when we think of landfill. A dump is an open hole in the ground that solid waste is buried in, whereas **landfill** is a carefully designed structure that is isolated from the environment using a bottom liner and is covered with soil daily. The bottom liner of a landfill pit prevents the leakage of toxic liquid from solid waste (known as leachate) into the soil and groundwater, contaminating it. Many materials that end up in landfill contain toxins that can leach into the soil and groundwater. A good example of this is electronic waste (**e-waste**) that contain many hazardous chemicals, including mercury, arsenic, cadmium, PVC, solvents, acids and lead. In 2019, the world generated 53.6 million tonnes of e-waste but only 17.4% was formally recycled. It is unclear what happened to the remaining 82.6% of the e-waste and how much of it ended up in landfill. The dumping of e-waste in landfill is also a waste of valuable finite resources, such as rare earth elements and precious metals.

The daily covering of landfills with soil can prevent bad odours from being released into the atmosphere and deter pests such as flies, rats and birds from accessing organic waste (see Figure 7.4.6). Approximately 60% of landfill from households is organic waste. When this organic waste reaches landfill, it is compacted and covered with soil, thereby removing oxygen. This results in its decomposition in anaerobic conditions (without oxygen), releasing methane as a by-product. **Methane** is a greenhouse gas that is 25 times more effective at trapping heat in the atmosphere than carbon dioxide. Methane is also highly flammable and can become dangerous if levels become too concentrated. These problems can be reduced and even eliminated by diverting organic waste from landfill.



Figure 7.4.6: Waste that ends up in landfill is a loss of resources but if not covered can attract pests such as gulls.

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Recycling

Foods are often packaged to protect them during transport and to increase their shelf life. All packaging requires the use of resources to make them. Paper and cardboard packaging is made from trees and the metals used to make tin cans and the **fossil fuels used to make most plastics** have to be **mined** from the earth's crust. The harvesting of these resources has significant negative effects on our environment, including **deforestation**, destruction of habitats, **reduced biodiversity** and emission of greenhouse gases that fuel **global warming and climate change**. Therefore, it is important to **recycle** our food packaging appropriately to reduce the negative effects on the environment, divert them from landfill and allow the resources they are made of to be turned into **new products**. Some examples of new products that paper and cardboard can be recycled into are egg cartons, paper plates, newspaper, new cardboard, tissues and paper towel. Glass can be recycled into new bottles, jars and fibreglass and plastics can be recycled into a range of new products (see Figure 7.4.7).

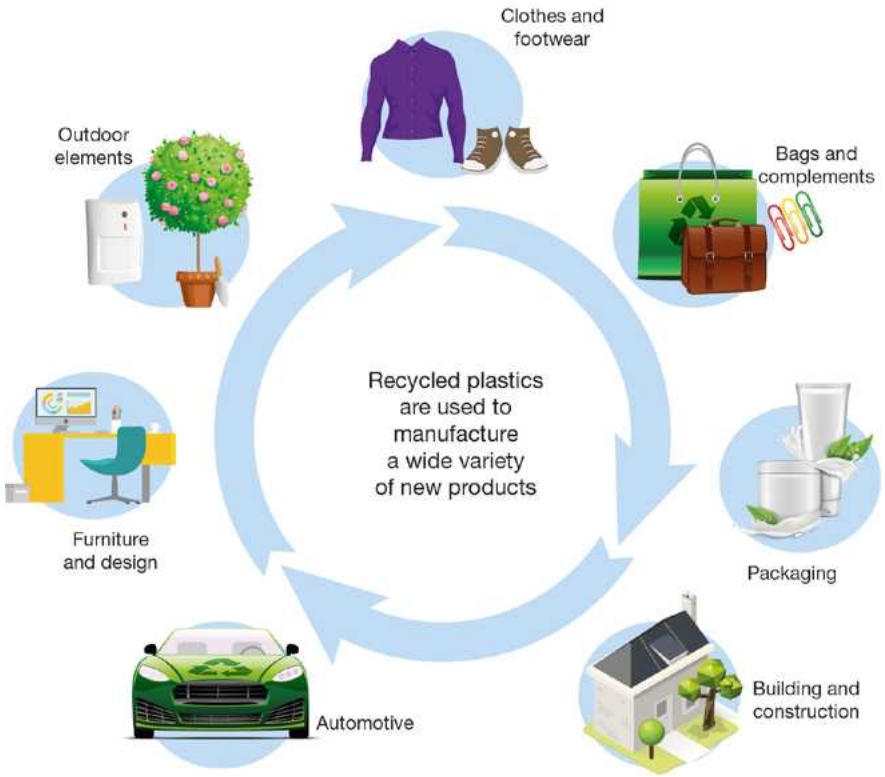


Figure 7.4.7: Some examples of new products that can be made from recycled plastic.

Organic waste

Organic waste is any organic material made from plants or animals. Some examples are food, tissues, tea bags, paper towels, eggshells, garden clippings, paper and **compostable packaging**. Compostable packaging is predominantly made from organic plant-based materials and its decomposition does not produce any toxic materials or microplastics. Compostable packaging can be easily broken down in composting systems through microbial action.

Organic waste should be placed into green bins. When the green bins are collected, the organic waste is taken to be industrially **composted** for 8 to 10 weeks. The compost then goes through a screening process to remove any plastics, metals, rocks and other contaminants from the compost. The end result is rich and fertile compost, soil and mulch that can be used on farms and family gardens to provide nutrients for new crops and garden plants to grow.

Helpful online resources

TED-Ed: Vermicomposting: How worms can reduce our waste–Matthew Ross

https://www.youtube.com/watch?v=V8miLevRI_o

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Littering

Food packaging options range in the amount of time they take to decompose. This means they if they are not disposed of correctly and are instead littered, they can remain in the environment for a very long time. Some plastics can take 500 to 1,000 years to decompose and it is estimated that glass can take up to one million years to decompose (see Figure 7.4.8 for decomposition of packaging types).



Figure 7.4.8: Approximate degradation times of various waste products.

Plastic waste that ends up in the environment, especially waterways, can **kill wildlife**. Plastic packaging such as six-pack rings and single use plastic bags can cause **suffocation** of animals such as turtles and fish. Animals can also **eat plastic waste** causing them to **starve**. This is because the plastic takes up space in their stomach and the stomach acids cannot break the plastic down to digest it, so it remains there, blocking food from entering the small intestine. Plastic waste that enters the environment can also **degrade into microplastics**, which animals can consume, entering the food chain. The effect of microplastics on humans is not currently well understood and further research needs to be conducted. Some research has linked microplastics with disrupting hormonal pathways, inflammation and infertility.

Helpful online resources

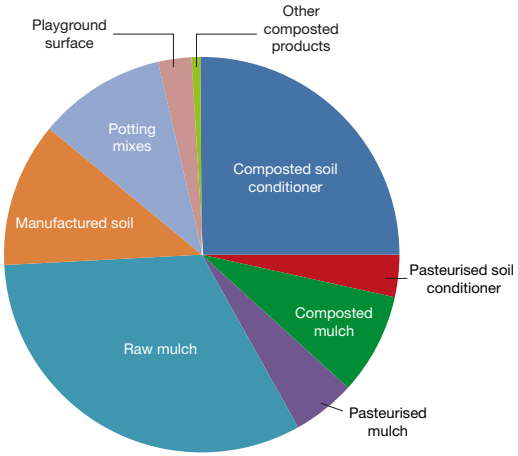
Kurzgesagt: Plastic Pollution: How Humans are Turning the World into Plastic

https://www.youtube.com/watch?v=RS7IzU2VJIQ

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7.4 Review questions

1. Refer to the graph below, which shows the breakdown of products made from recovered organics to answer the following questions:



(a) Name **three** products that can be disposed of in the green bin.

(3 marks)

(b) Describe what happens to organic waste after it has been collected by the organic waste garbage truck.

(2 marks)

(c) With reference to the graph, determine the percentage of *composted soil conditioner* that was produced from recovered organics.

(1 mark)

(d) Explain the importance of compost for organic farms.

(3 marks)

(e) Explain how organic waste that ends up in landfill contributes to carbon emissions.

(3 marks)

2. (a) Describe what 'ugly' fruit and vegetables are.

(2 marks)

(b) Describe why approximately 20 to 40% of all Australian fruits and vegetables never make it off the farm and are wasted.

(1 mark)

(c) Identify **one** example of how a food processor could use 'ugly' potatoes to divert them from landfill.

(1 mark)

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(d) Identify **one** example of how a food processor could use 'ugly' oranges to divert them from landfill.

(1 mark)

(e) Describe **two** ways that supermarkets could reduce their food wastage.

(2 marks)

3. (a) Explain how recycling food packaging made from paper and cardboard can reduce deforestation.

(3 marks)

(b) It is important to recycle plastic packaging, but soft plastics cannot be disposed of in the yellow recycling bin. Explain why this is the case.

(1 mark)

(c) Describe how soft plastics can be recycled.

(1 mark)

(d) State **two** examples of new products that plastics can be recycled into.

(2 marks)

(e) Describe how littered plastic waste can reduce biodiversity.

(4 marks)

E Extension question

Sweden's recycling system is so efficient that it often sends less than 1% of household waste to landfill and has to import waste from other countries to keep its recycling plants open and running. Research the Swedish recycling system **and** discuss some of the positives and negatives of this system.

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7.5 Foodbank and OzHarvest

Nutrition Understanding

The number of Australian households experiencing food insecurity is increasing. In 2022, approximately 33% of Australian households experienced severe or moderate food insecurity. Foodbank and OzHarvest are two charities that are fighting hunger by providing food relief.

Foodbank

Foodbank is Australia's largest **food relief charity** that sources and rescues over 40 million kilograms of food each year. Foodbank works directly with farmers, manufacturers and suppliers, and wholesalers and retailers to collect food at various points along the food supply chain. Foodbank distributes food to its approximate 2,625 charity partners and 2,500 schools as part of its food relief program. This is important to stock community pantries, mobile soup vans and fuel school breakfast and lunch programs. By rescuing food and distributing to the food insecure, Foodbank makes a significant positive impact on the lives of many Australians. If it wasn't for Foodbank, millions of Australians would go hungry. Foodbank is also combatting Australia's food waste problem. As Foodbank is collecting food that would otherwise be wasted, it is **diverting the food from landfill**. In 2019 alone, Foodbank saved approximately 81 million kilograms of carbon dioxide emissions due to its diversion of food from landfill. Therefore, Foodbank is also helping the environment and reducing the effect of food production and waste on global warming.



Figure 7.5.1: Foodbank is Australia's largest food relief charity and provides approximately 70% of rescued food for food relief charities Australia wide.

Helpful online resources

Foodbank is Australia's Largest Food Relief Charity

https://www.youtube.com/watch?v=DB57zlbS7zI

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OzHarvest

OzHarvest is a food rescue organisation that aims to feed the food insecure and reduce food wastage. OzHarvest collects excess food from over 3,500 food donors and delivers them to approximately 1,300 charities throughout Australia. OzHarvest diverts over 180 tonnes of food from landfill every week and redistributes it to help eliminate hunger in Australia. OzHarvest has opened Australia's first rescued food supermarket in Sydney called the OzHarvest Market. The OzHarvest Market has a 'take what you need, give what you can' philosophy, meaning that those who cannot afford to pay can also access food. OzHarvest also has a strong emphasis on engaging with and educating the public about preventing food waste and sustainability.



Figure 7.5.2: OzHarvest is a food relief charity that redistributes quality surplus food across Australia and diverts millions of kilograms of food from landfill.

Helpful online resources

We Are OzHarvest

https://www.youtube.com/watch?v=ZKTZBOq4Brw

Science Inquiry Skills 8: Design Practical

Design and Cook a Suitable Meal to Donate to the Hutt Street Centre or Another Suitable Charity

Please note that the Science Inquiry Skills 8 is suggested as a formative practical activity and not an assessed piece. It is also recommended that teachers contact Hutt Street Centre prior to organising this activity to ensure they are welcoming food donations.

Aim

To design and cook a suitable batch of food to be donated to the Hutt Street Centre or other suitable charity and support the homeless.

Introduction

The Hutt Street Centre is a charity that helps rebuild the lives of the homeless. The Hutt Street Centre supports more than 2,000 South Australians and serves over 40,000 meals every year. Your task is to support the Hutt Street Centre (or another suitable charity) by designing and cooking an appropriate batch of food. This could be a large batch of soup or pasta or even a large batch of chocolate chip muffins.

Helpful online resources

The Hutt Street Centre

https://www.huttstcentre.org.au

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Ex Possible Excursion 6

Plan and hold a food drive at your school to engage your local community and help others in need. The proceeds can be donated to Foodbank and/or OzHarvest. Food drives can be registered with Foodbank through their website and then they will respond with flyers and information to help plan the food drive. OzHarvest also has information on running food drives on their website. They have a list of seven easy steps to plan the food drive and provide links to flyers to help advertise the food drive.

Helpful online resources

Foodbank School Food Drive

https://www.foodbank.org.au/SA/foodbank-sa-school-food-drive-registration/?state=sa

OzHarvest Food Drive

https://www.ozharvest.org/give-a-little-love/donate-time/food-drives/

7.5 Review questions

1. List **four** types of outlets that Foodbank and OzHarvest might collect food waste from.

(4 marks)

2. In 2019, Foodbank saved approximately 81 million kilograms of carbon dioxide emissions due to its diversion of food from landfill. Explain how diverting food from landfill reduces carbon emissions.

(4 marks)

E Extension question

Research the charity SecondBite **and** discuss the focus and aims of this food rescue charity.

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Topic 7 Review Test

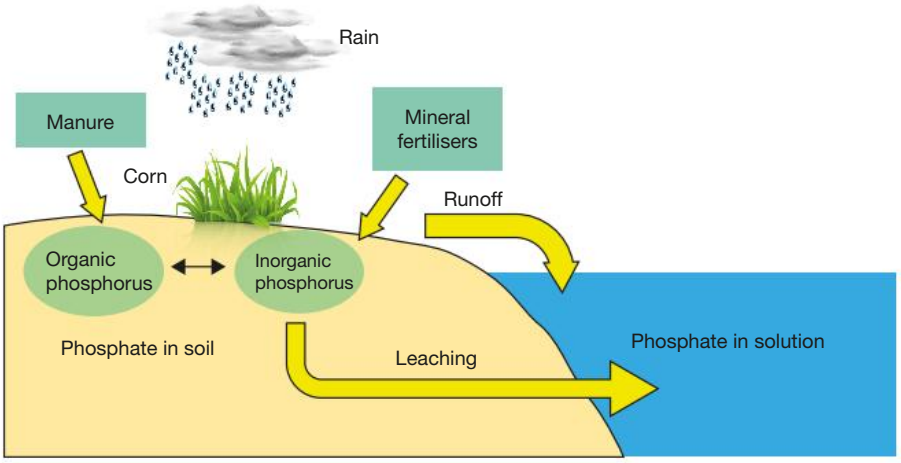
1. (a) Describe what a genetically modified organism is.

(2 marks)

(b) Explain how genetically modified pest resistant crops can increase yields.

(3 marks)

Refer to the diagram below to answer the following question:



(c) Identify **and** explain the event that is likely to occur in the body of water as a result of the processes outlined in the diagram above.

(4 marks)

(d) Pig farmers feed their pigs corn or cereal grains but these foods contain a type of phosphorus that pigs are unable to digest. Currently, pig farmers also feed their pigs an enzyme called phytase so they can digest this type of phosphorus. However, ingested phytase is much less efficient at digesting phosphorus and this results in pig urine and manure being very rich in phosphorus. This phosphorus in the pig manure can runoff into waterways.

(i) Using the information in the passage above, describe how scientists could genetically engineer pigs to be more efficient at digesting phosphorus from their feed.

(2 marks)

(ii) Using your understanding of Science as a Human Endeavour, discuss **two** economical impacts that genetically engineered pigs that are more efficient at digesting phosphorus could present.

(4 marks)

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(e) Explain how legumes can be used to reduce the reliance on fertilisers and increase soil quality.

(4 marks)

2. Explain **two** ways that vertical farming minimises carbon emissions.

(4 marks)

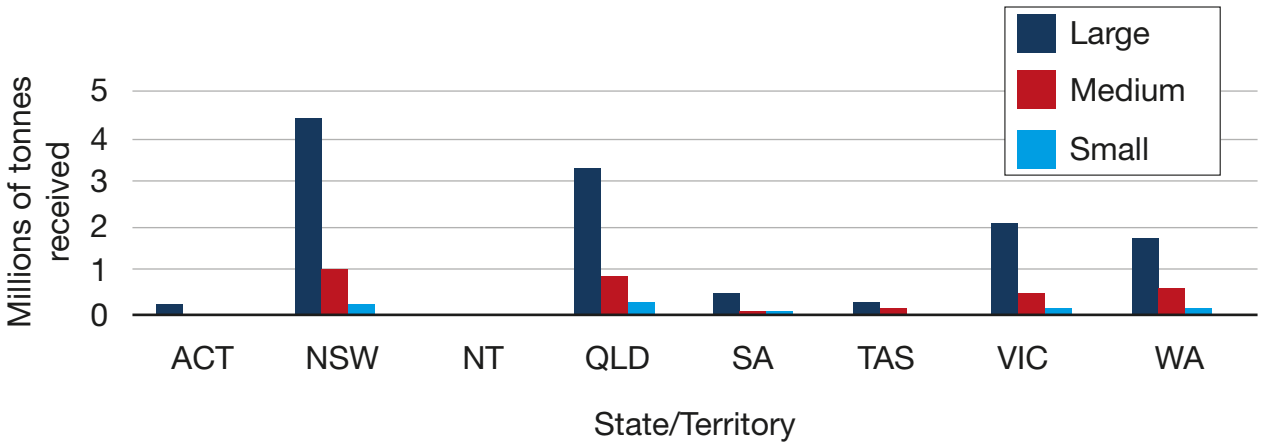
3. (a) Describe why sending waste to landfill is not sustainable.

(2 marks)

(b) Explain how food waste that ends up in landfill contributes to global warming.

(3 marks)

Refer to the following graph which shows the reported tonnes of waste deposited by landfill size and state/territory to answer questions (c) and (d).



(c) Using data, describe how many more millions of tonnes of waste were deposited in large landfills in NSW compared to SA.

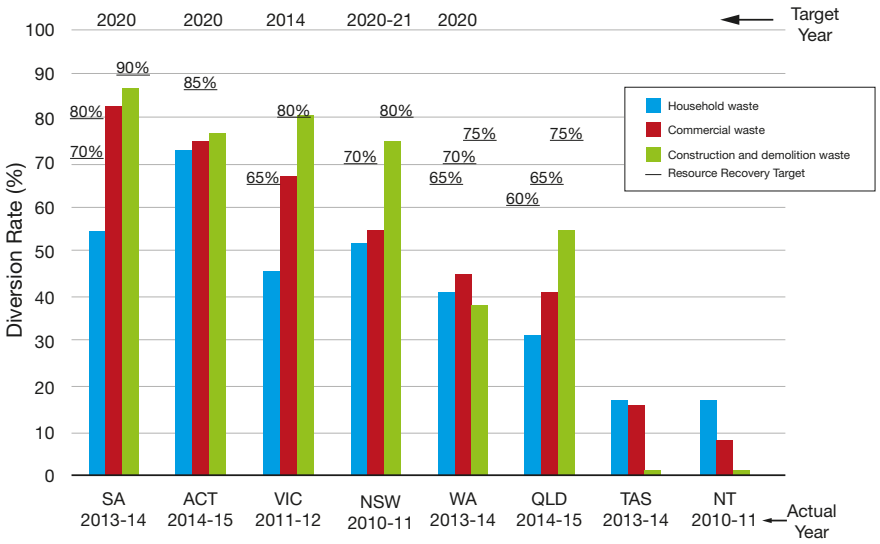
(1 mark)

(d) The Australian government is implementing measures to reduce the amount of waste that ends up in landfill. If landfill was reduced by 40%, determine how many millions of tonnes would the large landfills in NSW receive

(2 marks)

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Refer to the following graph which shows the National Resource Recovery targets to divert three sources of waste from landfill by state/territory to answer questions (e) and (f):



(e) Using data, determine which state/territory has set the most ambitious target to divert household waste from landfill.

(2 marks)

(f) With reference to the data, determine which states/territories have surpassed their target for diverting commercial waste from landfill.

(2 marks)

(g) With reference to the graph, determine which state/territory is the furthest away from meeting its target for diverting household waste from landfill.

(2 marks)

(h) Suggest a reason why the state/territory you mentioned in part (g) could be far away from their target of diverting waste from landfill.

(1 mark)

4. (a) Explain why water borne diseases are more common in developing countries.

(3 marks)

(b) State how a lack of water supply could lead to poor hygiene practices and increased risk of disease.

(1 mark)

(c) State **two** symptoms of cholera.

(1 mark)

(d) Describe **two** ways mothers could reduce the risk of water borne diseases being transmitted to their infant who is formula fed.

(2 marks)

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(e) Describe **three** ways contracting a waterborne disease can impact a community.

(3 marks)

(f) A safe water supply is needed for food production. Describe how a lack of water could result in food insecurity.

(2 marks)

(g) Food shortages can lead to famine. Outline **two** causes of famine other than lack of water supply.

(2 marks)

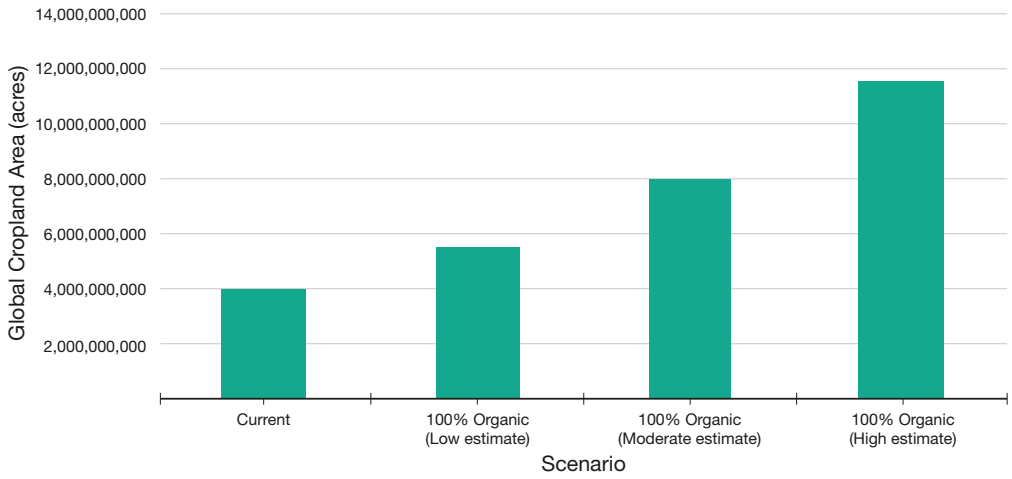
5. (a) Organic farming uses natural predators to combat pests. Describe **one** example of this.

(1 mark)

(b) Using an example, describe how the mixed farming technique can reduce the need to use herbicides.

(2 marks)

Refer to the following graph, which shows the cropland expansion needed to grow all food organically, to answer questions (c) and (d):



(c) With reference to the graph, state how many more acres of land would be needed if all crops were grown organically (moderate estimate).

(1 mark)

(d) With reference to the graph, state the difference between the low and high estimate for how many more acres of land would be needed if all crops were grown organically.

(1 mark)

(e) Explain why more land is required to grow food organically in comparison to conventional farming.

(4 marks)

Total: /60

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Topic 8 Food processing



Concept: Sustainable food systems

8.1 Food Safety Australia New Zealand
8.2 Food contamination
8.3 Safe food handling
8.4 Preservation methods
8.5 Fresh versus processed foods
8.6 Food packaging and labelling
Topic 8 Review Test

8.1 Food Safety Australia New Zealand

Nutrition Understanding

The majority of foods are not suitable for consumption without some form of processing. **Food processing** can involve operations such as washing, chopping, blanching, freezing, sterilising, additives, fortification and packaging. Processing can make raw foods more suitable for consumption by ensuring they are safe to eat, extending their shelf life, increasing convenience and improving the nutritional quality.

It is important that all businesses in the food processing chain uphold a high standard of food safety to prevent contamination and widespread food poisoning. **Food Safety Australia New Zealand (FSANZ)** is an independent agency that sets the food standards for all food businesses in Australia and New Zealand. The **Food Standards Code** regulates the labelling requirements, food additives, vitamin and mineral fortification, microbiological limits and processing requirements, contaminants and residues, and the use of new technologies, such as irradiation and genetic modification of foods. FSANZ works with the food industry, public health professionals, consumers and government departments to develop and update the food standards to ensure consumers are protected. Throughout this topic, these food standards will be explored further.

FOOD STANDARDS Australia New Zealand
Te Mana Kounga Kai – Ahitereiria me Aotearoa

Figure 8.1.1: The Food Safety Australia New Zealand logo.

Helpful online resources

FSANZ: Who we are and what we do

https://www.youtube.com/watch?v=XeMHXehEBHw

8.1 Review Questions

1. State a definition for food processing.

(1 mark)

2. Describe why foods are processed in modern society.

(2 mark)

3. Describe what Food Safety Australia New Zealand (FSANZ) is.

(1 mark)

4. Outline **three** areas regulated by the Food Standards Code.

(3 marks)

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8.2 Food contamination

Author's note: The concepts of food contamination and safety are relevant to both Topic 6 (Nutrition and food safety during pregnancy and lactation) and Topic 8 (Food processing).

To prevent duplication, the content and questions for food contamination is covered in Topic 8.2. There is a strong focus on food safety during pregnancy embedded throughout this chapter as well as other immunocompromised groups of the community.

This information is important to understand for all individuals given that everybody prepares food for themselves and other people at some point in their life. It is also important to know how different types of foods should be prepared and foods that should should be avoided to reduce risk of contracting food poisoning. This is especially important for individuals that are immunocompromised.

Nutrition Understanding

Food contamination is the tainting of food with something that should not be in it. **There are three types of food contamination**: **physical, microbiological and chemical** (see Table 8.2.1). Food contamination may result in **food poisoning** or other health issues for individuals who consume the food and possible consequences to the business that sold the contaminated item. Food poisoning is the illness that results from consuming spoiled, contaminated or toxic food and is generally associated with symptoms such as fatigue, vomiting, diarrhoea and dehydration. The most common cause of food poisoning is from excess microbiological growth and the resulting toxins but chemical contamination with some toxins can also cause food poisoning. Microbial contamination that causes food poisoning can commonly go **unnoticed before the food is consumed** due to its lack of sensory indicators. **Most bacteria that cause food poisoning and the toxins they release have no smell or taste**. Foods that do smell putrid are generally caused by pseudomonas, which are non pathogenic bacteria. This is why safe food handling processes should be observed to reduce its likeliness of occurring.

Table 8.2.1: Some examples of the different types of physical, chemical and microbiological food contamination.

Physical	Chemical	Microbiological
You can generally see this	*You may be able to smell or taste chemicals in food*	*You generally cannot see, smell or taste microbes in food*
Dirt	Pesticides and fertilisers (excess residue on produce)	Bacteria (e.g. salmonella & listeria)
Hair and fingernails	Heavy metals (e.g. mercury, lead & cadmium)	Viruses (e.g. norovirus & hepatitis A)
Insects	Cleaning chemicals (e.g. sanitiser)	Fungi (e.g. Claviceps purpurea – ergot)
Metal	Medications (e.g. antibiotics)	Parasites (e.g. toxoplasma gondii)
Glass	Additives (higher than acceptable concentrations)	
Jewellery	Microplastics	
Band aids		
Pests and droppings		

Food poisoning is not to be confused with food spoilage. Food spoilage is defined as any undesirable change to a food. It can result from physical, chemical or microbiological changes. Most food spoilage occurs due to microbiological activity, which results in the production of certain chemicals that can change the colour, texture and odour of foods. **These sensory cues can indicate that the food may be unsafe to eat** and can therefore be detected by humans, preventing them from consuming it. It is important to note that food spoilt by microbes should not be consumed because it could still cause illness, such as vomiting, and it is a lot less nutritious than its fresh counterpart. **Microbiological spoilage** can result from different microorganisms, such as fungi and bacteria. Spoilage by fungi includes the growth of moulds on breads, cheese, fruits and vegetables (see Figure 8.2.1). If food spoilt by fungi is consumed it could cause food poisoning, but it is a lot less common and dangerous than food poisoning by bacteria. The majority of microorganisms that cause food spoilage are not pathogenic (disease causing) to humans.

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Figure 8.2.1: An example of microbial spoilage of a mandarin by fungi.

Food can also become spoilt through **physical factors,** such as damage to the food causing bruising and openings incurred during processing or transport. This can reduce its appeal and increase the surface area for microorganisms to grow further, reducing its shelf life. Fruits and vegetables begin to deteriorate after they are harvested, caused by a change in **chemical reactions**. These chemical reactions can involve enzymes that promote self-destruction, increasing suitability for microorganisms that cause food spoilage (see Figure 8.2.2). In addition, when fruits or vegetables are exposed to oxygen, **enzymatic browning** can occur, reducing their appeal for human consumption (see Figure 8.2.2). This can be further enhanced by physical damage that causes bruising and openings in the fruit or vegetable. Furthermore, **fats and oils** and certain foods can **become rancid** and break down into fatty acids through extended exposure to heat, light and oxygen. The chemical reactions that cause rancidity often result in the food product developing a bad smell and change in colour.



Figure 8.2.2: An example of how physical damage to an apple can increase its spoilage and enzymatic browning.

Did you know?

Many fruits release a gaseous hormone called ethylene. One of ethylene's roles is to assist in fruit ripening. When ethylene is released from a piece of fruit, it will respond and begin ripening. If the ripening fruit is in a bowl with other fruit, the ethylene gas will also increase the ripening of the surrounding fruit. This enzymatic ripening can increase the rate of food spoilage in a fruit bowl.

The consequences of food contamination for **pregnant woman** can be severe and can lead to **birth defects, miscarriage or stillbirth**. It is therefore important that food safety measures are implemented at all stages of the food processing chain and that pregnant women understand the extra food safety measures they need to take due to their increased risk.

Physical contamination

Physical contamination is when **any physical object accidentally or purposefully makes its way into the food.** This can render the food undesirable and a possible health hazard. Some examples of physical contaminants are highlighted in Table 8.2.1.If a physical object is unknowingly consumed it **could result in physical harm**. Such physical harm could result in minor or major injury, surgery to remove the item or even death, depending on the object consumed. Some common injuries from physical contamination are lacerations of organs in the digestive system, such as lips, mouth, oesophagus, stomach and intestines, chipped teeth and choking.

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Did you know?

A recent example of physical contamination that occurred in Australia was the deliberate physical contamination of strawberries with sewing needles. This occurred in 2018 at a strawberry farm in Queensland. There were over 186 reports of physical contamination and this deliberate physical contamination caused widespread public alarm, injury to individuals who consumed the needles and financial harm, especially to the strawberry industry. Because of the widespread contamination, farmers were forced to dispose of tonnes of strawberries, supermarkets had to pull them off the shelves, many people lost their jobs and sales decreased because consumers were scared of the needle-contaminated strawberries. Supermarkets put in place methods to mitigate concerns, such as metal scanning of the punnets of strawberries to ensure their safety, but customer confidence had been eroded and sales remained low. An employee of the strawberry farm was arrested in late 2018 and charged with several counts of contaminating goods.

Microbiological contamination

Microbiological contamination is when harmful microorganisms, such as bacteria contaminate food. This can lead to food poisoning and food spoilage. **Food poisoning** occurs when **pathogenic** (disease causing) microorganisms spread to food and are consumed. When pathogenic organisms contaminate food, they can multiply exponentially, especially in optimum conditions, and **release toxins** that can be harmful when consumed. As previously mentioned, food poisoning from consuming microbiological contaminated food can be much harder to detect because the microorganisms and their toxins generally cannot be seen or smelt, so they can easily be consumed unknowingly. The best way to avoid food poisoning is by practicing safe food practices like washing hands before preparing foods and following the correct storage instructions.

There is a general misconception that the last thing eaten always causes the case of food poisoning but given the time it takes for symptoms to develop, this is not always the case. If an individual does contract food poisoning, symptoms generally become apparent between two to three hours and two days after the contaminated food is eaten. **Some common symptoms** include stomach pains, a headache, vomiting, diarrhoea and general fatigue. If symptoms last more than three days or are severe, such as blood or mucus in diarrhoea, urgent medical attention is required. Furthermore, some food poisoning bacteria can cause the onset of reactive arthritis, which causes inflammation of joints a couple of weeks after the food poisoning case. This can be a symptom of an undiagnosed autoimmune disease and should be followed up with a medical professional. In serious cases, food poisoning can lead to death.

Risks for immunocompromised

It is also important to note that certain groups in society are at a greater risk of food poisoning, such as the elderly, infants, **pregnant women** and people who are **immunocompromised** (have a weakened immune system). The **elderly** are at a greater risk of food poisoning because the **immune system weakens with age**. This is because fewer immune cells are produced and the established white blood cells become less efficient at responding to new infections. **Infants** are also immunocompromised because their **immune system is not fully developed**, and they rely on breastmilk from their mothers to be supplied with developed immune cells and specific antibodies to fight infections. **Pregnant women** are temporarily immunocompromised due to the increased presence of the hormone progesterone. The mother's **immune system is suppressed** during this period because she has a 'foreign' organism growing within her (i.e. the foetus, which includes the father's genetic material). If the mother's immune system was not suppressed during pregnancy, her immune system could attack the 'foreign' developing foetus. Pregnant women are **up to 13 times more likely** to contract food poisoning (such as listeriosis) from contaminated food than the average healthy adult. In some cases, food poisoning can lead to serious illness of the foetus, **premature birth, stillbirth or miscarriage**. Some additional groups within society that are immunocompromised are cancer patients receiving **chemotherapy** (kills rapidly dividing immune cells), those infected with **human immunodeficiency disease (HIV)** and those affected by **auto-immune diseases** (where the immune system mistakenly detects certain host cells as foreign and starts attacking them).

Helpful online resources

What Happens If You Eat Mould?

https://www.youtube.com/watch?v=6vIogSJ7kTo

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Microorganism requirements

Some foods are more prone to microbiological contamination. These **high-risk foods** provide the ideal requirements for growth, such as nutrition, the correct pH and water. When these high-risk foods are left in the **temperature danger zone** for too long, rapid division can occur increasing production of toxins and the likeliness of food poisoning. Under ideal conditions a single bacterium can multiply into approximately two million bacteria within 7 hours. Some examples of high-risk foods include:

- Meat
- Poultry and eggs
- Seafood
- Pre-packaged fruits and vegetables
- Raw fruits and vegetables such as sprouts and rockmelon
- Dairy products
- Unpasteurised juices

As previously mentioned, the growth of microorganisms can be affected by multiple factors. Understanding how these factors affect their growth can enable us to preserve food for longer and keep our food safe to eat. Some of these factors are outlined over the following pages.

Temperature

Food must be kept within a certain temperature range to slow down microbial growth and the production of toxins. If food is left out on the bench in the **temperature danger zone**, microorganisms such as bacteria can thrive and increase in number exponentially (see Figure 8.2.3).

Exponential growth of bacteria

Time	Number of Cells	
0 min	1	$= 2^0$
20 min	2	$= 2^1$
40 min	4	$= 2^2$
60 min	8	$= 2^3$
80 min	16	$= 2^4$
100 min	32	$= 2^5$
120 (2hr)	64	$= 2^6$
⋮	⋮	⋮
4 hr	4,096	$=2^{12}$
⋮	⋮	⋮
12 hr	68,719,476,736 = 2^{36}	

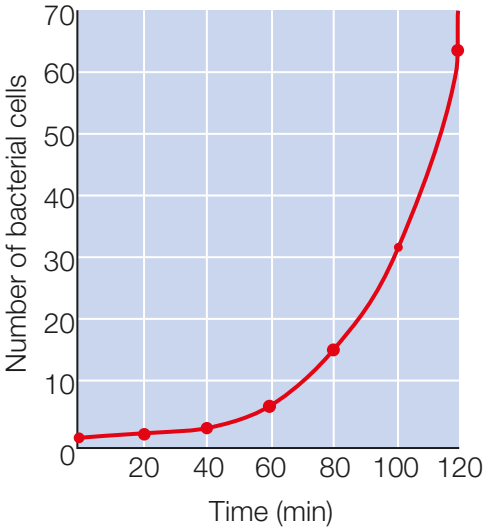


Figure 8.2.3: An example of the exponential growth of bacteria that divide every 20 minutes.

The temperature danger zone is **5°C to 60°C** and bacteria can divide every 4 to 20 minutes in the danger zone. If food is left in the **danger zone for four hours**, the number of bacteria that has grown in that time generally renders the food unsafe for consumption. This is also why frozen food should not be defrosted on the bench at room temperature. It may be more convenient because it will defrost quicker but it increases the risk of food poisoning because the food is left in the danger zone making conditions more ideal for bacterial growth. Food should instead be defrosted in the fridge at a temperature below 5°C.

Fridges should be set at a temperature between **0°C and 5°C** because this is below the temperature danger zone and slows bacterial growth and division. For example, at 1°C, some bacteria double approximately every 6 hours. Food will generally last days in the fridge between 0°C and 5°, but the length does differ between food types. Food that will not be eaten within days should be stored in a **freezer at -18°C** to increase its storage life. At this temperature, the **water in the food needed for chemical reactions by bacteria to grow and divide is frozen** and unavailable to use, so bacteria become dormant. This means that bacterial growth will be paused until conditions become more favourable again. **Putting food in the freezer does not kill the bacteria**. The ideal temperature for freezers to be set at is -18°C but freezers should definitely be set to at least below -10°C.

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This is because at -10°C bacteria can still double every 60 hours and if left for too long in the freezer at or above this temperature, its consumption can still result in food poisoning.

When reheating food, the food needs to be reheated to a temperature above the upper end of the danger zone of 60°C. Most bacteria cannot grow above 60°C so this slows their growth. If heated for long enough at a high enough temperature, the **bacteria are killed**. For example, salmonella is killed at 71°C. Therefore, when food is cooked or reheated it is **recommended to heat it to a temperature above 75°C** to be safe. This is especially important for **the immunocompromised** when reheating food. Even if food is heated to 75°C, the **heat cannot destroy the toxins already released by bacteria or any dormant spores** they may have produced. Some bacteria are able to form dormant spores that are very resistant to environmental stresses, such as extremely high temperatures, to ensure its survival. Once the environmental stress passes and conditions return to normal, the spores are able to reactivate, and the bacterial growth can continue. See Figure 8.2.4 for a summary of how temperature affects microbial growth.

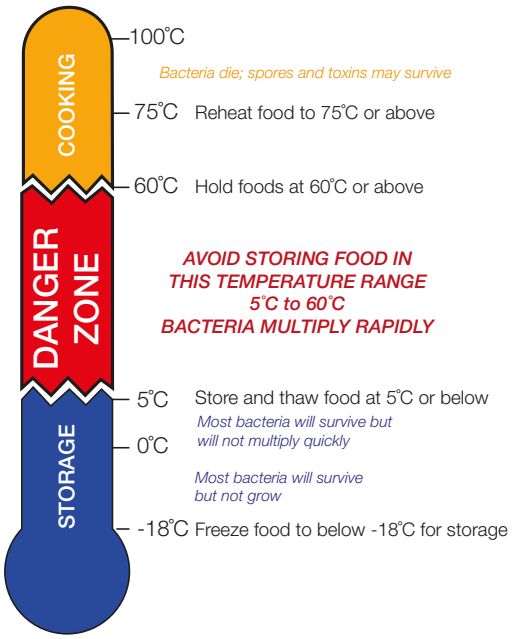


Figure 8.2.4: A summary of the storage, cooking and danger zone temperatures to reduce the risk of contracting food poisoning.

pH

pH is a measure of how acidic or alkaline an environment is. The pH scale ranges from 0 to 14. At a pH of 7, the environment is neutral. As the pH decreases towards 0, it becomes progressively more acidic; as pH increases towards 14, it becomes progressively more alkaline (see Figure 8.2.5). The majority of microorganisms prefer a pH closer to neutral in the range 6.6 to 7.5 for optimal growth. Each species of bacteria generally grows at a specific pH whereas fungi tend to grow over a wider pH range. As **most species cannot grow in an acidic environment below a pH of 4**, altering the environment of particular foods to make them more acidic can increase the shelf life of foods and reduce risk of food poisoning.

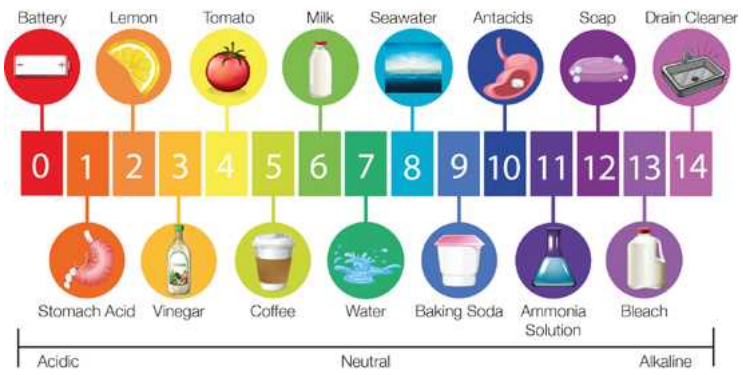


Figure 8.2.5: The pH scale and some examples of substances at the various levels of the pH scale.

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Moisture

Microorganisms require water to perform many chemical reactions and they obtain this from their environment. Each food varies in its water content; for example, lettuce and tomatoes are 95% water whereas poultry is 72% water. However, a lot of the **water in foods is bound to salts (e.g. Na^+)** or cell structures and is unavailable for microorganisms to use for chemical reactions. **The amount of free water** that is available to support microbial growth is a better measure and is known as **water activity (a_w)**. Water activity is measured on a scale of 0.0 (no free water) to 1.0 (pure water). Most pathogenic bacteria require a water activity above 0.9 and bacterial growth is inhibited below a water activity of 0.75 (see Figure 8.2.6 for some specific examples). However, some yeasts and moulds can still grow below a water activity of 0.75. Foods that have water activity below 0.6 prevent all growth of microorganisms. **When foods are dehydrated or frozen the water activity is reduced preventing microbial growth**.

Product	a_w
water	1
meat	0.97 - 0.99
milk	0.97
juice	0.97
cheeses	0.93 - 0.96
bacon	<0.85
jams	0.82 — 0.94
saturated solution of NaCl	0.75
room air	0.5 - 0.7
honey	0.5 - 0.7
dry fruits	0.5 - 0.6
crackers	0.3
infant formula	<0.2

Microorganism	a_w
Clostridium botulinum	0.97
Pseudomonas fluorescens	0.97
Escherichia coli	0.95
Clostridium perfringens	0.95
Salmonella	0.95
Vibrio cholerae	0.95
Clostridium botulinum A, B	0.97
Bacillus cereus	0.93
Listeria monocytogenes	0.92
Bacillus subtilis	0.91
Staphylococcus aureus	0.87
Most of the moulds (fungi)	0.70
No development	0.60

Figure 8.2.6: Some examples of the water activity in various foods and the minimum water activity various microorganisms can survive at.

Oxygen

Many microorganisms are aerobic. **Aerobic organisms require oxygen to respire and produce energy** for cellular activity and division. If oxygen availability is reduced, aerobic microorganisms cannot grow and divide as efficiently. An example of aerobes is *Escherichia coli (E. coli)* bacteria. Many *E. Coli* strains are harmless but some can cause serious food poisoning. Conversely, some microorganisms are **anaerobic**. These microorganisms do not need oxygen to produce energy and can survive in environments very low in oxygen. An example of an anaerobe is the bacterium *Clostridium botulinum*, which can survive in the very low oxygen environment of tinned cans.

Listeria

Listeria is bacteria that can cause **listeriosis**. Listeriosis is a serious condition and if listeria bacteria reach the blood, one in five people die. **Listeria are present in dirt** and dust and are therefore likely to contaminate **ground fruits and vegetables**, especially any that are not cleaned thoroughly prior to eating. Listeria can also contaminate processing machinery and therefore affect fruits and vegetables that are processed and frozen. Vulnerable groups in society such as the immunocompromised**,** are at higher risk of contracting listeriosis. Pregnant women are immunocompromised and need to take extra care because even mild infections that may not present symptoms can have severe consequences for the foetus including premature birth, severe brain damage to the foetus, **miscarriage or stillbirth**. Listeria is also tolerant to low temperatures so they can grow and divide on food stored in the fridge increasing risk of infections.

Some examples of foods that are high-risk of listeria infection are:

- **Bean sprouts**
- **Processed rockmelon** (listeria is found in dirt and if a melon is not cleaned properly before processing the knife transfers the listeria from the outside of the skin to the inside as the melon is cut)
- Unpasteurised dairy products and soft serve ice cream
- Eggs that have not been cooked thoroughly and retain a runny yolk and products that include raw eggs such as freshly made mayonnaise

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- Raw meat
- Soft cheeses such as brie, camembert and ricotta
- Some processed meats at the deli and sandwich bars
- Some seafood especially smoked seafood and raw seafood used in sushi
- Packaged salads and fruit salads
- Untreated water

Some **strategies to reduce the risk of listeria contamination** for vulnerable groups include:

- Washing fruits and vegetables thoroughly, especially if eaten raw.
- Leftovers should be refrigerated as soon as possible and only eaten within the 24 hours after cooking.
- Reheat leftovers until steaming hot (above 75°C) to kill bacteria.
- Frozen meats should be thawed in the fridge and not at room temperature in the 'danger zone'.
- Use by dates should be checked prior to eating and adhered to.
- Raw foods should be stored low in the fridge reducing the risk of contaminating other products (by leaking from upper shelves).

Helpful online resources

FSANZ: Listeria

https://www.youtube.com/watch?v=vpBGyfkGZic

Salmonella

Salmonella is a type of bacteria that is **found in the gut of healthy animals**. Salmonella poisoning is therefore generally associated with consuming animal products. Because salmonella is found in the gut of animals it can contaminate dirt and water through animal faeces and the use of animal manure as fertiliser. This can ultimately infect food grown in the soil or watered with infected water.

Salmonella poisoning is **most likely to affect children under five**. The immunocompromised (including pregnant women) are also at a higher risk. Common symptoms of a salmonella infection are stomach cramps, fever, vomiting and diarrhoea.

Salmonella poisoning in **pregnant women** is not as severe as listeria poisoning. It generally only affects the mother but the associated **vomiting and diarrhoea can dehydrate the mother**. Hydration is crucial for the development of the foetus and dehydration can result in low amniotic fluid, preterm delivery and birth defects. Therefore, it is important for the mother to drink lots of water to replace the lost fluids. In serious cases, where the infection reaches the mother's blood, salmonella poisoning can result in miscarriage but this is rare. Salmonella can cross the placenta of pregnant women and infect the foetus but this is also rare.

Salmonella is typically found in:

- Animal products left in the temperature danger zone for too long.
- **Inadequately cooked meats** (e.g. chicken not thoroughly cooked).
- Eggs or products containing eggs that have been inadequately cooked.
- Unpasteurised dairy products.
- Some raw fruits and vegetables e.g. sprouts, melons and leafy vegetables.

Salmonella can **spread by cross contamination** either directly through contact with other food sources or indirectly through utensils. Spread of salmonella can be prevented by:

- Separating raw food from cooked food (e.g. keeping raw meats in a separate bag from deli meats at the supermarket and storing them on different shelves within the fridge).
- Thoroughly cooking meat, chicken and eggs above 75°C to kill salmonella.
- Avoiding leaving food for over four hours at room temperature (in the danger zone).
- Refrigerating food below 5°C.

Helpful online resources

Let's Learn About Bugs: Salmonella - a quick introduction and overview

https://www.youtube.com/watch?v=xOamez79hLA

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Chemical contamination

Chemical contamination occurs when chemicals make their way into our food. Some examples of possible chemical contaminants are highlighted in Table 8.2.1. Also, **chemicals can bioaccumulate** in our food. An example of this is seafood, which can accumulate chemical toxins, such as **mercury**, dioxins and polychlorinated biphenyls (PCBs). If humans consume too much affected seafood in a short amount of time, the chemical(s) can accumulate in the human body and lead to adverse health effects.

Helpful online resources

FSANZ: Chemicals in Food

https://www.youtube.com/watch?v=njX0CgRS2_w

Mercury

Heavy metals are a form of chemical contamination in our food sources. One example of this is **methylmercury poisoning.** Methylmercury is a very toxic compound that builds up in living tissues and can affect **neural development and reproduction** in humans. Methylmercury can form naturally in the environment but human activities such as **burning fossil fuels like coal releases a significant amount of methylmercury** into the atmosphere. Rain then washes the airborne methylmercury into the oceans where they start to accumulate in small organisms like plankton, thereby entering the food chain. This chemical cannot be expelled faster than it is absorbed and results in bioaccumulation. Because the methylmercury remains in the organism, when it is consumed the methylmercury is transferred to the consuming organism. This higher order consumer generally eats multiple lower order organisms and therefore there is a greater build-up of mercury in this organism. This is called **biomagnification** (see Figure 8.2.7). This trend continues up the food chain putting the highest order consumer, in this case **humans, at the highest risk.**

Methylmercury can have toxic effects on the nervous, digestive and immune systems. Developing foetus' and infants are at high risk of the negative effects of methylmercury, which is obtained through their **mother's diet**. Therefore, mothers need to take care with the amount of seafood they consume during pregnancy and lactation. The foetus is sensitive to mercury, which can affect the developing nervous system, and high levels of mercury are associated with **lower learning capabilities.**

Fish are an important part of a varied diet and are an excellent source of protein, **omega-3 fats**, iodine and are low in saturated fats. Fish should therefore still be consumed during pregnancy and lactation. The number of serves of different types of fish that pregnant women and women planning pregnancy can eat safely according to Food Standards Australia and New Zealand are outlined in Table 8.2.2. It is important to note that pregnant women should take care when ordering the classic 'fish and chips.' A lot of the 'fish' under the batter is actually **shark**. In Australia, the term '**flake**' is commonly used for shark meat. As shark is a higher order consumer it can contain high levels of methylmercury (see Figure 8.2.7) and should be eaten only once a fortnight by pregnant women (with no other fish consumed during that time). Unless labelled, the shark meat could be from any type of shark, including endangered species.

Table 8.2.2: The Food Standards Australia and New Zealand recommendations for the number of serves of different types of fish for pregnant women. The serving size is 150g.

One serve per fortnight	One serve per week	Two to three serves per week
Shark (flake) or billfish (swordfish, broadbill, marlin) AND NO OTHER FISH THAT FORTNIGHT	Orange rough (deep sea perch) or catfish AND NO OTHER FISH THAT WEEK	Any other fish not listed in the first two columns.

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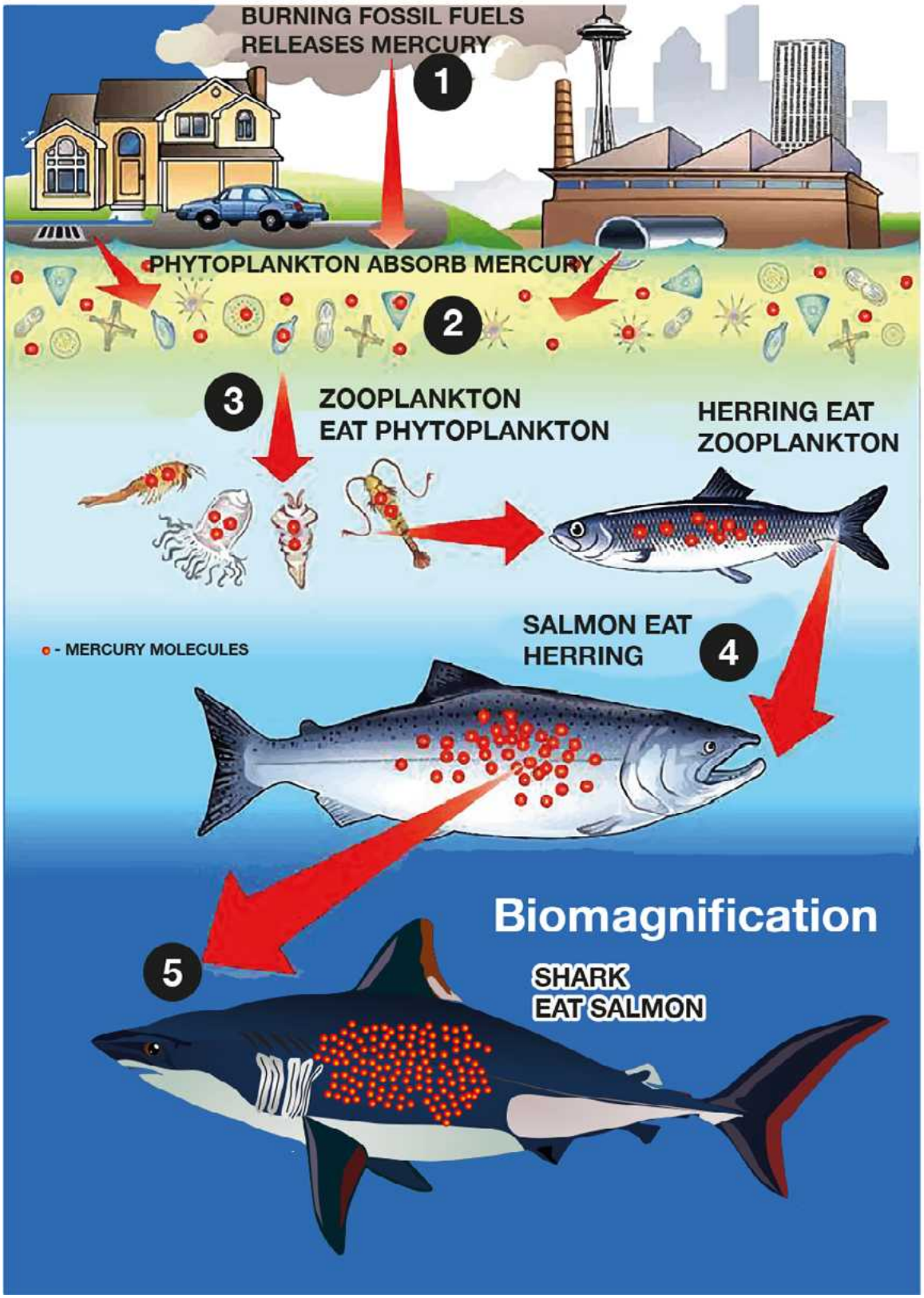


Figure 8.2.7: An example of how mercury can biomagnify through a food chain and lead to chemical contamination of seafood.

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Microplastics

The use of plastics for packaging foods is a convenient and cost-effective option. Plastics have therefore been used worldwide to keep food safe and extend shelf life for years. However, not all plastic packaging is disposed of correctly or recycled and a significant amount of it ends up in our oceans. It is currently estimated that 8 million tons of plastics end up in the ocean every year and it is predicted that the amount of plastic in the oceans could outweigh the amount of fish in the oceans by the year 2050. In our oceans, plastic breaks down into smaller pieces, known as **microplastics,** through chemical reactions facilitated by exposure to UV radiation from the sun. Microplastics are defined as pieces of plastic that are smaller than 5mm in diameter and it is currently estimated that there are over 51 trillion microplastics in the ocean. These microplastics are entering the food chain through marine life that swallow them and accumulate through **biomagnification** (see Figure 8.2.8). Microplastics can also leach from our food packaging into our food and water and have been found to contaminate food through soil and air. This is another reason why it is important to wash fruits and vegetables prior to consumption. One of the biggest sources of microplastics is plastic water bottles. Many studies have shown that microplastics leach into the water from the bottle. This is why it is recommended not to continuously refill and reuse single use bottles, especially if it has been left in a hot environment, which increases the leaching. Similarly, heating microwave meals packaged in plastic can increase the leaching of microplastics into the meal. It is estimated that we are consuming over 70,000 microplastics annually through our food and water.

The consumption of microplastics is currently inevitable but the consequences are not fully understood. **There is some evidence to suggest that Bisphenol A (BPA) in plastics can interfere with our hormonal system because BPA mimics the shape of the hormone oestrogen**. BPA consumption above the tolerable daily intake (TDI) has been linked to low sperm counts and infertility in men, increased risk of developing obesity and diabetes, and prostate and breast cancer in men and women, respectively. In Australia, FSANZ's current view is that the amount of BPA consumed by Australian's daily is within the TDI and poses no appreciable health risk. However, not all governing bodies are unanimous on BPA. In 2018, BPA was reclassified as a substance of 'very high concern' by the European Chemicals Agency because of its 'probable serious effects' on human health. More research is required into the health effects of microplastics on humans to determine if they are toxic and at what concentration.

Did you know?

Researchers at McGill University in Canada discovered that approximately 11.6 billion microplastics and 3.6 billion nanoplastics leached from plastic tea bags into a cup of boiling hot water. This study indicates that tea drinkers could be consuming significantly larger amounts of microplastics every day. It also indicates that it could be better to buy tea bags that use natural fibres; however, they still contain plastic glues to seal the tea bag. To fully avoid plastic in tea, one would need to brew lose leaf tea. The same team also tested the toxicity of the microplastics and nanoplastics from plastic tea bags on water fleas and found that they caused developmental and behavioural issues.

Helpful online resources

Kurzgesagt: Plastic Pollution: How Humans are Turning the World into Plastic

https://www.youtube.com/watch?v=RS7IzU2VJIQ

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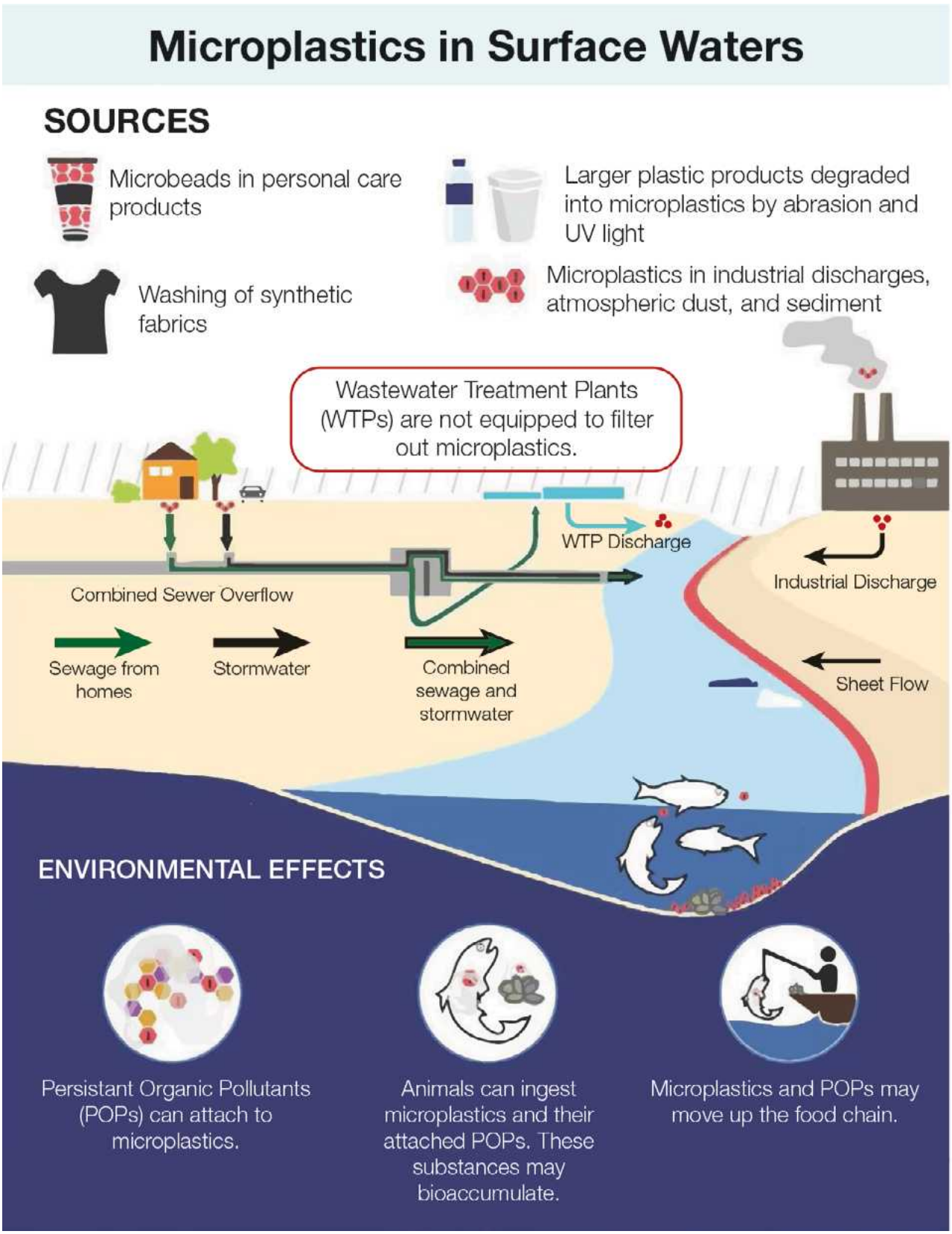


Figure 8.2.8: The use of plastics in society can result in microplastics in waterways that can enter the seafood chain and humans.

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Food fraud

Do you really know what is in the food you eat? Are you sure that the beef mince you eat is actually beef? Do you know that the honey you are purchasing is 100% honey? What about take away food? Do you know if the lamb curry you bought was actually lamb? As a consumer, there is currently no easy way to test your food. Many individuals and businesses are deliberately deceiving consumers by substituting products or diluting them with others to save money and in doing so are committing food fraud. **Food fraud is the intentional deception of consumers, using food for economic gain.** Food fraud encompasses deceptions such as substitution, addition, dilution, tampering, counterfeiting or misrepresentation of food, food ingredients or food packaging. Food fraud is considered to be one of the leading concerns the global food industry is currently facing, and it is estimated to cost the global industry approximately US$50 billion every year. This is particularly concerning for consumers because they are not receiving what they have paid for. **It is most concerning for those with allergies or intolerances** who are more vulnerable.

In January 2013, the Food Safety Authority of Ireland discovered that approximately **40% of the hamburgers they tested contained horse meat**. Offenders had been substituting horse meat for the more expensive beef and this resulted in millions of hamburgers, sausages and microwave meals being recalled across Europe. The horse meat scandal highlighted the lack of controls and accountability the food industry had implemented to deal with the potential of criminal activity within their food supply systems. It also brought international attention to food fraud and highlighted that almost every food product is vulnerable to food fraud.

It is clear that the criminals committing food fraud do not care about consumer safety. For example, an organised criminal gang in Derbyshire, United Kingdom established an illicit vodka processing plant. They were making counterfeit vodka on an industrial scale with no regard for consumer health. The criminals were using **car windscreen cleaner instead of vodka** in counterfeit Smirnoff Vodka bottles. Windscreen cleaner is clearly not fit for human consumption and generally contains methanol which is poisonous and can cause vomiting, blindness and even death if enough is consumed.

Organised crime syndicates are also moving into **stealing live produce**. This is concerning because **the food safety standards cannot be upheld**. The criminals do not care about the quality of the meat and this results in contaminated meat entering the food chain. This includes meat from old animals that are unfit for human consumption and animals that may have medications that are still in their systems after being treated for conditions, such as infestations. In addition, the vehicles used to transport the meat can be very dirty and unrefrigerated, which is unacceptable for the transport of meat. This further increases the risk of microbiological contamination and puts consumers at risk.

In Australia, a study by Choice recently discovered that only 5 out of 12 brands of oregano herb were 100% oregano. The remaining samples were less than 50% oregano, with two of them approximately only 10% oregano (see Figure 8.2.9). Also, when honey was tested, almost half the samples of honey from supermarket shelves had been diluted with substances like corn syrup and were not 100% honey.



Figure 8.2.9: The amount of oregano in various oregano brands as determined by Choice.

Currently, it is impossible to know how widespread food fraud is within the food industry. Testing all foods that enter the food chain is near impossible and would be very expensive. It can also be **hard to detect without genetic testing techniques**. However, with greater monitoring, species identification through genetic techniques and adequate punishments for committing food fraud offences it could be reduced. Furthermore, there are always new technologies being developed, such as TruTags advanced anti-counterfeit technology, to combat food fraud (see Science as a Human Endeavour 19 (on the next page) for more information).

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Science as a Human Endeavour 17

Food trust platform

Consumer trust in food is a growing concern and a problem that businesses and society must address. There are many counterfeit foods being sold all over the world and it is estimated that this costs the global food industry between US$40 and US$50 billion annually. For example, Australian beef is highly sought after and for every kilogram of legitimate Australian beef that arrives in China, an equal amount of counterfeit 'Australian beef' is sold. This is generally beef from other countries where regulations might not be as strict or even meat from another animal. PwC Australia (PwC) has developed a Food Trust Platform to assist Australian food exporters to track their products and increase consumer trust. PwC has collaborated with SSAFE, Wageningen University and Vrije Universiteit Amsterdam, and consulted with food industry leaders around the world to develop a food fraud vulnerability assessment for companies to assess their food fraud risk. They have also collaborated with TruTag Technologies to develop an advanced anti-counterfeit technology solution for food fraud. This technology allows foods and their packaging to be labelled with microscopic scannable tags known as a 'crypto anchors.' The microscopic tags have been called 'crypto anchors' because they are invisible to the naked eye, are almost impossible to replicate and can withstand extreme environmental conditions. The microscopic silicon dioxide tags have unique identifiable codes that can be detected by a device using the complementary app. PwC's Food Trust platform has also developed a blockchain technology solution that stores all applicable data from paddock to plate within the tag. This allows food producers and processors to protect their brand internationally and has the potential for consumers to scan their foods using their device to determine if the item they are about to purchase is legitimate or counterfeit. This increases consumer confidence as they can also view the entire processing history of the food they are about to purchase. The silicon dioxide tag has already been approved by the FDA as safe to consume and to track pharmaceuticals and has many other possible tracking applications. However, it has yet to be assessed as safe to use on fresh consumables such as meat, fruit and vegetables in Australia.

Questions

1. Explain two **applications** of TruTags microscopic edible barcodes.

(4 marks)

2. Suggest how **communication and collaboration** was necessary for the development and application of PwC's Food Trust Platform.

(4 marks)

3. Explain two **limitations** of the TruTag microscopic edible barcode technology..

(4 marks)

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Science as a Human Endeavour 17

Helpful online resources

TruTag Technologies' Security Labels & Documents Solution

https://www.youtube.com/watch?time_continue=5&v=VC3Jd_rDFTQ&feature=emb_logo

PwC's Food Trust Platform

https://www.youtube.com/watch?v=VKWmS9CxAKA



CS Possible case study 8

Jess has an immunocompromised five year old son named Kai who is about to start school. Jess needs to plan suitable recess and lunch options for Kai but she is concerned about food safety given Kai is immunocompromised and is at increased risk of contracting food poisoning. Evaluate the nutritional and food safety needs of Kai and make some recommendations for suitable lunchbox options.

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8.2 Review questions

1. Identify whether the following examples are a form of physical, chemical or microbiological contamination.

Example of Contamination	Physical, Chemical or Microbiological
A caterpillar in the bacon, lettuce and tomato burger	
Mercury in battered fish	
Norovirus on lettuce	
A fingernail in a bowl of pasta	
Clostridium botulinum infection in tinned chickpeas	
Rodent hair	
Microplastics in honey	
Carrot cut on the same board as chicken	
Hand sanitiser	
Cross contamination	
Biomagnification of PCBs in seafood	
Soil from the ground when harvesting	

(12 marks)

2. Describe the difference between food poisoning and food spoilage **and** why it can be harder to detect food poisoning than food spoilage.

(4 marks)

3. Explain how physical damage to fruit and vegetables can accelerate their spoilage.

(2 marks)

4. Explain why a 70 year old man is at greater risk of contracting food poisoning than a young adult.

(2 marks)

5. Explain why frozen meat should be defrosted in the fridge and not on a bench.

(4 marks)

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6. Describe how food should be reheated to reduce the risk of food poisoning.

(2 marks)

7. Identify **two** risks of food poisoning (such as listeriosis) to a pregnant woman.

(2 marks)

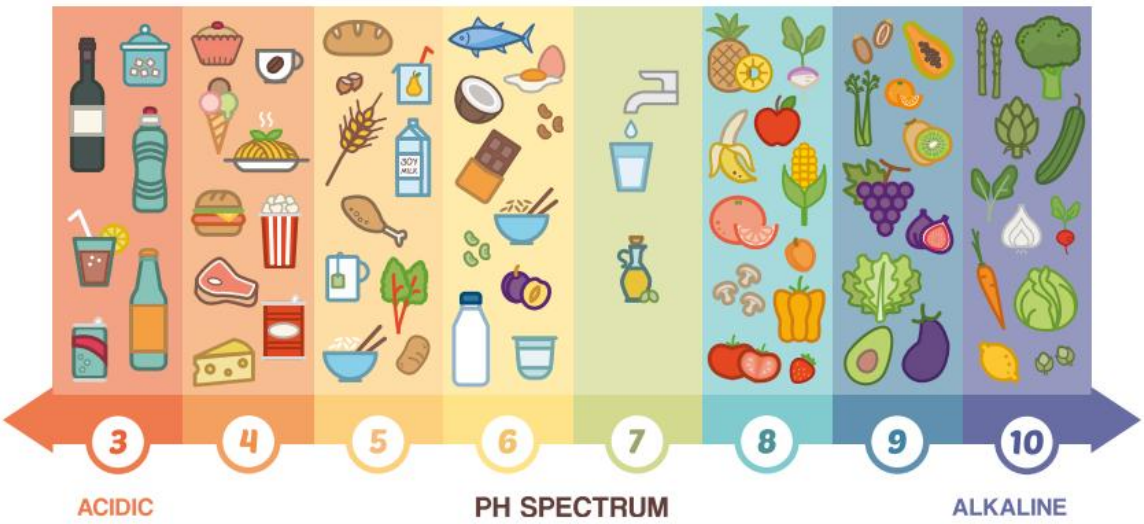
8. State **four** foods that immunocompromised individuals should avoid to prevent contracting listeriosis.

(4 marks)

9. Name what type of food salmonella is more likely to contaminate **and** describe how this occurs.

(3 marks)

10. Refer to the pH scale and the table below to answer questions 10 (a) to (c):



Bacterial Species	Preferred pH Range
Vibrio cholerae	8.0 to 11.0
Lactobacillus acidophilus	3.5 to 6.8
Salmonella enterica	5.0 to 8.0
Ferroplasma acidiphilum	0.0 to 2.9

(a) With reference to the pH spectrum and table above, identify the species most likely to contaminate oil.

(1 mark)

(b) Identify which of the listed species is most likely to be able to survive in the pH environment of the stomach **and** justify your answer.

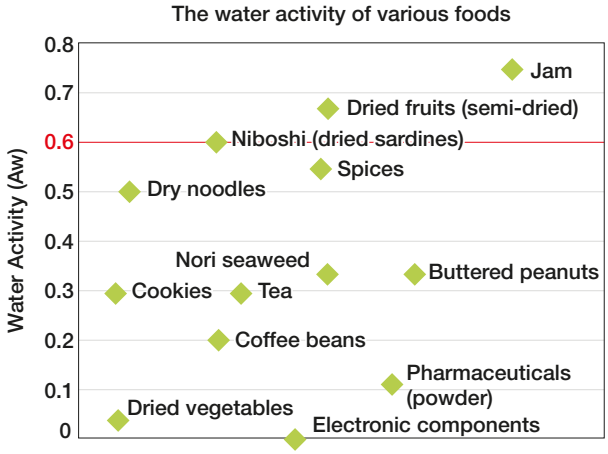
(2 marks)

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(c) The optimal pH for *Lactobacillus acidophilus* is 5.0. With reference to the pH scale above, name **two** foods that are at the optimal pH for *Lactobacillus acidophilus*.

(2 marks)

11. Refer to the following graph to answer questions (a) to (c):



(a) Identify the food that has the highest risk of food poisoning based on water activity alone.

(1 mark)

(b) Explain your answer to part (a).

(3 marks)

(c) State the significance of the red line at water activity of 0.6.

(1 mark)

12. (a) Explain how the biomagnification of methylmercury occurs in an ocean food chain.

(4 marks)

(b) Describe why pregnant women have to take care with the type and quantity of seafood they consume.

(3 marks)

(c) Describe how microplastics enter the ocean food chain.

(3 marks)

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(d) Describe another way that microplastics can enter the human food chain.

(2 marks)

13. (a) Define food fraud **and** provide **one** example.

(2 marks)

(b) A study by Oceana discovered that 20% of 449 fish tested for sale in the United States were labelled incorrectly. State **two** possible consequences of fraudulent seafood.

(2 marks)

14. (a) Explain why pregnant women should avoid eating sliced rockmelon.

(3 marks)

(b) Explain why pregnant women should avoid eating smoked salmon.

(2 marks)

E Extension question

Research how food can become contaminated with norovirus and the effects it can have on individuals.

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8.3 Safe food handling

Nutrition Understanding

Safe food handling is required by businesses to ensure their food is safe to eat but it is also required when preparing food at home. All consumers need to know how to handle, prepare and store food optimally to reduce the risk of contamination and contracting foodborne illnesses. According to OzFoodNet, there are 5.4 million cases of foodborne illness in Australia every year, which costs the economy approximately $1.2 billion. Many of these cases could be prevented if greater food safety measures were applied.

Hygiene and food handling

It is essential to always apply safe food handling and the use of proper hygiene techniques. This requires proper cleaning and sanitising of surfaces involved in food preparation and cooking, including all utensils. **Prior to handling food, hands should always be washed properly**. Hands should be washed rigorously with soap for 20 seconds and then rinsed. This is an effective technique to destroy many different microorganisms that contain a cell membrane. The cell membrane is made of lipids that soap molecules bind to ripping the cells apart, destroying them (see Figure 8.3.1). Rubbing hands against each other rigorously creates greater friction, destroying and removing more microorganisms from hands. It is also important to wash hands after handling certain foods that could cross contaminate other foods or cooking equipment, such as raw and processed meats.

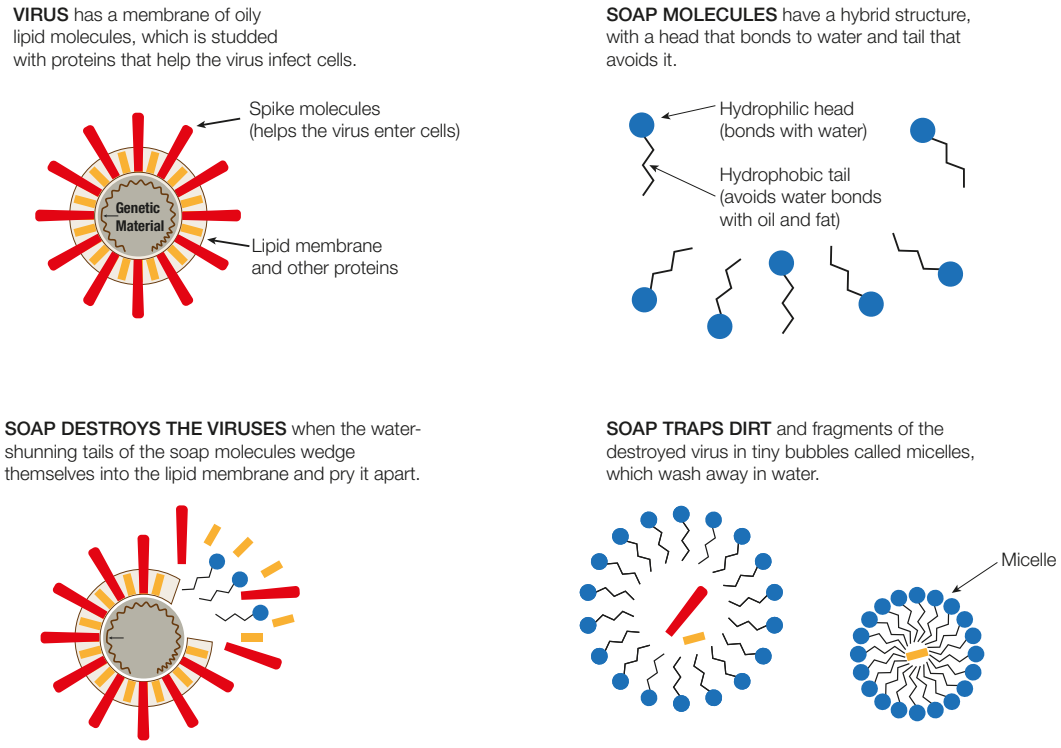


Figure 8.3.1: How soap and water work to destroy and dislodge microorganisms from hands.

Cross contamination is when microorganisms are transferred from a person, food, surface or utensil to another food. Raw foods such as meat and other animal products contain microorganisms, which can easily be transferred between surfaces. This is why it is important to take care when preparing foods. Meats and vegetables should be prepared using separate cutting boards and utensils, and cooked foods should never touch equipment used to process raw meats. Cooking chicken properly kills the microorganisms on and within it making it safe to consume. If the cooked chicken is placed back on the cutting board it was prepared on, the raw chicken residue can transfer from the cutting board to the cooked chicken contaminating it. This can transfer living pathogenic microorganisms, increasing the risk of food poisoning. Furthermore, **raw meats should always be stored below cooked meats in the fridge**. This storage technique alleviates the risk of fluid leaking from the raw meat packaging onto cooked meats on a shelf below, contaminating them.

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Food preparation and cooking

Before foods can be prepared, they need to be purchased. When purchasing foods, the **packaging should be checked for any damage or tampering**. For example, swollen cans should not be purchased as they indicate microbial growth within the can. Also, supermarket employees can accidentally cut through food packaging when opening boxes. Any slits in the packaging can allow oxygen to enter, promoting microbial life and increasing the rate of food spoilage. **The use by date of foods should also be checked** prior to purchasing to ensure it can be used before the use by date and that it has not already passed. When packing purchased foods for transport, cold foods should be placed in insulated bags to help maintain their low temperature. They should then be placed in the refrigerator or freezer as soon as possible. Hot foods should also be kept separate from cold foods to prevent the transfer of heat between them, making the temperature of both foods more suitable for microbial growth.

As previously mentioned, proper hygiene and food handling techniques should be implemented whenever food is being prepared. This includes washing hands properly and using clean equipment that hasn't been used on other foods to prevent cross contamination. If an individual has diarrhoea and/or vomiting they should not prepare food for others and should arrange for someone else to do it. There are also some other preparation techniques that should be followed to reduce the risk of microbial contamination. Food should be **defrosted in the fridge** and not on the bench at room temperature. This is because when defrosted at room temperature, the food is in the 'danger zone' and this can promote increased microbial growth and division. As chicken is a high risk food that contains a high level of microorganisms, it needs to be cooked all the way through and should not be consumed if any part of it is uncooked. Also, when cooking or reheating food, it needs to be **heated to 75°C or above** to ensure that enough microorganisms have been killed to make it safe to eat. This can be tested using a food thermometer (see Figure 8.3.2).



Figure 8.3.2: Using a food thermometer can help to ensure food is heated to a temperature above 75°C and all the way through.

Food storage

All foods need to be stored appropriately to maximise their shelf life and reduce the risk of food poisoning. Consumers should adhere to the instructions provided on the individual food product's packaging. The instructions generally give the storage location and how many days the item can be used after opening.

Some foods are at risk of **contamination by pests**. Large bags of grains or grain products should not be stored on the floor. Doing so allows easy access to pests, such as cockroaches, mice and rats. These pests can damage the packaging allowing microorganisms to enter and promoting conditions for food spoilage. Another pest that can contaminate dry foods is pantry moths. These moths generally enter the pantry through larvae in contaminated dry foods. They can quickly spread and can chew through cardboard and soft plastic packaging, spreading to other dry foods. Pantry moths are very hard to eradicate and doing so generally requires a complete pantry cleanout (with all food disposed of) and thorough cleaning. To prevent infestation from pantry moths, dry foods should be stored in **airtight containers** in the pantry.

Cooked foods also need to be stored appropriately. It is important that cooked food is not left on the bench in the danger zone for more than four hours, otherwise it should be discarded. Instead, the cooked food should be '**cooled rapidly' to 5°C** (usually in the refrigerator) and stored in a refrigerator or freezer. 'Cooled rapidly' is

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defined as foods being cooled to 21°C within 2 hours and then 5°C within a further 4 hours. Large casseroles or pots of soup that have just been cooked can take approximately 24 hours for the entire meal to cool to 5°C in a refrigerator. This means the **centre of the meal is within the temperature danger zone for a long period of time**, providing a suitable environment for microbial growth and increases the risk of food poisoning. To ensure safe food storage, the casserole or soup should be stored in **multiple shallow airtight containers** instead. If stored in the fridge, it should be consumed within a couple of days.

When storing foods in the fridge, one should firstly confirm that the temperature of the fridge is set between 0°C and 5°C and not at a temperature in the danger zone. However, the placement of food products in the refrigerator is also important. For example, **high risk foods**, such as meats and expressed breastmilk **should be stored at the back of the fridge, where it is the coldest**, to reduce microbial growth and not in the fridge door. In addition, vegetables should not be washed prior to entering the fridge as this can provide moisture for microorganisms to grow. They should also be stored in the salad drawer, which regulates airflow and maintains the humidity surrounding your vegetables, keeping them fresher for longer (see Figure 8.3.3).



Figure 8.3.3: The recommended storage technique of foods in a fridge.

Food recalls

When physical, chemical or microbiological contamination occurs to a product, it must be recalled to protect consumers. Food businesses are generally responsible for the recall of their products but the Australian state and territory governments can force recalls if necessary. FSANZ cannot order a food recall but it is involved in the process. FSANZ coordinates the recall with the relevant bodies and also publishes it on their website and social media platforms to notify consumers.

Helpful online resources

FSANZ: Recalling food in Australia

https://www.youtube.com/watch?v=tsEe_ylW5vM

8.3 Review questions

1. Explain why it is important to wash your hands after handling ham when making a ham, cheese and salad sandwich.

(4 marks)

2. Recipe and meal kit delivery services are becoming more popular in Australia.

   (a) Discuss why it is important to choose an appropriate delivery time for raw foods to reduce the risk of food poisoning.

(4 marks)

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(b) All the ingredients for the recipes are generally provided in one box. Describe why the raw meats are packaged in a sealed plastic bag within the box.

(3 marks)

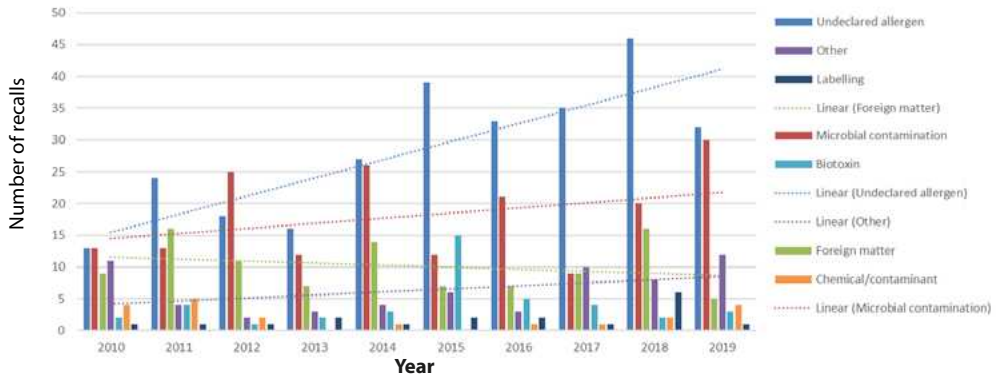
(c) Multiple items such as pita wraps, rice and spices come in airtight packaging. Describe why these products must be stored in airtight packaging.

(4 marks)

3. Mary's granddaughter Natalie has just had a baby and Mary has cooked her a large casserole as a kind gesture. Explain why Mary should not transfer the large casserole dish from the oven directly into the fridge to cool down **and** what she should do instead.

(4 marks)

4. Refer to the following graph that shows the number of food recalls coordinated by FSANZ each year, shown by recall classification, between 1 January 2010 and 31 December 2019.



(a) State how many cases of microbial contamination there were in Australia in 2019.

(1 mark)

(b) Using data, describe the trend of undeclared allergen recalls from 2010 to 2019.

(2 marks)

(c) Name **two** possible undeclared allergens that could warrant a food recall.

(2 marks)

E Extension question

Visit the FSANZ website and identify the five most recent food recalls.

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8.4 Preservation methods

Nutrition Understanding

Foods are processed and **preserved to decrease the rate of food spoilage** and reduce the risk of food poisoning occurring. Food preservation aims to eliminate microorganisms already residing on food, deactivate enzymes involved in food spoilage and prevent future contamination by microorganisms by sealing the food. Food preservation is essential to modern society because it ensures a safe, continuous and plentiful supply of food by **reducing nutrient loss and increasing shelf life** (see Figure 8.4.1). Food preservation **increases the convenience** of certain foods by allowing some foods to be available all year round, saving time preparing foods and potentially reducing costs. Without food preservation techniques, we would have less food options and would have to shop more frequently to purchase foods that are safe to eat. Examples of preservation techniques include heat treatments, reducing temperature, controlling water activity, changing the pH, oxygen reduction and irradiation.

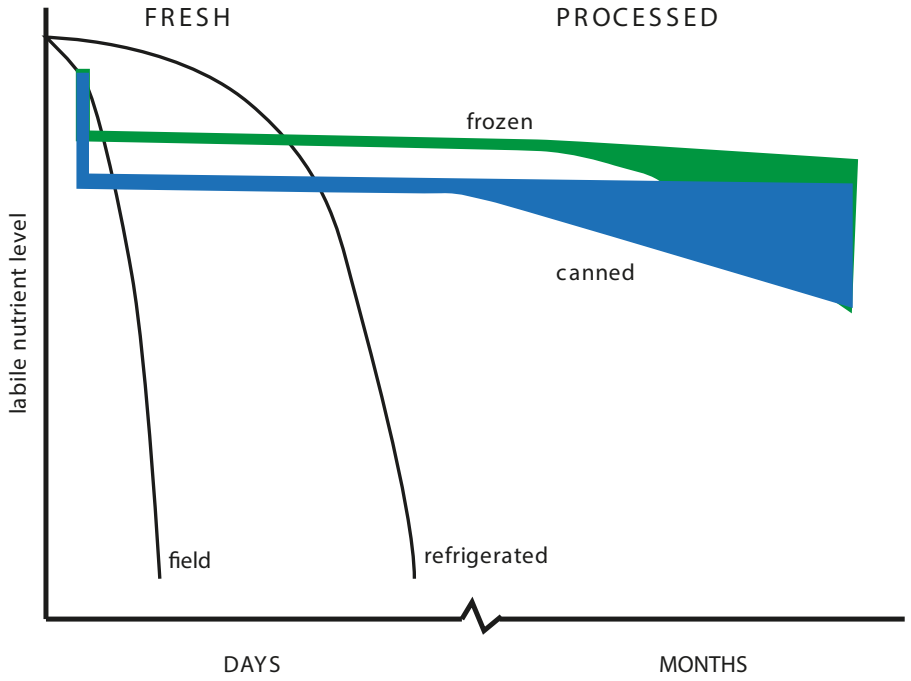


Figure 8.4.1: Food preservation can increase shelf life and preserve nutrients in foods. This graph illustrates that nutrients decrease significantly for fresh products even if they are stored in the fridge. However, foods that are processed and frozen or canned prevent nutrient loss and do not have a sharp decline. They can be preserved for months or years.

Did you know?

Some preservation techniques have been used for hundreds or thousands of years to preserve foods and create new ones, such as salami, cheeses and even chocolate. There are many food products that we eat that rely on preservation techniques, such as salting and fermentation. Watch the following video to find out more:

Helpful online resources

MinuteEarth: Why Do We Eat Spoiled Food?

https://www.youtube.com/watch?v=9yswzlTbAbA

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Heat treatments

Foods can be preserved by subjecting them to high temperatures for a required time to **kill microorganisms and deactivate enzymes** involved in chemical decomposition. Some preservation methods involving high temperature are cooking, canning sterilisation, pasteurisation and ultra-high temperature.

Cooking

Cooking foods **above the temperature danger zone for a certain period of time** can eliminate microorganisms and reduce the risk of contracting food poisoning. It is recommended that foods are cooked above 75°C to be safe. There are many cooking methods including frying, baking, boiling, steaming and microwaving.

Canning sterilisation

Canning sterilisation involves **placing foods into cans, jars or similar containers and heating them to temperatures above 100°C** to eliminate microorganisms that cause food spoilage and poisoning. This process also eliminates *Clostridium botulinum* bacteria and their spores. The temperature the food is heated to depends on the acidity of the food. Foods above a pH of 4.6 require higher sterilisation temperatures of 116°C to 129°C, whereas foods with a pH below 4.6 only require a temperature of 100°C. The canning process also drives oxygen out and is **vacuum sealed preventing air exposure and microorganisms from entering**.

Did you know?

Clostridium botulinum is a type of bacteria that is naturally found in soil and can contaminate canned foods because it can survive in low oxygen environments. The toxins released by *Clostridium botulinum* affect the nervous system and can cause botulism. The toxin can cause loss of muscle control and can spread to the respiratory system, which can cause death by suffocation. Botulism is the most common foodborne illness caused by damaged food packaging and can occur when cans are dented or damaged. If cans are swollen, this suggests that there has been an error in the canning process and microorganisms are growing and multiplying inside. Furthermore, when a can is dented, it can create microscopic openings in the can, which allows microorganisms to enter the can. This allows bacteria to grow and multiply, contaminating the food. It is rare for small dents in cans to result in botulism; however, larger dents to the seams of the can are a greater risk. It is therefore recommended not to purchase dented or swollen cans to reduce risk of food poisoning and botulism.

Pasteurisation

Pasteurisation extends the shelf life of products such as **milk and juices** by killing most pathogenic and food spoilage microorganisms. Pasteurisation involves heating the product for a short amount of time to minimise nutrient and sensory quality. The temperature and time applied during pasteurisation are dependent on the pH of the food but the **standard heat treatment for pasteurising milk is heating it for 15 to 20 seconds at 72°C**. As pasteurised products are not sterile, they **also require refrigeration** to preserve their shelf life and keep them safe. Pasteurised products can last up to 14 days if refrigerated properly.

Ultra-high temperature pasteurisation

Processing milk and juices using ultra-high temperature (UHT) pasteurisation can significantly extend their shelf life when compared to pasteurised products. If the product is placed in an aseptic container (see Figure 8.4.2) after UHT processing, it can **last for 6 to 12 months at room temperature** prior to opening the packaging. UHT pasteurisation involves **heating the product to 138°C for two seconds.**



Figure 8.4.2: Long life milk has been preserved using UHT pasteurisation and can last six months to a year without being refrigerated.

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Reduced temperature

Temperature reduction can prolong the shelf life of foods by **slowing the growth of microorganisms**.

Refrigeration

Refrigeration **keeps food out of the temperature danger zone**, providing a less suitable environment for microorganisms' growth and multiplication. This slows their growth and reduces the rate of food spoilage and risk of food poisoning. Refrigerators are generally set at 3°C and should be set **between 0°C and 5°C**. Foods such as meats, vegetables, eggs and dairy products can be stored in refrigerators. Refrigerated food can last for days to weeks, depending on the product. Refrigerating foods does not improve the quality or decomposition of food; it merely reduces the rate of decomposition.

Freezing

Freezing food preserves it by **reducing the water availability for microorganisms by converting the water in foods to ice**. Microorganisms require water to perform chemical reactions, which are essential for growth and multiplication. Freezing food stops microorganism growth and reduces enzyme activity involved in food spoilage. Freezing food does not eliminate microorganisms; they remain dormant and can continue growing and dividing once conditions become favourable again, such as defrosting on a bench in the danger zone. **Freezers should be set at or below -18°C** to ensure food is being stored safely.

Helpful online resources

Minute Earth: The Story of Frozen Food

https://www.youtube.com/watch?v=uWZwncX_4hk

Controlling water activity

As previously discussed in Topic 8.2, microorganisms **require water to perform many chemical reactions** and they obtain this from their environment. The amount of free water that is available to support microbial growth, known as **water activity (a_w)**, helps us to determine a specific foods risk of food spoilage and poisoning. Most pathogenic bacteria require a water activity above 0.9. Bacterial growth is inhibited below a water activity of 0.75, and foods that have water activity below 0.6 prevent all growth of microorganisms. Therefore, **foods with a high water activity (a_w) are more susceptible to growth of pathogenic microorganisms** and food spoilage.

The **water activity (a_w) of foods can be reduced** through multiple methods, thereby extending the shelf life of the food. When food is **dehydrated** the water activity (aw) is reduced, preventing microbial growth. Food can be dehydrated by air drying, using commercial **food dehydrators**, **freezing** or **smoking**. Food can also be dehydrated using **additives**, **such as salts or sugars**. Salts and sugars are added to foods like jams and cured meats, where they bind to free water molecules, reducing water availability for microorganisms. In all processes, the concentration of available water content is reduced, **slowing the growth of microorganisms and preserving the food**.

Oxygen reduction

Aerobic organisms require oxygen to respire and produce energy for cellular activity and division. **If oxygen availability is reduced, aerobic microorganisms cannot grow and divide** as efficiently, delaying food spoilage and reducing risks of food poisoning. Most fungi and some bacteria involved in food spoilage require oxygen to survive and, in turn, decompose foods.

The presence of oxygen can also increase food spoilage through enzymatic activity and oxidation of foods. Foods naturally contain oxidative enzymes that react with oxygen and promote its self-destruction; for example, the increased respiration rate in fruits after being harvested that result in their ripening and eventually spoilage. When fruits such as apples are exposed to oxygen, **enzymatic browning** can also occur. Furthermore, **fats and oils** and certain foods can **become rancid** and break down into fatty acids through oxidation.

As the atmosphere consists of approximately 21% oxygen, removing air and providing airtight barriers can preserve various foods. **Processes such as canning and bottling, modified atmosphere packaging (MAP), vacuum packaging and the use of oxygen absorbers can reduce the oxygen availability for microorganism**

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growth, enzymatic activity and oxidation of foods (see Figure 8.4.3). Modified atmosphere packaging extends the shelf life of foods by removing the atmospheric gas and replacing it with a specific mixture of gases. Each product has a specific mixture of gases based on its physical and chemical qualities to optimise its shelf life. One example is processed meats, such as salami, which contain packaging with 30% carbon dioxide and 70% nitrogen. Vacuum packaging removes the atmospheric gases from the product and is sealed tightly to reduce the amount of oxygen in the packaging. Whereas oxygen absorbers are little packets of chemicals inserted into certain products, such as pita wraps. The chemicals in the packet absorb oxygen, reducing the availability of oxygen that can react with the food and for aerobic microorganisms to use.



Figure 8.4.3: An example of modified atmosphere packaging (left), vacuum packaging (middle) and oxygen absorber (right).

Changing pH

Microorganisms have an optimal pH at which they grow and divide at their optimal rate. If this **environment is changed to one that is more acidic, it becomes less suitable for microorganisms to grow and survive**. This is because the increased acidity can deactivate important enzymes that are essential for survival. The majority of microorganisms and their spores that are subjected to a **pH lower than 4.5** cannot survive, however, this environment will not deactivate any toxins that have already been produced.

Pickling can preserve some foods, such as fruits, vegetables, meats and eggs. The pickling process can involve submerging the food in **acetic acid (vinegar) or anaerobic fermentation** in a saltwater solution. Acetic acid has a pH of 2.4, therefore foods placed in acetic acid do not have to be sterile prior to being immersed because the acidic environment will kill most microorganisms. Conversely, using saltwater solutions results in the dehydration of the food and promotes anaerobic bacteria to ferment, producing **lactic acid** as a by-product. Lactic acid has a pH of approximately 3.5; therefore, its production by bacteria progressively lowers the pH making it unsuitable for microorganisms to survive (see Figure 8.4.4).



Figure 8.4.4: Pickling vegetables can increase their shelf life by reducing the pH, killing microorganisms that cause food spoilage and poisoning.

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Food irradiation

Certain foods can be exposed to ionising radiation in the form of gamma rays, x-rays or high energy electron beams to increase preservation. **The high energy ionising radiation passes through the food, destroying organisms involved in food spoilage** such as insects, parasites, bacteria and other microorganisms. Food irradiation is an alternative to heating and chemical preservation methods and generally has comparably less effect on the appearance, flavour and texture.

All irradiated foods must go through a strict safety assessment by FSANZ prior to being irradiated and **must be labelled to display to consumers that it has been irradiated** (see Figure 8.4.5). In Australia, only herbs, spices, herbal infusions and some fruits and vegetables are allowed to be irradiated. Food irradiation cannot be used to treat contaminated and unsafe food. It is important to note that the food does not become radioactive itself because it does not contact the energy source and the dose is low.



Figure 8.4.5: The International Radura symbol on foods to notify consumers that the food has been irradiated.

Changes in nutrients

Food preparation and preservation is very important to extend shelf life and ensure food is safe to consume; however, the amount of **nutrients in foods are reduced during the food preparation and preservation processes**. Extended exposure to high levels of **heat, light, oxygen, pH, water** and **fat** (cooking oil) can cause nutrient losses (refer to Figure 8.4.6 for specific examples). The amount of nutrients lost depends on many factors such as the type of food, length of exposure and temperature exposed to. Some nutrients are more easily destroyed than others and this depends on their chemical makeup. For example, most vitamins in food are very sensitive to heat but vitamin B2 and vitamin B3 are very stable. Furthermore, water-soluble vitamins leach out of foods into water and fat-soluble vitamins leach out of foods into oils used in cooking or preservation processes. This results in nutrient losses from foods but the nutrients can be salvaged if the water or oil is still consumed; for example, the remaining oil could be used in a sauce or dressing. The packaging used on a product can also contribute to the amount of nutrients lost. Vitamin B2 is sensitive to UV light and milk exposed to light for two hours can lose between 20% and 80% of its vitamin B2 content. This is one reason why milk can be packaged in cartons and stored in a dark fridge. Minerals are much more resistant to heat. The main mineral that is affected by food processing is potassium, which isn't destroyed but leaches out into cooking liquids.

External Factors Influencing Vitamin Stability

VITAMIN	Temperature	Oxygen	Humidity	Light	pH Acid	pH Alkaline
Vitamin A	✓✓	✓✓	✓	✓✓	✓	•
Vitamin B_1	✓	✓	✓	•	•	✓✓
Vitamin B_2	•	•	✓	✓	•	✓
Vitamin B_3	•	•	•	•	•	•
Vitamin B_9	✓✓	•	✓	✓✓	✓✓	•
Vitamin B_{12}	✓✓	✓	✓	✓	•	✓
Vitamin C	✓✓	✓✓	✓✓	✓	•	✓
Vitamin D	✓	✓✓	✓	✓	•	✓
Vitamin E	•	✓	•	•	•	✓
Vitamin K	✓	✓	✓✓	✓	✓✓	✓✓

• = Stable ✓ = Slightly Sensitive to Sensitive ✓✓ = Very Sensitive

Figure 8.4.6: The sensitivity of some vitamins to various external factors.

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Freezing foods and irradiation are the two processing methods that arguably result in the greatest amount of nutrient retention. The main nutrient loss associated with frozen foods is the processing prior to freezing. Many fruits and vegetables are blanched prior to freezing, which involves a short exposure to boiling water. The heat will kill some pathogenic and decomposing microorganisms and also deactivate some of the enzymes associated with decomposition; however, the heat and exposure to water can destroy and leach some vitamins. Furthermore, when frozen foods are defrosted, the melting ice can also leach water-soluble vitamins. Proper storage of frozen foods can result in the majority of the remaining nutrients being maintained. This is because freezing temperatures do not destroy vitamins like heat does. Also, the freezing cold temperatures significantly slow down the activity of the remaining decomposing enzymes in foods, preserving nutrients. After a year of storage, the slow accumulation of nutrient breakdown adds up and it is generally not recommended to eat frozen foods past this date.

If food irradiation is administered correctly and oxygen is excluded when the food is irradiated, there is generally minimal nutrient loss. Vitamins A, E and B1 are three of the more sensitive vitamins to radiation and some of these vitamins are destroyed during exposure to the radiation. Irradiating foods does not have a significant effect on proteins and therefore the enzymes involved in food spoilage are not deactivated with the low radiation dose. This is great for retaining the sensory attributes of the food but irradiated food generally will not last as long as frozen foods because the decomposing enzymes are still functional.

In summary, when cooking or preserving foods, the amount of nutrients destroyed or lost will increase as:

- The temperature gets higher;
- The amount of time the food is exposed to higher temperatures is increased;
- The amount of water or oils exposed to is increased; and
- The acidity or alkalinity of the environment is increased.

Helpful online resources

SciShow: Does Microwaving Food Destroy Its Vitamins?

https://www.youtube.com/watch?v=SlkLa9Ezt00&t=28s

ASAP Science: This Is NOT NATURAL

https://www.youtube.com/watch?v=bkhhCi7nMFI

ASAP Science: Fresh vs Frozen Food

https://www.youtube.com/watch?v=zjsOOT347cA

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New Haelen milk preservation process

A Queensland food technology company called Naturo has developed and patented a milk preservation process, called Haelen, that it claims can keep milk fresh for at least 60 days in the fridge without the use of any additives. Naturo had already developed a technology using air pressure to prevent the browning of avocados and have been able to modify this design to be applied to milk. The Haelen technology is different to pasteurisation and UHT because it does not involve heating. This means that there is greater retention of nutrients such as vitamin B2 and B12 in the milk, and the milk still tastes fresh. Additionally, studies from the CSIRO have confirmed that Haelen processed milk is twice as digestible than all other processed milks currently available in Australia. Consumer trials also showed that two thirds of the subjects that normally experience adverse reactions to processed cow's milk, had the adverse reactions elimination or reduced when consuming Haelen processed milk. The Dairy Foods Safety Victoria have independently confirmed that the Haelen processed milk meets the Food Standards Code and that it kills more pathogens in raw milk than pasteurisation. It is also the only process that kills a specific pathogen common to milk called *Bacillus cereus*. This also means that fresh milk could be shipped to markets previously out of reach of fresh milk. Naturo launched two products in 2023 and are currently advertising for investors, partners and licenses to use the Haelen technology.

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Questions

1. Explain how Naturo's new milk preservation process could **influence** society.

(4 marks)

2. Explain two **limitations** of Naturo's new milk preservation process.

(4 marks)

8.4 Review questions

1. Describe **two** advantages of preserving food.

(2 marks)

2. Explain why freezing food is a more effective preservation method than refrigeration.

(4 marks)

3. Explain how the use of oxygen absorbers can increase the shelf life of sandwich wraps.

(3 marks)

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4. It is a requirement of the Food Standards Code that milk is pasteurised or equivalently processed.

   (a) Describe why raw unprocessed milk should not be consumed.

(2 marks)

   (b) Explain why UHT milk can be stored in the pantry but pasteurised milk needs to be stored in the fridge.

(4 marks)

   (c) Describe why some vitamins are lost in the pasteurisation process.

(2 marks)

5. Refer to the following table:

Food	Water Activity
Apricot	0.981
Dried Apricot	0.720

   (a) Describe **one** preservation process that could have been used to cause the difference in water activity between apricots and dried apricots.

(2 marks)

   (b) Explain why dried apricots have a longer shelf life than fresh apricots.

(4 marks)

   (c) State another process that can preserve foods by reducing water activity, which wasn't described in 5(a).

(1 mark)

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6. Food preservation is important for food safety and increasing shelf life but it can also result in nutrient losses.

   (a) With reference to nutrient loss, explain why it is recommended to steam vegetables instead of boiling them.

(2 marks)

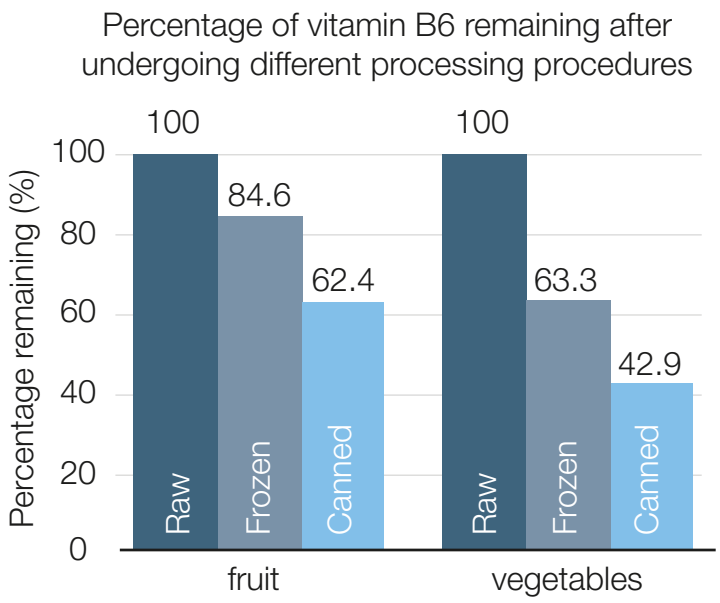
   (b) Describe the difference in the amount of nutrients between raw and UHT milk.

(2 marks)

   (c) Describe why microwaving frozen foods would retain more nutrients than baking them.

(2 marks)

7. Refer to the following graph:



   (a) Using data, explain why canned vegetables have less vitamin B6 than frozen vegetables.

(3 marks)

   (b) Using data, explain why frozen fruit has less vitamin B6 than raw fruit.

(2 marks)

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8.5 Fresh versus processed foods

Nutrition Understanding



Figure 8.5.1: Some examples of whole foods that have been minimally processed include meat, fruits, vegetables, legumes, nuts, seeds and wholegrains.

It is commonly thought that 'fresh' foods are always more nutritious and better for you than processed foods but it is more complicated than that. **Processed foods** are defined as foods that have undertaken any change to their natural state. This includes washing, drying, packaging, storing, cutting, blanching, freezing, pasteurising, heating, dehydrating, canning and mixing, amongst others. By this definition, virtually all foods we purchase are processed and not 'fresh.' This is why 'fresh' foods are more widely recognised as **whole foods** or **minimally processed foods**. Whole foods are generally considered to be **nutrient-dense** and consist of one ingredient and include the edible parts of animals and plants. Some examples are illustrated in Figure 8.5.1. Many whole foods are minimally processed for the purpose of food preservation and food safety. Some examples of processing techniques used on whole foods are: cleaning the dirt and pesticides off fruits and vegetables; cutting off inedible parts of animals and plants such as skin, bones and stems; the pasteurisation of milk; refrigeration during transport and at the supermarket; and packaging of vegetables into plastic bags and then freezing them. Because whole foods are minimally processed, there is **minimal loss of nutrients** through processing. This is one of the reasons whole foods are considered more nutritious and healthier. However, after whole foods are harvested, they rapidly deteriorate through loss of water and degradation by enzymes and microorganisms. This results in the loss of nutrients and quality of the wholefood. For example, in the first 48 hours after peas are harvested they lose approximately 50% of their vitamin C content. Alternatively, 'fresh' fruits and vegetables can be blanched to denature the enzymes that degrade food and snap frozen quickly after harvesting to significantly slow down the decomposition by microorganisms and retain nutrients. Studies comparing the vitamin, mineral and fibre content of fresh and frozen fruits and vegetables have shown that there are no significant differences between them. In fact, some frozen fruits and vegetables actually contained more vitamin C and B2 than their fresh counterparts.

In comparison to whole foods, **highly processed foods** are generally considered **energy-dense**, undergo a lot more processing and consist of many ingredients. Because highly processed foods contain a lot of ingredients mixed together and are energy dense, they are often addictive and are partly attributed to the rise in obesity and other diet related disorders. Some examples of highly processed foods are illustrated in Figure 8.5.2. These foods can also include **additives,** such as antioxidants to preserve the food, and artificial sweeteners, flavourings and colourings to enhance the taste and appeal of the food. **In general, the more a food is processed, the more nutrients it loses.** However, food manufacturers can fortify their foods with nutrients to restore nutrients lost through processing. In fact, the **fortification** of some vitamins and minerals is mandated for certain foods. Food fortification can help prevent nutrient deficiencies in the general population and the health consequences associated with them, thereby reducing unnecessary suffering.

Food additives



Figure 8.5.2: Some examples of highly processed foods include biscuits, pizza, pastries, milkshakes and soft drinks.

A food additive is a substance **intentionally added to foods** during processing. There are a large variety of additives that can help foods meet the needs of consumers and manufacturers. It is important to note that not all processed foods contain additives. Consumers can determine foods that contain additives by checking their label. **The Food Standards Code requires that all additives are declared on food labels**. This allows consumers to make informed choices about the foods they consume. For the majority of people, additives are not a concern, but some people can have intolerances or allergies

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to specific additives. For these individuals, it is important that a medical diagnosis is obtained by a medical professional as allergies and intolerances should never be self-diagnosed. If the diagnosis is positive, the medical professional can provide tailored advice.

Food manufacturers can only use food additives that have been approved safe by FSANZ in their products. FSANZ conducts safety assessments on all potential food additives and will only approve them for use if they determine that there is likely to be no harmful effects. FSANZ also constantly monitors scientific literature related to the food safety of additives to make sure the standards are up to date and makes amendments if necessary. Please refer to Table 8.5.1 for a list of some types of additives, their functions and benefits to consumers and manufacturers.

Table 8.5.1: A list of some types of additives, their functions and some benefits to consumers and manufacturers.

Type of Additive	Function	Benefits to Consumers/Manufacturers
Antioxidants (such as ascorbic acid - vitamin C) and tocopherols - vitamin E)	Reduces the oxidation of molecules, increasing shelf life.	• Helps maintain the quality of food by reacting with oxygen, reducing the rate of deterioration of the food. • Keeps food palatable and appealing for longer by reducing oxidation that causes rancidity, browning and unpleasant taste.
Preservatives (such as sodium benzoate, sodium nitrate and sulfur dioxide)	Chemicals that prevent microbial growth, reducing food decay and the likeliness of food poisoning.	• Increases the shelf life of foods by reducing microbial action and decay. • Transport of products is cheaper because manufacturers can export in bulk. • Helps reduce food wastage as shelf life is extended.
Artificial sweeteners (such as saccharin, aspartame and stevia)	Alternatives to adding sugar that increase the sweetness of foods making them more appealing and provides options to people with conditions such as diabetes.	• Reduces sugar content and therefore kilojoules, giving consumers who are weight conscious sweet alternatives. • Allows manufacturers to create alternative products to target weight conscious consumers and increase profits. • Can be added to a range of products targeted at diabetics who cannot consume large amounts of sugar.
Flavour enhancers (such as MSG)	Added to foods to restore some flavour lost during processing and increase the intensity of a flavour.	• Can reduce costs to manufacturers as a substitute to real flavouring ingredients that may be more expensive. • Can add to taste and odour of foods making them more appealing to consumers and can help increase sales.
Colourings (both natural and synthetic colours)	Are added to make foods look more attractive and restore colour after processing.	• Added colours can make foods and drinks more attractive or can restore the 'natural' colour of foods after processing to make them more appealing to consumers, and increase sales.
Emulsifiers (such as lecithin - egg emulsifier)	Added to foods to help mix ingredients that normally stay separated in layers. This allows fats/oils and water to mix.	• Emulsifiers allow manufacturers to produce products that remain stable and layers do not separate, increasing the visual appeal of the food product. • They allow certain products like mayonnaise to have a smooth and creamy texture, improving its consistency (see Figure 8.5.3). • Allow the production of low fat spreads giving consumers a low fat alternative option if they need to reduce fat intake (e.g. high cholesterol).
Glazing agent (such as wax)	Improves the appearance of foods by adding a shiny coating to fruits like apples. It can also help protect the food from losing water by evaporation.	• Helps to maintain freshness of foods for longer; for example, crunchier apples. • The fruits are more visually appealing to consumers, so they are more likely to buy them, increasing sales.

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Mayonnaise without emulsifier

Mayonnaise with emulsifier

Figure 8.5.3: The effect of the addition of emulsifiers on mayonnaise.

Helpful online resources

European Food Additives Council: What are food additives?

https://www.youtube.com/watch?v=Hy3-QHhzvPE

TED-Ed: Are food preservatives bad for you?–Eleanor Nelsen

https://www.youtube.com/watch?v=ZJU34yTJL4M&t=1s

TED-Ed: What is MSG, and is it actually bad for you? - Sarah E. Tracy

https://www.youtube.com/watch?v=EKgEj5asL3o

Did you know?

There is some thought that artificial sweeteners can cause cancer but there is currently no evidence to support this in humans. However, scientists have been studying the effect of artificial sweeteners on the microbiome and have found that it can reduce the diversity of species in some individual's microbiome. This can increase inflammation in the body and contribute to a wide range of conditions. See Topic 3: Digestion, Malabsorption and the Microbiome for more information on the microbiome and the consequences of disrupting it.

Food fortification

Food fortification is the **addition of extra nutrients to foods to decrease the occurrence of nutrient deficiencies and benefit public health**. Food fortification can benefit people living in developed countries like Australia as well as developing countries with reduced food availability. Food fortification can be a cost effective way of consumers accessing vital nutrients. Not all people can access fresh meats, seafood, grains, vegetables and fruits and, as a result, could be deficient in vital nutrients like iron, vitamin D, vitamin B1 and vitamin B9. In addition, fresh foods are perishable, and if available, may not last the transport process to certain communities. Fortifying staple foods with vital nutrients can allow the community to access them, increasing public health outcomes by reducing nutrient deficient disorders and the demand on the public health system. In Australia, there are certain foods that require the addition of vitamins and minerals due to **mandatory fortification** (see Table 8.5.2).

The Food Standards Code also permits food manufacturers to add vitamins and minerals to their product(s) through **voluntary fortification** (provided they are permitted by the Code and are within the regulated amounts). For example, vitamin D and A are added to some milks and dairy products; fluoride can be added to bottled water; calcium can be added to chewing gum; and a range of vitamins and minerals can be added to cereals and caffeinated beverages.

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Table 8.5.2: The four mandated nutrient fortifications in Australia and their purpose.

Nutrient	Food Fortified	Purpose
Vitamin B9 (folate)	The synthetic form of folate, folic acid, is required to be added to wheat flour used to make breads. N.B. there is no requirement for organic bread to be fortified with folic acid.	Folic acid is added to wheat flour because most people eat bread regularly; it therefore ensures almost everyone is consuming some folic acid. This is especially important for **unplanned pregnancies** because folate is required for the healthy development of the foetus. A lack of folate in the month prior to and first three months of pregnancy can cause **neural tube defects** such as spina bifida. In the first few weeks, the mother is generally unaware she is pregnant and in unplanned pregnancies the mother is unlikely to be supplementing with folic acid.
Iodine	Iodised salts are required to be used for making bread. N.B. there is no requirement for organic bread to be fortified with iodine.	Recently, **mild iodine deficiency** has re-emerged in Australia. Some possible reasons for this are the decreased use of iodised salt in processed foods and cooking at home and restaurants, and less iodine in the soil due to non-sustainable farming techniques. Iodine is an essential trace mineral that the body needs to make a hormone in the thyroid called thyroxine (also known as T4). Thyroxine is an important hormone in the regulation of metabolism, thermoregulation (controlling body temperature) and growth. If women are iodine deficient during pregnancy and lactation it can result in stunted growth, diminished intelligence and even retardation in the baby.
Vitamin B1 (thiamin)	Added to wheat flour used for making breads.	Vitamin B1 is added to combat the prevalence of Wernicke-Korsakoff syndrome (WKS). WKS is a neurological disorder caused by a thiamin deficiency and can be fatal.
Vitamin D	In Australia, edible oil spreads require the addition of vitamin D.	Vitamin D increases the absorption of calcium in the small intestine and is important for the formation and maintenance of strong bones and teeth. A deficiency in vitamin D also results in a deficiency of calcium, which can lead to reduced bone density and increased risk of developing osteoporosis. A deficiency during pregnancy and lactation can cause **rickets** in infants where the bones fail to develop and skeletal abnormalities such as bowed legs can form.

Helpful online resources

Global Alliance for Improves Nutrition (GAIN): Understanding Micronutrient Food Fortification

https://www.youtube.com/watch?v=NYvxUNhOGUU

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8.5 Review questions

1. (a) Describe why fresh food can be more nutritious than processed foods.

(2 marks)

(b) Provide an example of when a processed food can be more nutritious than fresh foods **and** explain why.

(3 marks)

2. Food additives are intentionally added to foods to help meet the specific needs of consumers.

(a) Vitamin C is an antioxidant that can be added to foods. Describe the purpose of adding antioxidants to foods.

(2 marks)

(b) Explain the purpose of adding an emulsifier to a low fat mayonnaise.

(2 marks)

(c) Describe **two** benefits to consumers of sweeteners being added to foods.

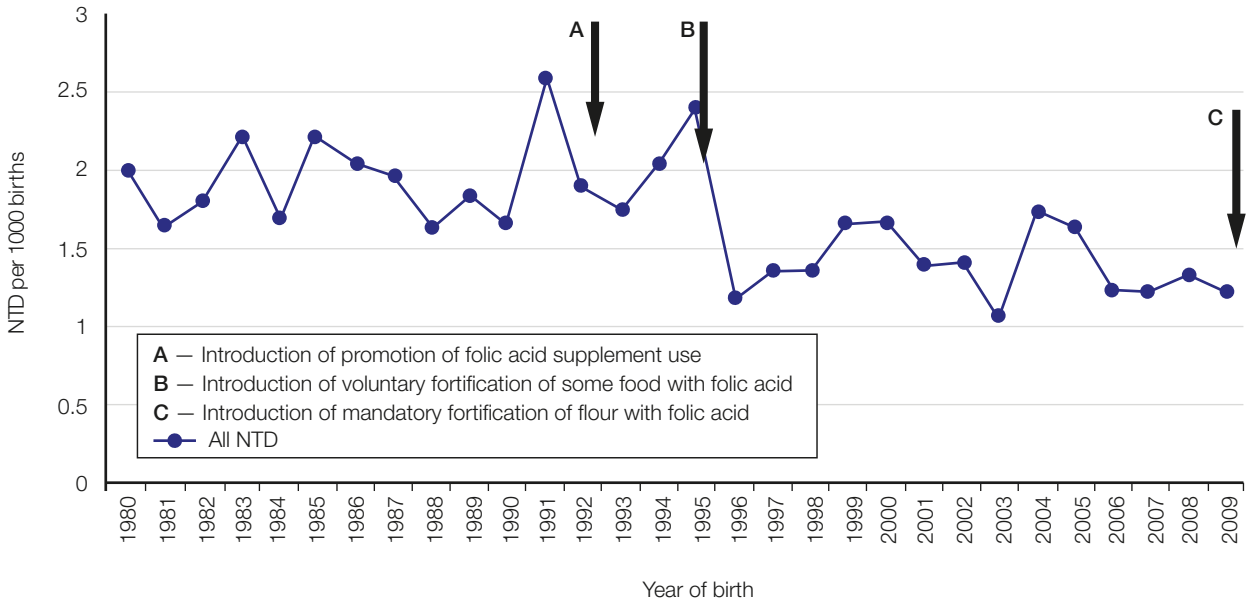
(2 marks)

(d) Wild salmon get their reddish pink colour from carotenoids found in algae they consume but farmed salmon have a food colouring called astaxanthin added to their feed to replicate the natural colour of wild salmon. Explain the benefit of applying this food colouring to farmed salmon feed for manufacturers and consumers.

(2 marks)

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3. Refer to the following graph that shows the number of neural tube defects (NTD) from 1990 to 2009:



(a) Using data, explain what happens to the number of neural tube defects at point B.

(2 marks)

(b) Describe how the fortification of folic acid in Australia reaches a large percentage of the population.

(2 marks)

(c) Name **one** target demographic of folic acid fortification **and** explain why this is important.

(2 marks)

(d) State the food product that is required to be fortified with vitamin D **and** explain why this is a good choice.

(2 marks)

(e) State **two** likely reasons why mild iodine deficiency has re-emerged in Australia **and** bread is now mandated to be fortified with iodised salt.

(2 marks)

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8.6 Food packaging and labelling

Nutrition Understanding

Food packaging is important to protect food products from microbiological, chemical and physical contamination. The packaging also helps to maintain the quality of the food product and extend its shelf life. There are many different types of packaging that can be used, and each type of packaging serves specific functions and food types. Some packaging types are used to make food products more convenient for consumers, whereas others are focused on protection, especially for its transportation. Another function of packaging is to supply information to consumers, including the mandated nutritional requirements.

Functions of packaging

Convenience

Life is busy, and a key factor for many consumers is **convenience**. Food manufacturers can package their products to increase their ease of use, transport or storage. Some examples are:

- Microwaveable plastic containers and films so frozen meals do not have to be defrosted prior to heating.
- Resealable plastic bags on food products like tortilla wraps to protect leftover wraps from exposure to oxygen and help maintain quality until eaten.
- Cans with ring pull tops do not require can openers.
- Purposefully designed packaging to separate dips and biscuits so that biscuits do not become soggy and quality is maintained.
- Honey can be purchased in squeeze bottles so that it can be easily distributed to meals without getting stuck to a spoon.
- Foods can be packaged with forks, spoons, straws and pop-tops so that they can be packaged into school lunchboxes and consumed whilst in transit.

Protection

Packaging allows foods to be transported and is designed to limit the chances of food coming in to contact with conditions that may spoil or contaminate it. The packaging needs to supply a suitable barrier that is specific to the food to inhibit oxygen, moisture, light, chemicals, pests and/or microorganisms from entering the product. As a result of its protective nature, packaging can **increase the shelf life** of foods adding to the convenience for consumers because they have a greater time period in which to consume it (see Figure 8.6.1 for some examples). This can also help combat the amount of **food wastage** ending up in landfill. The packaging also needs to be durable to prevent physical damage such as breakage and spillage. Packaging that has been compromised or opened can result in a loss of quality and increased risk of food poisoning. Damaged packaging can be seen by consumers but sometimes it is missed, especially if the damage is not obvious. Food manufacturers need to choose the correct material to reduce the likeliness of physical damage to their product as consumers can choose not to purchase it resulting in decreased profits.

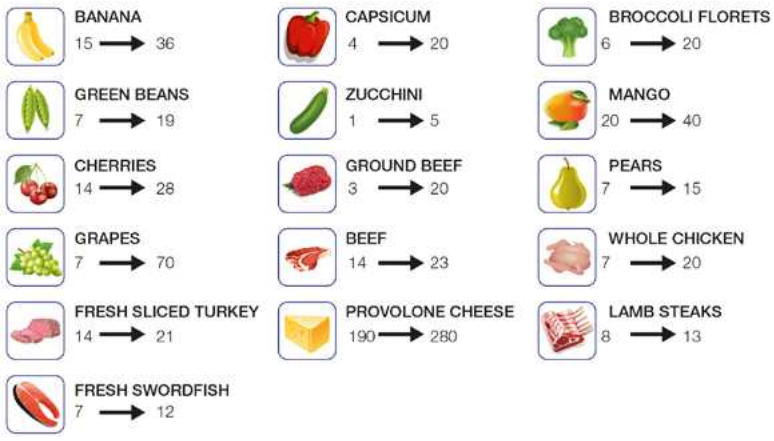


Figure 8.6.1: A Flexible Packaging Association study in 2014 documented the extension of shelf life (in days) for a variety of products using modified atmosphere packaging, vacuum packaging and active packaging.

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Supply information

Packaging also allows the manufacturer to **communicate information** to their consumers. Many packaging materials can be printed on, such as cardboard and plastic. Some packaging, such as metal tins and glass jars, are harder to print on and can require additional paper packaging to print information on. There are 12 requirements by Food Safety Australia New Zealand (FSANZ) that are required to be printed on food products. This is discussed in more detail later in this subtopic. Manufacturers can also use the packaging as a marketing tool to attract specific groups within the community.

Types of packaging

Table 8.6.1: The four main packaging materials and some of their advantages and disadvantages.

		Advantages	Disadvantages
Packaging Material	Plastics	• Plastics are lightweight and easy to carry. • Plastic prevents water and oxygen from entering products. • There are multiple types of plastics that can be used for packaging different items (see Figure 8.6.2). • Plastic can be transparent, and consumers can check the product's quality. • Plastic can be flexible to squeeze product out of, such as a plastic tube.	• Does not decompose easily and some types can take up 600 years to decompose. • Each type of plastic has a different recycling process. • Soft plastics have to be separated from hard plastics and dropped off at designated bins, which is less convenient. • Products made from multiple plastics are hard to recycle. • A lot of plastic ends up in the environment and especially the oceans, killing wildlife. • The decomposition of plastics that end up in waterways is a significant contributor to greenhouse gases and global warming. • Microplastics can leach from the packaging into the product and be consumed.
	Glass	• Glass is non-reactive with the food, reducing risk of chemical contamination. • Glass is strong and durable. • Glass can resist high temperatures and can be sterilised. • Glass can be easily sealed, preventing oxygen and moisture from entering. • Glass is transparent and consumers can check product's quality.	• Glass is easily broken when dropped. • Glass is heavy and can be harder for some members of the community to transport, especially when carrying multiple glass packaged foods. • Because it is transparent, light can penetrate it, destroying light sensitive nutrients, especially vitamin B2. • It is estimated that glass takes one million years to decompose and this will remain in the environment if not recycled.
	Paper/cardboard	• Paper and cardboard are cheap, reducing costs for manufacturers and consumers. • Paper and cardboard are lightweight, making them easier to transport. • Paper and cardboard both block light, preventing loss of light sensitive nutrients such as vitamin B2 (e.g. milk cartons). • Paper and cardboard are easily printed on to communicate information. • Paper and cardboard can be moulded into specific shapes, such as egg cartons to ensure the eggs are not touching each other and reduce breakage.	• Paper and cardboard are easily damaged by water, so manufacturers often have to use a combination of packaging types (e.g. cereals have a cardboard box but also a plastic bag to prevent water from making the cereal soggy). • Multi-ply cardboards can be difficult to recycle.
	Metals	• There are multiple types of metals that can be used, such as aluminium, tin and steel. • A thin layer of tin can be applied on the inside and outside of steel to prevent rusting and to make a tin can. • Tin cans are heat resistant so they can be sterilised at very high temperatures. • Metals block light, preventing loss of light sensitive nutrients such as vitamin B2. • Tin cans are easily sealed, preventing oxygen and water entering. • Metals are easily recyclable, reducing the impact on the environment.	• Tin cans are not resealable, so they have to be used in one meal or transferred to another container. • Metal cans can be easily dented, which can allow oxygen and microorganisms in, reducing its quality and increasing the risk of food poisoning. • Metal cans cannot be microwaved and have to be emptied into another container prior to microwaving. • Metal packaging takes significant energy to be produced, which mostly relies on fossil fuels. • Metals can take up to 100 years to decompose if not recycled.

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Type of plastic	Common examples	
1 PET		Water and soft drink bottles, salad domes. salad dressing and peanut butter container
2 HDPE		Milk bottles, freezer banks, dip tubes, crinkly shopping bags, ice cream containers, juice bottles, shampoo chemical and detergent bottles
3 PVC		Cosmetic containers, commercial cling wrap
4 LDPE		Squeeze bottles, cling wrap, garbage bags
5 PP		Microwave dishes, ice cream tubs, potato chip bags and dip tubs
6 PS		CD cases, water station cups, plastic cultery, imitation 'crystal glassware', video cases
6 EPS		Foamed polysterene hot drink cups, hamburger take-out clamshells, foamed meat trays, protective packaging for fragile items.
7 OTHER		Water cooler bottles, flexible films, multimaterial packaging

Figure 8.6.2: Examples of different types of plastics and some of their uses.

Did you know?

Recently, it was discovered that as plastic waste degrades in the presence of sunlight it releases methane and ethylene. Methane is a greenhouse gas that is approximately 25 times greater at holding heat in the atmosphere than carbon dioxide. Prior to 2018, emissions from plastic degradation were not accounted for when predicting future greenhouse gas emissions. Plastic production is also expected to double over the next 20 years because of its wide range of uses and durability, further impacting greenhouse emissions.

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Environmental impact

Food packaging options range in the amount of time they take to decompose. This means they can sit in landfill for a very long time. Some plastics can take up to 600 years to decompose and it is estimated that glass can take up to one million years to decompose (see Figure 8.6.3 for decomposition of packaging types).



Figure 8.6.3: Approximate degradation times of various waste products.

These materials often require heat, light and oxygen to decompose but when these materials sit in landfill, the majority of waste is piled on top, preventing access from oxygen and light. As conditions are not favourable for decomposition, their lifespan is further increased, as is the amount of **carbon emissions** released from their decomposition by anaerobic microorganisms. Also, plastic waste can end up in the environment, especially waterways, **killing wildlife**. Plastic packaging such as six pack rings and single use plastic bags can cause **suffocation** of animals such as turtles and fish. Animals can also eat plastic waste causing them to **starve** (see Figure 8.6.4). This is because the plastic takes up space in their stomach and the stomach acids cannot break the plastic down to digest it, so it remains there, blocking food from entering the small intestine. Plastic waste that enters the environment can also degrade into **microplastics**, which animals can consume, entering the food chain. The effect of microplastics on humans is not currently well understood and further research needs to be conducted. Some research has linked microplastics with disrupting hormonal pathways, inflammation and infertility.

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Figure 8.6.4: A representation of the 30kg of plastic waste consumed by a sperm whale that washed up on shore in Spain in 2018.

Helpful online resources

Kurzgesagt: Plastic Pollution: How Humans are Turning the World into Plastic

https://www.youtube.com/watch?v=RS7IzU2VJIQ

Compostable packaging

To reduce the environmental impact of packaging, alternative options are being developed and used. **Compostable packaging** is predominantly made from organic plant-based materials and its decomposition does not produce any toxic materials or microplastics. Compostable packaging can be easily broken down in composting systems through microbial action and placed in **green waste bins** for industrial composting and recycling into fertiliser. However, compostable packaging can be more expensive and is not as sturdy as plastic packaging as it can tear or break more easily.

Compostable packaging should not be confused with **degradable** and **biodegradable** packaging. Both degradable and biodegradable packaging need to be disposed of in the **general waste** bin and are **not compostable or recyclable**. Degradable packaging is made from plastic and other chemicals such as heavy metals that break down into microplastics and release toxins into the environment when exposed to sunlight and heat. As previously mentioned, these microplastics can enter the food chain. Biodegradable packaging is very similar to degradable packaging except that microorganisms are able to facilitate its decomposition. **There is a misconception that biodegradable packaging is the same as compostable packaging but this is not true**. In fact, putting biodegradable packaging in the green compost bin is a big concern because it can result in microplastics ending up in the processed fertiliser that is used on the soil on our farms and consequently our food. Beware of degradable and biodegradable rubbish bags that market themselves in a way that consumers could be mistaken to believe they are environmentally friendly.

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Figure 8.6.5: An example of compostable packaging is BioPak, who were the first packaging company in Australia to become carbon neutral and provide environmentally sustainable packaging options. BioPak is used by many eateries, including school tuck shops, in Australia.

E Extension questions

Investigate the types of packaging used at your School's tuck shop and determine whether they are compostable, recyclable or to be send to landfill. Make recommendations to your School leaders if you believe more sustainable packaging options are available than those currently being used.

Investigate the waste sorting and disposal options available at your School. Form a view as to whether there are sufficient options to dispose of compostable and recyclable packaging. Make recommendations to your School leaders if you believe additional waste sorting and disposal bins are required.

Food labelling

The majority of foods are required to have a label to provide consumers with important information so they can make informed decisions about their food choices. Food Safety Australia New Zealand has set the labelling requirements through the Food Standards Code. There are 12 food labelling requirements set by FSANZ listed below. **For an elaboration on each requirement please see Figure 8.6.6**.

1. Nutrition Information Panel (NIP)
2. Percentage labelling
3. Food identification
4. Information for people with food allergies or intolerances
5. Date marking
6. Ingredient listing
7. Labels must tell the truth
8. Food additives
9. Directions for use and storage
10. Legibility requirements
11. Country of origin
12. Nutrition and health claims

Not all foods are required to abide by the food labelling requirements set by the Food Standards Code. **Some of the exemptions include**:

- Unpackaged foods such as fresh meat, fruit, vegetables and nuts.
- Pre-packaged and cut fresh fruit and vegetables that can be seen through the packaging, such as fruit salads.
- Individual serves within larger packaging, for example, individual fun size chocolates. However, the NIP must be on the outer packaging.
- Food sold in a restaurant.
- Food made and packaged on the premises from where it is sold, such as a bakery.
- Food packaged in the presence of the customer, such as a takeaway food shop.
- Food delivered at the customer's request, for example, pizza.
- Food sold at a fundraiser, such as bake sales and sausage sizzles.

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FOOD STANDARDS Australia New Zealand
Te Mana Kounga Kai – Ahitereiria me Aotearoa

FOOD LABELS
WHAT DO THEY MEAN?

1 Nutrition information panel

This panel shows the average amount of energy, protein, fat, saturated fat, carbohydrate, sugars and sodium in a serve and in 100 g (or 100 ml) of the food. The amount of any other nutrient or substance about which a nutrition content or health claim is made must also be shown (e.g. the amount of calcium must be shown if a claim about calcium is made).

2 Percentage labelling

Food labels must show the percentage of the key or characterising ingredients or components in the food. This allows similar foods to be compared. The characterising ingredient for this strawberry yoghurt is strawberry and the ingredient list states that it contains 7% strawberries.

3 Food identification

To help identify a food, food labels must show:

- the name of the food
- the name and business address in Australia or New Zealand of the supplier of the food
- the lot identification of the food.

The name or description of the food must reflect its true nature (e.g. strawberry yoghurt must contain strawberries). If the yoghurt contained strawberry flavouring rather than real fruit, then the name would need to indicate that it is strawberry-flavoured yoghurt.

4 Information for people with food allergies or intolerances

Some food ingredients and substances can cause severe allergic reactions and must be declared when present in a food. These ingredients are peanuts, tree nuts (e.g. cashews, almonds, and walnuts), crustacea, fish, milk, eggs, sesame, soybeans, wheat and lupin.

Sulphites (if added at 10 mg or more per kg of food) and cereals containing gluten (e.g. wheat, oats, barley, rye and spelt) also need to be declared.

5 Date marking

Foods that should be eaten before a certain date for health or safety reasons must be labelled with a use–by date.

Otherwise a best–before date is required if the food has a shelf life of less than two years. Although it may be safe to eat a food after its best–before date, it may have lost quality and some nutritional value.

6 Ingredient list

Ingredients must be listed in descending order (by ingoing weight). So if an ingredient is listed near the start of the list, then the food contains more of this ingredient than others lower down the list.

7 Labels must tell the truth

Under Australian and New Zealand consumer laws, labels must not be false, misleading or deceptive.

Suppliers must also label foods with accurate weights and measures information. The National Measurement Institute in Australia (www.measurement.gov.au) and the Ministry of Consumer Affairs in New Zealand (www.consumerprotection.govt.nz) ensure that correct weight and measurement information is used on food labels.

8 Food additives

Food additives must be identified in the ingredient list, usually by their class name (e.g. 'thickener' or 'colour') followed by the food additive name or number. A thickener has been used in this yoghurt and it is labelled as 'thickener (1442)'. A full list of food additive names and numbers is available from www.foodstandards.gov.au

9 Directions for use and storage

Where specific storage conditions are required for a food to keep until its best-before or use-by date, those conditions must be included on the label.

If the food must be used in accordance with certain directions for health or safety reasons, those directions must be included on the label.

10 Legibility requirements

Any labelling requirements must be in English, be legible and prominent so as to contrast distinctly with the background on the label.

11 Country of origin

Australia and New Zealand have different country of origin labelling requirements.

In Australia, the country of origin of packaged and some unpackaged foods must be stated on the label. Read more about country of origin labelling on the Australian Competition and Consumer Commission website at www.accc.gov.au

In New Zealand, country of origin labelling is required on wine only. Further information is available on the Ministry for Primary Industries website at www.mpi.govt.nz

12 Nutrition and health claims

Nutrition content claims are claims about the content of certain nutrients or substances in a food, (e.g.'contains calcium'). Health claims refer to a relationship between a food and health. There are rules for when nutrition content or health claims are made on food labels.



For more information on food labelling

visit www.foodstandards.gov.au/foodlabelling

Or follow us on www.facebook.com/Food.Standards www.twitter.com/FSANZnews and @foodstandardsanz

Disclaimer: This poster has been produced as a guide to consumers only. Industry and enforcement agencies should refer to the Food Standards Code.

Figure 8.6.6: The food labelling poster by Food Safety Australia New Zealand detailing the 12 food labelling requirements.

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8.6 Review questions

1. Describe **two** examples of convenient packaging.

(2 marks)

2. Explain how food packaging can increase shelf life and reduce food wastage.

(4 marks)

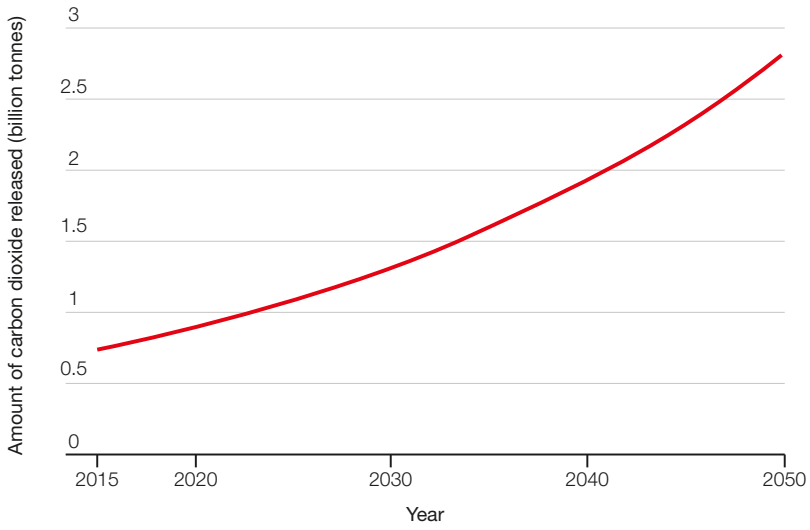
3. Describe **two** advantages **and two** disadvantages of glass packaging.

(4 marks)

4. Describe **two** advantages **and two** disadvantages of metal packaging.

(4 marks)

5. Refer to the following graph that shows the predicted annual carbon dioxide emissions from the production and incineration of plastics.



(a) Using data, describe the pattern of predicted annual carbon dioxide emissions from the production and incineration of plastics.

(2 marks)

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(b) Identify **one** possible reason to explain the trend seen in the graph.

(1 mark)

(c) Describe **two** other concerns of plastic waste littering waterways.

(4 marks)

(d) Describe why compostable packaging is more environmentally friendly than plastics.

(2 marks)

(e) Describe **two** disadvantages of compostable packaging.

(2 marks)

(f) Explain the difference between compostable and biodegradable packaging.

(4 marks)

6. *Refer to the following Nutrition Information Panel to answer questions (a) to (c) below.*

NUTRITION INFORMATION (AVERAGE)

servings per package - 11
average serving size - 30g (¾ metric cup†)

	quantity per serving	%daily intake per serving	per serve with ½ cup reduced fat milk
PROTEIN	1.9 g	**4%**	7.1 g
FAT, TOTAL	0.5g	**0.6%**	2.5g
- SATURATED	0.2 g	**0.6%**	1.5 g
CARBOHYDRATE	25.7 g	**8%**	32.7 g
- SUGARS	11.4 g	**13%**	18.4 g
DIETARY FIBRE	0.7 g	**2%**	0.7 g
SODIUM	141 mg	**6%**	210mg
POTASSIUM	33 mg	**—**	266 mg

(a) Describe why it is important for labels to display important information.

(1 mark)

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(b) With reference to the Nutrition Information Panel above, identify **two** pieces of missing information on the panel that is required by the Food Standards Code.

(2 marks)

(c) Other than the Nutrition Information Panel, name **three** additional labelling requirements outlined in the Food Standards Code.

(3 marks)

(d) Some food products are exempt from the food labelling requirements set by FSANZ. Outline **two** examples that do not require food labels.

(2 marks)

E Extension question

Research **and** discuss the labelling requirements for genetically modified foods.

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Topic 8 Review Test

1. Food Standards Australia New Zealand (FSANZ) is a bi-national government agency that develops and administers the *Australia New Zealand Food Standards Code*.

   (a) State **two** responsibilities of FSANZ that help ensure the supply of safe food.

   (i) Responsibility1:

   (1 mark)

   (ii) Responsibility2:

   (1 mark)

   (b) FSANZ mandates the addition of 2 to 3 milligrams of folic acid (the synthetic form of vitamin B9) per kilogram of wheat flour used in bread products (except in organic bread) in Australia.

   State the target group of this mandate **and** explain why the addition of folic acid was considered necessary.

   (i) Target group: *(1 mark)*

   (ii) Explanation:

   (2 marks)

   (c) Discuss **one** circumstance under which a nutrition information panel is **not** required.

   (2 marks)

2. Students conducted an experiment to investigate the growth of bacteria on chicken stored at different temperatures for 10 days.

   One piece of chicken was stored at 3°C, and another was stored at 30°C.

   Every second day a sample was taken from each piece of chicken, and the proportion of the sample that contained bacteria was recorded.

   Refer to the following table, which shows the results of the experiment:

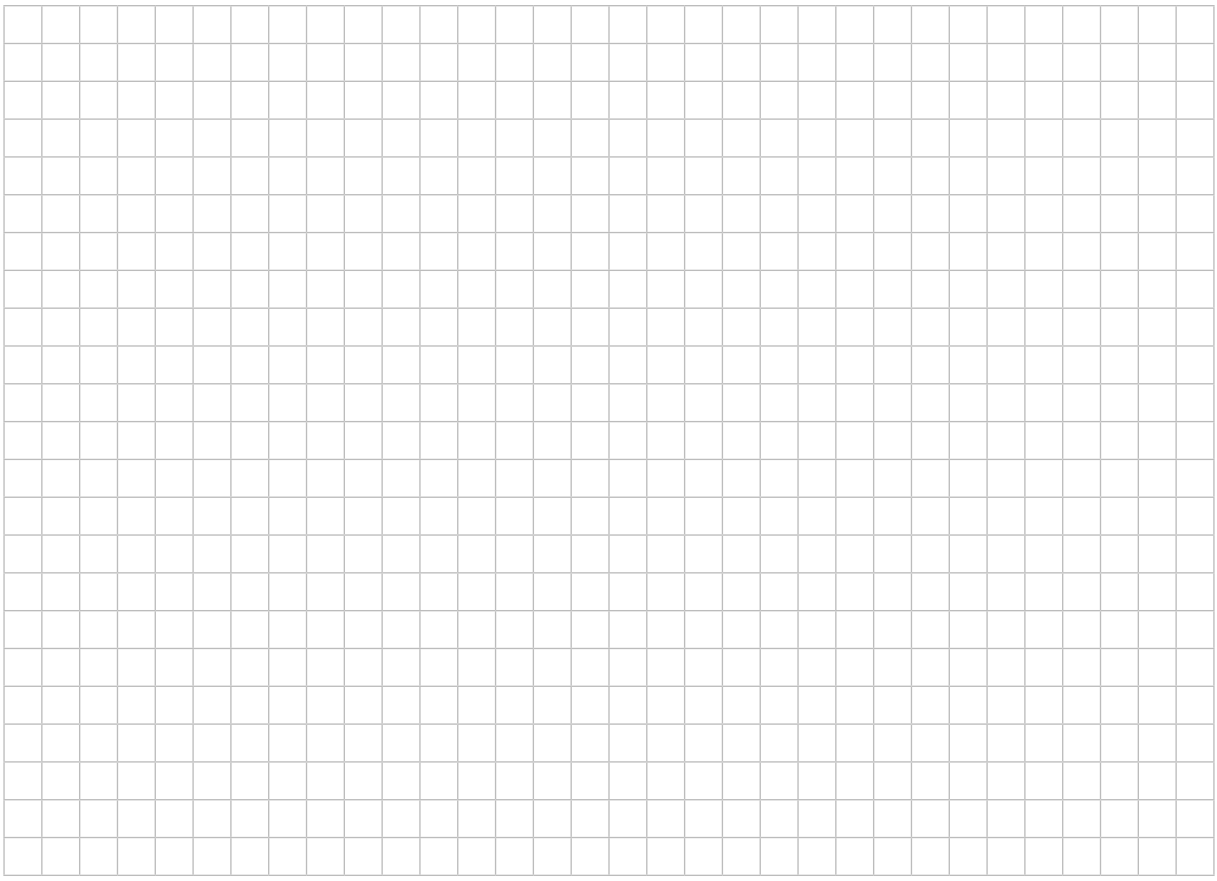
	Proportion of sample with bacteria (%)					
Temperature °C	Day 0	Day 2	Day 4	Day 6	Day 8	Day 10
3	0	0	0	2	15	28
30	0	2	20	35	50	54

   (a) (i) State the dependent variable.

   (1 mark)

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(ii) Graph both sets of data from the table on the same set of axes in the space provided below.



(5 marks)

(iii) State **one** variable that the students would have controlled throughout the experiment.

Variable:

(1 mark)

(iv) Using data from the graph constructed in part (a)(ii), explain why there is a difference in the rate at which bacteria grew at the different temperatures during the test period.

(4 marks)

(v) It was suggested that 10 pieces of chicken rather than just one should have been tested at each temperature.

Explain the effect of sample size on the results of an experiment.

(2 marks)

(vi) State a possible systematic error in this experiment **and** explain its effect on the results of this experiment.

(3 marks)

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(b) Some forms of bacteria that grow in food can cause food poisoning in humans. To prevent the growth of bacteria, food is often preserved.

One method of preserving food is canning.

(i) Explain **two** principles of the canning process that provide canned food with a longer shelf life than fresh food.

(1) Principle 1:

(2 marks)

(2) Principle 2:

(2 marks)

(ii) Explain **two** disadvantages of using cans to package food.

(1) Disadvantage 1:

(2 marks)

(2) Disadvantage 2:

(2 marks)

(c) Explain how the addition of additives to food products could help preserve their shelf life.

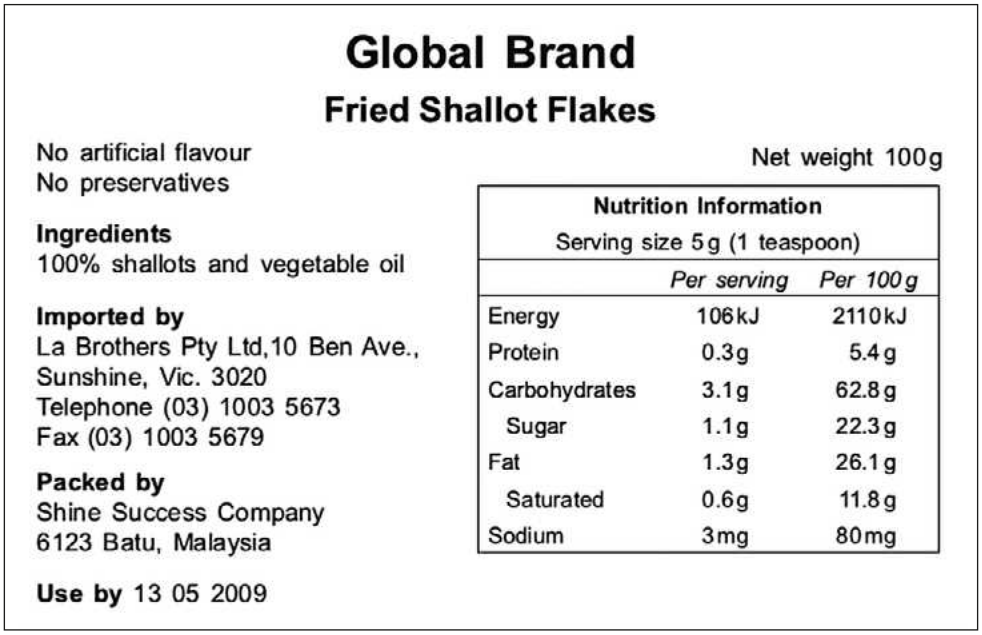
(2 marks)

(d) Describe the difference between food spoilage and microbial contamination.

(2 marks)

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3. *Refer to the following label, which shows nutrition information for fried shallot flakes.*



Global Brand

Fried Shallot Flakes

No artificial flavour
No preservatives

Net weight 100g

Ingredients
100% shallots and vegetable oil

Imported by
La Brothers Pty Ltd,10 Ben Ave.,
Sunshine, Vic. 3020
Telephone (03) 1003 5673
Fax (03) 1003 5679

Packed by
Shine Success Company
6123 Batu, Malaysia

Use by 13 05 2009

Nutrition Information Serving size 5g (1 teaspoon)		
	Per serving	*Per 100g*
Energy	106kJ	2110kJ
Protein	0.3g	5.4g
Carbohydrates	3.1g	62.8g
Sugar	1.1g	22.3g
Fat	1.3g	26.1g
Saturated	0.6g	11.8g
Sodium	3mg	80mg

(a) Identify **one** piece of information on the label that does not conform to Australian law **and** explain why this information is required.

Information:

Explanation:

(2 marks)

(b) State **one** nutritional claim that the company makes about this product.

(1 mark)

(c) Describe why the fried shallot flakes are considered a processed food.

(1 mark)

4. (a) A number of people were diagnosed with a food-borne illness that was caused by eating pre-packaged fresh fruit salad. The fruit salad had been contaminated during harvesting or production with pathogenic bacteria.

(i) State **one** possible source of the bacteria.

(1 mark)

(ii) Identify **one** group of people who would be particularly susceptible to developing a food-borne illness **and** outline why they would be susceptible.

(2 marks)

(iii) Bacteria can double in number every 20 minutes when exposed to favourable conditions.

State **two** conditions that would increase bacterial growth in pre-packaged fresh fruit salads.

(1)

(1 mark)

(2)

(1 mark)

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(b) With reference to an example, explain how to prepare raw meat in order to make it safe for human consumption.

(2 marks)

5. Food is often transported over long distances before it reaches the consumer.

(a) Describe **one** environmental disadvantage of transporting food over long distances.

(2 marks)

(b) Packaging protects food from damage, spoilage, or contamination that would reduce its quality. For each of the three foods listed below ((i), (ii), and (iii)):

- Identify **one** risk factor that could reduce the quality of the product
- Suggest **one** packaging material that manufacturers could use to reduce this risk factor
- Explain how the suggested packaging material reduces the risk factor.

(i) *Fresh milk*

Risk Factor:

Packaging material to reduce risk factor:

How packaging material reduces risk factor:

(3 marks)

(ii) *Breakfast cereal*

Risk Factor:

Packaging material to reduce risk factor:

How packaging material reduces risk factor:

(3 marks)

(iii) *Fresh eggs*

Risk Factor:

Packaging material to reduce risk factor:

How packaging material reduces risk factor:

(3 marks)

Total: /57

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Topic 9 Sports nutrition



Concepts: Principles of nutrition, physiology and health & Health promotion and emerging trends

9.1 Basal metabolic rate, energy balance and energy systems

9.2 Nutrient requirements of athletes

9.3 Relative energy deficiency in sport (RED-S)

9.4 Factors affecting hydration

Topic 9 Review Test

9.1 Basal metabolic rate, energy balance and energy systems

Nutrition Understanding

Author's note: It is recommended to read Topic 1: Fundamentals of nutrition before reading Topic 9: Sports nutrition. This is to ensure you have a general understanding of the roles of macronutrients, micronutrients and water in the human body, prior to applying it to the information covered in this topic.

Basal metabolic rate (BMR)

Basal metabolic rate (BMR) is the rate at which your body **uses energy while at rest and in a fasting state to keep vital functions going.** It is generally a measure of oxygen consumption, which is required for aerobic respiration (energy production in cells). Some examples of vital functions are breathing, keeping the heart beating, maintaining our body temperature at 37°C and generally keeping all vital organs functioning. In recent times, nutritionists have developed several prediction equations to estimate an individual's BMR from simple body measures, such as body mass, age and gender. In this course, we will only focus on one simple version of calculating BMR. This method is calculated based on the rough estimate that 1kg of body weight in males burns 1.0 calories per hour and 1kg of body weight in females burns 0.9 calories per hour. To express BMR in kilojoules (the measurement used for energy in Australia), the answer in calories must be multiplied by 4.2. The simple BMR formulae for males and females are represented below:

π Formula

Males

BMR = Body weight in kilograms × 1.0 × 24 hours × 4.2

Females

BMR = Body weight in kilograms × 0.9 × 24 hours × 4.2

To determine the BMR of an individual, the weight of the individual needs to be inserted into the appropriate formula based on the individual's gender.

Example question

The average weight of an adult male is 70kg. Calculate the basal metabolic rate of an average adult male.

BMR = Body weight in kilograms × 1.0 × 24 hours × 4.2

= 70 × 1.0 × 24 × 4.2

= 7,056 kJ

N.B. Don't forget to include your units.

Estimated energy requirement and physical activity levels

The BMR represents the amount of energy our body requires without performing any activities. To put this in context, it effectively represents the amount of energy our body requires if we lay in bed all day doing nothing, including not eating. However, humans cannot maintain a lifestyle like this. Therefore, we need to calculate our **Estimated Energy Requirement (EER)**, which is the total daily amount of energy our body needs to support daily activities. To calculate one's EER, their **Physical Activity Level (PAL)** must be determined first. The PAL of each individual differs. The PAL is split into **five categories**: sedentary, lightly active, moderately active, very active and extra active. Each category has a **PAL factor** that the BMR needs to be multiplied by to calculate the EER. Refer to Table 9.1.1 for the PAL factors.

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Table 9.1.1: Table representing the descriptions of lifestyles and associated physical activity levels.

Physical Activity Level (PAL) Category	Physical Activity Level (PAL) Units	Description of lifestyle	Examples of occupations
Bed rest	1.2	At rest, exclusively sedentary or lying (chair-bound or bed-bound).	Old, infirm individuals. Unable to move around freely or earn a living
Sedentary[1]	1.4 – 1.5	Exclusively sedentary activity/seated work with little or no strenuous leisure activity*	Office employees, precision mechanics
Slightly active[2]	1.6 – 1.7	Sedentary activity/seated work with some requirement for occasional walking and standing but little or no strenuous leisure activity*	Laboratory assistants, drivers, students, assembly line workers
Moderately active[3]	1.8 – 1.9	Predominantly standing or walking work*	Domestic duties, salespersons, waiters, mechanics, traders
Very active	2.0 – 2.4	Heavy occupational work or highly active leisure	Construction workers, farmers, forest workers, miners, high performance athletes

** For individuals who participate in significant amounts of sport or strenuous leisure activity (i.e. 30–60 minutes, 4–5 times per week) in addition to PAL category[1, 2 or 3] above, add 0.3 extra PAL units.*

Example question

The basal metabolic rate of an average adult male is 7,056kJ. Calculate the estimated energy requirement for an average adult male who lives a sedentary lifestyle and has on office-based job. Round off your answer to the nearest whole number.

Estimated energy requirement = BMR × PAL Factor

= 7,056 × 1.4

= 9,878.4 kJ

= 9,878 kJ

Helpful online resources

TED-Ed: What is a calorie?–Emma Bryce

https://www.youtube.com/watch?v=VEQaH4LruUo

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Did you know?

Every activity we do in our lives requires energy but how can we determine how much energy each task burns? One way of reporting the energy required by various activities is by using metabolic equivalents (METs), which represent multiples of BMR. One MET is the equivalent of resting or sitting for one hour. Over the years, scientists have determined the METs for many sports and daily tasks and have compiled them in the 'Compendium of Physical Activities'. Some of the daily activities that have a calculated MET include cleaning the house, milking a cow, typing on a computer and playing the violin.

To calculate the amount of kilojoules a particular activity burns per hour, you need to determine the amount of METs using the 'Compendium of Physical Activities' (see link below) and then use the following formula.

Amount of kilojoules burnt per hour = MET of activity x body weight (kg) × 4.2

For example, walking at a moderate pace for an hour is 3 METs. Therefore, for the average adult male who weighs 70kg, you would multiply his weight by the number of METs and 4.2 (to convert from calories to kilojoules). See example below:

Example question

Amount of kilojoules burnt per hour $= 3 \times 70 \times 4.2$

$= 882$ kJ/hour

To work out the amount for a half an hour walk, you would simply divide the answer by two. This is the easiest way to get a science-backed estimate of kilojoules burned in an activity. However, this sort of calculation does not take into account individual differences such as body mass, body fat, age, gender or efficiency of movement. Also, these calculations are calculated based only on time spent in movement and therefore may not always be an accurate representation. For example, the MET for playing netball may not take into account specific circumstances, such as if much of the action was at the other end of the court and some players spent half of the game standing around. To gain a more accurate result in such circumstances, the amount of kilojoules burnt per hour should be divided by two (to take into account that only half of the game was spent in movement) in order to gain a more appropriate representation of the energy burnt.

To use the 'Compendium of Physical Activities' website, you firstly need to click on the 'Activity Categories' tab at the top of the page and select the category you are looking for (e.g. water activities, sport, etc.) Then use the 2011 MET values (these are currently the most recently updated values). Please note the **BLUE** MET values are **backed by published research** and the **RED** values are **estimated values**.

Helpful online resources

'Compendium of Physical Activities' website

https://sites.google.com/site/compendiumofphysicalactivities/

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Factors affecting basal metabolic rate

There are many factors that affect basal metabolic rate (BMR) and having an understanding of what affects our metabolic rate can help us when planning our diet and exercise routines (including weight management plans). Some people have a high metabolic rate and can appear to eat whatever they want and not put on weight; whereas, other people put on weight easily, even when consuming less food. A person's BMR is one factor that can contribute to this. It is also important to note that 'being skinny' isn't necessarily a sign of healthiness. If a skinny person does no or little exercise and frequently eats unhealthy food (termed 'skinny fat') they are generally unhealthy and have an increased risk of developing many diseases and dying at an earlier age. You also may have heard your parents say that their metabolism is 'slowing down'. This can be true, as after the age of 30 our muscle mass decreases and our BMR can decrease by approximately 0.3% each year. However, completing strength training can reduce the impact of this natural loss and even increase BMR. Some factors that can affect our basal metabolic rate are highlighted in Table 9.1.2.

Table 9.1.2: Some factors that affect basal metabolic rate (BMR).

Factor	Explanation
Body composition	Lean muscle mass has a greater metabolic activity than fat tissue. Therefore, the BMR will increase as muscle mass increases.
Gender	Males are generally larger and have a greater amount of lean muscle mass in comparison to females. Women's bodies store more essential fat in preparation for pregnancy. As a result, male's BMRs are generally 5% to 10% higher than females.
Age	After the age of 30, our bodies naturally reduce the amount of muscle mass. Consequently, the BMR also decreases. Adults often find less time to exercise after the age of 30 due to work commitments and raising children, and this can contribute to the decline in BMR.
Exercise	Exercise increases BMR both during exercise and for hours to days after the exercise depending on the intensity. Exercise, especially resistance training, can also result in more lean muscle mass increasing BMR further.
Infection and injury	When our body is sick or healing, our body expends a lot of energy on recovery. The BMR can increase up to two times its resting rate. When we are sick, our body focuses energy use on getting better and temporarily stops less essential processes such as growth. The longer we are sick when we are young, the less likely we are to reach our maximum growth potential.
Hormones	The thyroid releases hormones (e.g. thyroxine) that help control our BMR. An increase in the amount of thyroxine released will result in an increased metabolic rate. Individuals that have an underactive thyroid (hypothyroidism) produce less thyroxine and have a reduced BMR.
Pregnancy	During pregnancy, the BMR increases due to the increased energy needed to fuel the growing foetus and the growth of the placenta, etc. The BMR can increase up to two-fold and increases even further during the birthing process.
Body and external temperature	Our body needs to maintain its internal blood temperature at approximately 37°C to ensure optimal performance of chemical reactions. If the external temperature is colder, for example, when we go swimming or experience a very cold winter, our body needs to increase chemical reactions to produce more heat to replace the heat being lost; this increases the BMR.
Drugs	Caffeine is a drug that has been shown to increase BMR. It does this by increasing the amount of adrenaline in the blood. Adrenaline mobilises fat stores, which are then oxidized (burnt) for energy.
Diet	The BMR of an individual generally decreases if they are undertaking a kilojoule restricting diet, fasting or do not have access to food. This is because if our body does not have enough energy to perform its vital functions through diet, it has to obtain it from our stores. This involves the muscles being broken down (muscle atrophy) to convert it into glucose. A decreased amount of muscle reduces the amount of energy the body requires.

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Did you know?

Exercise generally increases the amount of muscle you have and the more muscle you have, the greater your BMR will be. Some studies show that strength training (also known as resistance training or weight training) builds muscle more effectively and increases BMR. However, other research suggests that **short bursts of intense exercise** may be as effective as, if not better than, long periods of moderate exercise.

One study, which required 10 people to complete a one minute of warm up, four minutes of high intensity intervals and a one minute of cool down (a total of six minutes of exercise), highlights this. The results of the experiment showed that energy use during the six minutes of exercise increased to 17 Metabolic Equivalents (METS). This caused a shift in metabolism that lasted more than 24 hours after the exercise. Even the next morning, metabolism was still almost 10% higher than the two previous days. The highest achieving individual in the group burned 470kJ during the six minute exercise and **1,449kJ** in the 24 hours that followed, for a total amount of energy burned of 1,919kJ over the 24 hour period.

Another study published in "Medicine and Science in Sports and Exercise" examined young male subjects who exercised vigorously on exercise bikes for 45 minutes (aerobic exercise). After completing their workouts, their metabolisms increased for an average of 14 hours and they burned an average of **798 additional kilojoules** above their resting metabolic levels.

In summary, modern exercise studies are showing that you don't have to run a marathon to lose fat. High intensity exercise (e.g. sprints) for a short duration can be as effective. For more information, you can watch *'Michael Mosley's: The Truth About Exercise'* on Vimeo and the YouTube video *'High Intensity Training (HIIT) – Maximum Results, Minimum Time'*. Both are accessible from the links below:

Helpful online resources

The Truth About Exercise

https://vimeo.com/51836895

High Intensity Interval Training (HIIT)–Maximum Results, Minimum Time

https://www.youtube.com/watch?v=2GgKm_54kXI

Energy balance

Every day we consume food that supplies our bodies with energy but we also perform activities, such as exercise, that burn energy. If a person's energy intake through food and drink is higher than their energy expenditure, known as a **positive energy balance**, then their body will **store the excess energy** (as glycogen and fat). However, if their energy intake is lower than their energy expenditure, known as a **negative energy balance**, their body will burn stored energy (see Figure 9.1.1). In reality, an individual's energy balance is very complex and there are many factors that play a role, such as genetics, how much fibre has been consumed, and the types of carbohydrates and fats consumed. A simple way to calculate an individual's energy balance is to use the following formula:

Formula

Energy balance = daily energy intake – daily energy expenditure

N.B. An energy balance with a **negative sign** represents energy is being **burned** and a **positive sign** represents energy is **stored**. It is therefore very important that the formula is written correctly, otherwise it will result in an incorrect sign, and energy balance.

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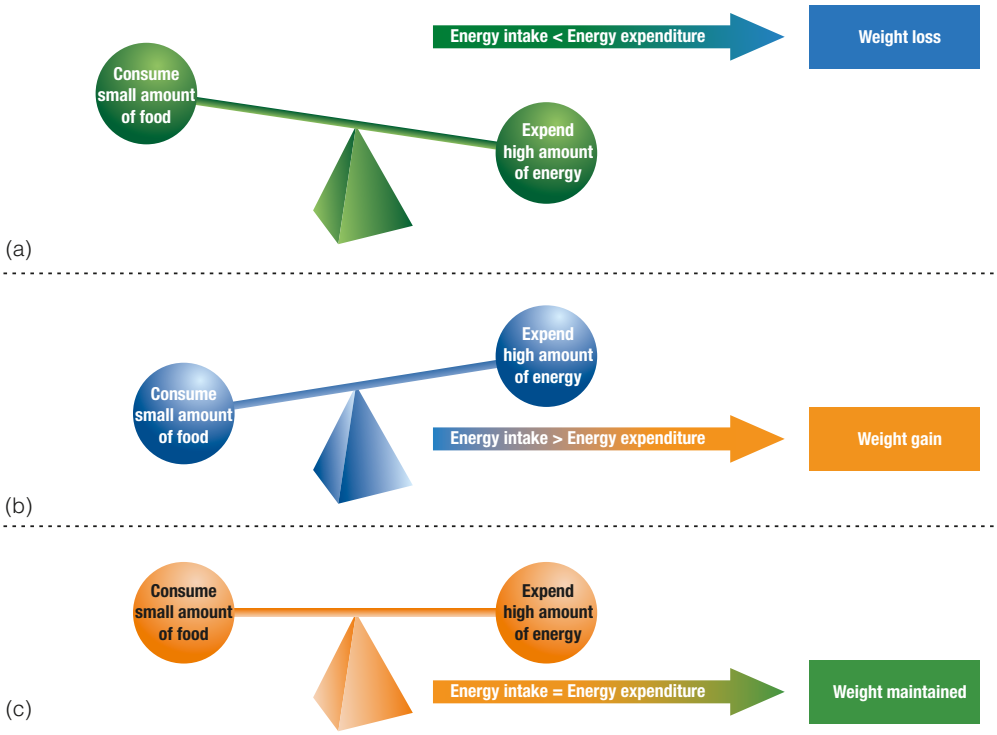


Figure 9.1.1: The different energy intake versus energy expenditure scenarios and resultant effect on weight management.

Generally, calculating the daily **energy intake** involves recording all food and beverages consumed within the day and calculating the total kilojoules consumed from that food and drink.

To calculate the daily **estimated energy expenditure**, the basal metabolic rate (BMR), the thermic effect of food (TEF) and the daily energy expended through physical activity are all calculated, and then added together (see Figure 9.1.2). Calculating an estimation of an individuals' BMR is discussed earlier in this chapter (see page 410). The **thermic effect of food (TEF)** is the energy used by our body to digest, absorb, and metabolise the nutrients consumed. The TEF is approximately **10% of daily energy intake**. Finally, to calculate the **energy expended through physical activity**, the energy expended by each daily activity needs to be added together.

π Formula

Estimated energy expenditure = BMR + TEF + energy expended through physical activity

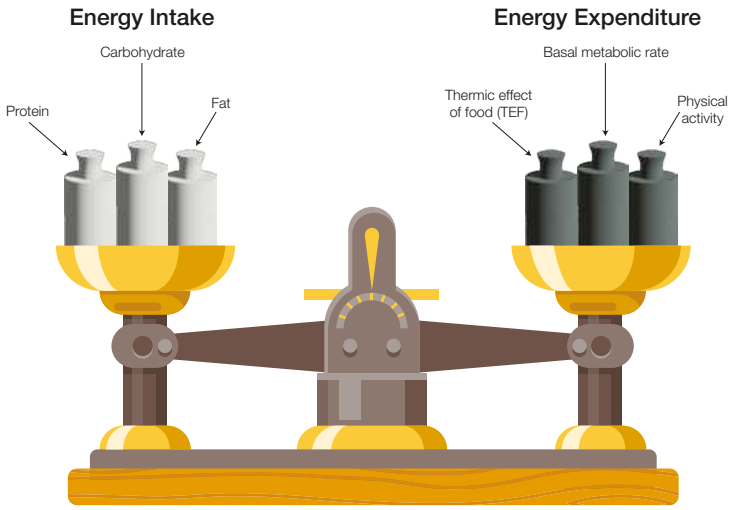


Figure 9.1.2: The various factors that affect energy balance.

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Example question

Gerard is a 40 year old male who weighs 75kg and is moderately active. On average, he burns 800kJ cycling to and from work and another 600kJ walking each day. Because of his moderate activity level, Gerard gets quite hungry and consumes an average amount of 12,150kJ each day.

(i) Calculate Gerard's BMR.

BMR (for a male) = Body weight in kilograms × 1.0 × 24 hours × 4.2
= 75 × 1.0 × 24 × 4.2
= 7,560kJ

(ii) Calculate the thermic effect of food (TEF).

TEF = Daily energy intake × 10%
= 12,150 × 10/100
= 1,215kJ

N.B. multiplying by 0.1 is the same as multiplying by 10% (i.e. 10/100).

(iii) Calculate the average energy expended through physical activity.

Energy expended through physical activity = 800 (cycling) + 600 (walking)
= 1,400kJ

(iv) Calculate Gerard's average estimated energy expenditure.

Estimated energy expenditure = BMR + TEF + Energy expended through physical activity
= 7,560 + 1,215 + 1,400
= 10,175 kJ

(b) Calculate the average energy balance for Gerard.

Energy balance = Daily energy intake – daily estimated energy expenditure
= 12,150 – 10,175
= 1,975kJ

(c) What is the likely effect on Gerard's weight if he continues to maintain this energy balance?

He is likely to gain weight. Gerard has a positive energy balance and is consuming 1,975kJ more than he is expending each day. This is likely to be stored as fat and he will continue to gain weight if he maintains this energy balance.

Energy systems

The human body is fueled by complex energy systems that keep it functioning optimally. These systems work together to provide the energy necessary for every bodily function, from the beating of the heart to the firing of neurons in the brain. There are **three major energy systems** that enable cells to regenerate a key high-energy molecule called **adenosine triphosphate (ATP).** These three major energy systems are: the immediate creatine phosphate system, the short-term lactic acid system, and the long-term aerobic system. Each of these systems play a vital role in providing the body with the energy it needs to perform various activities, from sprinting to sustained endurance exercises. Understanding how these systems function is fundamental to comprehending human performance and overall health.

Adenosine triphosphate (ATP)

Adenosine triphosphate, or ATP, is often referred to as the "currency of energy" in the cell. It is a molecule that stores and transfers energy within living organisms. The primary macronutrients - carbohydrates, fats, and proteins - are essential sources of ATP production in the body. Carbohydrates are readily broken down into glucose, which is used to generate ATP through lactic acid fermentation (anaerobic respiration) and aerobic respiration. ATP's importance to cells is paramount, as it provides the immediate energy required for various cellular functions, such as muscle contraction, protein synthesis and nervous communication.

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When ATP is utilised to perform work within the cell, the chemical bond between the second and third phosphate groups is broken, **releasing free energy for cellular use**. The resulting molecule is called **adenosine diphosphate (ADP).** However, the cell can regenerate ATP by adding a phosphate group back to ADP. The energy to re-form the high energy bond between the second and third phosphate group is primarily provided by the breakdown of carbohydrates (glucose), however, fats and proteins can also be used to regenerate ATP. This cycle of energy conversion and regeneration is called the **ATP/ADP cycle** (see Figure 9.1.3), and it ensures a constant and readily available source of energy for cellular activities.

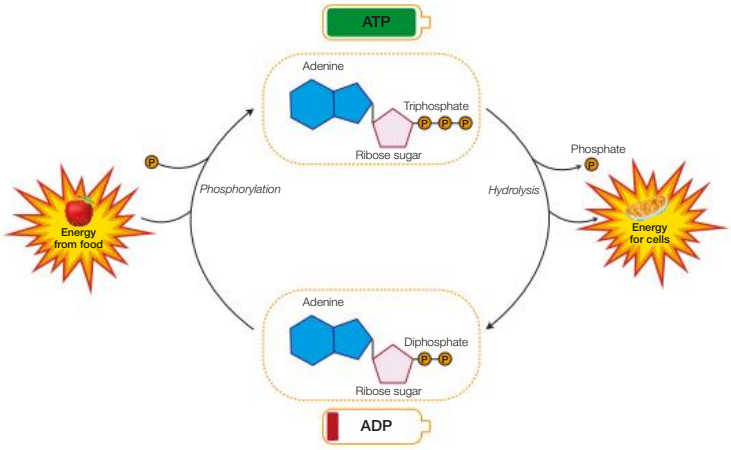


Figure 9.1.3: The ATP/ADP cycle. The macronutrients in our food can be converted through different metabolic pathways to replenish ATP molecules, primarily carbohydrates. ATP then breaks down, releasing its third phosphate group and free cellular energy.

Helpful online resources

RicochetScience: ATP (Adenosine Triphosphate)

https://www.youtube.com/watch?v=NN5Y57NbnrU

Creatine phosphate (CP)

The creatine phosphate energy system, often referred to as the **phosphagen system**, is one of the three primary energy systems in the human body. It **provides rapid but short-lived bursts of energy**, making it crucial for intense and brief activities, such as weightlifting, sprinting, and high-intensity sports. This system relies on the molecule creatine phosphate (CP), which is stored in muscles. When the body requires a sudden surge of energy, CP is broken down to creatine and a phosphate group, which is transferred to an ADP molecule (see Figure 9.1.4). This process **rapidly generates ATP without the need for oxygen.** However, the drawback is that the **CP stores are limited and can be depleted within seconds of intense effort** (approximately 10 seconds). The ATP can then be broken down to provide free cellular energy. Despite its brief duration, the CP energy system plays a vital role in powering explosive movements and complements the other energy systems to meet the dynamic energy demands of the human body.

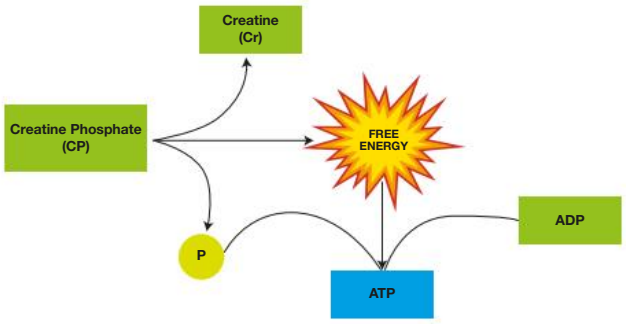


Figure 9.1.4: Creatine phosphate (CP) is broken down to creatine and a free phosphate (P) molecule, which is transferred to an ADP molecule, replacing the third phosphate group to form ATP.

Did you know?

Some bodybuilders and other athletes take supplements in the hope of building muscle and improving performance. One supplement is called creatine. Muscles have limited stores of ATP that are constantly regenerated. Creatine phosphate (CP) is one molecule that can help regenerate ATP stores, but CP stores are limited in cells. Athletes who consume creatine do so in the hope that their muscles will store more CP so they can train harder, and muscles adapt to the increased intensity of training. Some studies show that performance of high-intensity activities can be improved by CP supplementation, but not endurance-based activities.

However, some individuals use this supplement to help increase muscle mass. It is true that creatine supplementation can increase muscle mass, but not all the weight gain is from new muscle development. Creatine attracts water, so if there is more creatine stored in the muscle, there is also more water retention in the muscles. This gives the impression of greater muscle mass and greater gains but some of this weight gain is the muscles holding more water in them.

The safety of creatine supplementation continues to be studied. Large doses of creatine supplements are a generally viewed as concerning, especially for those who consume a lot of meat (which contains creatine). Additionally, creatine supplementation is risky for individuals with kidney disease and other kidney disorders. This is because creatine breaks down into a waste product called creatinine, which is excreted by the kidneys. Increased creatine leads to increased creatinine production and can put extra stress on the kidneys and dehydration. Dehydration in athletes can decrease performance of athletes (see Topic 9.4). **As always, a qualified medical practitioner, such as a doctor, should always be consulted prior to taking any supplement.**

Lactic acid fermentation

The creatine phosphate system is important for short bursts of energy, but most sporting activities require energy for more than 10 seconds. The lactic acid system, also known as anaerobic respiration, provides muscle cells with a quick source of ATP molecules for up to 3 minutes of intense exercise. This anaerobic pathway enables the rapid production of ATP through the conversion of **glucose into lactic acid**. While it is less efficient in terms of ATP production (2 ATP) compared to aerobic respiration (36 ATP), it is essential for activities like sprinting and weightlifting. Lactic acid accumulation is often associated with muscle fatigue and the burning sensation experienced during intense exercise, but this is **a common myth** (see the 'Helpful online resources' below for more information). This energy system provides a temporary solution to maintain energy production when **oxygen supply is limited** (as oxygen is not required for lactic acid fermentation), allowing individuals to push their physical limits, albeit for relatively short durations.

Formula

$$C_6H_{12}O_6 \rightarrow 2C_3H_6O_6$$

glucose → lactic acid + 2ATP

Helpful online resources

SciShow: Does Lactic Acid Really Cause Muscle Pain?

https://www.youtube.com/watch?v=cdphJJcR-Og

TED-Ed: The surprising reason our muscles get tired - Christian Moro

https://www.youtube.com/watch?v=rLsimrBoYXc

Aerobic respiration

Aerobic respiration is the primary energy system in the human body for **sustaining long-duration activities** and is often referred to as the "endurance" energy system. It involves the complete breakdown of glucose **in the presence of oxygen** to produce a large amount of ATP (36ATP). Unlike anaerobic systems, which produce lactic acid and have limited endurance, aerobic respiration is highly efficient and sustainable, making it ideal for activities like long-distance running, cycling, and even daily activities. While it is not as quick to produce energy as the other systems, its capacity for long-term, steady energy production is essential for maintaining activities that extend beyond a few minutes.

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π Formula

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$$

glucose + oxygen → carbon dioxide + water + 36ATP

Comparison of energy systems

During exercise, the muscle cells are using a mixture of the three energy systems. As discussed previously, one of the energy systems is predominantly being used based on the intensity and duration of the activity (see Figure 9.1.5). For example, 95% of ATP production during a 100m sprint is generally supplied by the CP system, whereas 90% of ATP production during a marathon is generally supplied by the aerobic system. Refer to Table 9.1.3 for a summary of the major differences between the three energy systems.

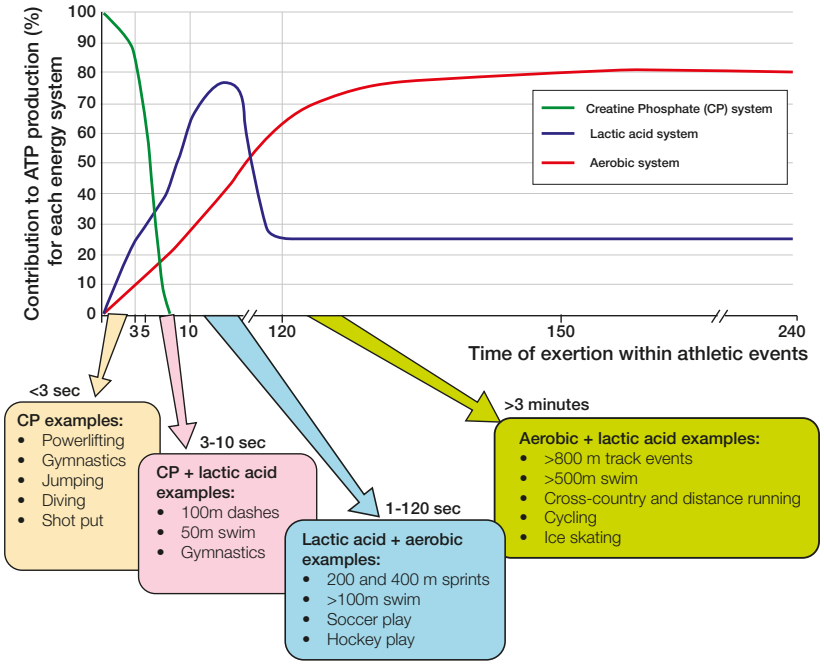


Figure 9.1.5: The relative amount of energy that each system provides changes with varying exercise intensity and duration.

Table 9.1.3: A summary of the major differences between the three energy systems.

System	Power (rate of ATP production)	Capacity (total ability to produce ATP)	Fuels Used
Creatine phosphate system (5-10 seconds)	Very high	Very low	• Creatine phosphate • Stored ATP
Anaerobic system (10 seconds → 2 minutes)	High	Low	• Blood glucose • Muscle & liver glycogen
Aerobic system (>2 minutes)	Low	Very high	• Blood glucose • Muscle & liver glycogen • Adipose & intramuscular fat

Helpful online resources

PE Buddy: Learn the 3 Energy Systems! ATP-PC, Lactic Acid & Aerobic

https://www.youtube.com/watch?v=PIrhiSJcapc

9.1 Review questions

1. State the definition of basal metabolic rate (BMR).

(1 mark)

2. Explain why the elderly generally have a lower BMR than adults.

(2 marks)

3. Explain how kilojoule restrictive diets, fasting and starvation can reduce BMR.

(2 marks)

4. Calculate the BMR of an adolescent female who weighs 62kg. Round your answer to the nearest whole number.

(2 marks)

5. Calculate the estimated energy requirement (EER) for a woman who weighs 65kg and who identifies as having a very active physical activity level (PAL) of 2.2. Round your answer to the nearest whole number.

(3 marks)

6. An 18-year-old male named Philip and a 16 year-old female named Nola are training for a swimming competition. They are completing the same training regime and have also been provided with the same diet routine.

   (a) State who is likely to have the highest BMR based on the information supplied.

   (1 mark)

   (b) Explain **two** factors that could account for the difference in BMR between Philip and Nola.

   (4 marks)

   (c) Philip weighs 89kg. Calculate his BMR. Round your answer to the nearest whole number.

   (2 marks)

   (d) Philip's total daily energy intake is 12,455kJ and the energy he expends in his daily activities is 3,420kJ. Calculate his total daily energy expenditure and round your answer to the nearest whole number.

   (3 marks)

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(e) Calculate the difference between Philip's energy intake and his energy expenditure, to the nearest whole number.

(1 mark)

(f) This training program was performed for three months. State **and** explain the likely effect of this energy balance on Philip after three months.

(2 marks)

7. There are two females that both weigh 73kg. Hannah is a tall and slim woman and has a moderately active lifestyle. Her friend Cassandra is shorter, slightly overweight and lives a sedentary lifestyle.

(a) State who is likely to have the higher BMR based on the information supplied **and** justify your answer.

(3 marks)

(b) Hannah is moderately active. In an average day, Hannah burns 1,052kJ through her general daily activities and burns a further 1,268kJ through exercise. Her average daily energy intake is 10,550kJ. Calculate the difference between Hannah's energy intake **and** her energy expenditure. Round your answer to the nearest whole number.

(6 marks)

(c) State the likely effect of this energy balance on Hannah if her current lifestyle is maintained. Justify your answer.

(2 marks)

8. There are three energy systems that enable the body to produce a key high energy molecule.

(a) (i) State the name of this key high energy molecule that enables cells to perform work.

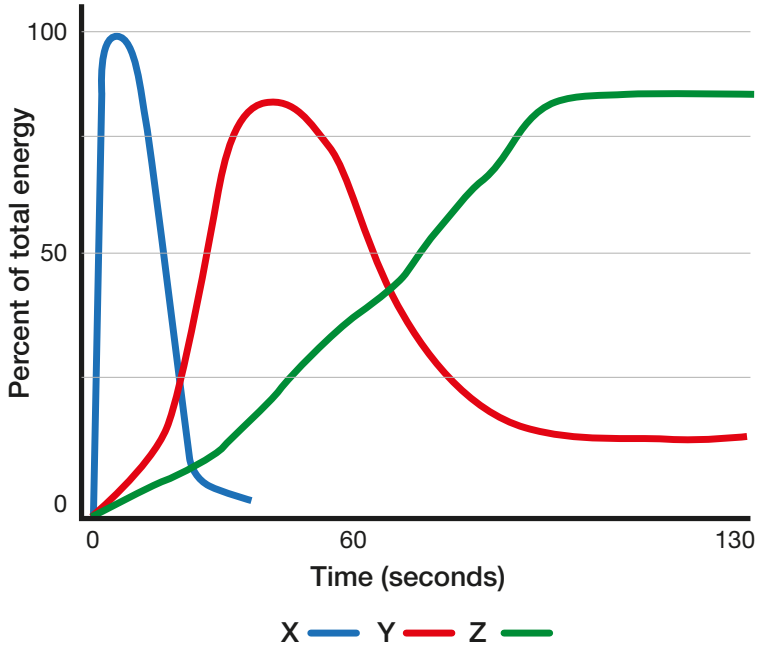
(1 mark)

(ii) Describe how the molecule identified in part (a) provides energy to cells to perform work.

(2 marks)

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Refer to the graph below to answer the part (b).



(i) Identify the three energy systems represented by lines X, Y and Z in the graph.

X:

Y:

Z: *(3 marks)*

(ii) Identify **one** activity that predominantly uses each of the three energy systems: X, Y and Z.

X:

Y:

Z: *(3 marks)*

(b) Explain how anaerobic and aerobic energy systems differ in terms of energy production.

(2 marks)

(c) Explain why there are three different energy systems cells use to obtain energy and not just one.

(4 marks)

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9.2 Nutrient requirements of athletes

Nutrition Understanding

Nutrition plays a key role in enhancing sporting performance. A well-balanced diet not only fuels the body with essential nutrients but also promotes optimal physical and mental health, improving endurance, strength, and agility in athletes. An athlete's diet should generally align with the Acceptable Macronutrient Distribution Ranges (AMDRs) recommended to the general public and consist of 45 to 65% carbohydrates, 20 to 35% fat and 15 to 25% protein. However, athletes who exercise every day at a high intensity for over an hour may require a higher carbohydrate intake to meet their energy needs.

Metabolism of macronutrients

Metabolism is the collection of all chemical reactions that occur in the body. The products of digestion (glucose, amino acids and glycerol/fatty acids) are transported around the body, so that cells can use them for energy production, synthesise new molecules or store them. **Please review Topic 3.1 The digestive system** for more information about the digestion, absorption and transport of macronutrients and refer to Figure 9.2.1 for a summary.

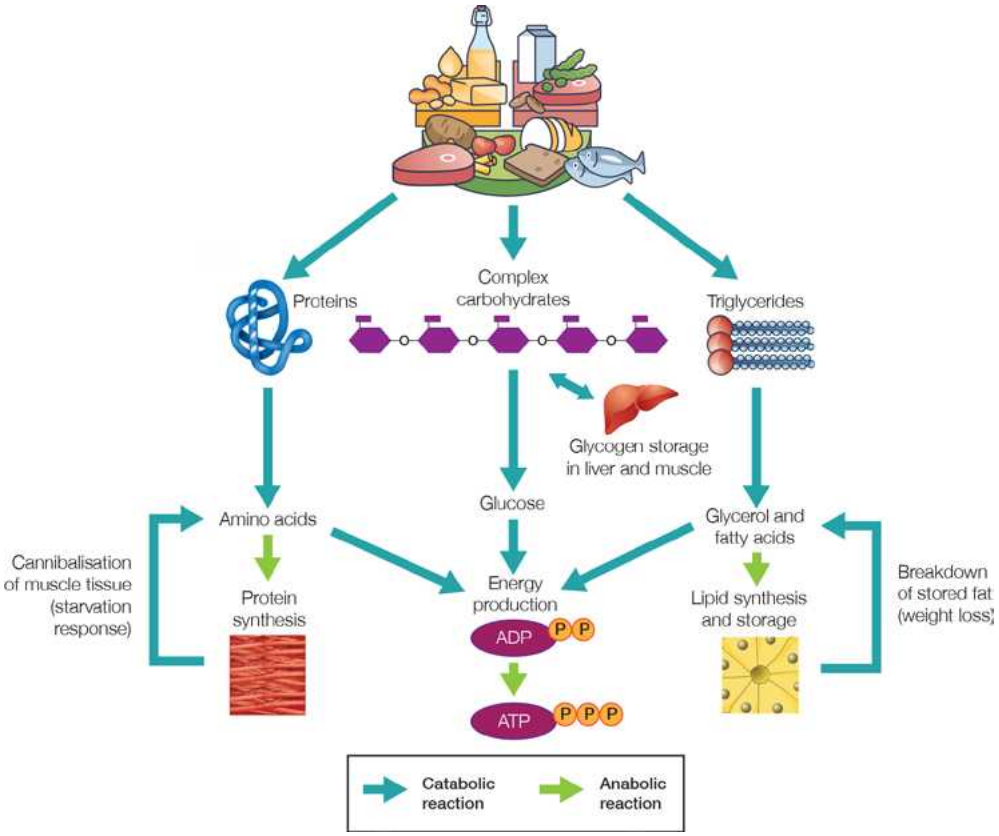


Figure 9.2.1: A summary of some major processes in the metabolism of macronutrients.

Carbohydrates

Carbohydrates are the **primary source of energy** during any length of exercise. Carbohydrates are stored as glycogen in the liver and muscle cells. During exercise, the liver breaks down its glycogen stores and releases glucose into the blood. Glucose is required by cells to perform aerobic and anaerobic respiration to produce energy in the form of ATP. Humans contain approximately 500g of glycogen stores in the muscles and 100g in the liver, but **the amount stored in the muscles can be increased through training**. The greater the glycogen stores in the muscles, the longer the muscles can be supplied with energy to perform their work, improving performance. Alternatively, when glycogen stores are depleted, muscles become fatigued. **Muscles depleted of glycogen have greater insulin sensitivity in the 2 hours post-exercise.** Therefore, to ensure optimal replenishment of glycogen stores, foods high in carbohydrate content should be consumed within the 2 hours following exercise.

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Carbohydrate loading

The amount of carbohydrates consumed directly affects the amount of glycogen stored in the liver and muscles. This understanding has given rise to the sports nutrition strategy "carbohydrate loading,' which involves increasing carbohydrate intake in the days leading up to a major competition to maximise glycogen stores. **Carbohydrate loading can significantly extend an athlete's endurance and performance**, particularly in endurance sports like marathons and long-distance cycling (see Table 9.2.1). The process typically begins with a period of reduced training and low carbohydrate intake to stimulate the body's responsiveness to carbohydrates. Then, in the days prior to the event, athletes increase their carbohydrate consumption, ensuring that their glycogen stores are fully replenished. Properly executed carbohydrate loading can make a substantial difference in elite sports by delaying fatigue and helping athletes maintain a competitive edge during extended, high-intensity activities.

Table 9.2.1: The effect of diet on physical endurance. Studies have shown that an athlete's endurance can be tripled by consuming a high carbohydrate diet.

Type of diet	Maximum endurance time (min)
Fat and protein diet	57
Normal mixed diet	114
High carbohydrate diet	167

Carbohydrate use during physical activity

The intensity and duration of exercise have a significant impact on glycogen utilisation in the body. **Glycogen stores are used quickly during high intensity activities**, such as sprinting or weightlifting as the muscle primarily break down glucose anaerobically to produce ATP rapidly. However, high intensity activities can generally only be maintained for up to 3 minutes (400 to 800m sprint) due to the accumulation of lactic acid.

Moderate activities, such as jogging, tend to use glycogen stores more slowly as the aerobic system is the primary energy system involved. This involves the aerobic breakdown of both glucose and fatty acids. During the first 20 minutes of moderate exercise, the muscles primarily rely on their own glycogen stores to provide energy. If the moderate exercise continues for longer than 20 minutes, the muscles start to use less glycogen and **use more fatty acids to provide energy** for their work.

Effect of training on carbohydrate use

Training plays a crucial role in **increasing the storage of glycogen in muscles**. Regularly depleting muscle glycogen stores through training, signals the muscle cells to adapt to store more glycogen. Additionally, **training helps to condition muscle cells** to rely more on fat for energy and less on glycogen stores. This increased efficiency of glycogen use enhances an athlete's endurance and performance. The muscles of individuals with little or no training rely more heavily on anaerobic respiration, which depletes glycogen stores quickly. The combination of training and nutritional strategies is key to maximising glycogen stores, ensuring that athletes have the energy needed to excel in their chosen sport.

Insufficient carbohydrate consumption

The **depletion of glucose stores** during intense or extended exercise can cause an individual's body to 'shut down.' This is known as '**hitting the wall'** resulting in extreme fatigue, muscle weakness and becoming disorientated. Even though glucose stores are depleted at this point, the essential bodily functions will continue to operate (such as the beating of the heart), because there are still other energy stores that can be used to ensure an ongoing supply of glucose to the body's cells. If glucose stores are depleted, the liver can convert some amino acids into glucose to provide some additional energy. As muscles are made of protein, they are a source of energy for the body when glucose is depleted. To reduce the risk of muscles being broken down to fuel the body, sufficient carbohydrates need to be consumed before, during and after exercise. The amount of carbohydrates required by an individual depends on their exercise level (see Table 9.2.2).

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Table 9.2.2: The effect of diet on physical endurance. Studies have shown that an athlete's endurance can be tripled by consuming a high carbohydrate diet.

Exercise level	Amount of carbohydrates (g/kg/day)
Light intensity exercise (30 mins/day)	3 - 5
Moderate intensity exercise (60 mins/day)	5 - 7
Endurance exercise (1 to 3 hours/day)	6 - 10
Extreme endurance exercise (more than 4 hours/day):	8 - 12

Fats

Fats are an important macronutrient because they are the most energy dense, providing 37.7kJ/g. If an athlete consumes below the recommended 20 – 35% of their energy from fat, they may not meet their energy requirements, which can affect performance. Conversely, research has shown that endurance athletes that consume a high-fat, low-carbohydrate diet, have decreased performance outcomes due to the fast depletion of their small glycogen stores.

Intensity and duration of physical activity

Fats consist of three fatty acids and a glycerol molecule. **Fatty acids can be broken down in the presence of oxygen (aerobically)** to provide cells with energy in the form of ATP. This process is known as **fatty acid oxidation,** and it occurs in an organelle within cells called a mitochondrion.

During **low to moderate-intensity activities exceeding 20 minutes,** such as walking or casual cycling, the body predominantly relies on fat stores for fuel. At this intensity, the breathing rate is slightly raised but steady, indicating that the body can supply the required oxygen to cells for fatty acid oxidation to occur. However, during high-intensity, short-duration exercise, like sprinting or heavy lifting, the breathing rate is elevated significantly indicating that the cells cannot get the required oxygen for fatty acid oxidation to be the main source of energy. As the breakdown of fatty acids is not efficient for rapid energy release, the body shifts to using carbohydrates for quick bursts of energy. Refer to Figure 9.2.2 for more information on the effect of intensity of exercise on the rate of fatty acid oxidation.

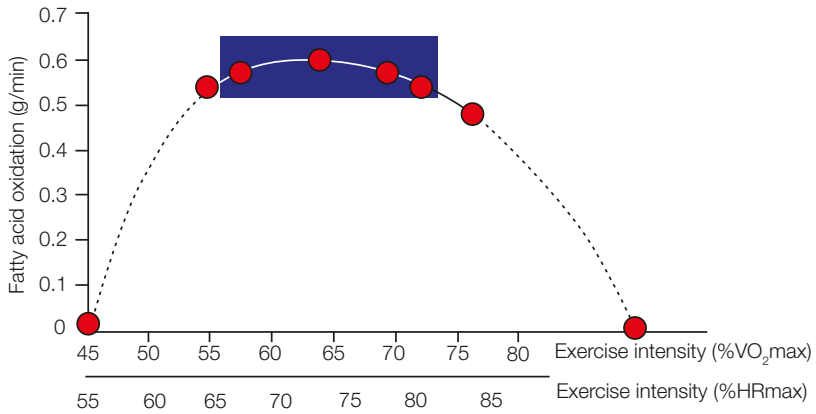


Figure 9.2.2: The effect of exercise intensity on fatty acid oxidation. Exercise intensity is expressed as both percentage of maximum heart rate (%HRmax) and percentage of maximum volume of oxygen consumption (%VO_2max). The blue area highlights the zone of exercise intensities where the greatest rates of fatty acid oxidation are occurring.

Effect of training on fat use

Training has been shown to increase the body's ability to use fat as a source of energy during exercise. Training stimulates muscle cells to produce a greater number of mitochondria so that they can burn fat at a faster rate. Training also increases the strength of the heart and lungs, improving oxygen delivery to cells for the aerobic breakdown of fatty acids to occur. These adaptations help to spare glycogen stores, enhancing endurance and promoting overall athletic performance.

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Protein

Proteins are also an energy providing macronutrient, but protein is not used as a major fuel for exercise. Instead, **protein is primarily used for building and repairing tissues such as muscle**. As protein is associated with muscle building, it is often overconsumed by individuals seeking to increase their muscle mass. However, the recommended amount of protein for athletes is only slightly higher than for the general public (see Table 9.2.3). Therefore, the protein needs of athletes are generally met or exceeded for those consuming a balanced diet that meets their energy needs. Furthermore, even though the protein needs of athletes are slightly increased, it is more important for an athlete to meet their carbohydrate intake requirements first. Sufficient carbohydrate intake prevents the breakdown and conversion of proteins into glucose when needed during exercise.

Table 9.2.3: The recommended amount of protein intake for an average adult and different types of athletes.

Category	Recommended amount of protein (g/kg/day)
RDI for an adult female	0.75
RDI for an adult male	0.84
Recommended intake for endurance athletes	1.2 – 1.4
Recommended intake for power athletes (strength or speed)	1.2 – 1.7

Protein use during physical activity and in muscle building

During exercise, muscle cell protein synthesis is generally inhibited. After exercise however, muscle cell protein synthesis increases to facilitate the repair of damaged cells and increase muscle growth. The increased muscle growth is triggered to adapt to the new stresses encountered by the muscles during exercise. In addition, the muscle cells adapt to the type of stress encountered. If an individual is weight training, the body adapts by increasing muscle mass, increasing the muscles strength as a result. Conversely, if the muscle cells are exposed to aerobic training (e.g. jogging), different signals are activated, resulting in the re-modelling of the types of proteins expressed in muscle cells. An increased number of mitochondria are also produced in the muscle cells to increase efficiency of energy supply during the jogging sessions. Overall, after a few jogging sessions, the cells are more suited to deal with the energy demands of a jogging session and the jogging becomes easier. This ability of the muscles to adapt to different types of exercise, allows individuals to train their bodies to different types of exercise throughout their lives.

Helpful online resources

TED-Ed: What makes muscles grow?–Jeffrey Siegel

https://www.youtube.com/watch?v=2tM1LFFxeKg

Intensity and duration of physical activity

The intensity and duration of exercise can impact the use of proteins as an energy source in the body. Both endurance and power athletes require more protein intake than an average sedentary adult, but for differing reasons. For aerobic endurance athletes who train regularly for more than an hour, glycogen stores may be depleted towards the end of each training session. As a result, the body may require energy from protein sources towards the end of these training sessions. However, in high-intensity, short-duration exercises, such as resistance training or sports involving explosive movements, extra protein is required to build muscle, not for supplying energy during exercise.

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Vegan diet considerations

As most plant-based foods are not complete proteins, athletes practicing a vegan diet need to plan their meals carefully to ensure they **incorporate enough complete and complementary protein sources**. Refer to Topic 1.3 Proteins for more information on essential amino acids and complementary proteins. Additionally, vegan athletes generally contain **decreased creatine phosphate stores**. This is because creatine phosphate rich animal products are not consumed as part of a vegan diet. For vegan athletes to improve strength and performance in short-term high intensity activities, creatine phosphate supplementation could be considered.

Protein powder supplements

As stated previously, the protein needs of athletes are generally met or exceeded for those consuming a balanced diet that meets their energy needs. Therefore, for most athletes there is little need to consume protein supplements. Instead, athletes should focus on the timing of their protein intake. It is important for athletes to **consume approximately 20 to 30g of protein within 1 to 4 hours following any activity involving muscle resistance.** The muscles need some rebuilding following exercise involving muscle resistance, therefore sufficient amino acids supply during this timeframe is required to maximise muscle recovery. This 20 to 30g of protein is generally consumed by an individual in a normal meal, so if a meal is consumed during the 1 to 4 hours post exercise, a protein shake is not required. However, protein supplements can be helpful for times when athletes cannot access a meal following training or events, such as when they are travelling.

Athletes who choose to consume protein shakes also need to consider some additional risk such as:

- Protein shakes generally do not include other essential nutrients such as vitamins and minerals, whereas balanced meals do.
- Protein supplements are often very expensive and must be consumed within a relatively short time frame.
- There supplement could be contaminated with toxic heavy metals or banned substances.
- Manufacturers may misidentify prohibited substances on labels, or they may omit prohibited substances from labels altogether.
- Athletes always assume the risk of testing positive for prohibited substances or experiencing negative health effects when they use supplements.
- There are potential long term negative health impacts on kidney function (especially those with a family history).

Nitric oxide

Nitric oxide (NO) is a molecule naturally produced in the body from two amino acids: L-arginine and L-citrulline. NO plays a role in the circulatory system by enhancing blood flow and oxygen delivery to cells by relaxing the blood vessels (a process called vasodilation). An increase in NO production has therefore been associated with improved endurance, reduced fatigue, and faster recovery. Although some studies have shown some performance benefits through NO (L-arginine) supplementation in some types of sports, others have shown little or no benefit. As these studies had small sample sizes and were primarily conducted on young males, further research is required into the performance advantages for athletes.

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Science as a Human Endeavour 19

Athlete microbiome project

Microbiologists have determined that the most elite athletes have a specific gut microbiome that allows them to perform better than others. The Athlete Microbiome Project at the Jackson Laboratory of Genomic Medicine is studying the stool samples of professional and amateur cyclists. The project has discovered that a microbe, *Prevotella*, was in all elite athletes and is found in less than 10% of non-athletes. *Prevotella* is thought to enhance muscle recovery. The project has also revealed another microorganism that is prevalent in elite athletes called *Methanobrevibacter archaea*. This microbe is thought to be performance enhancing by increasing the efficiency of extracting energy from complex carbohydrates. One of the research scientists working on the Athlete Microbiome Project performed a faecal transplant from an elite cyclist on herself. She had complications from contracting Lyme disease earlier in her life and found that she had much more energy after the faecal transplant. She went from struggling on the bike trainer to winning pro races months after the transplant. The findings of this project could lead to what is referred to as 'poop doping' in elite athletes in the future.

Please review Topic 3.3 The microbiome for more information about the gut microbiome and some of the important roles it plays in the human body.

Questions

1. Discuss how this discovery could **influence** elite sport.

(4 marks))

2. Explain two possible **limitations** of 'poop doping' in elite sport.

(4 marks)

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Micronutrients

Author's note: Please review Topics 1.5 Micronutrients, 1.6 Vitamins and 1.7 Minerals for more information about the sources and functions of micronutrients for the human body.

The nutritional demands of athletes extend beyond just energy and macronutrients; they also encompass a complex interplay of micronutrients essential for optimal performance and overall health. These micronutrients, which include vitamins and minerals, play vital roles in energy metabolism, immune function, and the maintenance of bone and muscle health. Athletes often have increased requirements for these micronutrients due to the physical stress their bodies endure during training and competition. Additionally, some micronutrients can be lost through sweating and injuries involving blood loss (e.g. cuts and bruises). Therefore, some **micronutrient deficiencies can negatively affect athletic performance.** However, if an athlete is meeting their nutritional requirements, there is generally **not any additional athletic advantages from consuming excess micronutrients**. Some important micronutrients for athletes to ensure they are consuming sufficient amounts of are summarised in Table 9.2.4.

Table 9.2.4: Some important micronutrients for athletes to maintain sufficient consumption of to ensure deficiencies do not negatively affect athletic performance.

Micronutrient	Summary of role(s)
Iron	Iron is required for the increased production of blood produced by athletes to carry oxygen to muscles for energy purposes. It is also required to make myoglobin, which is a protein in muscles cells that holds oxygen for aerobic respiration. Iron can be lost from the body through sweat and blood. Female athletes can also lose blood naturally through menstruation. This is discussed further in Topic 9.3 Relative energy deficiency in sport (RED-S).
Vitamin E	Exercise significantly increases the development of free radicals that can attack cellular components. Vitamin E is a powerful antioxidant that helps protect the cell membrane from damage caused by free radicals.
Vitamin D and calcium	Vitamin D is required to absorb calcium. Therefore, both are required in sufficient amounts to ensure peak bone mass is achieved and help reduce the chance of bone breakages from impact injuries.
Vitamins B_1, B_2 and B_3	These three enzymes help to release energy from macronutrients. They do not provide any energy directly.

Meal planning for events

To maximise performance and endurance, it is important for athletes to get the timing of their energy and water intake correct too. Athletes should practice their nutrition and hydration strategies during training to find what works best for them before, during and after an event.

Before exercise

Proper meal planning before exercise is crucial to provide the body with the necessary fuel and nutrients. Athletes should consume a **high-carbohydrate meal about 3 - 4 hours before a training or competition** to allow enough time for the meal to be fully digested. This meal should primarily consist of complex carbohydrates, such as whole grains, fruits, and vegetables, to provide a steady source of energy. **A small snack 1 – 2 hours prior to exercise may also increase endurance and performance.** Adequate hydration with water or sports drinks containing electrolytes is vital to prevent dehydration and maintain optimal performance. It's advisable to avoid foods high in fiber and fat right before exercise, as they can lead to digestive discomfort. Pre-exercise meals help ensure that an athlete's energy levels are optimised for training or events.

During exercise

Well-planned nutrition during exercise can **help delay fatigue.** For activities lasting longer than 60 minutes, like football matches or triathlons, athletes often require energy and hydration during the event. Between 30 and 60g of easily digestible sources of carbohydrates, such as energy gels, sports drinks, and energy bars, can provide the necessary glucose to keep muscles fueled and maintain endurance.

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After exercise

Post-exercise nutrition is critical for recovery and preparing the body for subsequent training or competition. Athletes should aim to consume a meal or snack within 30 minutes to two hours after exercise. This meal should again be **high in carbohydrates to replenish glycogen stores.** Many athletes do not feel hungry after exercise, therefore a sports drink or juice may be an easy way to consume some carbohydrates post-exercise. Also, **20 to 30g of protein should be consumed in the 1 to 4 hours post exercise** involving muscle resistance to improve muscle repair and recovery. Easily digestible options like a protein shake with a banana or a turkey sandwich on whole-grain bread can also be excellent choices. Additionally, rehydration with water and electrolyte-rich beverages is essential to replace fluids lost through sweating. Adequate post-exercise nutrition aids in reducing muscle soreness and promoting optimal recovery, ensuring that athletes are ready for their next performance.

9.2 Review questions

1. (a) State the name of the molecule that makes up glycogen.

(1 mark)

(b) Identify the major impact of carbohydrate loading on the endurance of an athlete.

(1 mark)

(c) Outline why it is recommended for athletes to consume a food or beverage high in carbohydrates in the 2 hours post-exercise.

(1 mark)

(d) Compare the amount of glycogen stores used during low and high intensity activities.

(1 mark)

The depletion of glucose stores during extended exercise can result in an individual 'hitting the wall.'

(e) (i) State **two** symptoms associated with 'hitting the wall.'

(2 marks)

(ii) Explain why an athlete's body will not shut down completely when the body's glycogen stores are depleted.

(2 marks)

2. (a) State the primary function of protein in the body.

(1 mark)

(b) Explain the impact of an athlete meeting their protein intake requirements but not their carbohydrate intake requirements.

(3 marks)

(c) Explain why it is important for athletes to consume sufficient protein in the few hours post-exercise.

(2 marks)

(d) Explain why protein supplements are generally not required by athletes eating a balanced diet that meets their energy needs.

(2 marks)

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(e) Identify **one** specific example where an athlete may find protein supplements helpful.

(1 mark)

(f) Suggest **two** supplements that a vegan athlete could consider taking **and** justify each suggestion.

Suggestion one:

Justification:

(3 marks)

Suggestion two:

Justification:

(3 marks)

(g) A recent study has discovered that approximately 40% of sports supplements that are purchased online do not contain detectable amounts of at least one ingredient listed. Another 50% only tested contained the wrong amount listed on the label and worryingly, 12% contained illegal additives including one substance that has never been approved in any country.

Using the information provided in the text above, discuss **two** risks for athletes who choose to consume sports supplements.

(4 marks)

3. (a) (i) State the name of the mineral that is essential for transporting oxygen around the body and is lost through sweating and injuries involving bleeding.

(1 mark)

(ii) Identify **two** rich sources of the mineral identified in part (a)(i) above.

(1 mark)

4. (a) During exercise, an increased number of free radicals are produced that can attack the membranes of cells. Identify the micronutrient that protects the cell membrane from damage caused by free radicals.

(1 mark)

(b) Identify the **two** main molecules required for fatty acid oxidation to occur.

(2 marks)

(c) Explain why the fatty acid oxidation system is not the primary system used by the body for high-intensity, short-duration activities.

(3 marks)

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5. There is a type of supplement called branched chain amino acids (BCAAs) that athletes use to increase their intake of three of the essential amino acids, namely leucine, isoleucine and valine. It is suggested that BCAAs increase muscle growth and reduce fatigue (allowing increased strength during workout) but there is little scientific evidence to support this at this stage.

   A new study has, however, highlighted some possible negative effects of BCAA supplementation. In the study, mice fed double the typical intake of BCAAs (which is an exceptionally high amount) all became obese, had a shorter lifespan and an increased risk of depression. The explanation for this is that the increased concentration of the three BCAAs outcompeted the transport and absorption of other important amino acids by the brain, such as tryptophan. Tryptophan is used to make the hormone serotonin which is associated with 'feeling good' and sleep. The decreased serotonin in the brain also resulted in increased appetite, which led to the obesity in the mice.

   (a) Explain **two** limitations of this study.

(4 marks)

   (b) Discuss how the findings of this study could influence society.

(4 marks)

   (c) Discuss how the Australian Federal government could apply the findings of this study **and** the impacts this could have on Australian citizens?

(4 marks)

E Extension question

Research what beta-alanine is **and** discuss the possible performance benefits for high-intensity exercises such as sprinting.

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9.3 Relative energy deficiency in sport (RED-S)

Nutrition Understanding

Relative Energy Deficiency in Sport (RED-S) is a complex and often overlooked condition that can have profound implications for the health and performance of athletes. This syndrome goes beyond simply consuming inadequate energy; it involves **an imbalance between energy intake and energy expenditure for an extended period**, impacting various physiological systems. RED-S can affect athletes of all genders and levels, from recreational enthusiasts to elite competitors, and its consequences extend beyond impaired performance to include serious health issues.

Originally, the negative health and performance effects were thought to be a syndrome that primarily occurred in women and was called the '**female athlete triad**'. The American College of Sports Medicine defined the female athlete triad as the '*relationship between three inter-related components: energy availability (EA), menstrual function and bone health'* (see Figure 9.3.1). However, as an insufficient energy intake affects a range of bodily functions and also affects males, a more encompassing term was required for this syndrome - relative energy deficiency in sport (RED-S). Understanding the comprehensive nature of RED-S is essential for athletes, coaches, and healthcare professionals to ensure the wellbeing and optimal performance of those involved in sports and physical activity.

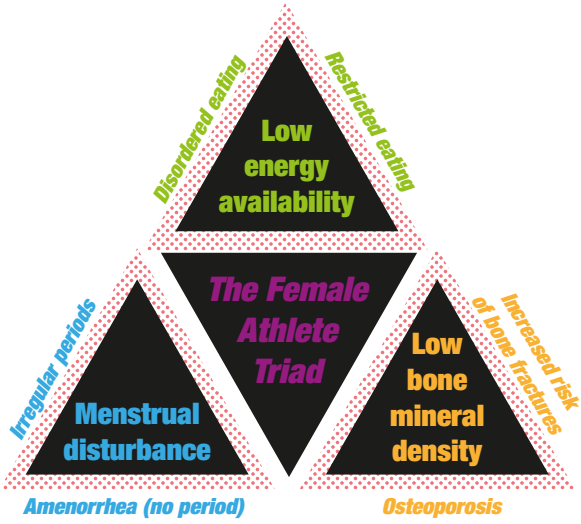


Figure 9.3.1: The female athlete triad is a medical condition in females that is characterised by low energy availability, changes in menstrual cycles and reduced bone mineral density.

Helpful online resources

Demystifying Medicine McMaster: Relative energy deficiency in sport (RED-S)

https://www.youtube.com/watch?v=AVD—7bMuNg

Causes of RED-S

The underlying cause of RED-S **is a dietary energy intake that** is insufficient for an individual's energy expenditure required to maintain essential bodily functions and perform their daily activities. This is called a **low energy availability (LEA)**. LEA can occur because of a **low energy intake or because of an increased energy expenditure** (e.g. an increased training load). Both male and female athletes are affected by LEA, but the number of female athletes affected is slightly higher than males. Chronic (weeks to months) of LEA can result in the development of RED-S and associated health consequences. Some health consequences can occur in as little as 5 days of LEA. LEA is often associated with disordered eating, but it can also arise from many other factors. **Teenage athletes also have a higher risk** as they need to consume enough energy to support their exercise but also their growth during puberty. Refer to Table 9.3.1 for some additional factors that can contribute to LEA and RED-S.

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Table 9.3.1: Some factors that can affect achieving a sufficient energy intake and increase the risk of developing RED-S.

Factors affecting sufficient energy intake	
Lack of understanding of energy needs	Limited nutritional knowledge
Altitude or heat training	Limited cooking skills
New training routine or location	Changes to eating habits
Changes to study and/or work routines	Interstate or overseas travel
Changes to living arrangements	Financial hardship

Health consequences of RED-S

The potential health consequences of RED-S are extensive and includes both short-term and long-term effects (see Figure 9.3.2). In the short term, RED-S can lead to disruptions in hormonal balance, which **may result in menstrual irregularities in female athletes and decreased testosterone levels in males.** These hormonal disturbances can lead to weakened bones, **increasing the risk of stress fractures (about 6 to 7 times greater risk)**, and osteoporosis over time. RED-S can also impair immune function, leaving athletes more susceptible to illness and infections. Furthermore, the cardiovascular system may be compromised, with athletes experiencing changes in heart rate and blood pressure. In the long term, the cumulative impact of RED-S on bone health, hormonal regulation, and overall physiological function can have serious consequences, potentially leading to irreversible damage to an athlete's health and wellbeing. Early detection of RED-S is crucial for preventing its negative consequences.

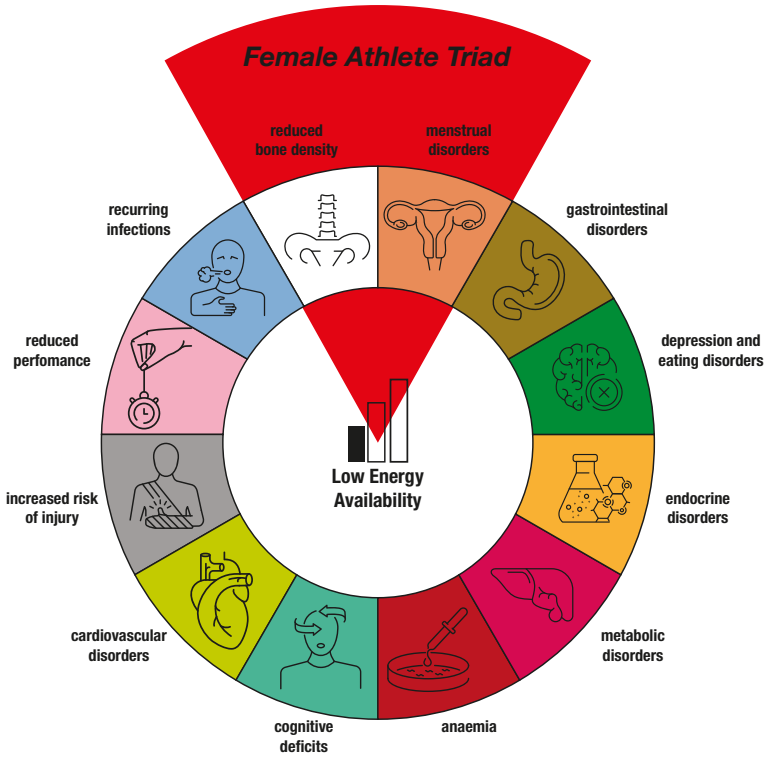


Figure 9.3.2: Some factors that can be affected by relative energy deficiency in sport (RED-S) including the female athlete triad.

Potential performance effects of RED-S

RED-S can have significant performance effects on athletes. When an athlete has a dietary energy intake that does not meet their energy expenditure, their body **may prioritise essential functions over athletic performance**. This can lead to a range of factors that negatively impact performance (see Table 9.3.2).

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Table 9.3.2: Some factors associated with RED-S that can negatively impact athletic performance.

Factor	Explanation
Increased susceptibility to catch an infectious disease	RED-S can impair immune function. Some studies show that more than 22 training days are lost to sickness for individuals with a deficient energy intake.
Decreased glycogen stores	Can cause decreased muscle strength, endurance, coordination, and recovery.
Decreased concentration and increased irritability	Reduces ability to train with correct techniques to maximise gains and remember individual/team strategies.
Depression	Reduces motivation to train and perform at a high level.
Hormonal imbalances	Can result in decreased bone density, which increases the risk of stress fractures and injuries. There is a higher probability of injuries occurring and time is required to recover from injuries, reducing ability to train.

According to the Australian Institute of Sport, up to 75% of female athletes may be under-fuelling and one third of female athletes experiences two or more symptoms of under-fuelling. It is recommended that athletes experiencing two or more of the symptoms outlined in Table 9.3.3 speak to a sports dietician for advice on their fuelling requirements to match their training and competition demands. **Early intervention can reduce the negative impacts of RED-S on performance and general health.**

Table 9.3.3: An example checklist for an athlete to determine if they are eating enough to fuel their performance.

Symptom	Checklist
Feeling irritable	
Persistent fatigue	
Low motivation for training	
Unintentional weight loss	
Pressure to lose weight from self and/or others	
Inability to alter body composition	
New or persistent gut discomfort	
Loss of appetite or always feeling hungry	
Menstrual cycle changes (if not on the pill)	
Increased frequency of injury and/or illness	
Increased duration of rehabilitation from injury	
Decreased performance	

Treatment of RED-S

The treatment of RED-S generally focuses on restoring energy balance and addressing the various health issues associated with inadequate energy intake relative to energy expenditure. This often involves increasing energy intake through a well-balanced diet, managing training loads, and addressing any psychological factors contributing to disordered eating or overtraining. Medical professionals, nutritionists, and mental health experts collaborate to create individualised treatment plans. Additionally, monitoring hormonal and bone health, as well as providing ongoing education to athletes, plays a crucial role in successfully managing RED-S and promoting long-term wellbeing and performance.

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CS Possible case study

A 17-year-old female State and National volleyballer is experiencing symptoms of fatigue, low motivation to train and study, muscle weakness and amenorrhea. The National team's medical professionals have diagnosed her with RED-S. She has been referred to the National team's dietician to obtain further information about RED-S and some advice surrounding her nutritional requirements.

9.3 Review questions

1. Define what relative energy deficiency in sport (RED-S) is.

(2 marks)

2. (a) Outline **two** factors that can lead to a low energy availability (LEA).

(2 marks)

(b) Explain why teenage athletes tend to have a higher risk of LEA.

(2 marks)

3. RED-S can contribute to hormone imbalances.

(a) Identify the specific hormone in males **and** the specific hormone in females that RED-S is most likely to imbalance.

Males:

Females: *(2 marks)*

(b) Explain how this hormone imbalance can increase the likeliness of bone fractures occurring.

(2 marks)

(c) In female athletes, the hormonal imbalances associated with RED-S can also lead to amenorrhea, which is the cessation of periods. Explain why an individual with RED-S may experience amenorrhea.

(3 marks)

4. Explain how an impaired immune function associated with RED-S can impact performance.

(2 marks)

5. The recommended intake for the average 19-year-old male is 10,300kJ. Explain how a 19-year-old male athlete who is consuming this 10,300kJ could still experience RED-S.

(4 marks)

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9.4 Factors affecting hydration

Nutrition Understanding

Author's note: Please review Topic 1.10 Water for more information about water balance and the sources and functions of water for the human body. For a quick summary about the functions of water and minerals, watch this video:

Helpful online resources

Free Animated Education: What is Water and Minerals?

https://www.youtube.com/watch?v=SSmgbiAtbVc

Hydration is an essential factor in optimising sporting performance and supporting post-exercise recovery. As athletes push their bodies to the limits, whether in endurance events or strength training, the significance of maintaining proper fluid balance cannot be overstated. Dehydration can impair physical and cognitive functions, leading to reduced endurance, muscle cramps, and even heat-related illnesses. Furthermore, rehydration is a key component of the recovery process, helping to replenish lost fluids, support muscle repair, and enhance overall well-being. In this context, understanding the critical role of hydration in sports is vital for athletes looking to achieve their best results while safeguarding their health.

Helpful online resources

National Science Foundation News: Nutrition, Hydration & Health [Science of NFL Football]

https://www.youtube.com/watch?v=onv3QA6DC4Y

Fluids, electrolytes and athletic performance

When it comes to performance, energy intake is generally a common focus, but hydration is very important too. This is because **for every 2% of water loss there is also a 10% reduction in function of all systems** including reduced muscular function. Therefore, **to increase performance, it is vital to stay hydrated** as well as fuelled for events.

Dehydration

During exercise, an athlete's breathing rate increases to inhale additional oxygen for respiration, and sweat is released onto the skin to help the athlete cool down and maintain body temperature. **Athletes can lose significant amounts of water through increased sweating and breathing** though (especially in hot conditions or endurance events). This fluid loss must be replenished to maintain optimal performance and prevent dehydration. As water has many essential functions in the body (see Figure 9.4.1), **there are many consequences of dehydration for athletes**, such as:

- Dehydration can lead to a significant decrease in an athlete's endurance, strength, and power.
- Dehydration can impair cognitive function, focus, and decision-making, which can result in poor tactical choices.
- Dehydration can lead to muscle cramps and increased risk of muscle injuries.
- Proper hydration is vital for regulating body temperature during exercise. Dehydrated athletes are therefore more prone to heat-related illnesses, including heat exhaustion and heatstroke.
- As water facilitates the removal of metabolic waste products and enhances the delivery of nutrients to muscles, dehydration reduces post-exercise recovery.

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Helpful online resources

Osmosis from Elsevier: Hydration

https://www.youtube.com/watch?v=P8c9DIiAFz8

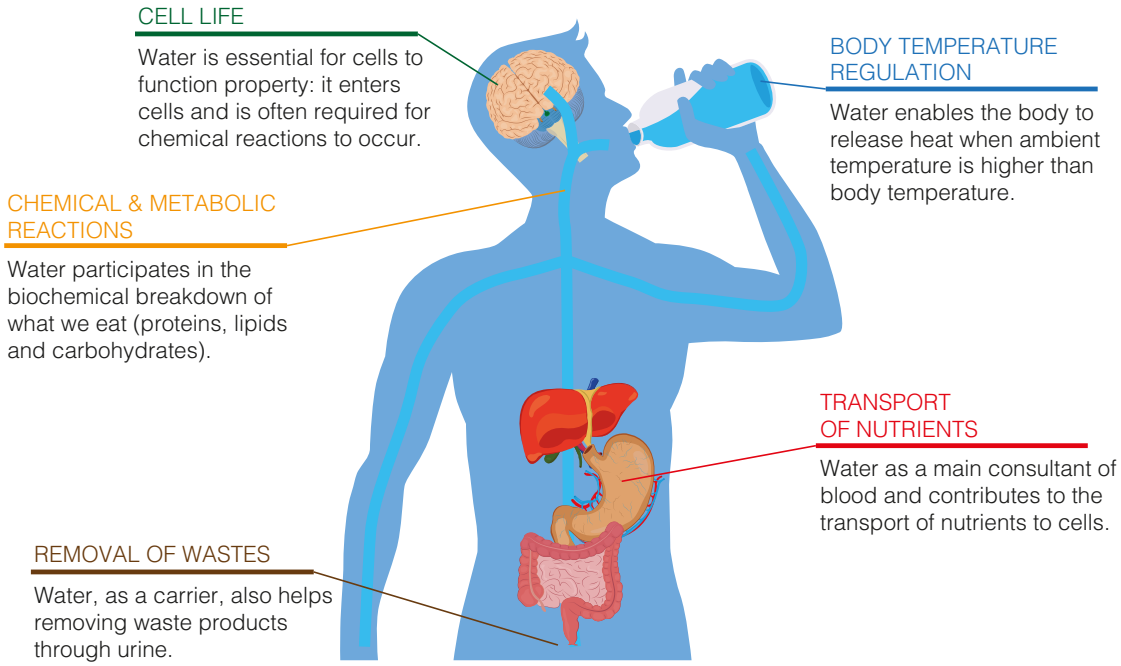


Figure 9.4.1: An outline of some of the roles water plays within the body.

Fluid replacement

During exercise, especially in endurance sports or under hot conditions, regular consumption of fluids is essential to compensate for the fluids lost through sweat and breathing. In fact, endurance athletes can lose approximately 1.5L of fluid per hour. This lost fluid needs replacing because if water loss reaches 7% of body weight, the athlete is likely to collapse. Water and sports drinks are the two main options for fluid replacement. In endurance events and hot conditions, sports drinks can be a good option because they include electrolytes, which can help increase water absorption.

Post-activity rehydration is equally crucial to replenish lost fluids and support muscle recovery. However, the post-activity fluids should not be consumed all at once because this can promote increased loss of water in the urine. Athletes should have a personalised hydration plan that includes regular monitoring of body weight and fluid intake (see Table 9.4.1 for an example hydration plan).

Table 9.4.1: An example hydration plan.

Timing of drink	Amount of water to consume
4 hours prior to activity	6.5 mL per kg
2 hours prior to activity	4.0 mL per kg
During activity	400 to 800mL per hour of exercise (with small amounts consumed frequently)
After activity	1 mL per gram of body weight lost

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Electrolyte replacement

The minerals we consume generally dissolve in the water and exist as charged particles called ions. Because these mineral ions are electrically charged, they are termed electrolytes. Some examples of electrolytes include sodium (Na^+), potassium (K^+), magnesium (Mg^{2+}) and chloride (Cl^-) ions. **Electrolytes work alongside fluids to maintain proper hydration and fluid balance in the body**. Sodium, in particular, helps regulate fluid levels, which is essential for preventing dehydration during exercise. However, **electrolytes can be lost from the body through sweating during exercise** and need replacing (along with water) to maintain hydration and performance. The amount of **electrolyte losses through sweating can be reduced through training**. This means that beginner athletes lose more electrolytes than experienced athletes and have a higher risk of dehydration. Electrolytes also play essential roles in maintaining various bodily functions, particularly during intense physical activity. Some examples are outlined in Table 9.4.2.

Table 9.4.2: Some essential roles of electrolytes in the body.

Essential bodily function	Main electrolyte(s) involved	Explanation
Hydration and fluid balance	Sodium (Na^+) Potassium (K^+) Chloride (Cl^-)	Bodily fluids are made up of water and electrolytes. Sodium is the main mineral found outside of the cell (extracellular) and is key in regulating fluid balance. The balance of water relative to sodium is essential. Potassium is the main electrolyte found inside cells (intracellular fluid) and helps to maintain sodium levels in the body (and therefore fluid balance). It's essential to keep a normal balance between water and electrolytes.
Muscle function	Calcium (Ca^{2+}) Magnesium (Mg^{2+})	Electrolytes are crucial for movement involving muscles. Calcium is required for muscle contraction and magnesium is required to relax the muscle following contraction. During exercise, muscle contractions are frequent and intense, requiring an adequate supply of these electrolytes to prevent muscle cramps and maintain strength.
Nerve function	Sodium (Na^+) Potassium (K^+) Calcium (Ca^{2+}) Chloride (Cl^-)	Proper nerve function is vital for coordination, reflexes, and muscle control. Specific electrolytes are required for nerve cells to generate electrochemical messages and communicate with muscles and other organs in the body.
Energy production	Calcium (Ca^{2+}) Magnesium (Mg^{2+}) Potassium (K^+)	Electrolytes do not contain stored energy that the body can use, but they are required to convert stored energy into ATP. Electrolytes support the complex reactions involved in the synthesis of ATP in cells. Maintaining the right balance of electrolytes ensures efficient energy metabolism, helping athletes sustain endurance and performance.

Athletes can replace electrolytes during exercise by consuming sports drinks specifically formulated with electrolytes. These drinks generally provide a mix of sodium, potassium, and other ions lost through sweat, and simple sugars for energy purposes. Additionally, consuming easily digestible energy gels or bars with added electrolytes can help maintain electrolyte balance during extended exercise sessions. Sports drinks and gels are also useful if an individual does not feel like eating during or after exercise, which is common. In addition to drinks and gels, athletes can consume snacks containing essential minerals, such as bananas (potassium) or yogurt (calcium). **Proper nutrition and hydration can help restore electrolyte balance and promote efficient recovery, reducing the risk of muscle cramps** and other potential issues.

It's essential for athletes to pay attention to their individual needs however and not overconsume electrolyte-rich products, as excessive intake can lead to other complications. Electrolyte levels must remain within specific ranges as **imbalances can cause adverse health and performance outcomes for athletes.** For example, if excess electrolytes are consumed, they can draw extra water into the intestines, leading to diarrhoea and dehydration. This is because the intestines try to expel the excess electrolytes along with the water, resulting in gastrointestinal discomfort and potentially disrupting an athlete's training or competition.

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Diuretics

Diuretics are substances **that increase water loss from the body, leading to dehydration**. Caffeinated beverages and alcohol are two examples of diuretics. When a diuretic is consumed, it inhibits the release of a hormone from the brain called antidiuretic hormone (ADH). ADH is required to communicate with the kidneys to reabsorb more water into the blood (resulting in less being excreted in the urine). As diuretics inhibit ADH from being released, their consumption inhibits the ability of the kidneys to reabsorb water into the blood. Consequently, more water is excreted through the urine, reducing hydration. **Reduced hydration decreases the efficiency of bodily system functions and therefore athletic performance.** In the case of alcohol, an excessive consumption can lead significant water loss, resulting in dehydration and a hangover. Alcohol has a greater diuretic effect than caffeine though. When caffeinated beverages like coffee and tea are consumed, the amount of water lost through their diuretic effect is generally replaced by the water consumed in the caffeinated beverage.

Did you know?

Diuretics medications may also be used illegally by some sportsmen and women. There are generally two reasons that diuretics are taken by professional sportsmen and women. The first reason is to reduce body weight for sports that require a weigh in. Diuretics increase water excretion and when urinated out the individual becomes dehydrated and lighter. This can be tempting for some individuals who are close to qualifying for a lighter weight class. Once they qualify, they can consume water to rehydrate and return to their heavier bodyweight. Secondly, diuretics can be used to mask the consumption of other drugs. As diuretics increase water excretion in the urine, this results in diluted urine and can sometimes dilute drugs below the threshold that traditional drug tests can detect.

Science as a Human Endeavour 20

Sweat sensors

Sweat sensors are innovative devices designed to monitor an athlete's performance and recovery by analysing the composition of their sweat. These sensors are non-invasive and work by detecting and quantifying the various biomarkers present in sweat, such as electrolytes, glucose and lactate (plus many more). As an athlete exercises, their sweat carries valuable information about their hydration status, energy expenditure, and overall physical condition. By continuously monitoring these biomarkers, sweat sensors can provide real-time data on an athlete's physiological state. This information is invaluable for adjusting hydration strategies, optimising nutrition, and tailoring training programs. Sweat sensors have the potential to offer personalised insights into an athlete's body, allowing for immediate adjustments to enhance performance and accelerate recovery. Refer to the following video links for more information:

Helpful online resources

Natural Cool Air: The Science Behind Saliva Testing

https://www.youtube.com/watch?v=-Bq90w9i68c

MX3 Diagnostics: MX3 Training - Sweat Test

https://youtu.be/RQvOVkMukFE?si=P2NxKSsS50ihb7oZ

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Science as a Human Endeavour 20

Questions

1. Discuss how society has **influenced** the development of sweat sensors.

(4 marks)

2. Discuss two possible **applications** of sweat sensors.

(4 marks)

9.4 Review questions

1. Identify **two** possible consequences of dehydration for athletes.

(2 marks)

2. Identify **and** explain two ways that athletes lose water during intense exercise.

(4 marks)

3. (a) Describe what electrolytes are.

(2 marks)

(b) Outline how electrolytes can be lost from the body during exercise.

(1 mark)

(c) Explain why the electrolytes calcium and magnesium are important for muscle function during exercise.

(4 marks)

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4. Identify **and** explain **two** reasons why sports drinks could be a good fluid replacement option for athletes to maintain hydration.

(4 marks)

5. (a) (i) Outline what a diuretic is.

(1 mark)

(ii) Describe the main reason why consuming diuretics could decrease athletic performance.

(2 marks)

(b) Explain why consuming a cup of coffee would effectively not count towards the two litres of water recommended per day.

(4 marks)

E Extension question

Research **and** discuss the impacts of alcohol consumption on an athlete's performance and recovery.

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Topic 9 Review Test

1. Kai is a 35-year-old male triathlete who weighs 98 kilograms.

   (a) (i) Using the following information, calculate Kai's total daily energy expenditure.

   - Daily energy intake = 15,870 kJ
   - Energy expenditure from daily activities = 6310 kJ

   Total daily energy expenditure =_____kJ *(3 marks)*

   (ii) Calculate the difference between Kai's daily energy intake **and** his total daily energy expenditure.

   Difference = _____kJ *(1 mark)*

   (iii) State the likely impact on Kai's weight if this difference between energy intake and energy expenditure continues.

   (1 mark)

   (b) State the name of the condition that Kai could develop if his current energy balance from part (a) continues for weeks to months.

   (1 mark)

   (c) Discuss **two** likely effects of Kai's current energy balance form part (a) on his on athletic performance.

   (4 marks)

   (d) Kai has been training for a half iron man triathlon and is trying to plan his competition nutrition strategy, but he requires some help. With reference to the three options pictured on the next page,, complete the table by matching each option with the most suitable timing to consume **and** justify each selection.

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Energy gel



Chocolate milk



Salad sandwich

Timing	Recommended selection (1 mark each)	Justification (2 marks each)
1 or 2 hours before competition		
During competition		
Shortly after competition		

(9 marks)

Kai hopes that if he gets his nutrition strategy correct that he won't experience the phenomenon "hitting the wall."

(e) (i) Explain what "hitting the wall" is.

(2 marks)

(ii) Identify **two** symptoms associated with 'hitting the wall.'

(2 marks)

(iii) Explain why essential bodily functions will continue to operate if Kai does 'hit the wall' during his half iron man.

(2 marks)

Kai has completed triathlons before and has experienced cramping in his legs following his last few events.

(f) Explain **one** likely reason Kai has been experiencing cramping following his triathlon events.

(3 marks)

2. (a) Write the word equation for aerobic respiration.

(1 mark)

(b) Compare the amount of energy provided by lactic acid fermentation and aerobic respiration.

(1 mark)

Refer to the table below to answer part (c).

	Percentage of energy system used (%)		
Type of Exercise	**Creatine phosphate**	**Lactic acid fermentation**	**Aerobic respiration**
A	53	44	3
B	12	50	38

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(c) Identify **one** type of exercise that is represented by the percentage of energy systems used for the two types of exercise (A and B) **and** justify your answers.

(i) Example of exercise A:

Justification:

(3 marks)

(ii) Example of exercise B:

Justification:

(3 marks)

Fats are another energy containing macronutrient.

(d) (i) State the name of the process that breaks down fatty acids to provide energy during exercise.

(1 mark)

(ii) Identify **one** type of exercise that this macronutrient is likely to be used as the main source of energy.

(1 mark)

(iii) Explain why fatty acids are likely to be the main source of energy for the type of exercise identified in part (d)(ii).

(2 marks)

(e) Explain **one** way that endurance training can help glycogen stores last longer and increase endurance performance.

(2 marks)

3. *Refer to the following information to answer Question 3.*

Due to strong scientific evidence, the Australian Institute of Sport (AIS) has classified beetroot as a Group A supplement for use in specific types of sports. Beetroots contain a high nitrate content, which is converted to nitrites by bacteria in the mouth and then to nitric oxide (NO) in the stomach. The beneficial nitrates found in beetroot can also be consumed through drinking beetroot juice or mixing beetroot powder into a shake. The AIS advises that beetroot supplementation should be consumed 2 to 3 hours prior to training or an event. However, the AIS also advises that beetroot supplementation is beneficial for exercise lasting between 4 and 30 mins or team sports with intermittent exercise.

(a) Describe how nitric oxide (NO) can improve athletic endurance.

(2 marks)

(b) Explain why the AIS advises that beetroot supplementation should be consumed 2 to 3 hours prior to a training or event.

(2 marks)

The AIS also advises against using antibacterial products such as mouthwashes to ensure the benefits of beetroot supplementation can be achieved.

(c) Explain why the AIS provides this advice for beetroot supplementation.

(2 marks)

Beetroot supplementation can change an individual's urine to red.

(d) Explain **one** impact this could have in assessing nutrition requirements for post-exercise recovery.

(2 marks)

Total: ___/50

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Topic 1: Suggested Solutions

1.2 Carbohydrates

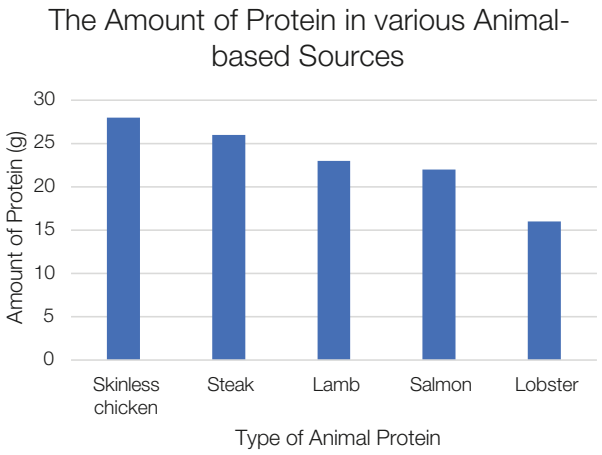
1. Carbon, hydrogen and oxygen.
2. Any dairy product such as milk, cheese, yoghurt. Lactose found in dairy products is made up of a glucose molecule bound to a galactose molecule.
3. (a) maltose
   (b) sucrose
   (c) lactose
4. Sucrose. It is made up of glucose and fructose.
5. Simple sugars are composed of only one or two monosaccharides, whereas complex carbohydrates are composed of ten to thousands of repeating monosaccharides bound together.
6. The function of glycogen and starch is to store energy, whereas cellulose has a structural function and is a component of plant cell walls. Both glycogen and starch consist of branching chains of sugar molecules (which makes it easier for enzymes to access and break down); however, cellulose differs structurally and consists of parallel arrays of sugar molecules.
7. (a) 2
   (b) 1: 33.7 – 15.5 = 18.2g; and (fibre is not subtracted because it is represented as its own entity on Australian food labels); and
   2: 18.6 – 18.6 = 0g
   (c) Food item 2 would raise blood glucose levels the quickest because it has the highest amount of sugar with 18.6g compared with 15.5g per serve (or 12.4g compared with 7.4g per 100g). Food item 2 also has no complex carbohydrates (especially fibre), which slow down digestion whereas food item 1 has 11.9g of fibre and 6.3 g of other complex carbohydrates that take time to digest and reduces absorption of sugars (must reference data to get full marks).
8. Cellulose is not found in any animal products and is only found in plant products. This is because cellulose makes up the cell walls of plant cells and animal cells do not contain cell walls.
9. Any two of: Soluble fibre dissolves in water forming a gel-like substance that expands in the stomach making us feel fuller for longer. This makes it less likely for us to overeat and put on weight; soluble fibre can also reduce the risk of developing type two diabetes by slowing down the absorption of glucose in the intestines and preventing rapid blood sugar spikes; soluble fibre binds to cholesterol (or fats) preventing them from being absorbed into the body and removing them from the body. This can help lower cholesterol levels and reduce the risk of cardiovascular disease; soluble fibre provides nutrition for the good bacteria in our intestines that ferment it releasing short chain fatty acids. These fatty acids boorish our intestinal lining reducing the risk of colon cancer.
10. Oats contain both soluble and insoluble fibre like the majority of plant products; however, they contain more soluble fibre than insoluble. Therefore, they are known as an excellent source of soluble fibre.
11. There are many foods rich in insoluble fibre. Some possible answers are: wheat, bran, celery, oranges, red kidney beans, almonds, flax seeds, etc. (please note that you must name a food item, not a group of foods such as nuts, etc.). Insoluble fibre is important to maintain regular bowel movement and prevent constipation (another acceptable answer is prevent the development of diverticular disease and colon cancer).
12. Any two of: They are an immediate energy source providing 16.7 kJ/g, which allows a person to participate in activities requiring energy; they are the primary fuel for the brain and prevents headaches and fatigue; they can be stored as glycogen for times when the body is carbohydrate deficient; they supply dietary fibre to regulate bowel movements and slow digestion, etc.; they make up structural components of cell membranes to allow recognition of cells and communication via hormones; they protect protein from being used as a primary energy source so that our muscles are not degraded.
13. Because our brain primarily uses glucose for its energy needs, and it cannot store glucose. If an individual is carbohydrate deficient, their blood glucose levels will be low and there will be low glucose supply to the brain. This results in a lack of energy for the brain, resulting in the individual feeling tired.

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14. Some possible answers are: The excess sugar intake could be stored as fat increasing the risk of becoming overweight and obese; the excess sugar intake could overstimulate the pancreatic cells that release insulin, increasing the likelihood of type two diabetes developing in the future; excess sugar intake can increase acid production in the mouth by bacteria (from fermenting sugar), increasing risk of developing dental caries (tooth decay); an appropriate answer about the increased risk of cardiovascular disease is also acceptable.

1.3 Proteins

1. Structure A because it contains the element nitrogen (N) which are present in amino acids and structure B does not contain nitrogen and displays two carbohydrate monomers joined together. Another possible justification is that structure A has a side chain 'R', which is present in amino acids.
2. Amino acids.
3. (a) Your graph should include the following:
    - title
    - labels on axes
    - scale
    - data plot
    - is a column graph



(b) It is likely that the steak consists of more fat than the skinless chicken which would account for the greater energy per serving.

(c) There are multiple possible answers. Some possible answers are: The diet would lack carbohydrates. Carbohydrates are an important energy source to supply the brain with energy. This could result in feeling tired etc.; the diet would lack carbohydrates and would be deficient in dietary fibre. Dietary fibre is important in maintaining bowel health and reducing the risk of constipation and diverticular disease; animal products generally contain saturated fat. This means that the individual would also be consuming high amounts of saturated fats that can increase risk of diseases such as obesity and cardiovascular disease.

4. Amino acids cannot be stored. Therefore, any excess protein is converted to glucose, which can be stored. Glucose can be stored as glycogen but if these stores are full, the glucose is converted to fats and stored in adipose tissue.
5. If someone is protein deficient, they don't have enough protein to maintain all bodily functions. This means the immune system could become impaired and less white blood cells produced. This can also impair the ability to produce antibodies, which are proteins made by white blood cells and released into the blood to fight off foreign disease-causing microorganisms. The inability of the body to defend itself effectively, increases the risk of infection.
6. There are multiple possible answers. Some possible answers are: Muscle fibres are made up of protein and this allows our muscles to contract and our body to move; protein is needed for growth. All cells require protein as part of their structure, so protein is needed to make new cells' protein is needed to make the blood clotting factors and protein net to clot blood to prevent us from bleeding out; protein can be used as a secondary source of energy, providing our body with an alternative energy source when deficient in carbohydrates; enzymes are proteins that are essential for our body to perform chemical reactions; protein hormones communicated messages from one area of the body to another; haemoglobin is a protein that makes up red bloods cells allowing transport of oxygen to all the body's cells; histone proteins are part of the structure of chromosomes and provide stability to chromosomes as the DNA molecule wraps around them.
7. (a) 28% (27 and 29% also accepted).

(b) 44% (43 and 45% also accepted)

(c) Animal sources of protein like beef generally contain all nine essential amino acids and are called **complete proteins**. Not all plant-based sources contain all nine EAAs and are called **incomplete proteins**.

(d) Soy is an example of a complete plant-based protein containing all nine EAAs, whereas rice is an incomplete protein and doesn't supply all of the EAAs (missing lysine).

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8. These modifications should increase the range of plant-based products in the salad and introduce complementary proteins. For example:
   (1) Add rice to the salad to introduce a grain and a complementary protein.
   (2) Add quinoa to introduce a complete protein to the meal.
   (3) Remove cannelloni beans and replace with crushed up corn chips to add a different texture and a complementary protein.
   (4) Add, pine nuts to the salad to include a nut to the salad and introduce a complementary protein.
9. Any two of the following: Grains and legumes, nuts and legumes; corn and legumes; vegetables and grains; vegetables and nuts; vegetables and corn.
10. Any two of: As protein is essential for growth, individuals may not reach their potential maximum height and weight; muscles atrophy (break down) can occur to supply the body with amino acids to make other essential proteins for survival; increased risk of bone fractures as protein is needed for strong bones; impaired immune system, increasing risk of infections, as antibodies could not be produced quickly enough; anaemia can develop as a result of insufficient haemoglobin in the blood; impaired skin, hair and nail development, which all require protein; females can experience amenorrhea, which is the absence of periods.

1.4 Lipids

1. Both carbohydrates and triglycerides consist of the same elements carbon, hydrogen and oxygen and don't have any nitrogen like protein does. Triglycerides have three fatty acid chains consisting of carbon and hydrogen that can be used to differentiate them from carbohydrates.
2. Fats are generally saturated fats found in animal products and are solid at room temperature, whereas oils are generally unsaturated fats found in plant products and are liquid at room temperature.
3. (a) Fatty acid 1 = saturated fat, Fatty acid 2 = polyunsaturated fat
   (b) Fatty acid 2 (polyunsaturated) is the healthier fatty acid. This is because it is a polyunsaturated fat which are associated with decreasing the risk of cardiovascular disease. Fatty acid 1 is a saturated fatty acid which is associated with increasing the risk of cardiovascular disease.
4. Because our body cannot make them, and they must be consumed through our diet.
5. (a) Because they are concerned that the fats and oils will lead to weight gain and increase risk of cardiovascular disease.
   (b) Any two of: A low-fat diet can result in a low intake of 'good' unsaturated fats. These fats are associated with a decreased risk of cardiovascular disease; there could be a low intake of polyunsaturated fats which are important for cognitive and visual function; A low intake of omega-3s can also result in increased inflammation, which increases risk of developing chronic diseases such as rheumatoid arthritis and type two diabetes; fats are needed to absorb fat-soluble vitamins and a lack of fats can lead to a deficiency in these vitamins; fats provide a good supply of energy and a lack of fats in the diet can result in a low energy level; fats are need for cell membranes to be formed , so a lack of fats in the diet can lead to lack of repair of cell membranes and formation of new membranes.
   (c) Monounsaturated and polyunsaturated fats because they are healthy fats associated with reducing 'bad' LDL cholesterol and reducing risk of cardiovascular disease.
   (d) Some possible answers are: Cutting the fat trims off your meat; consuming reduced fat products such as reduced fat margarine or skim milk; bake, boil or grill food products and avoid deep frying; use an air-fryer to reduce the amount of oils used; eat extra lean meats (e.g. extra lean 'heart smart' mince not regular mince); avoid cream and cheese-based sauces; eat more fish that contains healthy omega-3 fats instead of red meat.
   (e) Trans fats are artificially made fats that are made from unsaturated fats through the process of hydrogenation (adding hydrogens to saturate them with hydrogen atoms). They should be avoided because they increase 'bad' LDL cholesterol and decrease 'good' HDL cholesterol increasing the risk of developing cardiovascular disease.
   (f) Butter, margarine, any baked good (e.g. croissant, cake, pie, pasty, etc) or deep-fried food (deep fried chicken, French fries, doughnut, etc.). Answers must be 'foods' not a category of food.

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6. (a) Because most Australian's get enough omega-6 fatty acids in their diet. Omega-6 fatty acids are commonly found in oils used in processed and deep-fried foods.

   (b) Must be two plant-based sources: flaxseeds, chia seeds, walnuts, etc.

   (c) By taking microalgae oil as a supplement.

   (d) Any two of: Omega-3 fatty acids are essential for brain and eye development, so they are important for cognitive and visual function; they decrease 'bad' LDL cholesterol by increasing production of 'good' HDL cholesterol, lowering risk of cardiovascular disease; they are important component of myelin sheaths of nerve cells, increasing fluidity and improves efficiency of nervous communication; they can be converted into chemicals that decrease blood pressure; they can reduce inflammation that contribute to chronic diseases such as rheumatoid arthritis, reduced insulin sensitivity and type two diabetes.

   (e) There are different types of omega-3 fatty acids. Plant-based sources generally only contain the omega-3 ALA, which can be converted to the other omega-3 fatty acids but it is not converted efficiently. The two other main omega-3s, EPA and DHA are mainly sourced through animal products such as oily fish. The combination of plant and oily fish increases likelihood of having enough of the different types of omega-3s.

7. (a) Any two animal products such as beef, salmon, liver, eggs, cheese, etc.

   (b) Females have the highest total cholesterol with approximately 195mg/dL compared with males 185mg/dL. *N.B. the data must be referenced to get full marks and it can be within a few mg/dL for each gender, but the females' total cholesterol must be higher*

   (c) Females have a higher total cholesterol count, but this is because they have a higher HDL count than males (total cholesterol consists of HDLs and LDLs). Males have approximately 5-10mg/dL less of HDL in the blood. HDLs collect and transport excess cholesterol back to the liver for processing and reduced the risk of cardiovascular disease. Males having less HDLs than females putting them at a higher risk of cardiovascular disease.

   (d) The total cholesterol levels of females are approximately 195mg/dL, which is in the desirable range. The LDL cholesterol levels are approximately 140 mg/dL, which is in the borderline high range.

8. Some possible answers are: Fats provide energy (37.7kJ/g) and can be stored easily; fats increase the absorption of fat-soluble vitamins increasing their availability to the body's cells; fat's provide insulation helping us keep warm, especially 'baby fat'; phospholipids are part of the structure of membranes for cells and the membrane-bound organelles within cells; cholesterol is a structural part of cell membranes increasing their fluidity, which allows substances to move in and out of the cell more easily; fats provide the delicious flavours of foods, making them more palatable; fats can increase satiety (makes us feel full after eating), which makes us feel satisfied and less likely to overeat.

9. (a) Some possible answers include:

   - The WHO needs to communicate with all countries as to why trans fats should be banned and provide evidence to do so. This requires collaboration from staff to compile all the available research and present it in format suitable for government leaders.
   - The WHO will also have to communicate and collaborate with the food industry bodies to work out the logistics of phasing out trans fats. They would need to determine suitable replacements and costs associated with the phase out and communicate this information too.
   - This information also needs to be communicated to the public through their website and other sources. This ensures public awareness which could help in decreasing sales of products containing trans fats. Consumer demand could influence manufacturers to remove trans fats from their products.

   (b) Some possible answers include:

   - If trans fats were removed from all food products, this could reduce the number of cases of cardiovascular disease in society. Cardiovascular disease is a preventable disease and with reduced cases, hospital funding could be used on patients with non-preventable diseases.
   - If there are less cases of cardiovascular disease due to the banning of trans fats, this could influence the government to introduce warning labels on products containing saturated fats, or a saturated fat tax to further reduce cases of cardiovascular disease.

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1.6 Vitamins

1. Fat-soluble vitamins (or one of ADEK is also acceptable).
2. Fat-soluble vitamins because they are stored in fatty tissue in the body unlike water-soluble vitamins that are generally excreted in urine.
3. Some possible answers are:

Vitamin	Two Sources
B9	Leafy greens, legumes, citrus fruits, fortified grain products, etc.
B12	Animal products such as meat, milk, etc.
C	Citrus fruits, leafy greens, strawberries, etc,
A	Liver, fatty fish, dairy products, sweet potato, carrots, etc.
D	Fatty fish, sunlight, fortified butter and margarine, etc.
E	Plant based oils, leafy greens, whole grains, fatty meats, nuts, etc.
K	Leafy green vegetables, legumes, liver, eggs, etc.

   (a) An antioxidant is a molecule that stabilises free radicals (oxidants) and protects cells.

   (b) Roasted coffee beans have the highest antioxidant content with 22/23 mmol/100g (must reference data for full marks).

   (c) Because having both vitamin C and E ensures that both the water-soluble molecules and lipid-soluble molecules are protected. Vitamin C protects water-soluble and vitamin E protects lipid-soluble molecules. If only one of the two was present, then one of the water-soluble or lipid-soluble molecules would be exposed to free radicals and this would increase cell damage.

   (d) Vitamin C is added to protect the meat from oxidising, and this extends its life (it's added as a preservative).

4. (a) Folate (B9)

   (b) This is possibly due to the fortification of folate in grain products. Most people consume grain products like bread, and this increases the amount of folate the general public consumes. Therefore, less cases of neural tube defects are likely to occur.

   (c) Folate and vitamin B12 activate each other so they can perform their roles as coenzymes and synthesise DNA. This allows cells to divide and growth to occur.

   (d) Anaemia

   (e) Two of: Vegans because B12 is only found in animal products and therefore they are less likely to consume enough; individuals with coeliac disease because cells in their small intestine that are required to absorb it are destroyed; the elderly because they are more likely to have cells in their stomach damaged which release a protein that is needed for B12 absorption.

5. Vitamin C. Scurvy.
6. (a) Two of: Assists in **vision** and the development of cells in the cornea and retina of the eye; vitamin A is required for protein synthesis and cell division. This helps in maintaining cells that are regularly replaced such as skin and epithelial tissue (e.g. gut lining every two five days); vitamin A is needed for the development of sperm in men and normal growth and development of the foetus in women during pregnancy.

   (b) Two of blindness (xerophthalmia), increased risk of infectious disease, dry skin due to lack of replacement of skin cells, reduced growth and development, etc.

   (c) Because vitamin A is a lipid-soluble vitamin and it is stored in the fatty tissue. If too much golden rice is consumed, excess provitamin A could be stored leading to toxic levels. One sign of provitamin A toxicity is the skin turning yellow due to extra provitamin A being stored in the fat under the skin.

7. (a) Because the pigments associated with dark skin block more of the sunlight preventing the synthesis of vitamin D. Therefore, individuals with darker skin require longer exposure to the sunlight each day than Caucasians and are at higher risk of vitamin D deficiency.

   (b) Sunburn and skin cancer.

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(c) When clouds are present, they can block light from reaching our skin. This reduces light exposure and in turn, vitamin D synthesis. If the weather is consistently cloudy, this could contribute to vitamin D deficiency in some individuals.

(d) Vitamin D is important in absorbing calcium. Calcium is needed for strong bone formation. If there is a lack of vitamin D during childhood, the bones do not form normally and can lead to skeletal abnormalities such as bowed legs.

8. Antibiotics kill bacteria. The bacteria in our intestines produce vitamin K for us from our food. If they are killed, there is less vitamin K made available to our body and this could lead to a deficiency.

9. (a) C

(b) With a vitamin E supplement.

(c) Because vitamin E is a fat-soluble vitamin that requires fats to be absorbed. If less fats are being absorbed, then less vitamin E is also absorbed.

1.7 Minerals

1. False. All minerals are just as vital as each other for the body because they have different functions.

2. Calcium and phosphorus bind together to form calcium phosphate which hardens the bone.

3. During winter there in the United Kingdom, there is shorter days, which means there is less hours of available sunlight. Therefore, the residents are receiving less sun exposure. This means that their body produces less vitamin D which is needed to absorb calcium.

4. Some possible answers are: It is needed to carry oxygen to cells to provide them with energy; it is needed to provide energy for the growth of cells especially during adolescence; it is needed to prevent feeling fatigued; it is needed to provide muscle cells with a store of oxygen.

5. Some possible answers are: Some indigenous communities are located in remote areas and have less access to nutritious foods containing enough iron; some indigenous individuals could be disadvantaged and not have enough money to purchase nutritious foods; they may not have been taught about how to cook and eat healthy at school.

6. (a) Sodium attracts and holds water. An increased concentration of sodium in the blood increases the blood volume. This results in increased blood pressure (hypertension) and chronic hypertension can increase the risk of cardiovascular disease.

(b) Some possible answers are: Reduce eating processed meats with added sodium; instead of using sauces on meats, use herbs instead; buy low-salt products; use fresh vegetables in meals instead of canned vegetables; eat less takeaway food this has high salt content; replace potato crisps/pretzels with a piece of fruit.

7. (a) Cheese, yoghurt, broccoli and soybeans/tofu, etc. (has to be a food).

(b) Any two of: The primary function of phosphorus in the body is the **development of strong bones and teeth**. This is the same as calcium because a form of phosphorus, known as phosphate, binds to calcium to form calcium phosphate to form the hard structure of the bone; it is a structural component of DNA and RNA, which is the genetic material in our cells that code for all the proteins that make up the body. DNA and RNA consist of a sugar-phosphate backbone; phosphorus is an essential part of the main energy molecule in our cells called adenotriphosphate (ATP). ATP is formed from the breakdown of glucose in our cells and consists of three phosphates. When the bond between the second and third phosphate is broken, a consistent amount of energy is released, which is used to perform our daily activities; phosphorus is also needed as a buffer to help maintain the acid/base (pH) balance in the blood and urine. The blood pH needs to be maintained between 7.35 and 7.45 and this is very important as the blood pH determines our breathing rate; it is part of the structure of phospholipids that make up the membranes of cells and organelles.

8. (a) Fish such as cod and tuna and seafood such as shrimp, dairy products such as milk, cheese and yoghurt, seaweed, fortified breads (except organic bread), iodised salt, etc. (one must be suitable for a vegan).

(b) Iodine is important to make the thyroid hormones that are involved in regulating the metabolic rate (energy production).

(c) Two of: There is less iodine in soils today due to poor farming techniques and nutrient leaching through irrigation, rain, wind and natural disasters like flooding; salt is added to many processed foods, but they

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generally don't contain iodised salt and are therefore not good sources of this mineral; Australian's are using less iodised salt when cooking at home and in restaurants.

9. Iron deficiency. Iron is required to make haemoglobin, which makes up red blood cells. By donating blood regularly, the individual loses a lot of haemoglobin and iron. If the iron is lost quicker than it's replaced, iron deficiency could occur.

1.8 Increasing bioavailability of nutrients

1. No. Because not all iron in foods are absorbed. Only approximately 18% of iron in a Western diet is absorbed. Additionally, it could have been consumed with a source that reduces iron absorption such as coffee, tea, etc. (another acceptable answer is because not all iron is in the correct form to be absorbed).

2. (a) Add meat (contains haem iron), replace the lettuce with spinach (contains more iron), squirt lemon juice on the meat/salad (contains vitamin C, which increases iron absorption).

   (b) Any two of: Add sesame seeds/pine nuts (any seed/nut) to the salad to increase fat content, which helps with fat soluble vitamin absorption. Add an olive oil-based dressing to increase fat-soluble vitamin content and absorption.. Add sliced chicken or ham (any meat) that contains saturated fat, which will also increase fat-soluble vitamin absorption.

   N.B. two different answers are required. Answers can't be two different nuts added to the salad (this is the same answer).

3. Any caffeinated beverage (tea/coffee/Coke/etc.), soy products such as tofu, soy milk, seeds such as flaxseed, sesame seeds, nuts such as almonds, walnuts eggs or vegetables high in cellulose like celery etc.

   N.B. the answer must be a food/drink and not a category e.g. almond not nuts.

4. Any two of: The caffeine in the cappuccino can increase urine production, increasing calcium loss in urine and reducing bioavailability of calcium. The individual who consumed the cappuccino is vitamin D deficient, which is needed for calcium absorption. The milk used to make the cappuccino was not fortified with vitamin D. Under normal circumstances only 30% of calcium is absorbed by the average adult (not all calcium is absorbed generally).

5. Because females naturally lose more blood through menstruation and therefore lose more iron than males.

1.9 Nutrient and energy density

1. Nutrient density is a measure of the amount of a particular nutrient per kilojoule, whereas energy density is a measure of the amount of kilojoules (energy) per gram of a particular food.

2. White bread

   Folate density = $\frac{211}{1010}$ = 0.21µg/kJ

   Cooked broccoli

   Folate density = $\frac{200}{114}$ = 1.75µg/kJ

   Therefore, the cooked broccoli is more nutrient (folate) dense than white bread.

3. Block of Chocolate

   Energy density = $\frac{7887}{360}$ = 21.9kJ/g

   Potato Crisps

   Energy density = $\frac{3661}{175}$ = 20.9kJ/g

   Therefore, the block of chocolate is more energy dense than the packet of crisps.

4. (a) Energy dense

   (b) Nutrient dense

   (c) Nutrient dense

   (d) Energy dense

5. Energy from carbohydrates = 7.9 × 16.7 = 131.93kJ

   Energy from alcohol = 19.1 × 29.3 = 559.63kJ

   Total energy in the beer = 131.93 + 559.63 = 691.56kJ = 692kJ

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6. (a) Energy from carbohydrates = 41.3 × 16.7 = 689.71kJ

Energy from protein = 19.7 × 16.7 = 328.99kJ

Energy from lipids = 22.3 × 37.7 = 840.71kJ

Total energy in the burger = 689.71 + 328.99 + 840.71 = 1859.41kJ

(b) Energy distribution of carbohydrates = $\frac{689.71}{1859.41} \times 100 = 37.09\% = 37\%$

Energy distribution of protein = $\frac{328.99}{1859.41} \times 100 = 17.69\% = 18\%$

Energy distribution of lipids = $\frac{840.71}{1859.41} \times 100 = 45.21\% = 45\%$

Check = 37 + 18 + 45 = 100%

(c) **Carbohydrates**: The AMDR for carbohydrates is 45 to 65% and the energy supplied by carbohydrates in the chicken burger is approximately 37%. This is lower than the lower end of the AMDR by 8%.

Proteins: The AMDR for protein is 15 to 25% and the energy supplied by protein in the chicken burger is approximately 18%. This is within the AMDR for protein.

Lipids: The AMDR for lipids is 20 to 35% and the energy supplied by lipids in the chicken burger is approximately 45%. This is significantly higher than the upper limit of the AMDR by 10%.

7. (a)

100g of Beef	½ Cup of Raw Spinach
Energy from protein = 29.5 × 16.7 = 492.65kJ	Energy from carbohydrates = 4.7 × 16.7 = 78.49kJ
Energy from fats = 16.4 × 37.7 = 618.28kJ	Energy from protein = 2.4 × 16.7 = 40.08kJ
Total energy in the beef = 492.65 + 618.28 = 1110.93kJ	Energy from fats = 0.3 × 37.7 = 11.31kJ
= 1111kJ	Total energy in the spinach = 78.49 + 40.08 + 11.31 = 129.88kJ
	= 130kJ

N.B. To obtain full marks, don't forget to write the totals in the table as instructed in the question.

(b) Energy distribution of carbohydrates = $\frac{0}{1110.93} \times 100 = 0\%$

Energy distribution of protein = $\frac{492.65}{1110.93} \times 100 = 44.35\% = 44\%$

Energy distribution of lipids = $\frac{618.28}{1110.93} \times 100 = 55.65\% = 56\%$

Check = 44 + 56 = 100%

(c) **Carbohydrates**: The AMDR for carbohydrates is 45 to 65% and the energy supplied by carbohydrates in the beef 0%. This is significantly lower than the lower end of the AMDR and is recommended that the beef is consumed with some carbohydrates (or carbohydrates are consumed in other meals throughout the day).

Proteins: The AMDR for protein is 15 to 25% and the energy supplied by protein in the 100g of beef is approximately 44%. This is significantly higher than the upper limit of AMDR for protein (by 19%).

Lipids: The AMDR for lipids is 20 to 35% and the energy supplied by lipids in the beef is approximately 56%. This is significantly higher than the upper limit of the AMDR by 21%.

(d) 100g of Beef

Iron density = $\frac{2.6}{1110.93} = 0.002$mg/kJ

½ Cup of Raw Spinach

Iron density = $\frac{3.2}{129.88} = 0.025$mg/kJ

Therefore, the raw spinach is more iron dense than beef.

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(e) 100g of Beef

$$\text{Protein density} = \frac{29.5}{1110.93} = 0.027\text{g/kJ}$$

½ Cup of Raw Spinach

$$\text{Protein density} = \frac{2.4}{129.88} = 0.018\text{g/kJ}$$

Therefore, the beef is more protein dense than raw spinach.

1.10 Water

1. Because we can only survive days without water and the majority of chemical reactions in our body rely on water to occur (either directly or by occurring in water).
2. Because bodybuilders generally have more muscle than obese people. Muscle is composed of approximately 75% water, whereas fat is composed of approximately 25%. Therefore, the extra muscle in the bodybuilder would retain more water than the fat in the obese person.
3. The individual could check their urine the next time they go to the bathroom. If the urine is yellow in colour this can indicate that they are dehydrated. To ensure that this is not just because of the excess vitamins consumed, the individual should roughly compare the volume to previous visits. If the volume is low, then they are likely dehydrated.
4. No. The water in our food is useful but it doesn't supply us with enough water daily to meet the water lost through the urine, sweating etc.
5. Most water = banana,

   Least water = cube of sugar
6. Any two of: Helps transport essential nutrients such a glucose and amino acids around the body; helps maintain blood volume and blood pressure; helps transport waste products to the respective organs so that they can be excreted from the body (e.g. carbon dioxide and urea); helps in controlling our internal blood temperature through sweating; water act as a lubricant to help moisten organs that are lined with mucus such as the digestive and respiratory systems; water is needed to produce the amniotic sac and helps cushion the baby as the mother moves around during the day; water is part of the fluid that exists between bones to cushion the impact from movement preventing pain; water helps to form soft stools and prevent constipation.
7. Any two of: Thirst, dry mouth, feeling weak, exhausted, fatigue, loss of appetite, headache, loss of balance, delirium.
8. Some possible answers are: If it is a hot day, people are likely to sweat more which results in a greater loss of water than a normal day. Therefore, people would need to drink more water to replace the greater level lost; an increased amount of exercise would result in an increased loss of fluid through sweating. This requires an increased amount of water to replace the fluid lost; pregnancy and lactation require an increased amount of water to provide their bodies as the amniotic sac develops, blood volume increases and producing milk; water makes up 75% of muscle tissue. Therefore, people who have more muscle generally require more water than people with less muscle; alcohol has a diuretic effect. If someone drank too much alcohol this would result in a greater loss of water in the urine and would need to be replaced over the next couple of days.

Topic 1 Review Test

1. (a) 20g/100g

   (b) Sucrose

   (c) Approximately 40g/100g (Between 37 and 42g/100g is acceptable).

   (d) Carrots. Because it has the least total amount of simple sugars.
2. (a) A – Protein

   B – Fat/lipid/triglyceride

   C – Carbohydrate

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(b) (i) Any two of: Immediate energy source (16.7 kJ/g), primary fuel for brain and nervous system; stored as glycogen for later energy source; supplies dietary fibre from many food sources; structural component of cell membranes (carbohydrate receptors); protects protein from being used as a primary energy source; prevents headaches and fatigue; allows a person to participate in activities requiring energy.

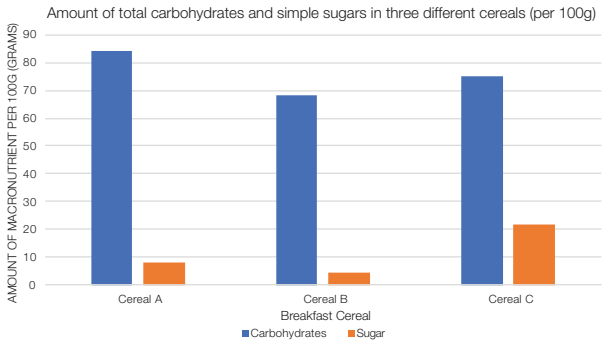
(ii) Nutrient dense: Fruit, vegetables, legumes, seeds, nuts, etc.

Energy dense: lollies, chocolate, doughnut, etc.

(iii) The cherry is the healthier option because it also contains fibre, whereas the jellybean does not. Fibre is important for making us feel fuller, slowing down digestion and helping prevent constipation.

(iv) Your graph should include the following:

- title
- labels on axes with units
- scale
- data plot with legend
- is a column graph



(c) A

(d) (i) Vitamin (or Vit.) A, D, E, K

(ii) As follows:

- A: Vitamin A is important for the development of the eyes and visual function. It is also important for maintaining healthy surface tissues such as epithelial and skin tissue. There are other acceptable answers such as helps with immune function and development of a foetus, etc.
- D: Vitamin D is needed to help absorb calcium, which helps promote strong bones and teeth. Without vitamin D, calcium cannot be absorbed, and this could result in reduced bone density (osteomalacia – soft bones) or even osteoporosis (fragile bones). Vitamin D is important for the skeletal development in a foetus/child and a lack of vitamin D can result in skeletal abnormalities and Rickets. Some other possible answers are enhancing the immune system to protect against disease and some studies have shown that vitamin D can help reduce depression.
- E: Vitamin E is a fat-soluble vitamin that is an antioxidant and protects our cells against free radicals in the parts of our cells made up of lipids such as the cell membrane. It is important for our immune system to function normally so pathogens can be eliminated from the body. Vitamin E may help protect against heart disease by preventing the oxidation of LDLs.
- K: Vitamin K is important in activating proteins involved in the blood clotting process. It is also important in the formation of healthy bones. It is needed to make proteins necessary for bone formation.

(e) (i) Omega-3 is necessary for optimal growth of the nervous system and brain in the developing foetus. It can also help reduce LDL cholesterol levels and protect against heart disease. This aids in reducing the chance of blood clots occurring in blood vessels and lowers blood pressure too.

(ii) (1) & (2) Oily fish (e.g. mackerel, salmon, sardines, tuna), nuts & seeds (e.g. walnuts, pecans, flaxseeds (linseed), hemp seed, chia seeds, tofu, soybeans & soy products, canola oil, etc. To get the two marks you need two different sources and you cannot write a category (it must be a single food e.g. chia seeds not just 'seeds').

3. (a) Protein: 10.4 × 16.7 = 173.68kJ

Fat/Lipid: 2.0 × 37.7 = 75.4kJ

Carbohydrates: 68.7 × 16.7 = 1147.29kJ

Total = 1396.37kJ = 1396kJ

N.B. you lose a mark if you haven't rounded off the total to the nearest whole number and you lose another mark is you haven't transferred the total to the table.

(b) **Method 1**

Percentage of Protein = 100 – (Fat% + CHO%)
= 100 – (14 + 59)
= 100 – 73
= 27%

S

Method 2

Energy from protein = Amount of protein × Energy per gram of protein
= 10 × 16.7
= 167kJ

$$\text{Percentage of Protein} = \frac{\text{Energy provided by protein}}{\text{Total energy in banana milk}} \times 100$$
$$= \frac{167}{630} \times 100$$
$$= 26.5$$
$$= 27\%$$

N.B. Answer needs to be transferred to the table for full marks.

(c) **Green Smoothie**

Carbohydrates: The AMDR for carbohydrates is 45 to 65% and the energy supplied by carbohydrates in the green smoothie is approximately 81%. This is greater than the higher end of the AMDR by 16%.

Proteins: The AMDR for protein is 15 to 25% and the energy supplied by protein in the green smoothie is approximately 13%. This is less than the lower end of the AMDR for protein by 2%.

Lipids: The AMDR for lipids is 20 to 35% and the energy supplied by lipids in the green smoothie is approximately 6%. This is significantly less than the lower end of the AMDR by 14%.

Banana Milk

Carbohydrates: The AMDR for carbohydrates is 45 to 65% and the energy supplied by carbohydrates in the banana milk is approximately 59%. This is within the AMDR range for carbohydrates.

Proteins: The AMDR for protein is 15 to 25% and the energy supplied by protein in the banana milk is approximately 27%. This is greater than the upper end of the AMDR by 2%.

Lipids: The AMDR for lipids is 20 to 35% and the energy supplied by lipids in the banana milk is approximately 14%. This is less than the lower limit of the AMDR by 6%.

N.B. Both drinks must be covered and data must be used when comparing the AMDR's to obtain full marks.

(d) One of the following:

- Folate – Folate helps make DNA and red blood cells. Adolescent girls have increased requirements for folate during puberty due to increased blood loss through menstruation.
- Iron – Iron is required to make red blood cells and prevent anaemia. Many adolescent girls have anaemia due to increased blood loss during menstruation.
- Calcium – Calcium is needed for the development of strong bones and teeth. Meeting the requirements during adolescence could help prevent osteoporosis in later years.
- Vitamin C – Vitamin C being water soluble needs to be consumed regularly in sufficient doses. It helps with iron absorption (especially non- haem iron), which is important for adolescent girls who are menstruating.

4. (a) Nitrogen
   (b) Essential amino acids
   (c) Any protein source (e.g. beef, eggs, soy, spinach, etc.).
   (d) Some possible answers include: muscle gain; muscle contractions; cell division; growth; regulating fluid balance; regulating acid-base balance; immune function (antibody production); protein synthesis; hormone production; repair; red blood cell production (haemoglobin).
   (e) The nutrition information section shows that there is no protein (0g) in the diet cola, suggesting that this drink is suitable for an individual with PKU. However, the ingredients list shows that this product contains aspartame and therefore contains phenylalanine (as aspartame consists of the amino acid phenylalanine), which means this drink is not suitable for individuals with PKU.
5. (a) Formation of strong bones and teeth – a lack of calcium reduces bone mass and increases the chance of fractures/breakages of bones and could result in osteoporosis in the future.

   Contraction of muscles – calcium is needed for muscle contractions and must maintain constant amount in the blood or deficiency could result in muscle spasms/cramps. The heart needs calcium to contract so this could also result in a heart attack or even death if hypocalcaemia occurs.

   Needed for blood clotting – if calcium deficient, the body could find it harder to clot blood and this increases the likelihood of the wound not healing or even bleeding out.

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(b) Vitamin D. Food source = salmon, tuna or butter/margarine, etc. (cannot have sunlight here because it is not a food source).

6. (a) Any four of: Don't drink enough water; sweat too much through exercise; sweat too much on a hot day; don't eat enough food that contains water, such as fruits/vegetables; drinks excessive alcohol which increases water loss; consumes diuretic medications that cause water loss; kidney malfunction.

(b) Dehydration: thirst–fatigue – headache – exhaustion – collapse (could also, have dry mouth, feeling weak, loss of appetite, loss of balance, delirium as symptoms). Three symptoms are required for the three marks in an appropriate order.

(c) Any three of: Helps transport essential nutrients such a glucose and amino acids around the body; helps maintain blood volume and blood pressure; helps transport waste products to the respective organs so that they can be excreted from the body (e.g. carbon dioxide and urea); helps in controlling our internal blood temperature through sweating; water act as a lubricant to help moisten organs that are lined with mucus such as the digestive and respiratory systems; water is needed to produce the amniotic sac and helps cushion the baby as the mother moves around during the day; water is part of the fluid that exists between bones to cushion the impact from movement preventing pain; water helps to form soft stools and prevent constipation.

7. (a) Vegans don't eat any meat or animal products. There are different types of vegetarians. Most vegetarians don't eat any meat, but they still eat animal products such as milk and eggs.

(b) Vitamin B12. Vitamin B12 is only found in animal products so vegans generally cannot obtain B12 unless they take supplements.

(c) Most plant-based products do not contain all of the essential amino acids (EAAs). Therefore, vegans need to eat complementary proteins to ensure they obtain the full set of these EAAs.

(d) Sesame seeds, chi seeds, flax seeds, almonds, seaweed, spinach bok choy, soybeans, tofu, etc (must be a food not a drink).

(e) For full marks the beef and parmesan cheese must be removed.

For example:

(1) Replace beef with lentils. Vegans don't eat beef and lentils will provide some protein lost by removing the beef.

(2) Remove the parmesan cheese and add some Italian herbs and spices. Vegans do not eat animal products such as cheese and the herbs will add some additional flavour to the pasta.

(f) Fat-soluble vitamins require fats to be absorbed into the intestinal epithelial cells. As spaghetti bolognaise contains fats (e.g. olive oil), an increased amount of fat-soluble vitamins can be absorbed with these fats and made available to the body.

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Topic 2: Suggested Solutions

2.1 Overnutrition and undernutrition disorders

1. Undernutrition is a form of malnutrition that results from a chronic or recurrent deficiency in one or more nutrients, whereas malnutrition encompasses all disorders related to both overnutrition and undernutrition.
2. Undernutrition disorders are more likely to occur in developing countries due to a lack of supply of fresh whole foods to supply their population. In addition, many individuals cannot afford food even if there is an availability.
3. (a) Obesity.

   (b) If an individual suffers from energy undernutrition due to starvation, then there is a lack of energy for the immune system to function efficiently leading to immunodeficiency; OR, if an individual is experiencing protein malnutrition, they may not have the necessary amino acids for their immune system to make antibodies.

   (c) If an individual is overconsuming unhealthy processed foods, they are likely to be overconsuming macronutrients leading to overnutrition disorders such as obesity and CVC. However, if there is a lack of fresh whole foods in their diet, they could be deficient in one or more micronutrients and fibre, which may lead to deficiency disorders such as anaemia or diverticulitis respectively.

2.2 Obesity

1. (a) $$\text{BMI} = \frac{\text{weight(kg)}}{\text{height(m}^2\text{)}}$$
   $$= \frac{90}{(2.02^2)}$$
   $$= 22.06$$

   (b) Paul has a BMI of 22.06, which is in the category of normal weight (between 18.5-24.9).

   (c) $$\text{BMI} = \frac{\text{weight(kg)}}{\text{height(m}^2\text{)}}$$
   $$= \frac{102}{(1.82^2)}$$
   $$= 30.82$$

   (d) Luca has a BMI of 30.82, which is in the category of obese (between 30.0-4.9).

   (e) BMI does not directly measure body fat, so it does not distinguish between the proportion of weight due to muscle or fat. Muscle weighs more than fat due to its retention of water and because of this, the BMI of muscular athletes can classify them as overweight or obese even though they do not have excess body fat.

   (f) It is important to know if the fat is concentrated above the waist as visceral fat surrounding the abdominal organs. Visceral fat is associated with a higher risk of developing weight related disorders.

   (g) A = pear or gynoid shape and B = apple or android shape

   (h) Fat distribution B (apple/android) is more common in men and is associated with a greater risk of developing weight related disorders. This is because more fat is stored as visceral fat in the abdomen.
2. (a) Cortisol is a stress hormone that increases appetite and cravings, especially of energy dense foods rich in sugar and fats. This can result in overeating and a positive energy balance, leading to weight gain and obesity.

   (b) Some possible answers are: alcoholic beverages are energy dense and provide empty 'kilojoules.' This energy is generally surplus to one's needs and can be stored as fat; alcohol can also increase one's appetite and increase one's risk of impulsively consuming energy dense foods, such as fast food.

   (c) Physical activity is important because it increases energy expenditure, which can contribute to a negative energy balance to help lose weight. It also increases BMR, which increases the body's energy needs and can result in weight loss.

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(d) Processed snacks are generally energy dense and high in fats and simple sugars. Overconsumption of processed snacks during this time could have led to positive energy balances, especially because people were locked inside living more sedentary lifestyles and this could have contributed to weight gain.

3. (a) Gastric balloons.

(b) Gastric bypass.

(c) Some possible answers are: A gastric bypass (B) is a surgical procedure whereas the insertion of gastric balloons (A) is not; the insertion of gastric balloons is a temporary procedure where the balloons can remain in the stomach for up to 9 months, whereas the gastric bypass is a permanent procedure where the majority of the stomach is bypassed; gastric balloons (A) can be used as a preparation procedure to lose weight and reduce risks of complications during a gastric bypass (B).

2.3 Diabetes

1. (a) Pancreas.

(b) Glucagon is the hormone released by alpha cells in response to detecting low blood glucose levels. Glucagon binds to its receptors on the liver promoting the breakdown of glycogen into glucose, which is released into the blood. Blood glucose levels increase as a result.

(c) Insulin is the hormone released by the beta cells into the blood in response to an elevated blood glucose level. Insulin binds to receptors on body cells, such as liver and muscle cells, stimulating them to take up glucose from the blood and lowering blood glucose levels. The body cells can use the glucose or store it for later use.

(d) The destruction of beta cells would result in a decreased ability to produce and release insulin into the blood in response to elevated blood glucose levels. Less insulin production results in a decreased ability to reduce blood glucose levels.

(e) Type 1 diabetes.

(f) An individual with type 1 diabetes has had its beta cells destroyed due to an autoimmune condition and cannot produce sufficient insulin. Type 1 diabetes is not associated with modifiable lifestyle factors and insulin resistance so insulin will still readily bind to its receptors when injected.

2. (a) More likely.

(b) Diabetics cannot reduce their blood glucose levels efficiently through the action of insulin so excess glucose is filtered by the kidneys and lost in the urine resulting in excessive urination.

(c) Thirst or dry mouth.

(d) A lack of sleep can result in elevated levels of the stress hormone cortisol, which increases insulin resistance. A lack of sleep can also result in a reduced release of insulin following consumption of carbohydrates. In addition, a lack of sleep can result in increased hunger and poorer food choices, which can accelerate weight gain and increase insulin resistance.

(e) The increased glucose can have an abrasive effect on the internal walls of the blood vessels that supply the kidney, injuring them. The kidney contains millions of small capillaries that filter the blood. Damage to these capillaries can impair the filtering system and can cause kidney disease or failure.

(f) If a diabetic cannot produce enough insulin or their cells resist insulin, the cells cannot take up sufficient glucose to fuel their activity. This can result in a lack of energy because the body's cells haven't been able to access enough energy.

(g) As exercise is energy intensive, it lowers blood glucose levels and burns fat resulting in weight loss. In addition, exercise can increase muscle gain, which raises the basal metabolic rate (BMR), resulting in additional weight loss and in some cases reduces insulin resistance. Exercise also increases the body's sensitivity to insulin counteracting any existing insulin resistance.

3. (a) A = High GI and B = Low GI

(b) There are many possible answers for this question. The food or drink for 'A' must be high GI, such as lollies, white rice, soft drinks, etc. The food or drink for 'B" must be low GI, such as non-starchy vegetables, bran, chickpeas, apples, etc.

(c) The spike in blood glucose levels at 'A' results in a large spike in insulin release to tell cells to take up glucose from the blood. Due to the excess glucose present, it is generally unable to be used up immediately and can be stored as fat. In comparison, a slower increase in blood glucose levels exhibited

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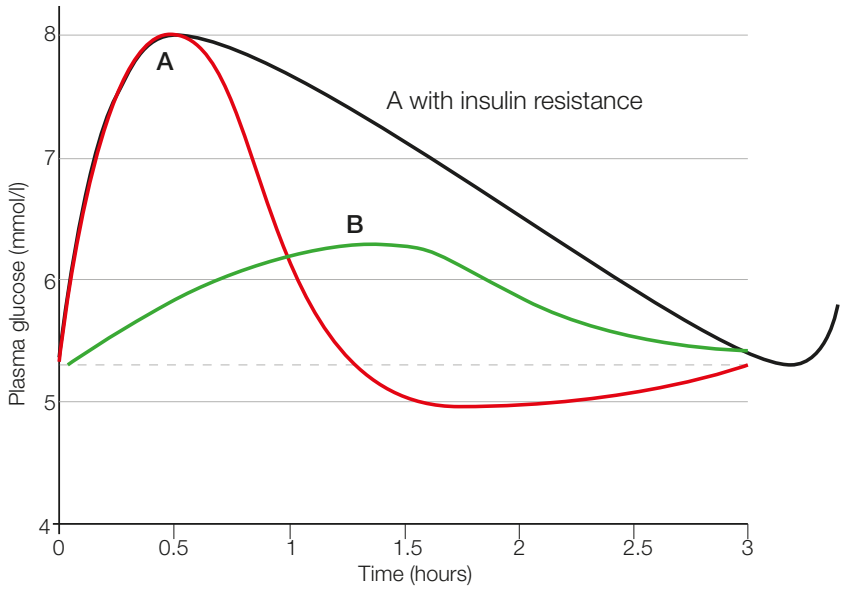
by line 'B' produce smaller fluctuations in blood glucose and insulin levels due to a sustained release of glucose. Low GI foods take longer to breakdown in the intestines and therefore the glucose is released slowly into the blood and is more likely to be used and less likely to be stored as fat

(d) Type 2 diabetes.

(e) Insulin resistance results in cell receptors being unable to respond to insulin. As a result, the glucose channels of those cells cannot open and the glucose remains in the blood causing high blood glucose levels.

(f) A diet high in saturated fat can increase the risk of fat accumulating inside muscle cells, which interferes with the signalling process of their insulin receptors. This interference means that the presence of insulin is unable to activate these cells to open their glucose channels, resulting in insulin resistance.

(g)



(h) The glycaemic index does not take into account the amount of carbohydrates present in each serve and only how quickly the glucose from that food is absorbed into the blood (whereas the glycaemic load accounts for both). It also does not consider other macronutrient and micronutrient contents of the food and how this could affect absorption.

4. This product consists of one serving and this serving has 14.2 g of sugar. As the serving size is 100g, the number of grams are effectively expressed as percentage. Therefore, a full serving of this product would be above the recommendation of consuming products consisting of less than 10% sugar by 4.2%. This product is therefore not suitable for a diabetic to consume regularly who has been given this recommendation.

2.4 Atherosclerosis

1. (a) Some possible answers are:

Modification: Remove the trimmings from rasher bacons.

Justification: This will reduce saturated fat from the bacon. Saturated fats increase LDLs and risk of atherosclerosis.

Modification: Substitute crumbed chicken fillets with grilled chicken breast.

Justification: The crumbed chicken fillets are highly processed and normally deep-fried resulting in a significant amount of saturated and trans fats. Both these fats increase LDLs and therefore, the risk of fatty deposits on artery walls.

Modification: Replace white bread with multi grain bread.

Justification: White bread is highly processed and does not contain much fibre but multi grain bread is higher in fibre content. Soluble fibre can bind to cholesterol in the intestines reducing the amount of cholesterol absorbed by the body.

Modification: Replace whole egg mayonnaise with low fat mayonnaise.

Justification: This would reduce saturated fat content. Saturated fats increase LDLs and risk of atherosclerosis.

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(b) The progressive buildup of plaques in arteries, narrows them and reduces blood flow. If a plaque ruptures, it triggers a blood clot to form which can completely cut off blood supply to tissues. If this blockage occurs in an artery supplying the heart (coronary artery), it can result in a heart attack.

(c) Salmon contains more omega-3 fatty acids than chicken. The consumption of omega-3s fats can increase HDL production, which collects excess cholesterol form body cells and blood vessels and returns them to the liver. This lowers LDL levels and risk of plaque build-up. Chicken also contains saturated fat that can increase LDL production and risk of plaque build-up.

(d) Exercise increases HDL cholesterol levels, which in turn lower LDL levels, decreasing the risk of atherosclerosis. A sedentary lifestyle can therefore decrease HDL levels, and as a result, increase LDL levels and the risk of developing atherosclerosis. Exercise also reduces blood pressure, which is a risk factor for atherosclerosis.

(e) Smoking damages the internal lining of blood vessels forming imperfections for plaques to start building up against. In addition, cigarette smoke contains nicotine that increases blood pressure further exacerbating the risk of atherosclerosis. Smoking also increases the risk of clots developing and as a result, blockages of blood vessels.

2.5 Hypertension

1. As the diameter of the artery lumen decreases, there is less space for blood to pass through, increasing resistance and blood pressure on the artery walls.

2. (a) Some possible answers are:

Modification: Replace pizza dough with a cauliflower pizza base.

Justification: Cauliflower pizza bases contain less salt than pizza dough. Salt can retain water and increase blood volume, increasing blood pressure. Less salt intake can help to reduce blood pressure.

Modification: Reduce the amount of tomato paste used to 60g (or use reduced salt tomato paste).

Justification: Tomato paste is a processed food that contains a lot of salt. Salt can retain water and increase blood volume, increasing blood pressure. Less salt intake can help to reduce blood pressure.

Modification: Replace Mozzarella cheese with reduced fat cheese.

Justification: Mozzarella cheese contains saturated fat that can increase LDL cholesterol levels. Increased LDL blood cholesterol is associated with greater risk of atherosclerosis, narrowing arteries.

Modification: Removing shredded ham, pepperoni and/or sardines.

Justification: Ham, pepperoni and sardines are processed foods that contain a lot of salt. Salt can retain water and increase blood volume, increasing blood pressure. Less salt intake can help to reduce blood pressure

(b) If hypertension is left untreated, the heart can become enlarged and less efficient at pumping blood around the body, causing heart failure.

(c) Diabetics have less ability to control blood sugar levels, therefore they are more likely to experience high blood glucose levels, which can increase blood volume and therefore blood pressure.

3. (a) Males have a greater prevalence of hypertension and this is evident with a greater percentage of males having hypertension from 14 to 75 years and over. For example, at the age of 75, approximately 45% of males have hypertension compared to the approximate 40% of females.

(b) The prevalence of hypertension increases with age. This is evident in the graph as the prevalence of hypertension in both males and females continually increase from 0% at birth to approximately 47% and 44% respectively.

(c) The risk of hypertension increases with age because the arteries lose their elasticity and become stiffer. With a reduced ability to expand, the arteries become narrower and blood pressure increases.

(d) Regular physical activity can reduce blood pressure by making the heart stronger. The stronger the heart is, the more easily it can pump blood through the arteries, reducing blood pressure.

(e) ACE inhibitors help relax arteries, increasing their diameter, which allows greater blood to flow through and reduces blood pressure.

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2.6 Cardiovascular disease

1. Coronary heart disease is the narrowing of the arteries that supply the heart with blood due to the build-up of plaques. As the blood supply to the heart is reduced from the narrowing of these blood vessels chest pain known as angina can occur. If the coronary artery becomes fully blocked, generally due to a blood clot, a heart attack can occur.
2. Heart failure occurs when the heart cannot supply enough blood to the body's cells. This can because it cannot fill with enough blood or cannot pump with enough force. However, a heart attack occurs when blood supply to part of the heart is completely blocked by a blood clot and the cardiac muscle in this part of the heart starts to die.
3. (a) Race.

   (b) African American males and females have the highest risk with approximately 53 and 32 more preventable deaths per 100,000 respectively than the next highest race group, American Indian Alaskan Native.

   (c) Males are at higher risk of cardiovascular disease than females for all groups represented by the graph. For example, white males have approximately 45 more preventable deaths per 100,000 than females and there are 33 more preventable deaths per 100,000 for Hispanic males than females.

   (d) The high blood glucose levels associated with diabetes can damage the internal walls of blood vessels, causing imperfections that plaques can start building up against. The longer an individual has had diabetes, especially if it is uncontrolled, the greater the risk of damage to the blood vessels and cardiovascular disease.

   (e) Some possible answers are: smoking damages the internal lining of blood vessels forming imperfections for plaques to start building up against; cigarette smoke contains nicotine that increases blood pressure further exacerbating the risk of atherosclerosis; smoking increases the risk of clots developing and as a result, blockages of blood vessels.

2.7 Anaemia

1. A deficiency in the number or quality of red blood cells.
2. (a) Individual B is more likely to anaemic due to their paler skin. Pale skin is a symptom of anaemia and is caused by a reduced number or quality of red blood cells travelling through the blood close to the skin.

   (b) Some possible answers are: tiredness, reduced energy, loss of appetite, motivation and enthusiasm, behavioural problems, reduced physical work capacity/productivity, premature births, pica.
3. (a) Approximately 210 million women.

   (b) Approximately 25 million women

   (c) Some possible answers are: there is greater availability and access to fresh food for the individuals within Europe than there is in South/Southeast Asia; there is greater access to affordable healthcare for the individuals within Europe than there is in South/Southeast Asia.

   (d) One of: Because females naturally lose more blood each month through menstruation. Therefore, a greater amount of nutrients is required to replace the lost red blood cells than males; because females are at greater risk of anaemia during pregnancy due to increased blood volume and loss of blood during childbirth.

   (e) Because they require greater blood supply due to increased energy requirements. They also require more iron for the development and repair of muscles, and any blood lost through internal and external bleeding through injury. Iron is also lost through heavy sweating during training and playing sport, especially at the elite level.
4. (a) Folate, vitamin B12 and protein.

   (b) Because vitamin B12 is almost only found in animal products, which vegans do not consume. Furthermore, vegans who do not plan their meals to ensure they are consuming enough complementary proteins could be deficient in one or more essential amino acids required to make proteins.

   (c) Initially, a review of the individual's diet could be warranted and result in a new diet being trialled. If required, iron supplements can be administered. For some individuals a medical professional might recommend an iron infusion, which is delivered through an IV drip.

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2.8 Osteoporosis

1. (a) The process of replacing old bone is more efficient when we are young, resulting in new bone being made faster than old bone is broken down. The rate of bone replacement generally slows down after the age of 20.

   (b) Peak bone mass.

   (c) A 30-year-old is likely to have reached their peak bone mass, therefore, if they have a minor fall their bones a very dense and the impact is unlikely to result in a fracture or breakage. In comparison, a 70-year-old reached their peak bone mass 40 years earlier and they have had gradual bone loss ever since resulting in less dense bones. A minor fall could therefore more easily result in a fracture or breakage.

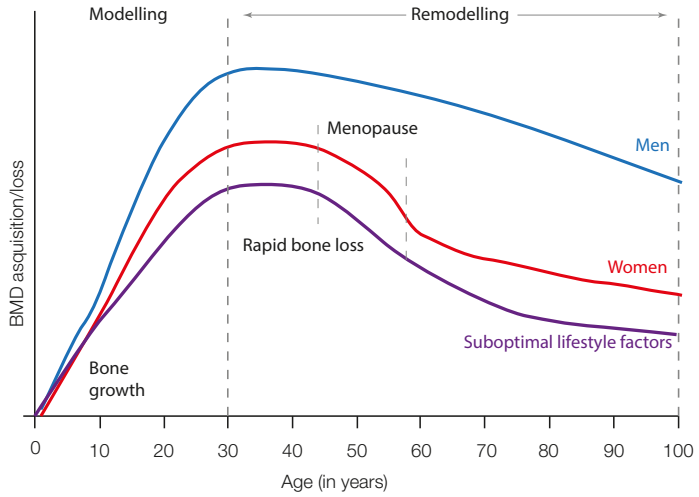
   (d) Menopause.

   (e) Oestrogen plays an essential role in building and maintaining bone density in females. As oestrogen levels drop in women during menopause**,** this results in accelerated bone loss.

   (f) Bones are the primary store of calcium in the body. When calcium intake is inadequate, calcium is exported into the blood from the bones resulting in reduced bone density. Chronic inadequate calcium intake can therefore lead to reduced peak bone mass and continued bone loss.

   (g) Weight bearing exercises, such as running and weightlifting, increase bone density and slow bone loss. When weight bearing exercises are performed, muscles are stimulated to work, which pull on the bones promoting bone strength. This results in increased bone replacement and bone density.

   (h)



   (i) A male who has lived his whole life in Northern Finland may not have obtained enough vitamin D through exposure to sunlight. Northern Finland is located at high latitudes where there is insufficient sunlight to produce enough vitamin D. When our skin is exposed to sunlight it can make its own vitamin D, which is required to absorb calcium from the diet. A vitamin D deficiency can therefore result in calcium deficiency and more calcium being resorbed from the bones increasing bone loss and decreasing the likeliness of reaching the peak bone mass.

   (j) Tea and coffee both contain caffeine. Caffeine can inhibit the absorption of calcium consumed. Consuming large amounts of caffeine, such as 8 cups of tea and coffee, will therefore reduce the amount of available calcium to the body, and can result in a decreased bone density and increased risk of osteoporosis.

2. (a) The percentage of self-reported osteoporosis cases is greater in females than males and this increases from the age of 45 to 75+. There are approximately 4% more females than males who self-report osteoporosis in the 45-54 age bracket and by the ages of 75+ this has increased to 19% more females than males.

   (b) Some possible answers are: as this data is based on self-reporting there could be a number of males who did not identify as having osteoporosis even though they did; males are less likely to seek medical advice and may have osteoporosis without knowing.

   (c) Some symptoms of osteoporosis are a curved posture, decreased height and bones that fracture more easily than normal.

   (d) The type of medication used to treat osteoporosis targets the cells that break down bone, called osteoclasts, making them less active. The cells that make bone cells, called osteoblasts, remain active and this reduces the amount of bone loss and risk of fractures over time.

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2.9 Diverticular disease

1. Diverticula are the pouches that form in the walls of the large intestine due to increased pressure and straining. Diverticulosis is the name of the condition given for the presence of diverticula, whereas diverticulitis is the name for the condition when the diverticula are inflamed, infected or ruptured.

2. (a) Diverticulitis.

   (b) The diverticula are bleeding and look inflamed/infected indicating that the intestines have diverticulitis.

   (c) Some possible answers are: pain, abdominal cramps, bloating, bleeding, diarrhoea, vomiting, fever, chills, nausea.

3. Fibre is only found in plant-based products and not animal products. If an individual is consuming a diet high in animal products, they are consuming less plant-based products and may not be getting enough fibre in their diet, increasing the risk of diverticular disease.

4. Constipation can cause the pressure in the intestine to increase and result in straining to pass the firm stools. The combination of increased pressure and straining can cause irritation and inflammation of the intestines and over many years can increase the risk of diverticula forming and becoming infected.

5. Dehydrated individuals are at an increased risk of experiencing constipation as less water is available to soften stools. Constipation can cause the pressure in the intestine to increase and result in straining to pass the firm stools increasing the risk of diverticular disease.

6. (a) The percent of the population with diverticulosis increases with age. At birth, 0% percent of the population have the condition, and this slowly rises to approximately 9% at 30. There is a sharp increase to 60% of the population at 70. The prevalence continues to increase to 90 with approximately 68% of the population with the condition, however, this increase occurs at a slower rate.

   (b) Exercise can increase the muscle tone of the gastrointestinal tract. This increased muscle tone can improve the motility of the gut promoting the stool to move through the intestines more quickly and easily. This helps to prevent constipation and therefore diverticular disease.

Topic 2 Review Test

1. (a) Males. 31% of males correctly identified the recommended intake of carbohydrates compared to 26% of females.

   (b) (i) Some possible answers are: an excess consumption of carbohydrate can result in excess energy being consumed (a positive energy balance), which can lead to weight gain and contribute to being overweight or obese; excess energy consumption can lead to weight gain. Increased weight gain, especially in the abdominal area, causes insulin resistance and in turn type 2 diabetes; excess consumption of carbohydrates can lead to increased blood glucose levels, which can contribute to hypertension.

   (ii) Some possible answers are: A decreased intake of carbohydrate can result in a deficient fibre intake. Constipation can result as a consequence of a lack of fibre and over time this could lead to diverticular disease; a lack of carbohydrates could lead to less energy available to make red blood cells. Anaemia could develop as a result.

   (c) (i) (1) **High GI:** Jellybeans, cola or white rice (2) **Low GI:** Baked beans, mature cheese or apple

   (ii) The type of carbohydrate is a factor. Foods that have more simple sugars and less complex carbohydrates will raise blood glucose levels more and are classified as high GI.

   (iii) Some possible answers are: Type 1, 2 or gestational diabetes sufferers; obese people; athletes.

   (d) A GI value only tells you how rapidly a particular carbohydrate turns into sugar and is absorbed into the blood, it does not tell you how much of that carbohydrate is in a serving of a particular food. The GL takes into account both the GI and the amount of carbohydrate per serving which is required to understand a food's full effect on blood sugar.

2. (a) Atherosclerosis is the gradual buildup of fatty deposits on the internal walls of arteries forming plaques. This results in the thickening of arteries, reducing blood flow to tissues.

   (b) Some possible answers are: Damage to the coronary arteries (including heart attack, heart disease); stroke; kidney damage; gangrene; vision loss.

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(c) Risk Factor: Alcohol

Explanation: Alcohol consumption increases blood pressure but the molecular mechanisms behind this are unknown. In some cases, alcohol can lower inhibitions leading individuals to make poor food choices that are often high in saturated fats and salt leading to increased cholesterol, which is a risk factor for hypertension.

Risk Factor: Smoking

Explanation: The nicotine in tobacco products stimulate the nervous system to release chemicals that can constrict blood vessels and harden their walls contributing to high blood pressure.

(d) (i) There are many possible answers. Some examples are processed meats such as ham and salami, pretzels, crisps, soy sauce, gravy, etc.

(ii) Some possible answers are: Cook at home more to reduce the consumption of fast foods and meals served at restaurants that are generally high in salt; replacing processed foods for more fresh fruits and vegetables, which are lower in salt; be disciplined and read all food labels to make informed decisions when purchasing foods to ensure they are low in sodium; use herbs and spices to add flavour to food instead of adding salt to meals.

(e) Two different answers are required. Each dot point below is worth 2 marks each.

- The application of rilmenidine for aging instead of hypertension in humans could have positive impacts on the health system and economy. If further research on humans show that this medication could be used to live longer and keep us healthier as we age, then there would be less reliance on the public health system by the elderly than there currently is. This would have a significant impact, especially considering we have an ageing population.
- The advances in scientific knowledge surrounding cellular biology and the technology associated with this combined with our ageing society has influenced research into how to slow down ageing. With many more Australian citizens soon to require aged care, this medication could have a positive influence in reducing the burden on the aged care system and in turn allowing the system to provide better care for those requiring it.

(f) **Modification:** Remove the salt.

Justification: Table salt contains sodium and a diet high in sodium is a risk factor for hypertension.

(g) **Modification:** Replace bacon with a half a cup of vegetables.

Justification: Bacon is an animal product that does not contain fibre and vegetables are plants that do contain fibre.

(h) Fibre helps to soften stools, which speeds up its movement through the bowels reducing pressure on the intestinal walls and the likeliness of **constipation** occurring. Constipation can cause the pressure in the intestine to increase and result in straining to pass the firm stools. The combination of increased pressure and straining can cause irritation and inflammation of the intestines and over many years can increase the risk of diverticula forming and becoming infected.

3. (a) Because the 'lite' butter has significantly less saturated fat (8g/100g compared with 30g/100g). Saturated fats promote production of LDLs and increases chance of plaque build-up in blood vessels (atherosclerosis).

(b) The Original butter has double the amount of polyunsaturated fats than the Lite butter (18.0g more per 100g). These unsaturated fats generally increase the production of good HDLs. HDLs collect LDLs from blood vessels and return them to the liver for processing, in turn reducing the risk of atherosclerosis and CVD.

(c) Processed foods are generally energy dense and high in saturated fats and simple sugars. Overconsumption of saturated fats and simple sugars can increase the chances of a positive energy balance and the excess energy being stored as fat.

(d) Some possible answers are: Eat lean cuts of meat and cut any visible fat off to reduce the consumption of saturated fats; remove the skin from chicken meat to reduce the intake of saturated fats; eat fish instead of fatty meats to replace saturated fat intake with healthy omega 3 fatty acids; eat low fat foods like vegetables, fruits, grains and cereals instead of highly processed foods, which are nutrient dense and contain more fibre; increase soluble fibre intake, which increases satiety and removal of cholesterol from the body through the faeces; consume low fat products that have less saturated fat than their full-fat equivalents; use cooking methods without adding extra fat such as grilling, steaming and microwaving instead of deep frying; snack on low fat foods like fruit and popcorn rather than chips and sweets; reduce alcohol intake which can reduce the amount of empty calories consumed and reduce storage of excess energy consumed.

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4. (a) George had a rapid spike in blood glucose levels from approximately 5.8-16mmol/L whereas Paul remained steady at approximately 6.0 for the first 2 hours.

   (b) As glucose attracts and holds water, increased glucose in the blood can increase the blood volume. This can increase blood pressure and chronic high blood pressure can contribute to a range of health issues.

   (c) Some possible answers are: Foods high in saturated fats can lead to obesity which results in increased fatty acids in the blood and inflammation causing insulin resistance; saturated fats promote fat accumulation inside muscle cells, which interferes with the signalling process of their insulin receptors. This interference means that the presence of insulin is unable to activate these cells to open their glucose channels, resulting in insulin resistance.

   (d) Please refer to Table 2.3.1 on page 126.

   (e) (i) $$\text{BMI} = \frac{\text{weight(kg)}}{\text{height(m}^2\text{)}}$$
   $$= \frac{115}{(1.61^2)}$$
   $$= 44$$

   (ii) Some possible answers are: Reducing intake of processed foods that are high in saturated fat can limit weight gain. Increased fat storage, especially in the abdominal area, can increase insulin resistance; reducing the intake of foods high in simple sugars. Simple sugars are high in GI, which are more likely to be stored as fat. Increased fat, especially in the abdominal area, can increase insulin resistance; reducing alcohol intake which are energy dense and often high in simple sugars, leading to greater weight gain. Increased fat, especially in the abdominal area, can increase insulin resistance; increasing consumption of fresh fruits, vegetables, legumes, nuts and seeds that have a low GI and are higher in fibre. High fibre foods can be more filling and can reduce chance of overeating. Low GI foods release carbohydrates more slowly and are less likely to be stored as fat reducing risk of developing insulin resistance.

   (iii) Some possible answers are: Joining a gym and increasing physical activity levels; making more home cooked meals that are suitable to diabetics (low carbohydrate serves); make diet and lifestyle changes with partner to increase chance of maintaining long term; park further away from work and walk to work from car park; limiting social gatherings that involve the consumption of alcohol; exercise with friends and set times and dates to increase chance of completing the exercise; pay to see a personal trainer to help with motivation; continue to see the dietician to regularly update plan; set targets and rewards when targets are met.

5. (a) Calcium or phosphorus

   (b) Phosphorus is found in all foods that contain animal or plant cells. If calcium was mentioned in part (a), some possible answers are: Milk, cheese, yoghurt, broccoli, spinach, sesame seeds, almonds, soya beans, tofu, sardines, salmon, legumes, stock made from bones/bone broth.

   (c) Some possible answers are: Undertaking regular weight bearing activities such as running and weightlifting to strengthen muscles and bones; increasing exposure to sunlight, which can increase vitamin D production and availability; limiting alcohol intake because an excess can kill the cells that make bone, called osteoblasts, and increase hormones, such as cortisol and parathyroid hormone, which increase the breakdown of bones; avoiding smoking because smoking reduces the blood supply to bone, reducing the production of osteoblasts (the bone producing cells); by visiting cafes less often and limiting coffee intake. The caffeine in coffee is a diuretic and limits absorption of vitamins and minerals, due to promoting urine.

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Topic 3: Suggested Solutions

3.1 The digestive system

1. Mechanical digestion involves physically breaking food into smaller pieces, increasing the surface area of the food. Chemical digestion involves enzymes that chemically break down large nutrients into smaller nutrients by facilitating the breaking of chemical bonds between subunits.

2.

Organ	Organ name	Functions
A	Mouth	Food enters the digestive system through the mouth and chewing physically digests the food.
B	Oesophagus	Transports the food bolus from the mouth to the stomach by peristalsis.
C	Liver	Produces and secretes bile directly into the small intestine but also to the gall bladder.
D	Gall bladder	Stores bile and releases it into the small intestine.
E	Small intestine	Finishes the chemical digestion of all macronutrients and absorbs the digested nutrients through the villi.
F	Anus	Sphincter that faeces is eliminated through.
G	Rectum	Stores faeces in preparation for elimination.
H	Large intestine	Absorbs water and salts from remaining indigested material.
I	Pancreas	Produces and secretes pancreatic enzymes into the small intestine.
J	Stomach	Churns the food and starts the chemical digestion of protein by pepsin. Stores food and slowly releases into the small intestine.
K	Pharynx	Aids in the process of swallowing. Food passes through and into the oesophagus.
L	Salivary glands	Releases saliva into the mouth to lubricate food for swallowing and starts the chemical digestion of carbohydrates through action of salivary amylase.

3. The chemical digestion of protein starts in the stomach where the enzyme pepsin digests protein into smaller peptides. The chemical digestion finishes in the small intestine where trypsin digests protein and the smaller peptides into amino acids.

4. Salivary glands release saliva into the mouth. The teeth in the mouth chew the food physically breaking up the dry food allowing the saliva to mix with it. The saliva lubricates the food making it easier to swallow.

5. The stomach has a very low acidic pH (1.5 – 3.5) due to the release of concentrated hydrochloric acid. The acidic environment denatures the salivary amylase and it can no longer digest starch.

6. (a) The triglyceride level decreases in the presence of bile from 100 mg/L to 0mg/L over 60 minutes, whereas it only decreases from 100mg/L to 63mg/L without bile (two marks for the patterns and one mark for using the data as instructed in the question).

   (b) The triglyceride levels are decreasing because they are being broken down into glycerol and free fatty acids. Bile emulsifies triglycerides into smaller fat droplets. This increases the surface area of the triglycerides allowing more efficient chemical digestion by lipase enzymes. Therefore, more triglycerides can be broken down in a shorter amount of time as represented by the graph.

7. The small intestine (duodenum). The chemical digestion of all three macronutrients are finished in the small intestine by pancreatic enzymes. In contrast, the mouth only chemically digests carbohydrates and the stomach only chemically digests protein.

8. The process is called peristalsis. After the food is swallowed it enters the oesophagus and a wave of involuntary muscular contractions propels the food bolus down the oesophagus and into the stomach.

9. (a) Villi

   (b) The absorption of nutrients.

10. If energy is not immediately required by the body and glycogen levels are full, the excess glucose can be converted to fat and stored as adipose (fat) tissue.

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11. (a) Amino acids are absorbed into the capillary of the villi and transported to the liver via the circulatory system. The liver processes the amino acids and can transport them the cells to be used to synthesise new proteins. If there is an excess or the body is low on energy, the amino acids can be converted to glucose and transported to cells (used as a secondary source of energy).

    (b) Glycerol and fatty acids are absorbed into the lacteal of villi and transported through the lymphatic system.

3.2 Malabsorption syndromes

1. (a) People that experience food intolerances generally blame the last food eaten for the symptoms that develop, in this case snow peas. However, it is usually due to the accumulation of a specific chemical such as salicylates present in multiple foods consumed throughout the day that eventually exceeds their tolerance threshold. It is unlikely that this individual is intolerant to snow peas and more likely that he/she is intolerant to salicylates.

    (b) When individuals are on holidays, they are more likely to be relaxed and less likely to be stressed. This is likely to increase their personal tolerance threshold and reduce the likeliness od symptoms to develop.

2. (a) 83%

    (b) Bloating occurs because of impaired carbohydrate and water absorption and increased gas production.

    (c) Individuals with non-coeliac gluten sensitivity develop symptoms like bloating and gas when gluten consumption exceeds their threshold, but they don't experience intestinal damage or long-term health effects. Whereas the consumption of gluten by coeliac sufferers results in the immune system attacking the villi in the small intestine. This can result in gastrointestinal symptoms and malabsorption of nutrients. The symptoms can be reversed with a gluten-free diet.

    (d) Individuals with coeliac disease are likely to have been exposed to gluten during their life. Exposure to gluten causes inflammation and the flattening of villi and this reduces the surface area for absorption to occur. Therefore, less nutrients such as vitamin B12 can be absorbed, resulting in malabsorption.

    (e) These individuals may be unknowingly experiencing malabsorption of certain nutrients. Therefore, they are at a higher risk of developing dietary disorders such as anaemia due to lack of vitamin B12, folate and iron, and osteoporosis due to reduced calcium and vitamin D absorption.

3. (a) Any food product that contains wheat, rye, barley or oats such as bread, cereals, pasta, cakes, pies, French fries and crisps.

    (b) Because there may be other individuals living in the house that don't have coeliac disease and they may consume bread that contains gluten. If they used a knife on butter or condiments it could cross-contaminate these products with crumbs from normal bread. If a coeliac sufferer then used these products, they could spread that product containing crumbs from normal bread and ingest gluten activating the auto-immune response and they could develop symptoms.

4. An individual with lactose intolerance lacks the ability to produce the enzyme lactase so they cannot digest lactose from dairy products. Coeliac disease is an autoimmune condition where the sufferers' immune system attacks the villi in the small intestine when it detects the presence of gluten.

5. Dairy products such as milk, yoghurt, ice cream, soft cheeses, cream and condensed milk.

6. There are a few possible answers such as: bacteria in the large intestine ferment the undigested lactose producing gas that can contribute to bloating and wind; bacteria in the large intestine ferment the undigested lactose producing acids that can irritate the cell lining causing pain; undigested lactose retains water that can lead to diarrhoea.

7. (a) Calcium

    (b) Osteoporosis

    (c) There are many possible answers. Some examples are tofu, almonds, sesame seeds and broccoli (must be a food).

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3.3 The microbiome

1. The gut microbiome is the collection of all microorganisms including bacteria, fungi, viruses, etc. that live on or within our gastrointestinal tract.
2. Because the environmental conditions of the stomach are less favourable. The stomach has a high acidity of about pH 1.5. This low pH kills a lot of microorganisms, whereas the small intestine is a more favourable pH (approximately 6-7.4).
3. The more diverse an individual's microbiome is, the less likely they are to develop adverse health outcomes. One reason for this is that the more diverse an individual's microbiome is, the more resilient it is. A resilient microbiome can recover more easily from disturbances such as infections and antibiotics. A healthy variety of gut bacteria are also more able to adapt to the broad range of foods we consume whilst maintaining their important functions such as preventing inflammation.
4. (a) False. The microbiome starts forming in the amniotic sac.

   (b) True. Because breastmilk contains prebiotics such as specific oligosaccharides that feed good bacteria in our guts.

   (c) False. Probiotics are foods that contain live bacteria not prebiotics. Prebiotics contain nutrients for gut bacteria.

   (d) False. Being born by C-section has been shown to increase risk of diseases later in life.
5. It generally takes a couple of years for a child's microbiome to develop. Antibiotics kill bacteria and if they are taken before the microbiome has developed it is less diverse and therefore less resilient. This can cause permanent changes in the diversity of microbes and increase risk of diseases later in life.
6. Short chain fatty acids nourish the gut lining and prevent inflammation. An increased amount of short chain fatty acids are therefore associated with less risk of diseases caused by inflammation such as gut disorders, colon cancer and cognitive decline.
7. Any two of the following (type of birth is not accepted because the question asks 'after birth'):

   Diet: the food we eat can provide nutrients for bacteria in our guts or even live microbes. A healthy diet including a range of prebiotics and probiotics can increase microbiome diversity.

   Mother and father's skin: there are unique colonies of bacteria on individuals' skin and as infants we are exposed to both our parents' microbes through skin to skin contact especially from our mother's when breastfeeding.

   Pets: animals can be dirty and are covered in different microbes to humans. Having pets as we grow up exposes us to different microbes through direct touch and hair on our clothes.

   Geographical location: individuals are exposed to different microbes from where they live. For example, there are different microbes in tap water in Adelaide when compared to Delhi in India.
8. (a) A – probiotic and B–prebiotic

   (b) Prebiotics provide 'food' for good bacteria to obtain energy from. Also, any two specific prebiotics from the food categories: fruits, vegetables, legumes, wheat products, herbs, spices, nuts and seeds need to be supplied. Some examples are bananas, artichoke, pepper, chickpeas and pasta. More specific examples such as resistant starch, fibre and oligosaccharides in breastmilk are also acceptable. and they provide 'food' for good bacteria to obtain energy from.

   (c) Yoghurt is a probiotic. It provides live cultures of bacteria (*Lactobacillus)* that can increase diversity of gut microbiome because the additional numbers can outcompete harmful bacteria in the guts promoting a healthy microbiome.
9. A diet high in processed foods including sugar, fats and protein (energy dense); OR a diet low in wholefoods such as fresh fruits, vegetables, nuts and seeds.
10. (a) Vitamins such as C, K, B1, B2, B5, B6, B7, B9 & B12.

    (b) Dysbiosis is when the microbiome becomes unbalanced, indicated by a marked loss of microbial diversity.

    (c) Two of: poor diets that are high in processed foods; chronic stress, lack of sleep; and some medications.

    (d) A current technique is to transfer a 'healthy' faecal sample with a diverse range of good bacteria to the infected patient to effectively 'reset' their microbiome. The good bacteria in the healthy donor faecal sample outcompete the Clostridium difficile bacteria and restore a balanced microbiome. After a faecal transplant the patient generally ends up with a microbiome that is similar to the donors. This can resolve the infection and save the patients' life in extreme circumstances.

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11. (a) False. It is better to live than to die and sometimes antibiotics might have side effects but the benefits can outweigh the negatives at times (they shouldn't be overused and misused such as taking them for colds).

    (b) False. They can have side effects such as transferring antibiotic resistant bacteria, increasing risk of obesity, and other unknown effects.

    (c) True. A faecal microbiota transplant from a skinny person to an overweight/obese person has shown promise in reducing weight gain.

12. (a) Two of: exercise regularly, get enough sleep, avoid stress, not smoking, not taking party drugs, only take antibiotics when needed and not drinking too much alcohol.

    (b) Any two of the following (must be specific foods not categories): fruits such as apples, bananas; vegetables such as spinach, potatoes; wheat products such as bread, pasta, cous cous, freekeh; nuts or seeds such as cashews, almonds, chia seeds; herbs or spices such as coriander, parsley, pepper; tea or coffee; dark chocolate; red wine (in small amounts); fermented foods such as kimchi, kombucha, sauerkraut, tempeh, kefir, miso and some soft cheeses; other probiotics such as yoghurt and Yakult.

3.4 The Digestive system, microbiome and the brain

1. If we eat junk food, this effectively also feeds our junk food loving bacteria, providing them with more energy to grow and reproduce. Therefore, their numbers increase and the number of signals to the brain for us to eat more junk food increases too. As we eat more junk food, the population of 'junk food eating bacteria' increases too, further signalling our brain to eat more junk food. This positive feedback loop increases the cravings we have for particular junk foods and can be hard to fight off as it is self-reinforcing.

2. Any two of: the gastrointestinal tract can communicate directly with the hypothalamus in the brain, which is responsible for regulating emotions, via the vagus nerve; bacteria in the guts can release metabolites such as free fatty acids that can alter activity of the cells in the blood-brain barrier and its permeability; bacteria in the guts can also release chemicals that stimulate intestinal cells to release hormones that can travel to the brain and communicate with it; gut microbes can interact with the immune system cells stimulating them to produce chemicals called cytokines that can communicate with the brain and influence its physiology; gut microbes can also play a role in the metabolism of an amino acid called tryptophan, which is the precursor to serotonin neurotransmitter. If the bacteria that are involved in this process are low in number due to disturbances, less serotonin is produced; other neurotransmitters such as dopamine, gamma aminobutyric acid (GABA) and brain derived neurotrophic factor (BDNF) are also produced by bacterial species in the gut.

3. The gut produces many neurotransmitters. Therefore, an imbalance in the microbiome could lead to an imbalance in neurotransmitter production and this could alter nervous communication and lead to anxiety/depression. Also, disruption to the microbiome can lead to leaky gut syndrome and neuroinflammation. Evidence suggests that neuroinflammation increases risk of anxiety/depression.

4. A nutrient dense diet that is high in fibre and low in fats, sugars and processed foods.

Topic 3 Review Test

1. (a) a–liver b–salivary gland c – oesophagus d–large intestine (or colon)

   (b) (i) Two, one-way sphincters regulate the transit of food into and out of the stomach. Once the food has been broken down by gastric juices it is passed into the small intestine/duodenum, through the pyloric sphincter, which prevents digested food from re-entering the stomach.

   (ii) Waves of smooth muscle peristaltic contractions mix and churn the food in the stomach with the gastric juice. This mixing is physical and increases the surface area for enzymes such as pepsin to digest chemically.

   (c) (i) (1) & (2) Any two of: kills ingested bacteria; activates pepsinogen into pepsin for the digestion of enzymes.

   (ii) The digestion of lipids starts and finishes in the small intestine (duodenum). Pancreatic lipase is released from the pancreas and hydrolyses (breaks down) dietary fats by converting triglycerides into free fatty acids and glycerol.

   (iii) Large intestine

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(iv) If we eat junk food, this effectively also feeds our junk food loving bacteria, providing them with more energy to grow and reproduce. Therefore, their numbers increase and the number of signals to the brain for us to eat more junk food increases too. As we eat more junk food, the population of 'junk food eating bacteria' increases too, further signalling our brain to eat more junk food. This positive feedback loop increases the cravings we have for particular junk foods and can be hard to fight off as it is self-reinforcing.

(d) Coeliac disease or Lactose intolerance

(e) Coeliac Disease–one of: diarrhoea, gas, bloating and abdominal pain because gluten is unable to be broken down remaining in the intestines, impaired water absorption and irritation from unabsorbed fatty acids; fatigue, weakness, irritability and lethargy that can develop due to a lack of carbohydrate, vitamin and mineral absorption; anaemia can develop due to malabsorption of folate, vitamin B12, iron and protein; weight loss due to decreased fat, carbohydrate, and protein absorption; muscle cramping due to decreased calcium, and potassium absorption.

Lactose intolerance: Because lactose is unable to be broken down it remains in the intestines retaining water and bacteria ferment it producing gas and weak acids that can cause abdominal pain, bloating, diarrhoea.

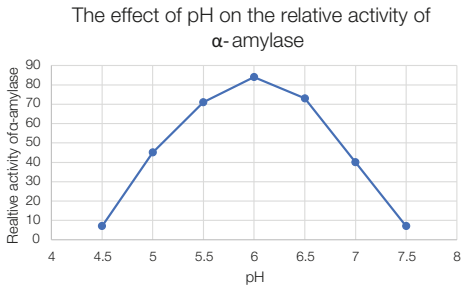
(f) There are many possible answers. Some examples are below:

Coeliac disease – bread, pasta, cereal, muesli, pies, cakes.

Lactose intolerance – milk, yoghurt, cream, soft cheese, ice cream.

2. (a) Your graph should include the following:

- title
- labels on axes
- scale
- data plot
- is a line graph



(b) pH 6.0

(c) pH

(d) One of: Temperature (37°C), amount of time (30 mins), same amount of starch, same volume of enzyme.

(e) Because after swallowing, the α-amylase would enter the stomach where the pH is much lower (more acidic) than the mouth. The acidic environment would deactivate/denature α-amylase reducing activity.

3. (a) Greater diversity increases resilience of our microbiome allowing it recover from disturbances more easily and reducing the risk of contracting diseases. A healthy variety of gut bacteria are also more able to adapt the broad range of foods we consume whilst maintaining their important functions such as preventing inflammation.

(b) Prebiotics are non-digestible carbohydrates that gut microorganisms feed on providing them with energy and promoting their growth and multiplication.

(c) There are many possible answers. Some examples are yoghurt, kefir, kombucha, sauerkraut, pickles and kimchi.

(d) Antibiotics kill both good and bad bacteria reducing the diversity of bacteria in our gut and our resilience to further gut disturbances such as infections. A reduced microbiome diversity is also linked to increased inflammation and diseases associated with inflammation such as inflammatory bowel disease, auto-immune disease and cognitive disorders. A reduced microbiome diversity is also linked with a reduction in neurotransmitters such as serotonin that can lead to anxiety and depression.

(e) A faecal transplant is when faecal matter is sourced from a 'healthy' individual and is inserted into the intestines of another patient. This transplant contains a diverse range of gut microorganisms that effectively 'reset' the microbiome and compete with the 'bad' C.diff bacteria for resources, eventually outcompeting it.

(f) One of: putting on weight. If the faecal sample comes from an overweight person their microbiome is more efficient at extracting energy from their food. This in turn extracts more energy from food for the new transplant recipient and can result in the patient becoming overweight/obese; OR, antibiotic resistance spread. The donor of the faecal matter could have antibiotic resistant bacteria in their microbiome. They could then be transferred to the patient spreading the resistance to antibiotics and increasing their chance of mortality to bacterial infections.

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(g) One of: the gastrointestinal tract can communicate directly with the hypothalamus in the brain, which is responsible for regulating emotions, via the vagus nerve; bacteria in the guts can release metabolites such as free fatty acids that can alter activity of the cells in the blood-brain barrier and its permeability; bacteria in the guts can also release chemicals that stimulate intestinal cells to release hormones that can travel to the brain and communicate with it; gut microbes can interact with the immune system cells stimulating them to produce chemicals called cytokines that can communicate with the brain and influence its physiology; gut microbes can also play a role in the metabolism of an amino acid called tryptophan, which is the precursor to serotonin neurotransmitter. If the bacteria that are involved in this process are low in number due to disturbances, less serotonin is produced; other neurotransmitters such as dopamine, gamma aminobutyric acid (GABA) and brain derived neurotrophic factor (BDNF) are also produced by bacterial species in the gut.

(h) One of: by consuming a diet high in prebiotics (fibre) that provides nutrition for a wide range of microorganisms increasing diversity in the intestines. This increases population size of microorganisms that produce neurotransmitters; by consuming a diet high in prebiotics (fibre) that provides nutrition for a wide range of microorganisms increasing diversity in the intestines. This increased diversity produces more bacteria, therefore more free fatty acid production that nourishes intestines reducing risk of inflammation and diseases associated with inflammation such as anxiety and depression.

4. (a) Because microbes can be spread from human to human.

(b) Some possible answers include:

- Because it would be unethical to eliminate the microbiome of a human to perform this study. This study would not get approved.
- Humans rely on the mutualistic relationship with their gut microbiome and they would not be ale to survive without it. Bacteria are essential to humans as they produce molecules such as vitamins and neurotransmitters required by the body.

(c) Some possible answers include:

- New research could be conducted on which specific bacterial species are producing/releasing delta-valerobetaine and then develop new drugs to target that process within the species or to kill those species without killing other beneficial microbes. Identified drugs could then be applied in trial studies to test their effectiveness in combatting obesity and identifying any side effects.
- This research could promote further research into other metabolites that the microbiome might release that impact processes promoting/reducing weight gain and obesity. Applying the technique of using microbiome-free mice to identify the impact of an identified molecule could be used to test an identified molecule(s) on interactions with known molecules that impact weight control.

Topic 4: Suggested Solutions

4.1 The psychology of food marketing

1. The repetitive nature of advertising can imprint food and drink brands in children's minds and once these brand preferences have been established it is very hard to reverse. Most of these food and drink advertisements are for products high in saturated fat, sugar and salt, which can lead to weight gain and childhood obesity when eaten regularly. By banning advertising of unhealthy products to children, they will be less likely to seek out these foods as children and this habit could follow through with them to adolescence. As a result, this could reduce the number of childhood/adolescent obesity cases projected for 2030.

2. Advertising has evolved to include online advertising. Many people use the internet daily and are exposed hundreds to thousands of times a day through email, social media, browsing the internet and many other sources.

3. (a) Adolescents use social media more frequently than other age groups and are therefore exposed to more advertising through this platform.

(b) A business could run a competition that involves consumers liking their page and referring a friend to be in the chance to win a prize.

4. (a) Energy drinks with 140% increased risk.

(b) Energy drinks generally contain a lot of sugar. The overconsumption of sugar can lead to weight gain as the excess energy that is not used can be stored as fat. In the long term it could contribute to obesity and diabetes.

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(c) People can consider yoghurts healthy because they are generally advertised as high in calcium and continuing probiotics. However, they often contain a lot of added sugar to sweeten the yoghurt.

(d) An adolescent may admire a particular celebrity and be influenced to purchase takeaway food directly or through the takeaway food service that this celebrity endorses. The adolescent could be more sympathetic to the food product if promoted by a celebrity that they admire.

4.2 Australian Dietary Guidelines

1. The Australian Dietary Guidelines (ADGs) are a set of five guidelines that promote healthy diet and lifestyle choices and reduce risk of dietary disorders. However, the Australian Guide to Healthy Eating is resource that complements the ADGs, especially the second guideline, to increase awareness of the food groups and number of serves the public should consume.

2. (a) Care for your food; prepare and store it safely.

   (b) The immunocompromised and pregnant women are more susceptible to food poisoning due to their compromised immune systems. This guideline provides information on how food should be stored and prepared to minimise the risk of contracting food poisoning and the consequences associated with it.

3. (a) Some possible answers are: Both models place a strong emphasis on eating plenty of foods from the Grains (cereal) foods, vegetables and fruits groups; both models recommend a variety of different coloured fruits and vegetables; both models recommend the intake of water in the diet daily; both models indicate that fats, oils and sugars should be eaten in small amounts.

   (b) Some possible answers are: The Healthy Living Pyramid (HLP) indicates the need for exercise whereas the Australian Guide to Healthy Eating (AGHE) does not; the HLP groups grains (cereal) foods, fruit and vegetables together, whereas the AGHE has them in separate groups; the HLP indicates that salt should be restricted whereas the AGHE does not specifically mention it.

   (c) Grain (cereal) foods, mostly wholegrain and/or high cereal fibre varieties.

   (d) Water.

   (e) Fruit juice is high in sugar and the majority of the fibre is lost in the juicing process, so it is less nutritious and filling than eating fruit.

   (f) These foods are termed 'discretionary choices.' Discretionary choices are energy dense foods and drinks that are generally high in saturated fat, sugar, salt and/or alcohol. Ongoing consumption of discretionary choices can increase weight gain and lead to dietary disorders, such as obesity, type 2 diabetes and CVD.

   (g) Males = 2.25 and Females = 2.0 serves.

   (h) Males = 5.5 – 2.25 = 3.25 serves

   Females = 5.0 – 2.0 = 3 serves

4.3 Indigenous Australians: Food changes from the traditional to the contemporary

1. Native and wild foods.

2. Traditional foods varied based on the geographical position and movement patterns of the Aboriginal tribe. The changing seasons also provided different sources of foods e.g. wattle gum in summer.

3. Aboriginal tribes favoured animal products and the men hunted animal meat (*paru*) which was harder to catch than the food sources women gathered.

4. The women gathered *mai* (vegetable food) and insects which were easier to come by and a more reliable source of food.

5. (a) There are multiple possible answers including: They are both split into the same five major food groups in the same proportions; they both have 'only sometimes and in small amounts' foods; they both suggest using oils in small amounts; they both suggest to drink plenty of water.

   (b) There are multiple possible answers including: The grains section in the Indigenous AGHE has different suggestions including bush bread (damper); the meats section in the Indigenous AGHE has kangaroo, goanna and crab but the 'normal' AGHE does not; the fruits section in the Indigenous AGHE has some native berries that the 'normal' AGHE does not.

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4.4 Nutrition in the life cycle

1. (a) Infancy.

   (b) Adolescence.

2. The elderly require less energy than children, relative to their body size, because they are generally less active and have likely lost muscle mass. Children also require more energy than the elderly, to facilitate their cognitive development and physical growth.

3. Infants receive an approximate four months' supply of iron from mothers in the third trimester and the introduction of solid foods helps supply infants with iron ongoing

4. (a) Extra protein is required for the growth spurt associated with adolescence when muscles grow, and bones increase in length to their final adult size. Extra protein is also required for the increased blood volume and the continued development of the primary sex organs.

   (b) Some possible answers are: During adolescence, teenagers may start their first job and start to earn their own money, allowing them to purchase their own food. This independence can result in poor food choices, especially if the individual is working in a fast food restaurant; A lack of nutritional literacy and cooking skills can be problematic and lead to poor food choices; adolescents can be influenced by peer pressure to make unhealthy eating choices; food companies use targeted advertising through social media to target adolescents to buy their product. Many of these food products are unhealthy and can result in poor food choices; A poor body image can lead to adolescents skipping meals and making poor food choices.

5. (a) The number of individuals meeting the exercise guidelines decreases from 18 to 79.

   (b) Approximately 24% of males meet the recommended exercise guidelines, which is 3% more than females with a total of 21%.

   (c) (i) Some possible answers are: Moving out of home can be a big lifestyle change and can be stressful. This could result in many adults' routines changing and exercise levels decreasing; during adulthood, having kids can be time consuming and tiring and adults may have less time and motivation to exercise; some adults may be focusing on their career and choosing to work over exercising.

   (ii) Some possible answers are: The accumulated loss of muscle and bone density can reduce the mobility of the elderly making it harder to exercise; the elderly are generally less balanced, increasing their risk of falling, and the thought of falling and breaking a bone during exercise can lead to the decision not to exercise; some elderly individuals could have dementia and forget to exercise, how to exercise and/or the importance of exercise; the elderly can lose loved ones, and individuals may lose the motivation to exercise, especially if they used to exercise with their lost partner.

6. (a) Menopause.

   (b) At menopause there is a significant reduction in the production of the hormone oestrogen. Oestrogen plays an essential role in building and maintaining bone density in females.

   (c) Oestrogen increases the 'good' high density lipoprotein (HDL) cholesterol count, which lowers the 'bad' low density lipoprotein (LDL) cholesterol by transporting excess cholesterol from the cells and blood back to the liver for processing. This reduces the risk of cholesterols building up against the artery walls and atherosclerosis and CVD developing.

7. (a) Some possible answers are: Required for the increased blood supply; for the development of the amniotic sac and the regular replacement of water within the sac; needed for the production of breastmilk; required for the increase in chemical reactions during pregnancy and lactation; to supply the developing foetus with its daily water needs to grow and perform chemical reactions.

   (b) Some possible answers are: Breastfeeding is safer for the baby as there is less risk of contamination of formula or bottles and contraction of diarrheic diseases; breastmilk provides babies with all their nutritional requirements and the nutritional profile changes across the course of the day and as the infant ages to supply the baby with additional nutrients as it develops; breastmilk supports immune function of babies providing them with antibodies and immune cells to help prevent contraction of and fight off pathogens; breastfed children are at lower risk of developing obesity and diabetes later in life and have shown to perform better on intelligence tests; breastmilk contains hormones that help with setting the circadian rhythm, pain and bonding with their mother; breastmilk is also important for the development of a healthy gut microbiome. Microorganisms such as bacteria are transferred through the breastmilk and through contact with the skin into the baby. Breastmilk also supplies food for the population growth of these good microorganisms; breastmilk is more easily digestible for infants than formula milk. Formula can increase the risk of digestive issues and irritability for the baby resulting in restlessness and difficulty sleeping.

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(c) Some possible answers are: It is more convenient as mothers do not have to pack formula, steriliser and bottles/teats when going out. Also, breastmilk does not need to be prepared; breastmilk results in increased oxytocin release, which increase the bond between the mother and her baby; initially, breastfeeding can help speed up the retraction of the uterus and help to lose any excess weight gained during pregnancy; mothers who don't breastfeed in accordance with the current guidelines also have an increased risk of breast and ovarian cancer, cardiovascular disease, obesity and type two diabetes, amongst other conditions.

4.5 Health promotion for specific community groups

1. The government has invested many resources into these health campaigns as a proactive approach to reduce health costs. These promotions educate the community, increasing awareness and hopefully reduce cases of preventable dietary disorders. Also, by investing in multiple campaigns different audiences can be targeted. Go for 2&5 targets families and children, whereas Measure Up targets individuals over 30.

2. (a) Adults of this age are targeted so that they can maintain or improve their own weight and be a good role model for their children.

   (b) These adults are targeted as many individuals in this age group reduce exercise and gain weight, leading to increased risk of dietary disorders that are preventable.

3. (a) (i) and (ii) Some possible answers are:

Type 2 diabetes	Fruit juice is energy dense and high in simple sugars. A large intake of simple sugars can lead to excess being stored as adipose tissue. Excessive adipose tissue can increase insulin resistance and the risk of developing type 2 diabetes.
Obesity	Fruit juice is energy dense and high in simple sugars. In addition, fruit juice is not very filling and can lead to overeating and a positive energy balance. This means that the excess energy is stored as adipose tissue and contributes to weight gain and obesity.
Hypertension	Fruit juices are high in sugar which can result in increased blood pressure. High blood pressure can cause hardening of the blood vessels.
Atherosclerosis	Increased blood glucose levels can also have an abrasive effect on the internal walls of blood vessels forming imperfections that plaques can build up against narrowing arteries.
CVD	Narrowed arteries can reduce blood flow to tissues and can eventually become blocked contributing to CVD such as heart attacks and strokes.
Constipation Diverticular disease	Fruit juices are highly processed and lose a lot of fibre through processing. Fibre helps prevent constipation by retaining water. A lack of fibre could lead to constipation and in the long term diverticular disease.
Dental caries	Children have soft teeth enamel in comparison to adults. Fruit juice is high in sugar and bacteria in the mouth can ferment remaining sugars producing acid that corrodes teeth enamel and cause dental caries. Fruit juice is also acidic ad exposure to the teeth can also contribute to dental caries.

(b) Some possible answers are: To establish healthy behaviours in children and increase likeliness to establish healthy eating behaviours in adulthood, reducing the risk of developing diet related disorders; A range of nutrients such as vitamins, minerals and fibre will be consumed, which are essential for good health, growth and development; to increase education of National Healthy Eating campaigns to promote healthy food choices and knowledge of food.

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Topic 4 Review Test

1. (a) Does knowledge about the Go for 2&5 campaign help people to improve their diet, lifestyle and health?

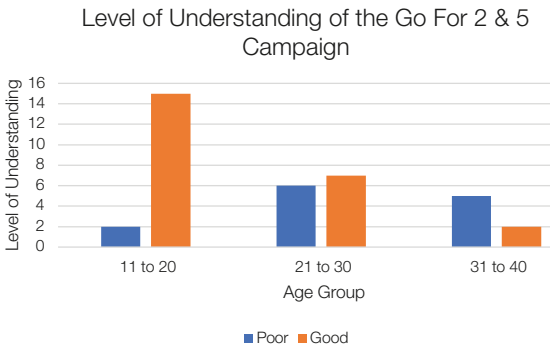
   (b) Some possible answers are: Organise a group of people that are both male and female and of a variety of age groups to survey; provide a copy of the Go for 2&5 Campaign for people to review; create a short survey that questions people's knowledge of the campaign and if it has impacted their life; record the answers from surveyed people in table and analyse results.

   (c) Some possible answers are: All participants receive the exact same survey; all participants receive the exact same copy of the Go for 2&5 Campaign; ensure that survey participants cannot talk to each other and influence others' responses.

   (d) Some possible answers are: There was non-verbal communication between participants that influenced responses; not all participants in survey received the same survey questions.

   (e) (i) Your graph should include the following:

   - title
   - labels on axes
   - scale
   - data plot with legend
   - Is a column graph

   (ii) There are multiple possible responses, one example is: People surveyed in the age group 11 – 20 years had the best understanding about the Go for 2&5 Campaign (must refer to data).

   (iii) Ensure that the same number of people in each age group were surveyed as there were 17 surveyed in the 11 to 20 age group compared to 7 in the 31 to 40 age group.

2. (a) Some possible similarities between both models are: Both models suggest water is essential; both models suggest limiting salt, sugar and fat intake (these are seen as 'Extras' or 'Sometimes or in small amounts' in the AGHE); foods are suggested in proportional amounts for both models; models are both circular and segmented; A variety of foods are required to be eaten.

   (b) Some possible reasons for not recommending the Food Wheels System are: There are no pictorial representations of appropriate food sources which could show cultural and alternative foods; there is no mention of legumes and meat alternatives to accommodate vegetarians in the Food Wheels System; the Food Wheels System recommends a very high carbohydrate intake, which is influenced by the high potato proportion; fruits and vegetables are not separated in the Food Wheels System and more vegetables should be eaten than fruits (portions are different); the Food Wheels System does not cater for different cultural and food intolerant groups as it doesn't provide alternative recommendations; the Food Wheels System does not display fish as a source of protein, only meat and fish are excellent sources.

3. (a) Some possible similarities between both models are: Both guides show suitable proportions for each food group; A variety of foods is encouraged in both models; foods are grouped according to the major nutrients supplied; both models indicate suitable processed and fresh foods; both limit the intake of 'Extras' and suggest eating in small amounts; both emphasize to drink plenty of water.

   (b) Some possible differences between both models are: The meat section is labelled differently and has different examples that are more reflective of Indigenous culture; there is greater recognition of native foods in Aboriginal and Torres Straight Islanders Guide to Healthy Eating; there is more emphasis on processed and packaged foods in the Aboriginal and Torrens Straight Islanders model; there are less examples and variety of fruits and vegetables in the Aboriginal and Torres Straight Islanders Guide to Healthy Eating; the title has a different focus, Aboriginal and Torres Straight Islanders poster Eat good food to be healthy and strong.

   (c) Traditional Aboriginal food sources varied based on the changing seasons. For example, in summer they relied more on wattle gum and edible roots were more available in the winter.

4. (a) Some possible answers are:

   - <u>Meat fish, poultry, eggs, nut and legume intake</u>

     The 4-7 age group is consuming over the recommended maximum and could result in increased fat intake from these sources contributing to obesity and increasing risk of other dietary disorders.

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- Extra foods:

  The consumption of extra foods is more than double the recommended maximum. These foods are low in nutritional benefits and are in high fat, salt and sugar.

- Vegetables:

  The consumption of vegetables is below the minimum requirements. This could result in not getting adequate micronutrients and fibre for good health.

(b) There are many possible answers but all answers need to identify the food group, the major nutrient provided by that food group and give an explanation. Some possible answers are:

- Bread, cereals, rice, pasta, noodles:

  Nutrient: Carbohydrate. Carbohydrates are important to provide the necessary energy for vital functions in the body to occur efficiently and for growth.

- Vegetables:

  Nutrient: Vitamin A. Vitamin A is important for healthy eyes and for an efficient immune system. There are many other possible nutrients and explanations such as carbohydrates and providing fibre.

- Milk, yoghurt, cheese:

  Nutrient: Calcium. Calcium is needed for the development of strong bones and teeth and to reach peak bone mass.

- Meat, fish, poultry, eggs, nuts, legumes:

  Nutrient: Iron. Iron is needed to make the protein haemoglobin that make up red blood cells which are constantly being replaced.

(c) The repetitive nature of advertising can imprint food and drink brands in children's minds and once these brand preferences have been established it is very hard to reverse. Most of these food and drink advertisements are for products likely to be in the 'Extra foods' category and are high in energy, saturated fat, sugar and salt. Behaviours developed in childhood are likely to follow through to adolescence and adulthood. This can lead to an overconsumption of these 'extra foods' contributing to weight gain and obesity.

5. (a) (i) Some possible answers are: Go for 2 and 5 promotes eating 5 vegetables. Parents can be educated to ensure their child is consuming enough serves per day; Swap it don't stop it. Families can be educated to swap processed foods for fresh vegetables e.g. chips for carrot sticks; Rite Bite (traffic lights). This program encourages schools to have more healthy foods as options that are presented to children in an easy to identify health scale.

(ii) There are many possible answers. Answers can be either a positive or negative influence. Some examples are: Having too much fun playing and not wanting to eat resulting in missed opportunities to intake vital nutrients from meals and healthy snacks; Fast food restaurants offer toys for children as part of their children's meals to attract children interest. They also often have playgrounds that children want to visit; the influence of friends at playdates can influence food choices as children generally want what their friends are eating; children parties often supply party food, which is highly processed, playdates and sleepovers with family members e.g. grandparents. Grandparents often like to spoil their grandchildren and can often feed them junk food options.

(b) (i) Some possible answers are: Eating a wide variety of nutritious foods provides a range of micronutrients such as vitamins, minerals and fibre, which are crucial to reduce a person's risk of reducing dietary disorders such as anaemia, diverticular disease, CVD and type 2 diabetes; to meet the nutrient requirements essential for good health a variety of foods from each of the five food groups daily need to be consumed. Each of the five food groups contain different foods, which vary in the amount of the key nutrients they provide; eating a wide variety of nutritious foods is sustainable long term (in comparison to fad diets); therefore, it is more likely for individuals to maintain a healthy body weight.

(ii) One of:

1. To achieve and maintain a healthy weight, be physically active and choose amounts of nutritious food and drinks to meet your energy needs.
3. Limit intake of foods containing saturated fat, added salt, added sugars and alcohol.
4. Encourage, support and promote breastfeeding.
5. Care for your food; prepare and store it safely.

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6. (a) Risk to pregnant woman: Anaemia.

Risk to foetus: May be born with neural tube defects such as spina bifida.

(b) There are many possible options but it cannot be an animal product. Some possible answers are spinach, broccoli, legumes, walnuts, flaxseeds.

(c) (i) There are many possible answers but the most obvious one is iron.

(ii) There are many possible options but it cannot be an animal product and it must be respective to answer in part (c)(i). Some possible examples are spinach, lentils, tofu, chia seeds, kale, quinoa.

7. (a) There are many possible answers. Some examples are provided in the table below:

Barrier	Strategy
Economic: Limited income to purchase food.	• She could use a senior's card for discounts at supermarkets. • She could apply for senior services through her local council for transport to shops, home cleaning, exercise classes, organised elderly activities of lunch and games. • She could plan her shopping list and purchase foods on special. • Buy in bulk to save money on purchase price and prepare meals in bulk that can be frozen and eaten throughout the week. • Buy in season and go to farmers markets to save money on produce.
Psychological: Loneliness as she is grieving and has no family support. She may lack desire to cook and eat alone. Lack of Education. Her husband could have been the cook of the household and she may not have the required skills.	• Use council services which promote and assist in social activities to attend supermarkets and lunches. This way Eleanor could make friends and shop with them. • Apply for meals on wheels in which food is delivered and social interaction is provided. This could address loneliness associated with loss of husband. • Prepare meals with foods that promote happy memories of times with husband. • Join social groups to find friends and increase social interaction. Could help increase happiness and therefore desire to cook more.
Physiological: Reduced mobility may result in inability to use equipment. This could be because of osteoporosis or muscle reduction.	• Apply for medication and use of medical allotments of physiotherapy and exercise classes to help with pain management. • Purchase semi-prepared or fully cooked meals that are ready to reheat to limit the physical pain of cooking meals. • Apply for meals on wheels to deliver food and therefore do not have to go out as often. • Use electronic kitchen tools which make food preparation easier, such as electric can openers. • Purchase foods with easy to use packaging such as pull lid cans.

8. (a) The number of children in NSW that meet the minimum recommendation of the Australian Dietary Guidelines for 4+ serves of vegetables/legumes is just approximately 11%.

(b) Boys generally require higher amounts of energy/protein/fibre than girls, and therefore plant sources of vegetables/legumes can supply this when consumed in higher amounts.

(c) Some possible answers are: Different coloured vegetables provide different key nutrients in large amounts. If only yellow vegetables were eaten an individual could be lacking key nutrients provided by other coloured vegetables; vegetables contain fibre which slows down digestion and makes us feel fuller helping with weight control. Fibre can also prevent constipations and prevents gastrointestinal diseases that occur due to lack of fibre such as diverticular disease; there are two types of vitamins: water soluble (B & C) and fat soluble (A, D, E & K). All of these vitamins are essential and must be consumed in the diet, therefore eating varied vegetables ensures all essential vitamins are eaten; each vegetable has its own unique phytonutrient profile. These phytonutrients are not essential but they can have unique benefits to the health of individuals. By consuming a variety of vegetables, a range of phytonutrients and health benefits can be obtained.

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Topic 5: Suggested Solutions

5.1 Fad foods and diets

1. (a) Kombucha is fermented and contains healthy bacteria and are known as probiotics that may improve gut health.
   (b) Some kombucha drinks are flavoured with fruit juice and contain added sugar. Sugary drinks supply excess energy and can increase the risk of obesity, type 2 diabetes and cardiovascular disease.
2. (a) The reason cold pressed juice is claimed to be healthier is because it doesn't use centrifugal fast spinning blades that produce heat and expose the fruit and vegetables to oxygen at the same time. Heat and oxygen can destroy some nutrients in juice such as vitamin C.
   (b) Drinking cold pressed juice is less filling and nutritious than eating the whole fruits and vegetables because juice does not include the skin and flesh providing nutritious fibre and other nutrients. Cold pressed juice also contains more sugar than whole fruits and vegetables.
3. Coconut oil is mostly saturated fat which can increase 'bad' low-density lipoprotein (LDL) cholesterol in the blood. This increases the risk of cholesterol building up in blood vessels and in turn cardiovascular disease.
4. (a) Some possible answers include breads, pasta, pastries, biscuits, cakes and cereals.
   (b) People without coeliac disease avoiding gluten (PWAG) increased from 44% in 2009/10 to 72% in 2013/14.
   (c) People have heard the benefits of eating a gluten free diet through word of mouth, without any medical or health expertise making it a trend.
   (d) The increase in diagnosis could be contributed to greater awareness in society and therefore greater testing.
   (e) The trending gluten free diet has resulted in a greater number and range of gluten free products available so people with coeliac disease have a greater variety to choose from and are more easily able to identify gluten free options.
5. (a) Intermittent fasting has the greatest average relevant interest of approximately 55 in comparison to the Paleo and Ketogenic diet, which have an average relevant interest of approximately 15 and 10 respectively.
   (b) The ketogenic diet has the least average relevant interest of approximately 10.
   (c) This ketogenic diet cuts out carbohydrates to put individuals into a metabolic state called ketosis where the liver converts fats into **ketones**. The aim of this is to for the body to become more efficient at using fats (rather than storing them) to supply the body with energy instead of using carbohydrates.
   (d) Grains.
   (e) Some possible answers are: Not all populations that lived during the paleolithic period consumed the same amount and types of foods. These populations generally consumed what was available in their land so that they could survive; therefore, there is not a one size fits all paleo diet; it is not possible to eat the diet that our paleolithic ancestors did because humans have selectively bred almost all the fresh produce we eat today and our paleolithic ancestor's food options are no longer available; our genomes have adapted to our changing diet and it is not necessary to cut out whole grains. Humans ability to digest starch has evolved over time with the change in food availability so that more energy can be extracted from the carbohydrates we consume.

5.2 Future foods

1. Because the human population is increasing, and more food is required to feed these extra people.
2. Because insects are a great source of protein, fats, vitamins and minerals. Insects such as crickets and locusts are high in protein and are comparable to beef, whereas others such as mealworm and black soldier flies are high in dietary fats. In fact, mealworms contain approximately the same amount of omega-3 and omega-6 essential fatty acids as fish and more than beef does. Also, some insects contain more minerals than beef such as locusts and mopane caterpillars.
3. Because insects are animals and would still have to be farmed. Many vegans do not consume any animal products, especially those that have been farmed due to ethical reasons surrounding the cruelty to animals in the production line. As algae are not animals, they would be a more appropriate alternative for vegans concerned with the ethical treatment of animals and algae such as spirulina and chlorella would provide them with a complete source of protein.
4. (a) Cultured meat is produced from culturing stem cells from animals in a lab instead of slaughtering animals to provide cuts of meat. The stem cells are provided with all the nutrients they need to grow and multiply quickly to form muscle fibres that results in a product similar to minced meat.

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(b) To allow for the increased demand due to the growing population.

(c) It is predicted to decrease from approximately 90% at 2025 to 40% at 2040.

(d) Some possible answers are: Animal farming requires a lot of land and this has resulted in a significant amount of deforestation for agriculture use. As a consequence, there are less trees to absorb atmospheric carbon dioxide, which also contributes to global warming. It is estimated that cultured meat will use approximately 99% less land, resulting in less deforestation. Individuals that are concerned with the sustainability of the environment could switch from eating conventional meat to cultured meat; animal farming also requires a lot of water. It is estimated that cultured meat production uses 90% less water than traditional animal farming. Individuals that are concerned with the sustainability of the environment could switch from eating conventional meat to cultured meat; some vegans support the development of clean meat because no animals are harmed and slaughtered in the process. Cultured meat has the potential to save the killing of billions of animals every year and could be an alternative protein option for vegans.

5. (a) A genetically modified organism is one that has had a gene or genes from other organisms transferred into its genome to provide it with a new specific trait.

(b) Not everybody has access to or can afford fresh fruits and vegetables every day and can lack vital intake of nutrients such as vitamin A. Rice does not naturally contain vitamin A so it has been genetically modified so that provitamin A is expressed in the rice grains instead of just the leaves. As rice is a widely available food and affordable, more people would be able to consume this new strain of rice and have access to vitamin A at the same time. This is especially important in developing Asian countries where vitamin A deficiency is more common.

(c) Genetically modified Atlantic salmon grow twice as fast as wild Atlantic salmon. By halving the amount of time Atlantic salmon takes to grow, twice as much farmed Atlantic GM salmon can be produced and supplied to the growing population.

6. Some possible answers are: Some high-end restaurants have incorporated food printers into their kitchen to print foods into patterns that are just not possible by humans to increase the appeal of their foods; some nursing homes are using 3D food printers to print food purees into more appetising meals. The elderly can find chewing more difficult and this can lead to under eating and malnutrition. By pureeing food, the elderly are more likely to consume the meal and reduce cases of malnutrition.

5.3 Harvest to plate

1. Some possible answers are: Consumers are seeking more information about their foods supply chain, such as where their food comes from, how it was processed and how far its travelled; consumers want to choose fresh ingredients that are locally grown and sourced; consumers want to support local farmers by purchasing their products; consumers are increasingly seeking sustainably sourced produce and purchasing directly from the source they can be assured of their purchase; purchasing directly from farmers can cut out processing and packaging saving the consumer money.

2. Farmers are able to connect directly with consumers increasing the profit margin for their product. Farmers can also be assured of the destination of their product. Some farmers may get greater satisfaction from this especially when they receive positive feedback from their customers.

3. Some possible answers are: Farmers might not be able to process their animals on site and may have trouble finding abattoirs that will process smaller amounts of animals regularly to meet the needs of consumers; to connect directly with consumers farmers also need administrative skills, packaging equipment and the ability to safely transport their product directly to the consumer; the initial costs for farmers to set up their harvest to plate business is expensive and some struggling farmers may not have the money to do so.

4. Because restaurants need to adapt to consumer trends to attract customers and increase profits. Implementing a harvest to plate business model allows restaurants to advertise this and promote that they are supporting local farmers which will attract consumers following this trend and consumers that care about supporting local farmers.

5. TruTag's anti-counterfeit technology allows foods to be tagged with a unique edible microscopic scannable tag. The microscopic tags have unique identifiable codes that can be detected by a device using a complementary iPhone or Android application. Blockchain technology stores all applicable data from harvest to plate within the microscopic tag. This allows consumers to scan their foods using their device to determine if the item they are about to purchase is legitimate and locally sourced.

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Topic 6: Suggested Solutions

6.1 Introduction

1. A healthy diet is important for the health of the mother because her body prioritises the foetus over her own needs and a depletion of her stores can increase the risk of some conditions/diseases. Also, a healthy diet can ensure enough nutrients are available for the healthy development of the foetus and reduce the risk of birth defects and developmental issues.
2. Malnutrition during critical growth periods of particular organs can increase the risk of chronic diseases of those organs due to a lack of nutrient availability and cellular growth during these periods. For example, malnutrition during the critical growth period of the pancreas can result in a reduced number of insulin producing beta cells and increased risk of diabetes type 2 developing later in life.

6.2 Nutrition during preconception

1. Because her nutrient stores can be depleted with pregnancies less than 12 months apart and this can put the mother at risk of health complications and the baby at risk of developmental issues.
2. Folate is important for DNA synthesis, which is required prior to cellular division.
3. As methotrexate prevents the absorption of folate into cells of the mother, her folate stores would be reduced. If her folate stores are reduced and she becomes pregnant again, it is less likely that she will have enough to provide to her developing baby. Folate deficiency during the early stages of pregnancy can result in neural tube defects such as spina bifida.
4. (a) Pregnant women or folate deficient anaemic individuals.

   (b) Because most people eat bread every day for breakfast or lunch and this targets a wide range of people in society.

   (c) If the pregnancy is unplanned, it is less likely that the mother has been consuming folate supplements and her folate stores may be reduced. Folic acid is needed for DNA synthesis and cell division and a lack of folate in early pregnancy can result in neural tube defects such as spina bifida. As It is hard to consume the required amount of folate in our daily diet, folic acid fortification is especially important for women with unplanned pregnancies to prevent these birth defects.

   (d) Any leafy green vegetable e.g. spinach, fruit e.g. banana, avocado, wholegrain breads and cereals, legume, almonds or yeast extract e.g. vegemite.

6.3 Food group recommendations for pregnancy and lactation

1. (a) False. The mother doesn't lactate during pregnancy.

   (b) True. The nutrient requirements increase to provide both the mother and growing foetus with nutrients such as folate.

   (c) False. The recommended dairy servings are increased by half a serve to ensure there is enough calcium for both the growing mother and foetus.

   (d) False. The fruits and vegetables servings increase to provide extra carbohydrates for energy and micronutrients.
2. An 18 year old woman requires 1 more serve of grains when lactating than when she is pregnant. This is because more energy is required by the mother during lactation than pregnancy.

6.4 Nutrition during pregnancy and lactation

1. (i) Gestational diabetes.

   (ii) Unmanaged gestational diabetes can result in high blood glucose levels (which puts extra pressure on the foetus' pancreas to increase insulin production and this results in the foetus storing the extra glucose). Unmanaged gestational diabetes is associated with increased birth weight, premature birth and increased risk of the infant developing diabetes and/or obesity later in life.

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2. It is essential that the mother consumes enough carbohydrates to fuel the growth of the foetus, especially its brain. If the mother does not consume enough carbohydrates, the protein consumed will be converted into glucose to supply the foetal brain with energy and this could result in a deficiency of protein needed for foetal growth.
3. Extra protein is required to supply the foetus/infant with amino acids for the production of proteins associated with making new cells during both pregnancy and lactation. Higher intakes of protein are also required for growth of the placenta, breasts, uterus, increased red blood cell production and production of milk.
4. Vegans only consume plant-based products, which when consumed individually do not contain all the essential amino acids. Vegans need to ensure they eat enough complementary proteins to obtain complete protein. If there is inadequate consumption of any essential amino acids by the mother, the baby will also be deficient in this amino acid(s) and this can inhibit protein synthesis and growth.
5. There are many possible answers. Table 5.4.3 can be used to identify complementary foods and design suitable meals. For example, beans, vegetables and rice would deliver complete protein as grains lack a different EAA lysine and has methionine.
6. Essential fats are vital for the brain and eye development of baby and are therefore important for cognitive and visual function.
7. The consumption of enough omega-3 fats are important for all mothers but vegan mothers may need to take more care because they can only get their omega-3 from plant sources. Plant sources contain the omega-3 ALA, which can be converted to EPA and DHA but this process is not very efficient. DHA is only found in animal source and EPA is mainly found in animal sources so vegans could find it harder to have adequate the omega-3 fatty acids DHA and EPA.
8. To reduce the risk of congenital birth defects such as cleft lip/cleft palate.
9. Vitamin B12. Vegans do not eat animal products and vitamin B12 is only found in animal products. Also, mothers with coeliac disease can have trouble absorbing nutrients such as vitamin B12 due to the destruction of villi in the small intestines.
10. Vitamin B12 is important for the maintenance of the myelin sheaths that protect nerve cells. Therefore, inadequate vitamin B12 can result in irreversible neurological damage to the baby.
11. Any three of: To support the growing placenta; extra iron is required to make the extra red blood cells associated with increased blood volume; the pregnant mother supplies iron to her foetus to aid its growth and development; to transfer enough iron stores to the baby to last the first 4 to 6 months.
12. The mother's body transfers iron to the foetus to be stored; however, these stores only last 4 to 6 months. Starting on solid food at this time allows infants to replenish their iron stores and reduce the risk of becoming iron deficient.
13. Severe anaemia can reduce the amount of oxygen delivered to the developing foetus. This can delay the development of the foetus and could result in premature birth which is associated with low birth weight and possible respiratory issues.
14. This is because the mother's body becomes more efficient at absorbing calcium from the diet. Under normal circumstances, about 30% of calcium is absorbed from the diet but a pregnant woman's body can absorb closer to 50% supplying 20% more calcium of the RDI.
15. The mother could experience reduced bone density which can increase her risk of bone breakages and osteoporosis.
16. Two of: Sunlight exposure, salmon, halibut, herring, tuna, Atlantic mackerel, oysters, shrimp, cheese, egg yolks, beef, fortified butter or margarine.
17. Vitamin D is a fat-soluble vitamin that requires fats to be consumed with it so that it can be absorbed across the intestinal lining and margarine is high in fat content. Also, most people consume margarine often with toast, sandwiches, etc. increasing the amount of people this fortification can reach. Another possible reason is that margarine is safe for pregnant and lactating women to consume again increasing the accessibility of this fortification.
18. (i) Rickets.

    (ii) Rickets is a disease where the bones fail to develop properly because there is not enough calcium and this results in skeletal abnormalities such as bowed legs.

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19. (i) Some possible reasons for this re-emergence are: the decreased use of iodised salt in processed foods and cooking at home and restaurants, and less iodine in the soil due to non-sustainable farming techniques (one required).

    (ii) To address this re-emergence, the Australian government has mandated iodine fortification of wheat flour used to make bread, etc.

20. Some possible answers are: Fish, such as cod and tuna and seafood such as shrimp; dairy products, such as milk, cheese and yoghurt; seaweed; fortified breads (except organic bread); iodised salt.

21. When an unplanned pregnancy occurs, the mother is less likely to be taking vitamin supplements that include iodine. As most women eat bread, they are able to get extra iodine from the bread they consume to help them reach the increased RDI during pregnancy. Iodine is essential to the development of the baby's brain and nervous system. If the mother is deficient during pregnancy it can result in stunted growth, diminished intelligence and even retardation. Severe iodine deficiency during pregnancy can cause cretinism, which is irreversible mental and physical retardation.

22. Zinc is essential for normal growth and development in bones, the brain and many other parts of the body. Zinc is also essential for DNA and RNA synthesis and thyroid hormone function.

23. Because vitamin E stores are transferred from the mother to the baby in the last couple of weeks of pregnancy. If the baby is born early and this transfer is unable to occur, the infant may need to be supplemented.

24. Vitamin K is produced by bacteria in the intestines; however, infants are not born with a developed microbiome and this takes time to develop. Therefore, vitamin K supplementation is required to reduce the risk of haemorrhaging and bleeding in the brain and brain damage.

25. Some possible answers are: Required for the increased blood supply; for the development of the amniotic sac and the regular replacement of water within the sac; needed for the production of breastmilk; required for the increase in chemical reactions during pregnancy and lactation; to supply the developing foetus with its daily water needs to grow and perform chemical reactions.

26. Some possible answers are: Breastfeeding is safer for the baby as there is less risk of contamination of formula or bottles and contraction of diarrheic diseases; breastmilk provides babies with all their nutritional requirements and the nutritional profile changes across the course of the day and as the infant ages to supply the baby with additional nutrients as it develops; breastmilk supports immune function of babies providing them with antibodies and immune cells to help prevent contraction of and fight off pathogens; breastfed children are at lower risk of developing obesity and diabetes later in life and have shown to perform better on intelligence tests; breastmilk contains hormones that help with setting the circadian rhythm, pain and bonding with their mother; breastmilk is also important for the development of a healthy gut microbiome. Microorganisms such as bacteria are transferred through the breastmilk and through contact with the skin into the baby. Breastmilk also supplies food for the population growth of these good microorganisms; breastmilk is more easily digestible for infants than formula milk. Formula can increase the risk of digestive issues and irritability for the baby resulting in restlessness and difficulty sleeping.

27. Some possible answers are: It is more convenient as mothers do not have to pack formula, steriliser and bottles/teats when going out. Also, breastmilk does not need to be prepared; breastmilk results in increased oxytocin release, which increase the bond between the mother and her baby; initially, breastfeeding can help speed up the retraction of the uterus and help to lose any excess weight gained during pregnancy; mothers who don't breastfeed in accordance with the current guidelines also have an increased risk of breast and ovarian cancer, cardiovascular disease, obesity and type two diabetes, amongst other conditions.

28. (a) 200mg

    (b) Some possible answers are:

    - Caffeine can interfere with iron and calcium absorption, reducing the bioavailability of these minerals for the mother to supply her baby with.
    - Caffeine can increase the blood pressure of the mother especially when consumed in large doses. The mother's blood pressure is already naturally increased during pregnancy putting extra pressure on the circulatory system.
    - There is a possible link between the excess consumption of caffeine during pregnancy and low birth weights of babies, indicating it could affect the short and long-term health outcomes for the infant.

    (c) Any three of: Hinder the development of the foetus; premature birth; stillbirth; miscarriage; birth defects; foetal alcohol spectrum disorder (learning and behavioural difficulties).

    (d) Alcohol can reduce the amount of breastmilk produced by the mother, decreasing the amount of food for her infant and this could decrease its growth and development.

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6.5 Food contamination

Author's note: Please see the questions and suggested solutions for 'Topic 8.2: Food contamination' for this subtopic.

Topic 6 Review Test

1. Some possible answers are:
   - This woman should immediately stop consuming alcohol (light beer) because it can cross the placenta and cause developmental issues in foetus. Instead she should replace the beers with water. Alcohol is a diuretic that can increase urine output. Water will help with the increased water requirements during pregnancy such as increased blood volume and the amniotic fluid.
   - She should stop eating processed meats in sandwiches such as fritz. The fritz and sauce should be replaced with cheese and salad. Processed meats have an increased risk of microbiological contamination (especially salmonella), which can lead to premature birth, still birth etc.
   - Instead of white bread for breakfast and lunch, she should consume wholegrain bread. This would provide her with more complex carbohydrates, healthy fats and micronutrients for the development of her foetus.
   - Another possible answer could be replacing the lamington with another healthier snack like carrot sticks and hummus or removing the sugar from tea/coffee. Too much sugar can increase risk of developing gestational diabetes and this can cause the baby to put on too much weight.
   - Another possible answer is swapping coffee/tea for water. Coffee and tea both contain caffeine. Too much caffeine could lead to lower birth weight in children. By replacing with water, there is more water available for increased requirements such as the increase in blood volume and amniotic sac.

2. (a) 51g [Units must be included]

   (b) **Reason 1:** Protein needs are increased by growth (structural proteins) and development of foetus

   Reason 2: Protein needs are increased for production of more red blood cells for mother and foetus

   Answers could also include points on muscle development, hormones, antibodies, enzymes, etc.

   (c) (1) 1200 mg (Units must be included)

   (2) Some possible answers are: Calcium is needed for development of baby's bones and teeth; calcium is taken from the mother's body even if she does not consume enough. This puts her at higher risk of reduced bone density that could lead to bone breakages and/or developing osteoporosis; calcium is used in the contraction relaxation of muscles, which is really important to supply heart muscle with so it can contract and circulate blood around the body.

3. (a) Because the mother's basal metabolic rate increases. There are increased energy requirements for the development of the placenta, productions of extra red blood cells, extra energy required for development of new foetal cells, etc. All of this requires more energy.

   (b) Carbohydrates (complex). Some great sources of carbohydrates are grains, legumes, vegetables, etc.

   (c) If the mother does not consume enough carbohydrates, the protein consumed will be converted into glucose to supply the foetal brain with energy and this could result in a deficiency of protein needed for foetal growth.

4. (a) Risk to pregnant woman: Anaemia.

   Risk to foetus: May develop neural tube defects such as spina bifida.

   (b) There are multiple possible answers. Some examples are spinach, kale, broccoli, lentils, fortified bread, etc.

   (c) (i) Vitamin B12 or Iron.

   (ii) Nutritional yeast or spinach (there are many possible answers for iron).

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5. (a) Some possible answers are: Women of child-bearing age (or pregnant women). Folate is needed to limit the risk of the foetus developing neural tube defects such as spina bifida. This is especially important for unplanned/unknown pregnancies; males intending to start a family. Folate is also needed for the healthy production of sperm cells (it is required for DNA synthesis). Consuming folate increases the likeliness of successful pregnancies; people with folate deficient anaemia. Most people in the population wat bread, therefore including folate in bread can reduce the risk of people developing folate deficient anaemia.

   (b) Iodine.

   (c) Iodine is essential to the development of the baby's brain and nervous system. Severe iodine deficiency during pregnancy can cause cretinism, which is irreversible mental and physical retardation.

6. (a) (i) Pregnant women are immunocompromised (suppressed immune system) due to the activity of the hormone progesterone. This is because she has a 'foreign; foetus growing inside her that has DNA from the father and a fully active immune system could result in the mother's immune system attacking the 'foreign' foetus.

   (ii) Some possible consequences to the baby include birth defects, premature birth, miscarriage and stillbirth (only 2 answers required).

   (b) (i) Some possible answers include any animal product (e.g. chicken), unpasteurised dairy products (raw milk), raw fruits and vegetables (e.g. sprouts, frozen berries).

   (ii) Salmonella poisoning can cause vomiting and diarrhoea. Both of these symptoms result in a loss of water for the mother causing dehydration.

   (iii) Water is important for the development of the foetus and dehydration during pregnancy can result in low amniotic fluid, preterm delivery and birth defects.

   (c) (i) Because listeria are present in dirt.

   (ii) Because rockmelons are grown in the dirt and may still have dirt on the outside of the rockmelon (and listeria). When rockmelons are cut by a knife or processed by machinery, the blades can transfer the listeria from the skin to the flesh of the melon (which then gets consumed).

   (iii) Aioli and mayonnaise can be made with raw eggs, which are a source of both listeria and salmonella.

   (d) (i) The number of cases increased from 1515 in 2011 to 2621 in 2019 (there was a decrease between 2019 and 2020 to 1876 cases though).

   (ii) Some possible reasons are: the increased human population means that there are more people that could possible contract listeria, there are more people getting tested for suspected food poisoning as awareness grows over time, etc. (Note: answer must be about population of EU and not at an individual level).

   (iii) The y-axis has the number 250 instead of 500 and is therefore a mistake in the scale, and the x-axis label is missing and should be "Year".

7. (a) Chemical contamination

   (b) Seafood like tuna, salmon and other fatty fish contain omega-3 fats (DHA and EPA) which are vital for the brain and eye development of the baby and are therefore important for their cognitive and visual function

   (c) Developing foetus' and infants are sensitive to toxic mercury. Mercury affects the development "of the nervous system in humans and high levels exposure during pregnancy is associated with lower learning capabilities in the affected child. As mercury is found in higher-order fish and obtained through the mother's diet, eating too much higher-order fish can increase the risk of these negative effects on the developing infant.

   (d) Alcohol can cross the placenta if consumed by the mother. The developing foetus/infant has very limited ability to digest the alcohol if exposed to it. High alcohol exposure during pregnancy can cause birth defects, foetal alcohol spectrum disorder (FASD), premature birth or miscarriage. Therefore, it is recommended not to drink any alcohol during pregnancy as no exposure to the developing foetus/infant is the safest way to eliminate the risks associated with consuming alcohol during pregnancy.

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Topic 7: Suggested Solutions

7.1 Water quality and health

1. (a) Australia has a slightly higher annual rainfall with 39mm more than South Africa and the water per capita per annum is significantly higher in Australia with 20429mm more.

   (b) Some possible answers are: Australia has a better water management system than South Africa; Australia has a lower population than South Africa so it has more water available per person.

   (c) Desalination plants produce freshwater by removing dissolved salts from seawater through reverse osmosis.

2. (a) The agriculture industry uses approximately 70% of freshwater used annually. Therefore, food security relies on a stable supply of freshwater to maintain agriculture practices.

   (b) Some forms of irrigation like flood and mist irrigation are inefficient delivery water systems because they can lose water through runoff and evaporation respectively.

3. (a) Two of: cholera, typhoid, infectious hepatitis, polio, dysentery and giardia.

   (b) Refer to Table 7.1.1. in Topic 7.

   (c) Diarrhoea causes the loss of excess water through faeces and results in dehydration. Serious cases of dehydration can cause death.

   (d) Some examples are: Using water from a water pump in the community to collect sanitized water for the family; boiling water to kill pathogens and sanitise it; using previously boiled water to cook, clean and prepare food with; using boiled water to prepare formula bottles for infants; separating bathing and washing from drinking sources of water; using available materials to make a water filter and filter water with it; the quality of water catchment could be improved by preventing contamination from faeces and fencing waterways to restrict access to animals.

   (e) Some possible examples are: The infected individual may be unable to work for the short term and earn money to pay for food and other necessities; some cases can result in death due to dehydration and this can affect household incomes and ability to pay for food and other necessities ongoing; some pathogens can remain present in the faeces for days after being infected and can result in infecting other family members. Shed faeces may also end up in the environment infecting other members of the community; children infected are unable to attend school and this can negatively affect their education; diarrhoea can result in malabsorption issues and lead to secondary malnutrition diseases such as anaemia.

4. Some possible answers include:

   (a) Birds and insects eating crops, damaged/dropped/bruised fruits/vegetables, transported in non-suitable conditions, does not meet the cosmetic standards set by supermarkets, not sold at supermarket and thrown out (past use-by date), etc.

   (b) It takes approximately 10 times the amount of water to make beef than bread (13807L more per kg). This is likely due to the fact that the main component of bread is wheat. However, cows require water to consume every day of their life, but they also require food. The crops grown to feed cows also require water to grow.

7.2 Famine

1. Famines are generally caused by multiple factors that include both environmental and political factors. An example is when a governments response or inability to respond to a natural disaster such as a drought could cause a famine.

2. (a) Asia.

   (b) Africa.

   (c) 1920s: 9 million + 1930s: 7 million + 1940s: 7 million = Approximately 23 million deaths.

   (d) Refer to Table 7.2.1 in Topic 7.

3. (a) Women are at greater risk of malnutrition in developing countries because in many cultures, women are seen as second-class citizens and can only eat what the men and boys haven't eaten (i.e. the leftovers). Many women in developing countries marry young and have large families to ensure some children survive. The numerous pregnancies decrease her iron and calcium stores and increase her risk of malnutrition.

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(b) Anaemia is a disease that involves the deficiency in the number or quality of red blood cells. Sufficient protein, iron, folate and vitamin B12 are required for the production of red blood cells and avoiding anaemia.

(c) Vitamin B3.

(d) Diarrhoea, Dermatitis and Dementia (the three D's).

(e) Because corn does not contain an absorbable form of vitamin B3, therefore citizens of Venda without access to other foods that supply vitamin B3 may become deficient and develop pellagra.

7.3 Sustainable food futures

1. Because the human population is increasing, and more food is required to feed these extra people.
2. (a) A genetically modified organism is one that has had a gene or genes from other organisms transferred into its genome to provide it with a new specific trait.

   (b) Herbicide resistant soybean can be sprayed with herbicide and will not be killed. This means that farmers growing this crop can spray their fields with herbicide and the weeds will be killed but the herbicide resistant soybean will not. As a result, there is less competition for nutrients with weeds and a higher yield of soybean is produced

   (c) If crops can be genetically modified to fix their own nitrogen from the atmosphere there is no need to apply nitrogen-based fertilisers to these crops. With reduced use of fertiliser there would be less runoff of into waterways and therefore less eutrophication and algae blooms.
3. (a) Organic farming does not use synthetic chemicals. These include synthetic fertilisers that provide nutrients for crops to grow efficiently and synthetic insecticides and herbicides that kill insects and weeds respectively. With less destruction of crops by insects and less competition with weeds for nutrients and increased yield is produced. Organic farming incorporates natural techniques that are not as effective and therefore require more land to produce the same yield as conventional farming.

   (b) Organic farmers can use a cover crop to protect particular crops and reduce the need for insecticides. For example, stinging nettle can be grown alongside broccoli. Stinging nettle is taller than broccoli and is used as a somewhat sacrificial crop that to protect the broccoli crop from pests and increase the yield of the more profitable broccoli.

   (c) Organic produce costs more for the consumer than conventional produce. This is because organic farms produce a lower yield than conventional farming and prices are adjusted to reflect this. For example, organic bananas and eggs are 67% more expensive than conventionally grown bananas and eggs.

   (d) Refer to Table 7.3.1 for a list of possible answers.
4. (a) Vertical farms involve growing crops in vertically stacked layers, which is more efficient than conventional farming. Vertical farms often repurpose old factories in urban areas that could otherwise remain uninhabited.

   (b) As vertical farms are generally built in re-purposed old factories in urban areas, the distances required to transport the produce to supermarkets is generally much less than from conventional farms. This reduces the 'food miles' travelled and the resultant carbon emissions from the fossil fuels used to power the transport vehicle.

7.4 Waste management

1. (a) Some possible answers are food, tissues, tea bags, paper towels, egg shells, garden clippings, paper and compostable packaging.

   (b) The organic waste is industrially composted for 8 to 10 weeks. The compost then goes through a screening process to remove any contaminants such as plastics and rocks.

   (c) 25%

   (d) Organic farms do not use synthetic fertilisers and instead use compost to return valuable nutrients to their soils. The compost contains nutrients such as nitrogen and phosphorus that improves soil quality and provides nutrients for growing crops.

   (e) Organic waste that ends up in landfill is compacted and covered with soil. This results in its decomposition in anaerobic conditions (without oxygen), releasing methane as a by-product, which is 25 times more effective at trapping heat in the atmosphere than carbon dioxide.

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2. (a) Ugly fruits and vegetables do not meet the cosmetic standards of supermarkets and generally have an odd shape or small bump/lump.
   (b) Because they do not meet the strict cosmetic standards set by supermarkets, so they are thrown away to decompose.
   (c) The ugly potatoes could be cooked and mashed and sold as frozen mashed potato in supermarkets.
   (d) The ugly oranges could be used to make orange juice.
   (e) Supermarkets can relax their cosmetic standards so that more food is acceptable and doesn't get wasted. The leftover food from supermarkets could be donated to Foodbank or OzHarvest who can redistribute to charities to feed the food insecure.
3. (a) Paper and cardboard are made from trees. By recycling food packaging made from paper and cardboard they can be made into new products also made from paper/cardboard and there is less need for deforestation to source more trees to make paper/cardboard.
   (b) Because soft plastics can get jammed in the automated sorting machines.
   (c) Soft plastics must be collected separately and dropped off at the RedCycle bins commonly located at supermarkets
   (d) Some possible answers are packaging, clothes, footwear, bags, furniture, outdoor elements, automotive and building and construction.
   (e) Plastic waste that ends up in the environment can kill wildlife. Plastic packaging such as six-pack rings and single use plastic bags can cause suffocation of animals such as turtles and fish. Animals can also eat plastic waste causing them to starve. This is because the plastic takes up space in their stomach and the stomach acids cannot break the plastic down to digest it, so it remains there, blocking food from entering the small intestine

7.5 Foodbank and OzHarvest

1. Some possible answers are: supermarkets, hotels, airports, wholesalers, farmers, corporate events, catering companies, shopping centres, delis, cafes, restaurants, film and TV shoots and boardrooms.
2. When food makes its way to landfill it is decomposed by microorganisms like bacteria. This decomposition of food wastage results in the release of greenhouse gases such as carbon dioxide and methane as by-products. Therefore, reducing the amount of food that ends up in landfill reduces the amount of greenhouse gases like carbon dioxide released through its decomposition.

Topic 7 Review Test

1. (a) A genetically modified organism is one that has had a gene or genes from other organisms transferred into its genome to provide it with a new specific trait.
   (b) Pest resistant crops are genetically modified to be more resistant to attack from pests such as insects. This is due to an introduced gene which produces a protein that pierces a hole in the insects' digestive system causing death from starvation. This results in in less crop damage from insects, producing a higher yield.
   (c) The environmental impact of using manure and mineral fertilisers on food crops can cause excess to run off into nearby waterways. This can lead to eutrophication (an increase in nitrogen and phosphate levels), causing an overgrowth of algae blooms. The growth and death of algae uses up oxygen available in the water, depleting oxygen availability and causing plant and fish to die in this ecosystem.
   (d) (i) Scientists could genetically engineer pigs to be able to produce their own phytase enzyme. The genetically engineered pigs would be more efficient at digesting phosphorus and less would be present in their urine and faeces.
   (ii) Some possible answers include:
   - The successful development of these GM pigs is likely to reduce the amount of phosphorus ending up in nearby bodies of water and algae blooms. This can benefit the Australian economy as it would result in less money being spent on combating algae blooms and treating the water.
   - The successful development of these GM pigs is likely to reduce the amount of phytase enzyme fed to pigs. This means its production is likely to reduce and could result in loss of jobs as the companies reduce their production of this product. This would negatively effect these individuals

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(e) Legumes are one of the few plants that are able to complete the process of nitrogen fixing. This allows legumes to convert nitrogen gas (N_2) from the atmosphere into ammonia (NH_3), enhancing soil quality. Nitrogen is an essential nutrient required for crop growth but require it in a useable form such as ammonia. This can increase crop production and reduce the use of synthetic fertilisers, which provide a source of nitrogen to the fields.

2. The trucks required to transport produce emit carbon emissions through the combustion of fossil fuels. Vertical farms are located in urban areas so the transport miles of the produce to retailers is reduced. Although energy is required to power the LED lights and other machinery in the vertical farm, they are run off of solar power. Solar power technology uses the sun to supply energy rather than the combustion of fossil fuels, significantly reducing carbon emissions. Vertical farms are also a more efficient use of space than conventional farming, which reduces the need for further land to be cleared which increases carbon emissions from the machinery used and the release of stored carbon from cleared trees.

3. (a) Because the earth's resources are finite and all materials sent to landfill contain valuable resources that are lost when they are sent to landfill.

(b) Food waste that ends up in landfill is compacted and covered with soil. This results in its decomposition in anaerobic conditions (without oxygen), releasing methane as a by-product, which is 25 times more effective at trapping heat in the atmosphere than carbon dioxide.

(c) 4 million tonnes

(d) $\frac{4.5 \times 60}{100} = 2.7$ million tonnes

(e) The ACT with a diversion goal of 85%.

(f) SA and VIC who have both passed their target of 80% and 65% respectively in commercial waste.

(g) QLD is the furthest from achieving their target of 60%. They are currently at approximately 31%.

(h) It could be that Queensland does not have a landfill levy and other states and territories do.

4. (a) It is common for urban wastewater in developing countries to be inadequately managed due to lack of infrastructure and policy. This water is contaminated with faeces and can end up in drinking sources such as rivers, lakes and other bodies of water. Ingestion of this water could lead to the transmission of water borne diseases.

(b) Because people prioritise drinking the low supply of water over handwashing and poor hygiene can transmit disease.

(c) Any two of: diarrhoea, dehydration, nausea, vomiting and leg cramps.

(d) By filtering the water if needed and then boiling the water to kill pathogens prior to making the formula bottle.

(e) Some possible answers are: Some cases can result in death due to dehydration. The loss of life can indirectly negatively affect the community as those who have passed away can no longer contribute to the community through work, skills, culture; some pathogens can remain present in the faeces for days after being infected and can end up in the environment infecting other members of the community; children infected are unable to attend school and this can negatively affect their education and community engagement; each water borne infection adds further strain on medical resources and further stretches the country's health system.

(f) The agriculture industry uses approximately 70% of freshwater annually. Therefore, food security relies on a stable supply of freshwater to maintain agriculture practices.

(g) Some possible answers are: Natural disasters, such as floods, droughts and earthquakes; changing weather patterns due to global warming and climate change; war; unfair trade agreements; lack of infrastructure; poor governance and corruption.

5. (a) Using ladybugs to eat aphids (or another suitable example).

(b) Animals on the farm, such as sheep and geese, can eat the weeds reducing the need to use herbicides.

(c) Just over 4 billion acres more (4,000,000,000).

(d) Approximately 6 billion acres more (6,000,000,000).

(e) Organic farming does not use synthetic insecticides and herbicides to kill insects and weeds respectively. Instead they use approaches that are less efficient at doing so. They also do not use synthetic fertilisers, which provide more nutrients for crops to grow. Therefore, organic farming cannot produce the same high yields as conventional farming.

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Topic 8: Suggested Solutions

8.1 Food Safety Australia New Zealand

1. Food processing involves one or more operations such as washing, chopping, blanching, freezing, sterilising, additives, fortification and packaging.
2. Food processing can make raw foods more suitable for consumption by ensuring they are safe to eat, extend their shelf life, increase convenience and even improve the nutritional quality.
3. FSANZ is an independent agency that sets the food standards for all food businesses in Australia and New Zealand.
4. Some possible answers are: labelling requirements, food additives, vitamin and mineral fortification, microbiological limits and processing requirements, contaminants and residues, the use of new technologies such as irradiation and genetic modification of foods.

8.2 Contaminated food

1. As follows:

Example of Contamination	Physical, Chemical or Microbiological
A caterpillar in the bacon, lettuce and tomato burger	Physical
Mercury in battered fish	Chemical
Norovirus on lettuce	Microbiological
A fingernail in a bowl of pasta	Physical
Clostridium botulinum infection in tinned chickpeas	Microbiological
Rodent hair	Physical
Microplastics in honey	Chemical
Carrot cut on the same board as chicken	Microbiological
Hand sanitiser	Chemical
Cross contamination	Microbiological
Biomagnification of PCBs in seafood	Chemical
Soil from the ground when harvesting	Physical (but soil can have chemicals and microbes in it too)

2. Food spoilage is the undesirable changes to foods through physical and chemical changes that makes food less appealing, reducing the likeliness of their consumption. Most microbes that cause food spoilage are not pathogenic to humans and its consumption may not cause illness. Food poisoning is the illness that results from eating spoiled, contaminated or toxic food. The microbes and their toxins that cause food poisoning can commonly go unnoticed because they can be hard to detect through sight or smell.
3. Physical damage to fruits and vegetables through their processing and transport cause bruising and openings through cuts. This can increase the surface area for microorganisms to grow further reducing its shelf life. Physical damage can also accelerate its chemical deterioration.
4. The elderly are immunocompromised because their immune system weakens with age. This is because less immune cells are produced and the established white blood cells become less efficient at responding to new infections.
5. Frozen meats should be defrosted in the fridge because it is set at a temperature between 0 and 5°C (generally 3°C), which is less than the lower limit of the temperature danger zone. The growth and multiplication of pathogenic microorganisms is slowed down at temperatures between 0 and 5°C, reducing the risk of food poisoning when defrosting the meat. Whereas defrosting meat on a bench is exposing it to the temperature danger zone between 5°C and 60°C (specifically room temperature), promoting the growth of pathogenic microorganisms.

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6. Food should be reheated to temperatures at or above 75°C because most bacteria are killed at this temperature reducing the risk of food poisoning.

7. A listeria infection during pregnancy can result in premature birth, stillbirth, severe brain damage to the foetus or result in miscarriage.

8. Any four of the following: Bean sprouts; processed rockmelon; unpasteurised dairy products; soft serve ice cream; runny eggs; raw meats; soft cheeses such as brie, camembert and ricotta; processed meats; seafood such as cooked prawns and smoked seafood; sushi; prepared fruit salads and prepared salads.

9. Salmonella is generally found in animal products. It is naturally found in the gut of healthy animals and it can get into dirt and water through animal faeces and use of animal manure as fertiliser. This can ultimately infect our food grown in the soil or watered with infected water.

10. (a) *Salmonella enterica*

    (b) *Ferroplasma acidiphilum*. This is because the stomach has a pH at approximately 1.0 to 2.0 and *Ferroplasma acidiphilum* is the only listed species that can survive in that pH range (0.0-2.9).

    (c) Any two of: bread, wheat, juice, chicken, tea, noodles, potatoes, hazelnuts, skim milk or rhubarb/swiss chard.

11. (a) Jam

    (b) Jam has the highest water activity (0.75 A_w) of all the foods on the graph. The food with the highest water activity has the highest amount of free water available for microbial growth. Microbes need water for chemical reactions and growth; therefore, the food with the greatest water activity has the highest risk of microbial growth and food poisoning.

    (c) This line represents the water activity at which all growth of microorganisms is prevented.

12. (a) Methyl mercury is a bi-product of burning fossil fuels and enters the air through the combustion of coal in power plants. Rain washes the airborne methyl mercury into the oceans where they start to accumulate in small organisms like plankton. Methyl mercury is absorbed faster than it is expelled so it accumulates in organisms and passes up the food chain. This results in biomagnification of methyl mercury with the highest accumulation in the predators at the top of the food chain.

    (b) Seafood can contain various amounts of methyl mercury depending on its level in the food chain. Methyl mercury is a toxic compound that can accumulate in humans if too much contaminated seafood is consumed in a short period of time. Methyl mercury can affect neural development in the baby and is associated with reduced learning capabilities.

    (c) Microplastics can directly enter the oceans or plastic packaging that enters the oceans can degrade through exposure to UV into microplastics. These microplastics can then be swallowed by lower order species in the food chain and then bioaccumulate and pass up the ocean food chains and eventually to humans.

    (d) One of the following: Microplastics are found in the soil and air so they can accumulate on the surfaces of foods. If these foods are not washed prior to eating they can enter humans; microwavable meals are generally packaged in plastic containers and films. The heat from the microwave accelerates the leaching of microplastics from the packaging into the meal, which can then be consumed; single use water bottles naturally leach microplastics into the water they hold; however, if they are reused or left in a hot environment the leaching is increased and when consumed can enter the individual.

13. (a) Food fraud is the intentional deception using food for economic gain, which includes substitution, addition, dilution, tampering, counterfeiting or misrepresentation of food, food ingredients or food packaging.

    (b) Some possible answers are: Someone with a seafood allergy could consume it if incorrectly labelled; the purchased seafood could have greater mercury content which is particularly concerning for pregnant women; there could be a higher risk of microbial contamination due to poor processing equipment and facilities; consumers who are trying to make ethical seafood decisions may be eating seafood caught unethically.

14. (a) Listeria is found in dirt and rockmelon grow on top of the soil so the skin can be contaminated with listeria from the soil. When the rockmelon is cut, the listeria on the outside can transfer from the skin to the inside as the melon is cut by the knife.

    (b) Because the smoked salmon could be contaminated with listeria. Smoked salmon has not been heated to temperatures above 75°C which is required to kill listeria.

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8.3 Food safety

1. Ham can contain pathogenic microorganisms. Washing hands is an effective technique to kill many different microorganisms left on the hands from handling the ham. The cell membrane is made of lipids that soap molecules bind to ripping the cells apart. This kills the microorganisms and the washing process removes them from the hands preventing the cross contamination of other ingredients such as cheese and salad that may be returned to the fridge and other surfaces the contaminated hands can come in contact with.

2. (a) It is important to choose an appropriate delivery time so that the ingredients that need to be refrigerated below 5°C or frozen at –18°C are not left outside in the danger zone all day. If the food is delivered in the morning but the family is out of the house until the evening, the food items cannot be placed in an environment out of the danger zone. This could result in increased microbial growth accelerating its decomposition and increase the risk of food poisoning.

   (b) Raw meats are packaged separately from the fruits and vegetables to prevent cross contamination. Raw meat contains a lot of microorganisms and if any fluid leaked it could contaminate the other ingredients within the box. The plastic packaging is air-tight and prevents the leakage of fluid from the raw meats to the other ingredients.

   (c) Airtight packaging prevents oxygen from entering the food packaging. Oxygen is needed by microorganisms to respire and its presence can increase their growth and the foods decomposition. This can reduce the shelf life of the product. Oxidation can also cause oxidation reducing the quality of the product such as making pita bread go stale.

3. Because large casseroles that have just been cooked can take approximately 24 hours for the entire meal to cool to 5°C in a refrigerator. This means the centre of the meal is within the temperature danger zone for a long period of time, providing a suitable environment for microbial growth and increases the risk of food poisoning. A casserole that has just been cooked can also warm surrounding foods in the refrigerator, exposing these foods to the temperature danger zone. To ensure safe food storage, the casserole should be stored in multiple shallow airtight containers instead and should be cooled to a temperature between 5°C and 60°C.

4. (a) 30

   (b) The number of undeclared allergen cases has increased from 2010 to 2019. With reference to the trend line, the number of cases has increased from approximately 15 in 2010 to 41 in 2019.

   (c) Any two of: milk, peanuts, wheat/gluten, tree nuts, eggs, soy, sesame, sulphites, shellfish, fish.

8.4: Preservation methods

1. Some possible answers are: Preserving food can kill and/or slow pathogenic microorganisms and prevent food poisoning; preserving food can increase shelf life by killing and/or slowing microorganisms involved in food spoilage and deactivating enzymes involved in food spoilage; by increasing shelf life and delaying food spoilage, nutrients are retained for longer periods of time; preserved foods increase convenience for consumers as they don't have to shop as frequently and there are greater options for meal preparation.

2. Refrigeration of foods only reduces the temperature to between 0 and 5°C, which slows the growth of microorganisms preserving foods for days to weeks. However, freezing foods at 18°C also freezes the water in foods, which removes the available water for microbial growth preventing their growth and division. Freezing foods also significantly reduces the activity of enzymes involved in food decomposition.

3. Oxygen absorbers reduce oxygen availability for aerobic microorganisms reducing their ability to respire and produce energy for growth and division. The reduced oxygen also reduces the activity of oxidative enzymes and oxidation of the wraps delaying them becoming stale.

4. (a) Raw milk contains a variety of pathogenic microorganisms including salmonella and listeria that can cause severe health complications and even death if consumed.

   (b) The pasteurisation of milk heats milk to 72°C for 15 to 20 seconds which kills a lot of the microorganisms in it but the milk is not sterile so it must be stored in the fridge. However, UHT milk is heated to 138°C for two seconds making it sterile and if it is packaged aseptically it can be stored at room temperature and last for 6 to 12 months.

   (c) Pasteurisation involves heating the milk to 72°C. The heating process can destroy some of the vitamins in the milk.

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5. (a) A food dehydrator could have been used to dehydrate the apricots by evaporating the water, reducing the water activity Alternatively, the apricots could have been air dried, which would have the same effect but would take longer. Sugar could have also been added to the apricots, which bind to free water molecules, reducing water availability for microorganisms.

   (b) The reduced water activity of dried apricots means there is significantly less available water for microorganisms. Microorganisms require water to perform chemical reactions and survive. Given that the water activity of dried apricots is 0.72 all bacterial growth is prohibited as bacteria require a water activity of 0.75 or higher. Some moulds and yeast may still be able to grow on dried apricots, but their growth and division will be reduced increasing the shelf life of dried apricots.

   (c) One of the following which are not described in 5(a): dehydration, air drying, smoking, salting, adding sugar or freezing.

6. (a) Boiling vegetables involves placing them in a large pot of boiling water, which can result in water-soluble vitamins leaching into the water; however, streaming vegetables exposes the vegetables to less water reducing the loss of water-soluble vitamins in the vegetables.

   (b) Raw milk will contain more nutrients than UHT milk because it hasn't been processed. UHT involves heating the milk to 138°C for two seconds which will destroy some heat sensitive vitamins.

   (c) Both microwaving and baking foods will expose foods to heat but the microwaving exposes it for a much shorter amount of time reducing the loss of nutrients.

7. (a) Canned vegetables have 42.9% of vitamin B6 remaining compared to the 63.3% remaining in frozen vegetables. This is because the canning process exposes the vegetables to a higher temperature of 121°C for a longer period of time destroying more vitamin B6 than the 100°C of blanching prior to freezing.

   (b) Frozen fruit has 84.6% of vitamin B6 remaining compared to the 100% remaining in raw fruit. Raw fruit has not been processed and because it is fresh it has retained its vitamin B6 content at the moment, whereas prior to freezing fruit is often blanched in boiling water which can destroy some of the vitamin B6.

8.5 Fresh versus processed foods

1. (a) Some of the mechanisms involved in food processing such as heat application can destroy nutrients, such as vitamin C. Fresh foods do not go through this processing or go through minimal processing and therefore do not lose the same amount of nutrients.

   (b) Fresh foods naturally deteriorate, and this is accelerated if they are not stored properly. Many frozen vegetables are frozen quickly after being harvested and retain their remaining nutrients as the deterioration process is slowed down significantly due the extremely cold temperatures. If fresh vegetables are not stored correctly or left too long in the fridge, their deterioration can result in it having less nutrients than frozen processed vegetables.

2. (a) Antioxidants can increase shelf life of foods by preventing oxidation of molecules such as fats, preventing them from going rancid.

   (b) The addition of emulsifiers allows the water and fats/oils to mix in low-fat mayonnaise. This increases the visual appeal of the mayonnaise because the water and fats/oils are not separated into layers and allows it to have a smooth a creamy texture.

   (c) Artificial sweeteners can reduce the sugar content in foods and therefore kilojoules. Sweeteners allow the production of suitable alternative food products for diabetics and consumers who are weight conscious.

   (d) The addition of food colouring to farmed salmon feed allows the fillets of salmon to also have a pink/reddish hue and replicate the same colour as wild salmon fillets. This increases the appeal of farmed salmon fillets to consumers and they are more likely to purchase and consume, increasing sales for manufacturers.

3. (a) At point B, the number of neural tube defects decreases significantly from approximately 2.45 cases per 1000 births to 1.2 cases per 1000 births. This is because voluntary fortification of folic acid was introduced to some foods at point B.

   (b) It is mandatory for folic acid to be added to wheat flour used to make breads. Most people eat bread regularly and this allows the fortification to reach a large percentage of the population.

   (c) Women of child-bearing age and pregnant women are targets of folic acid fortification. This fortification is especially important for unplanned pregnancies to prevent neural tube defects.

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(d) Edible oil spreads are high in fat are fortified with vitamin D because vitamin D is a fat-soluble vitamin and requires fats/oil present for it to be absorbed in the small intestine.

(e) Because the use of iodised salt in processed foods and cooking at home and restaurants has decreased and there is less iodine in the soil due to non-sustainable farming techniques.

8.6: Food packaging and labelling

1. Some possible answers are: Microwaveable plastic containers and films so frozen meals don't have to be defrosted prior to heating; resealable plastic bags on food products like tortilla wraps to protect leftover wraps from exposure to oxygen and help maintain quality until eaten; cans with ring pull tops do not require can openers; packaging can separate dips and biscuits so that biscuits do not go soggy and maintain quality; honey can be purchased in squeeze bottles so that it can be easily distributed to meals without getting stuck to a spoon and wasting honey; foods can be packaged with forks, spoons, straws, pop-tops so that they can be packaged into school lunchboxes and consumed whilst in transit.
2. Food packaging supplies a suitable barrier to inhibit oxygen, moisture, light, chemicals, pests and/or microorganism from entering the product. This protects foods from contamination and exposure to factors that accelerate its decomposition, increasing the shelf life. In doing so, there is more time for the food to be consumed reducing the likeliness of it ending up as food wastage.
3. Please refer to Table 8.6.1 on page 395 for example of advantages and disadvantages of glass packaging.
4. Please refer to Table 8.6.1 on page 395 for example of advantages and disadvantages of metal packaging.
5. (a) Increases exponentially from approximately 0.7 billion tonnes in 2015 to 2.8 billion tonnes in 2050.

   (b) As the population increases, there is greater demand for food products and plastic production also needs to increase to package the foods.

   (c) Plastic waste can kill marine wildlife. Some animals such as turtles and fish can suffocate in plastic such as plastic six pack rings. Animals such as seabirds and whales can consume plastic taking up space in their stomach as it is undigestible causing them to starve. Plastic waste can also breakdown into microplastics and enter the food chain. The effect of microplastics in the food chain is not well understood but they could have detrimental health concerns such as disrupting hormonal pathways.

   (d) Compostable packaging is a more environmentally friendly packaging type. Compostable packaging is made from organic plant-based materials that can is degraded and returns nutrients to the soil without production of toxins or microplastics. This packaging can also be recycled in the green waste bin into compost.

   (e) Compostable packaging are not as sturdy as traditional plastics and can break more easily. Some plant-based materials used in compostable packaging needs to be farmed and harvested taking up land space and resources. Also, compostable packaging is more expensive than plastic alternatives.

   (f) Compostable packaging can be easily broken down in composting systems through microbial action and placed in green waste bins for industrial composting and recycling into fertiliser and doesn't produce any toxins or microplastics. Biodegradable packaging is made from plastic and other chemicals such as heavy metals. They are broken down into microplastics and toxins by microorganisms that are released into the environment. Biodegradable packaging needs to be placed in the general waste bins.
6. (a) So that consumers can make informed decisions and purchase foods based on their nutritional requirements such as avoiding allergens.

   (b) The quantity per 100g and the amount of energy in the product.

   (c) Some possible answers are: percentage labelling; food identification; information for people with food allergies or intolerances; date marking; ingredient listing; labels must tell the truth; food additives; directions for use and storage; legibility requirements; country of origin; nutrition and health claims.

   (d) Some possible answers are: Unpackaged foods such as fresh meat, fruit, vegetables and nuts as product is raw and there is nowhere to put the NIP; pre-packaged and cut fresh fruit and vegetables that can be seen through the packaging such as fruit salads; individual serves within larger packaging, for example, individual fun size chocolates. However, the NIP must be on the outer packaging; food sold in a restaurant; food made and packaged on the premises from where it is sold such as a bakery; food packaged in the presence of the customer such as a takeaway food shop; food delivered at the customer's request, for example, pizza; food sold at a fundraiser such as bake sales and sausage sizzles.

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Topic 8 Review Test

1. (a) Some possible answers are: Developing labelling requirements; set the standards for the use of safe food additives; develops standards for vitamin and mineral fortification; determines microbiological limits and processing requirements; sets standards for contaminants and residues; conducts research into the use of new technologies such as irradiation and genetic modification of foods and sets the standards; helps coordinate food recalls and alerts consumers.

   (b) (i) Women of child-bearing age planning to conceive or pregnant woman.

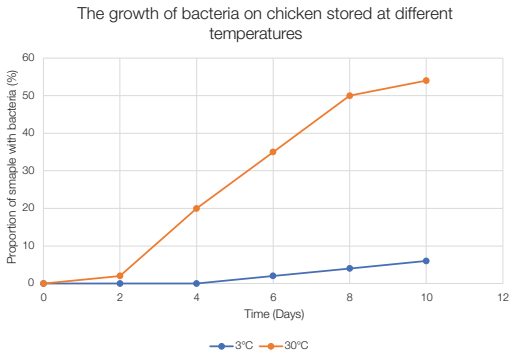
   (ii) Prior to pregnancy women need to build up their folate stores because it is required to prevent neural tube defects in the foetus. This is especially important for unplanned pregnancies. It is also needed during the first three months of pregnancy to reduce the risk of cleft palate/lip.

   (c) Some possible answers are: Unpackaged foods such as fresh meat, fruit, vegetables and nuts as product is raw and there is nowhere to put the NIP; pre-packaged and cut fresh fruit and vegetables that can be seen through the packaging such as fruit salads; individual serves within larger packaging, for example, individual fun size chocolates. However, the NIP must be on the outer packaging; food sold in a restaurant; food made and packaged on the premises from where it is sold such as a bakery; food packaged in the presence of the customer such as a takeaway food shop; food delivered at the customer's request, for example, pizza; food sold at a fundraiser such as bake sales and sausage sizzles.

2. (a) (i) Proportion of sample with bacteria (%).

   (ii) Your graph should include the following:

   - title
   - labels and units on axes
   - appropriate scales
   - data plot
   - appropriate graph type and legend



   (iii) Some possible answers are: Same size of chicken pieces; same surface area to volume ratio of the chicken pieces; meat samples are from the same chicken; age of the chicken; initial number of bacteria on piece of chicken; the same types of species on the piece of chicken (competition).

   (iv) Chicken at 30°C shows faster growth of bacteria, rising quickly from 0-54°% in 10 days, whereas the chicken at 3°C grew bacteria more slowly. This is because the chicken stored at 30°C is in the danger zone which is more favourable for microbial growth, whereas 3°C is out of the danger zone slowing the growth of microbes.

   (v) Increasing the sample size gives more samples that can be averaged reducing the effect of random errors increasing precision and reliability of the data.

   (vi) The recorded temperatures could be inaccurate due to a mis-calibrated thermometer and this could cause all data recorded to be inaccurate by the same degree. The results would be invalid.

   (b) (i) Any two of: Canning heats foods to temperatures over 100°C to kill bacteria; the canning process drives oxygen out and is vacuum sealed to reduce oxygen levels, which many microbes require for growth; the can is sealed before heating to prevent further contamination after heating.

   (ii) Some possible answers are: Many cans are not recycled and contribute to landfill and ending up in waterways; cans are not resealable, and they may require a can opener to be purchased separately; cans can become dented created micropores allowing oxygen in increasing microbial growth; therefore, the contents of dented cans shouldn't be eaten; the production of cans requires large amounts of energy are generally made using fossil fuels, which contributes to global warming; cans are made of a metal which cannot be microwaved and therefore has to be cooked or heated in another container making them less convenient than other types of packaging; nutrients such as vitamin C are lost due to heating in the canning process; cans are heavy and can be difficult for some people to carry especially if there are multiple cans purchased.

   (c) Vitamin C can be added to foods to preserve them. One way foods deteriorate is through oxidation when exposed to oxygen. If vitamin C is added, it is oxidised instead of the food preserving the food for longer.

   (d) Microbial spoilage is the end result of changes to the physical and chemical properties of the food through a process of progressive deterioration. This generally involves enzymatic action and decomposing microbes. However, microbial contamination is when pathogenic microbes have multiplied to unsafe levels for the food to be consumed. Food spoilage can also be detected due to visual cues that can

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indicate that the food may be unsafe to eat and can prevent humans from consuming it, whereas most bacteria that cause food poisoning and the toxins they release have no smell or taste and generally cannot be detected.

3. (a) **Information:** The ingredients list is incorrect.

Explanation: It states that it is 100% shallots but this cannot be true if it also contains vegetable oil.

(b) No artificial flavour or no preservatives.

(c) The shallots used to make the fried shallots would have been washed, cut, fried and packaged.

4. (a) (i) Some possible answers are: Natural bacteria in the soil or from contamination by faeces/manure; water used on the farm or to wash the fruit; pets and wild animals; contamination from harvesters including humans along the processing chain; cutting and packaging of fruit at the farm or factory.

(ii) One of the following with explanation:

- The elderly have a less efficient immune system that cannot fight off pathogenic microorganisms or their toxins as efficiently.
- Infants' immune system have not developed fully and are more susceptible to infection.
- Pregnant females' immune systems are temporarily less efficient so that they don't attack the 'foreign' developing foetus. Therefore, they are at greater risk of food poisoning.
- Any individual who is immune compromised such as people with HIV, autoimmune diseases and those on chemotherapy have weakened immune systems and more susceptible to foodborne illnesses.

(iii) Some possible answers are: More time; optimal pH conditions (generally neutral); greater water activity; temperature within danger zone 5-60°C; greater oxygen availability; less salt present.

(b) Some possible answers are: Mince can be stored correctly in the freezer at -18°C, making water unavailable for microorganism growth; chicken can be stored in the fridge at 5°C on the bottom shelf in sealed in containers, slowing down the growth of pathogenic microorganisms and reducing exposure to oxygen; hands should be washed before and after handling the raw meat such as beef, to prevent cross contamination; raw pork should be thawed in the fridge at 5°C and not on the bench, to prevent exposure to the temperature danger zone; raw meats should be kept separate from cooked ingredients and different utensils used to process them, to prevent cross contamination; meat needs to be cooked thoroughly at a temperature above 70°C to denature any possible pathogenic bacteria that could have contaminate the food source; meat needs to be cooked for a specific time to ensure that the high temperature reaches the centre or the thickest part denaturing any possible pathogenic bacteria.

5. (a) Some possible answers are:

- Transporting food over long distances, involves fossil fuels. Burning of fossil fuels creates greenhouse gases, which contribute to global warming.
- Using fossil fuels also results in the emission of other gases and particulates that cause air pollution, which are associated with reduced life expectancy.
- Long transportation distances intensify traffic congestion, resulting in lost productivity, and increase the need for more extensive infrastructure, such as more highways. This negatively impacts the environment by increasing the amount of resources such as bitumen and concrete which require fossil fuels to manufacture.

(b) (i) Some possible answers are:

Risk Factor	Packaging material to reduce risk factor	How packaging material reduces risk factor
Microbial contamination	One of: • Paper milk carton • Plastic bottle • UHT sterile packaging	• It is airtight preventing further microorganisms from entering. • Prevents oxygen from entering reducing growth of decomposing bacteria and increasing shelf life.
Loss of vitamin B2 (riboflavin)	One of: • Paper milk carton • UHT sterile packaging	Light destroys vitamin B2. Opaque packaging such as paper cartons prevents light from entering the carton.

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(ii) Some possible answers are:

Risk Factor	Packaging material to reduce risk factor	How packaging material reduces risk factor
Contamination by pests	Cardboard box with plastic bag insert.	It has two barriers and is airtight making it more difficult for pests such as insects and rodents to enter.
Water contamination	Cardboard box with plastic bag insert.	If exposed to water, the plastic bag insert prevents water from entering making cereals soggy and increasing water activity for microbial growth.

(iii) Some possible answers are:

Risk Factor	Packaging material to reduce risk factor	How packaging material reduces risk factor
Eggs cracking	Egg carton.	One of: • It separates eggs, reducing likeliness of contact and breakage. • Egg carton is sturdy enough to have other items placed on top of without eggs breaking.

Topic 9: Suggested Solutions

9.1 Basal metabolic rate, energy balance and energy systems

1. BMR is the amount of energy required by an individual while at rest and fasting to maintain vital bodily functions.
2. The elderly generally have a reduced muscle mass in comparison to adults because of muscle atrophy as they age. The less muscle a person has, the less energy is required by the body and this results in a lower BMR.
3. When people undertake kilojoule restrictive diets, their body is not receiving the amount of energy required to maintain their vital functions and daily activities. This can result in the body breaking down muscle to convert to glucose to use as energy. The more muscle lost, the less energy the body requires and the lower the BMR will be.
4. BMR = Number of Kilograms × 0.9 × 24 hours × 4.2
   = 62 × 0.9 × 24 × 4.2
   = 5624.64kJ
   = 5625kJ
5. BMR = Number of Kilograms × 0.9 × 24 hours × 4.2
   = 65 × 0.9 × 24 × 4.2
   = 5896.8kJ
   = 5897kJ

   EER = BMR × PAL Factor (very active)
   = 5897 × 2.2
   = 12,973.4 kJ
   = 10,172 kJ
6. (a) Philip

   (b) Philip is male, and males generally have more lean muscle mass than females which increases BMR. Secondly, Philip is also two years older, and has had two more years of growth than Nola. This increases the likeliness of Philip having more muscle than Nola and a higher BMR.

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(c) BMR = Number of Kilograms × 1.0 × 24 hours × 4.2
= 89 × 1.0 × 24 × 4.2
= 8971.2kJ
= 8971kJ

(d) Thermal effect of food (TEF) = 10% of total daily intake
= 0.1 × 12455
= 1245.5 kJ
= 1245.5kJ

Total daily energy expenditure = BMR + TEF + daily activity expenditure
= 8971 + 1245.5 + 3420
= 13,636.5kJ
= 13,637kJ

(e) Energy balance = total daily energy intake – total daily energy expenditure
= 12455 – 13637
= -1182kJ

(f) It is likely that Philip will lose weight because he has a negative energy balance. He is losing more energy than his body is gaining from his diet.

7. (a) Hannah

There are three possible answers:

- Hannah is taller than Cassandra, so it is likely that she has more muscle mass and therefore a greater BMR.
- Hannah is slimmer than Cassandra, therefore she could have a greater muscle mass than Cassandra and subsequently, a greater BMR.
- Hannah lives a more active lifestyle than Cassandra, therefore it is more likely that her body is composed of more muscle and has a greater BMR.

(b) BMR = Number of Kilograms × 0.9 × 24 hours × 4.2
= 73 × 0.9 × 24 × 4.2
= 6622.56kJ
= 6623kJ

Thermal effect of food (TEF) = 10% of total daily intake
= 0.1 × 10550
= 1055kJ

Daily activity expenditure = 1052 + 1268
= 2320kJ

Total daily energy expenditure = BMR + TEF + daily activity expenditure
= 6623 + 1055 + 2320
= 9998kJ

Energy balance = total daily energy intake – total daily energy expenditure
= 10550 – 9998
= 552kJ

(c) Hannah is likely to gain weight because she has a positive energy balance. The excess energy is likely to be stored as fat.

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8. (a) (i) ATP

(ii) ATP has a high energy bond between the second and third phosphate groups. This high energy bond is broken releasing energy for cells to perform work.

(b) (i) X: creatine phosphate system; Y: lactic acid fermentation; Z: aerobic respiration.

(ii) X: powerlifting; Y: 400m sprint; Z: marathon.

(c) Anaerobic respiration produced 2ATP compared to aerobics 36ATP. This is because glucose is broken down more completely in the presence of oxygen.

(d) They each provide energy for different types of activities. Creatine phosphate system provides immediate energy for short bursts of energy. Lactic acid fermentation provides energy quickly but can only be sustained for a couple of minutes. Therefore, another system is required to provide energy for activities lasting longer than a few minutes (e.g. endurance activities), which is aerobic respiration.

9.2 Nutrient requirements of athletes

1. (a) Glucose

(b) Increased endurance

(c) To replenish depleted glycogen store.

(d) Glycogen stores are used more quickly during high intensity activities.

(e) (i) Some examples include:

- extreme fatigue
- disorientation
- muscle weakness

(ii) Because there are two alternative energy providing macronutrients in protein and fat that can be utilised for the body's energy needs.

2. (a) Protein synthesis/building and repairing muscle.

(b) Sufficient carbohydrate intake prevents the breakdown and conversion of proteins into glucose when needed during exercise. Therefore, if there is insufficient carbohydrate intake, the energy can be sourced by breaking down muscle and converting to glucose.

(c) The muscles need some rebuilding following exercise involving muscle resistance, therefore sufficient amino acids supply during this timeframe is required to maximise muscle recovery.

(d) Because the protein needs of athletes are only slightly increased. Therefore, most individuals consuming a diet that meets their energy needs fulfil their protein intake requirements through their normal diet.

(e) When an athlete cannot access a meal following training or events (e.g. when they are travelling) or do not have much time to prepare a snack/meal events).

(f) Some possible examples include:

- **Creatine phosphate**. As vegan athletes do not consume animal-based products that are not consuming rich sources of creatine phosphate, which means their creatine phosphate levels could be lower than those of athletes following a diet including animal-based products.
- **Complete protein powders**: The majority of plant-based products are not complete proteins. Vegan athletes need to ensure they are not deficient in any of the essential amino acids and including a shake that has complete protein (derived from vegan sources) is one way of addressing this.
- **Vitamin B12**: As this vitamin is only found in animal-based products, vegan athletes require supplementation to ensure they have sufficient levels. This vitamin is required for maintaining healthy nerve cells and in the synthesis of new DNA and therefore cell growth and replacement (i.e. it is required for the building and repairing of muscle cells).

(g) Some examples of risks for athletes are:

- There supplement could be contaminated with toxic heavy metals or banned substances.
- Manufacturers may misidentify prohibited substances on labels, or they may omit prohibited substances from labels altogether.
- Athletes always assume the risk of testing positive for prohibited substances or experiencing negative health effects when they use supplements.

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- There are potential long term negative health impacts on kidney function (especially those with a family history).

3. (a) (i) Iron

   (ii) Some examples include: an animal based product (e.g. chicken or beef), a dark leafy green (e.g. baby spinach), tofu, legumes (e.g. kidney beans).

4. (a) Vitamin E

   (b) Fatty acids and oxygen

   (c) The breakdown of fatty acids requires a steady supply of oxygen. Cells cannot get the required oxygen for fatty acid oxidation to be the main source of energy during high-intensity exercise. As the breakdown of fatty acids is not efficient for rapid energy release, the body shifts to using carbohydrates for quick bursts of energy.

5. (a) Some possible answers include:

   - This study was only completed on mice and may result in different effects on humans due to different biochemistry. Further studies on humans are required to confirm this.
   - In this study, the mice were fed 'double the typical amount of BCAAs'. As this is not the standard amount, it is not clear if lower and more 'normal' serving sizes elicit the same response.

   (b) Some possible answers include:

   - This information could influence citizens purchasing of BCAA supplements. This could result in a reduction of BCAA sales and reduce profits for manufacturers and businesses.
   - A reduced intake of protein supplements could reduce the risk of individuals overconsuming protein in their diet. The overconsumption of protein can lead to dehydration, which can reduce the productivity of humans. Reduced work because of presenteeism can have significant effects on the amount of work conducted in a day, even more so than absenteeism. Collectively this reduces economic output.

   (c) Some possible answers include:

   - As a result of these findings, the Australian Government could ban the sales of BCAAs until further studies can confirm that they are safe for human consumption. This would involve funding further clinical studies.
   - Alternatively, the Australian Government could mandate that warnings need to be provided on the labels to make consumers aware.
   - Assuming the findings are replicated in human trials, the reduction in the consumption of BCAAs in society could reduce the cases of obesity and depression. This could reduce some of the burden placed on the health system.

9.3 Relative energy deficiency in sport (RED-S)

1. RED-S is an imbalance between energy intake and energy expenditure for an extended period, impacting various physiological systems.

2. (a) Some possible answers include:

   - Disordered eating
   - Low energy intake
   - Increased energy expenditure
   - Increased training intensity

   (b) Because teenagers are going through a growth phase and require significant amounts of energy on top of the energy required for their training and sporting events.

3. (a) Males – testosterone; Females – oestrogen.

   (b) This hormone imbalance can result in decreased bone density. As bone density increased, the bone is weakened and is more susceptible to fractures.

   (c) When an athlete has RED-S, their body may prioritise essential functions over athletic performance and bodily functions that it considers less important. As reproduction is not essential to survive at that point in time, the body conserves energy by stopping menstruation so that there is enough energy for the essential processes to continue and the individual to survive.

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4. An impaired immune function can lead to the increased susceptibility to infectious diseases and illnesses. Being sick can result in missed training days, loss of muscle and coordination and decreased performance overall.

5. The energy intake of 10,300kJ is the recommended amount for an average 19-year-old male. However, if a male athlete is consuming this intake, he is not consuming enough energy to account for the increased energy expenditure for his physical activity level and this leads to an imbalance between energy intake and energy expenditure (i.e. LEA). Chronic LEA can result in RED-S.

9.4 Factors affecting hydration

1. Some possible answers include:

   - A reduction in bodily functions.
   - Decreased endurance, power and strength.
   - Muscle cramps and/or injuries.
   - Increased risk of heat-related injuries.

2. Sweating occurs during exercise and consists of water that is then evaporated from the skin, removing it from the body. Water vapour is lost through breathing and during exercise the breathing rate increases; therefore, water vapour loss also increases.

3. (a) Electrolytes are mineral ions that are dissolved in water and contain a positive or negative charge (are electrically charged).

   (b) Electrolytes are lost through sweating along with water.

   (c) Calcium is required for muscle contraction and magnesium is required to relax the muscle following contraction. During exercise, muscle contractions are frequent and intense, requiring an adequate supply of these electrolytes to prevent muscle cramps and maintain strength.

4. Some possible answers include:

   - Because they include electrolytes, which can help increase water absorption.
   - Because sports drinks are specifically formulated with a mix of electrolytes to replace electrolytes lost through sweat.
   - Sports drinks can also be useful for athletes that do not feel like eating during or after exercise, as hey provide carbohydrates, electrolytes and water.

5. (a) (i) A substance that increases water loss from the body.

   (ii) Increased water loss leads to dehydration, which decreases the efficiency of bodily system functions and therefore athletic performance.

   (b) Coffee contains caffeine, which is a diuretic. Diuretics decrease hydration by promoting water loss in the urine. However, the water lost by the coffee's diuretic effect is effectively replaced by the water consumed in the coffee. This means there is generally no net loss or gain of water by consuming a cup of coffee.

Topic 9 Review Test

1. (a) (i) BMR = 98 × 1.0 × 24 × 4.2 = 9878.4kJ

   Thermic effect = 10% of intake
   = 10% of 9878.4kJ
   = 987.84kJ

   Daily energy expenditure = BMR + Thermic effect + Daily physical activity
   = 9878.4kJ + 987.84kJ + 6310kJ
   = 17176.24kJ

   (ii) Difference = Total intake – Daily energy expenditure
   = 15870 – 17176.24
   = -1306.24 kJ

   (iii) Kai is likely to lose weight due to his current negative energy balance of -1306.24kJ.

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(b) Relative energy deficiency in sport (RED-S)

(c) Some possible answers include:

- Kai may have decreased glycogen stores and/or a reduced ability to replenish his glycogen stores. This decreases the amount of energy available for energy purposes and his muscle strength and endurance.
- The negative energy balance can decrease concentration and therefore his ability to train with correct techniques to maximise gains during training and events.
- Kai could have impaired immune function due to his negative energy balance. This could increase his susceptibility to catch an infectious disease that he otherwise would not have caught, resulting in lost training sessions.

(d) See table below for some suggested answers:

Timing	Recommended selection	Justification
1 to 2 hours before competition	Salad sandwich	This classifies as a small snack that is generally recommended to be high in complex carbohydrates (which it is) to be consumed 1 – 2 hours prior to exercise to provide a steady source of energy and increase endurance and performance.
During competition	Gel shot	The gel shot is an easily digestible source of carbohydrates, which is quickly absorbed to provide the necessary glucose to keep muscles fueled and maintain endurance. It can also help delay the use of stored glucose and fatigue.
Shortly after competition	Chocolate milk	Chocolate milk is high in carbohydrates, which helps replenish glycogen stores. Some athletes do not feel hungry after exercise therefore a sports drink or juice may be an easy way to consume some carbohydrates post-exercise. OR Chocolate milk contains milk proteins. Proteins should be consumed in the 1 to 4 hours post exercise involving muscle resistance to improve muscle repair and recovery.

(e) (i) Hitting the wall is the shutting down of the body due to the depletion of the body's glucose stores during intense or extended exercise.

(ii) Some examples include: extreme fatigue, muscle weakness and becoming disorientated.

(iii) Because there are still other energy stores that can be used to ensure a supply of energy to the body's cells such as the conversion of amino acids to glucose, or fatty acid oxidation.

(f) Electrolytes are lost from the body through sweating during exercise. Electrolytes are crucial for muscle contractions, and the nervous messages sent to muscles during exercise. Kai has likely not been replacing his electrolytes efficiently and as a result has been experiencing cramping.

2. (a) Glucose + Oxygen → Carbon dioxide + Water

(b) Lactic acid fermentation provides 34ATP less than aerobic respiration.

(c) (i) 100m sprint. This is because most of the energy is supplied by the creatine phosphate (53%) and lactic acid systems (44%) and almost no energy supplied by aerobic respiration (3%) in A, which indicates a very short, high-intensity type of exercise.

(ii) 400m sprint: This is because most of the energy is supplied by the lactic acid fermentation system (50%), but the aerobic respiration (38%) has had some time to supply some energy in this type of exercise, indicating that this type of exercise is still high intensity, but has lasted longer than exercise type A.

(d) (i) Fatty acid oxidation.

(ii) Any activity of low to moderate intensity exceeding 20 minutes, such as walking or casual cycling.

(iii) During low to moderate-intensity activities exceeding 20 minutes, the body predominantly relies on fat stores for fuel. At this intensity, the breathing rate is slightly raised but steady, indicating that the body can supply the required oxygen to cells for fatty acid oxidation to occur.

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(e) Some possible answers include:

- Training has been shown to increase the body's ability to use fat as a source of energy during exercise. Training stimulates muscle cells to produce a greater number of mitochondria so that they can burn fat at a faster rate. This adaptation helps to spare glycogen stores.
- Training also increases the strength of the heart and lungs, improving oxygen delivery to cells for the aerobic breakdown of fatty acids to occur. This adaptation helps to spare glycogen stores.
- Training plays a crucial role in increasing the storage of glycogen in muscles. Regularly depleting muscle glycogen stores through training, signals the muscle cells to adapt to store more glycogen. The greater the amount of glycogen stores, the longer they last.

3. (a) Nitric oxide plays a crucial role in dilating blood vessels, leading to improved blood flow and oxygen delivery to muscles. This increased oxygen supply can significantly enhance an athlete's endurance.

(b) Because beetroot is not a direct source of nitric oxide (NO). Once consumed, it takes time for the nitrates in the beetroot to be converted into nitric oxide (NO) in the digestive system.

(c) Antibacterial products kill bacteria. Bacteria in the mouth is required to convert the nitrates in the beetroot into nitrates, to eventually convert into nitric oxide in the stomach. If the bacteria are killed, nitric oxide cannot be produced, and the performance benefits will not be achieved.

(d) Red urine can make it difficult to determine the level of dehydration post-exercise and therefore how much water and electrolytes are required to be consumed post-exercise.

Science as A Human Endeavour – Suggested Solutions

Topic 1: Fundamentals of nutrition

Science as A Human Endeavour 1 – Fat Burning Patch

Question 1 – Communication and Collaboration

- The scientists at Nanyang Technological University in Singapore needed to communicate their findings of this study to garner interest from biotechnology companies to fund further studies.
- If clinical trials are successful, communication will be required with the respective government bodies to get the patch approved for sale within respective countries

Question 2 – Development

- The development of the micro-needle patch required the review of a wide range of evidence prior to its development. The review of currently available delivery systems such as oral and injection produced too many side effects, so a new way of introducing the medication needed to be developed.
- The development and use of this patch could replace or complement old models of treating obesity. Instead of performing expensive and invasive surgeries, the patch could be trailed prior to approving surgery.

Question 3 – Influence

- A patch that could treat obesity would positively influence society. It could reduce the number of overweight and obese people in society and could also influence the cases of diseases associated with obesity such as diabetes and cardiovascular disease too.
- This patch could also influence plastic surgery. Each individual differs in where they store fat on their body. These patches could be used by plastic surgeons to target areas of concern for weight loss. It could possibly even influence the treatment of cellulite.
- The patches could influence the number of cases of childhood obesity. Those children that have been identified early as likely to be obese could be proactively treated using these patches to reduce the number of cases.

Question 4 – Limitations

- These studies have only been conducted on mice. It is unknown if the results will be replicated in humans at this point.
- It is unknown how many patches will be required to treat humans and if they have to be placed all over the body for there to be any benefit. Also, can these patches be used to treat cellulite? Further studies are required.

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Science as A Human Endeavour 2 – Vitamin Deficiency Wristband

Question 1 – Applications

- The application could reduce the amount of supplements society are taking unnecessarily and reduce/prevent some cases of hypervitaminosis. This could increase the health outcomes of Australian's and reduce the strain on the heath system.
- An unexpected economic consequence could occur from the application of the technology. If there is a significant decrease in vitamin sales due to the application of this device, this could lead to job losses along the vitamin chain of production and the possible closure of businesses.

Question 2 – Limitations

- The device measures vitamin loss from exercise and measuring weight and BMI, but it doesn't make any mention of accounting for someone's diet. A healthy diet may be able to account for most people's loss of vitamins anyway.
- The device measures the vitamins needed by an individual based on their exercise routine, but exercise intensity and length can differ from workout to workout and the weather. A limitation is that the packets are pre-ordered but may not be appropriate for every workout.

Science as A Human Endeavour 3 – Genetically Modified Rice

Question 1 – Applications

- The application of the genetically modified rice that produce extra micronutrients could significantly reduce the cases of iron, zinc and vitamin A deficiency in the world. This could provide a sustainable approach to improve the health outcomes of billions of people on the planet and save millions of lives each year.
- The application of the GM rice could have economic consequences for countries. Some countries export their crops to other countries where GM foods are banned. If GM rice was grown, some countries could lose their trade agreements with other countries where GM products are banned.
- This GM technology could also be applied to other crops such as bananas, which is a staple crop of Africa. This would enable African citizens that do not have access to good sources of iron, zinc and vitamin A to gain access and achieve better health outcomes. It would also be culturally respectful as bananas are a big part of their diet. Furthermore, GM rice may not be able to grow in all climates across Africa, whereas bananas can generally be grown in many areas of Africa.

Question 2 – Limitations

- The line of rice with all three micronutrients requires further study. The vitamin A content of this line is significantly less than current golden rice lines.
- Trials have only occurred in controlled environments and they need to be replicated in field trials. Only then can it be determined how much of the daily iron and zinc requirements the rice produces.
- If field trials are successful, the GM rice still needs to be approved by the relevant government body before it can be farmed, and the produce sold to consumers. There is no guarantee that the GM rice will be approved as many countries are hesitant to approve the farming of GM crops. This is because of the possible cross contamination with conventional crops, and the effect this could have on trade agreements with other countries (especially in the EU, where many countries have banned the growing and importing of GM crops).

Topic 2: Dietary disorders

Science as A Human Endeavour 4 – Tooth Mounted Sensor

Question 1 – Development

- The tooth mounted sensor developed by Tufts School of Engineering is not the first attempt at developing a sensor that can detect consumed nutrients. There have been previous models that have been much more obtrusive, such as mouthguard sensors, models that required bulky wiring and others that needed to be replaced frequently. This model is significantly less obtrusive and can stick to surfaces like tooth enamel reliably. The tooth mounted sensor is currently at the prototype stage and will require input from the engineers to extend its detecting abilities to other biochemicals and dieticians to oversee the nutrition advice that the mobile application provides is correct.
- The development of the tooth mounted sensor could improve the efficiency of counting kilojoules and amounts of other nutrients consumed. This could replace the old manual models, such as MyFitnessPal and Fitbit Health. In addition, the analysis of the data could be more efficient and notify the individual of any risks associated with undernutrition or overnutrition disorders through application alerts.

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Question 2 – Application

- The tooth mounted sensor can also detect biochemicals associated with stress and other psychological conditions. This sensor could monitor and analyse data that could be applied by dieticians and psychologists to develop tailored treatments for individuals based on their behaviour patterns and levels of biochemicals detected.
- The collection of data by the tooth mounted sensors could be analysed by health professionals on a mass scale and could give us a better understanding of the human diet and nutrition. This data could be applied to make data driven links between dietary intake and health, and identify groups that are at higher risk.

Science as A Human Endeavour 5 – Exercise Pill

Question 1 – Applications

- An exercise pill that increases Sestrin levels could be used to combat the breakdown of muscle in particular groups. It could be used to prevent muscle breakdown in individuals with injuries such as broken bones that require a cast. It could also be used for the elderly that are unable to exercise to help them reap the benefits of exercise and keep their BMR higher.
- If further research into the effect of Sestrins on humans find that it also increases fat burning without having to exercise (like it did in mice), then this could be a viable weight loss option in the future for overweight and obese individuals. This could reduce the burden on the health system, freeing up beds for patients with less manageable conditions.

Question 2 – Limitations

- At present, the effect of increased Sestrin levels have only been tested on fruit flies and mice. It is currently unknown if the same effects will be observed in humans. Further testing is required to determine these effects and what the possible side effects of increased Sestrins are. This will require additional funding and time. This means a possible treatment will not be available to the general public anytime soon.
- Even if future research determines that increased Sestrins in humans provide the same fitness and fat burning benefits as shown in mice, scientists still have to develop a drug that can be administered to humans to activate the overproduction of Sestrins. This could take a considerable amount of time and research to develop and it may not be possible.

Science as A Human Endeavour 6 –Type 1 Diabetes Vaccine

Question 1 – Influence

- A type 1 diabetes vaccine could eliminate the disease and improve the quality of life of this group within society. There would no longer be the need for type 1 diabetics to inject insulin prior to eating meals. They would also not have to worry about having a hypoglycaemic event as they slept and passing away in their sleep, improving mental health too.
- This vaccine would also have a positive influence on the economy. With less health issues associated with type 1 diabetes and eventually eradicating the disease, there would be less strain on the health system and less funding by governments required to maintain those wards within hospitals. There would also be less sick days taken, increasing productivity and economic output.

Question 2 – Limitations

- A vaccine to protect against the enterovirus CVB has been shown to be effective in protecting against this virus and preventing type 1 diabetes from developing in mice. Further clinical studies on humans are required to determine if it is successful on humans and this could take years for the trials, and then if successful to become available to the public.
- There are multiple enteroviruses and the vaccine developed that works on mice is only protective against one strain of enterovirus (CVB). It is unknown how many enteroviruses could trigger type 1 diabetes, and even if those genetically prone to developing type 1 diabetes had the vaccine for CVB administered, they could still develop it from another virus infection or environmental trigger. We don't yet fully understand the relationship between the predisposition to type 1 diabetes and all of the environmental triggers.

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Topic 3: Digestion, malabsorption and the microbiome

Science as A Human Endeavour 7 – Coeliac Disease Vaccine

Question 1 – Limitations

- The vaccine is only effective for 90% of individuals with coeliac disease. Therefore, the other 10% of sufferers still have to consume a gluten free diet. This could be more dangerous for them as food service businesses could relax their gluten free measures if the vast majority of the population is no longer affected.
- The vaccine is still only in trial phase and is not available to the public and it is unknown when this could be available and if it will pass all regulatory requirements.
- Pharmaceutical companies could charge a significant price for the vaccination and this could be unaffordable for certain families.

Question 2 – Influence

- The vaccine could influence the dietary choices of coeliac sufferers. It could make it possible for coeliac sufferers to expand their dietary choices and consume products that contain gluten. It also means that they would be at less risk of developing nutrient deficiencies as their immune system will not react to gluten and improving the quality of these individual's lives.
- It could also influence the gluten free industry as there could be a reduced demand for gluten free products. This could result in the loss of jobs in this industry if companies don't have the ability to diversify their products.

Question 3 – Communication and Collaboration

- The initial research was conducted by scientists at the Walter and Eliza Hall Institute of Medical Research (WEHI) and Royal Melbourne Hospital and this information was shared with scientists from ImmusanT Inc in the US. This communication was vital for the first Phase of trials to be conducted internationally. Additionally, ImmusanT Inc collaborated with WEHI following the Phase 1 trial so that Phase 2 trials could begin in Australia.
- Following the Phase 2 trials in Australia, the results need to be communicated with the scientific community to allow peer review. Furthermore, communication with governing bodies is required to gain approval for the use and sale of the vaccine.

Science as A Human Endeavour 8 – Genetically Engineered Probiotics

Question 1 – Limitations

- This study was conducted on mice and has not been confirmed to have the same effect in humans. As these genetically engineered probiotics may not have the same effect in humans, further research needs to be conducted.
- It is unclear whether the genetically engineered *Lactobacillus acidophilus* colonise the intestines permanently and are a long-term treatment option for colitis. Further studies need to be conducted to determine whether ongoing administration of the genetically engineered probiotics is required.

Question 2 – Applications

- Scientists could also research possible genetically engineered probiotics as treatments for other diseases associated with inflammation such as colon cancer, rheumatoid arthritis and psoriasis.
- If this treatment is approved for use on humans, its application could improve the quality of life for many people with colitis and potentially other intestinal disorders. This could also reduce the amount of sick days these individuals take increasing productivity at work, positively affecting the economy.

Topic 4: Food marketing and nutritional guidelines concepts

Science as A Human Endeavour 9 – Customer loyalty programs and artificial intelligence tracking

Question 1 – Influence

- Kitchens that could restock themselves would have a positive influence on quality of life. Many people are time poor due to the increased demands from work and increased competition within society. If the smart kitchen could detect what has been used and automatically place the order online for delivery, time is saved in both planning the shop and physically going to the supermarket.

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- Kitchens that can restock themselves could have a positive influence on health outcomes within society. With life being very busy, many households run out of fresh food and people find it difficult to get to the supermarket as often as they would like to. If there is no food to cook a nutritious dinner at home, people often resort to ordering take away food that can be energy dense and high in saturated fats. An automatically stocked kitchen could decrease the need to order takeaway meals and increase the number of nutritious meals cooked at home.

Question 2 – Communication and Collaboration

- Supermarkets need to invest in artificial intelligence (AI) technology that is designed specifically for retail. This requires communication with retail AI companies to research which AI company to analyse their consumer data so that targeted discounts can be applied.
- Most people now have smart phones and use it when they are at the supermarket. Supermarkets can communicate with app development companies to create or adjust supermarket apps to update functionality. Supermarket apps could be programmed to present targeted specials based on the login details. The app could even be programmed to present these targeted specials based on geographical location and the current aisle that customers are in.
- Collaboration between the supermarket, the retail AI company and the app development company would also be necessary to ensure that the processed data from the AI is compatible with the developed supermarket app.

Topic 5: Food trends

Science as A Human Endeavour 10 – Nutrigenomics

Question 1 – Applications

- Nutrigenomics could be applied by sports dieticians employed by professional sporting clubs to design personalised diets for athletes to maximise targeted qualities associated with their sport such as strength, endurance, speed, etc.
- Nutrigenomics could be applied to start a new type of business that designs meal kit plans based on an individual's or family's genetic markers to assist with personal goals such as diet management, weight loss or muscle gain.

Question 2 – Limitations

- It is still unclear how effective genetically matched diets actually are because there are many other factors that contribute to weight loss/gain. There are many environmental factors that play a role such as exercise, sleep, stress, psychological wellbeing and even the makeup of an individual's microbiome.
- With any collection of genetic information, there exists valid security issues with how the data is managed. Nutrigenomics companies also have to develop strong policies surrounding their collection and storage of genetic information and invest in cyber security software and employees to protect against hackers. Unless these concerns are addressed, they could limit their clientele base.

Science as A Human Endeavour 11 – Lab Grown Steaks

Question 1 – Limitations

- Growing lab grown steaks is much more complex than making lab grown burger patties because cuts of meat consist of more than just muscle cells. They also consist of blood vessels and other connective tissues. To produce lab grown steaks, complex scaffolding is required to support the various types of cell growth to replicate the cut of meat. This is very complex and more research is required before production is achieved.
- Clean meat companies are currently working on methods to upscale their production of clean meat patties to meet commercial production requirements. Until this is achieved, clean meat patties are not commercially viable to sell in supermarkets. Given that the production of clean meat patties is much further along in its development than that of lab grown steaks, and it is still not commercially viable, it may be a considerably long time before lab grown steaks become available to consumers.

Question 2 – Influence (science on society)

- The development of lab grown steaks could provide consumers with a viable protein option that is still made from animal cells but is ethically produced. This could influence consumers who are concerned about animal welfare to purchase lab grown steaks instead of cuts of meat harvested directly from animals. However, a trend towards lab grown steaks would have detrimental effects on the traditional meat industry. For example,

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it would likely result in a decreased need or demand for animal farming, which would negatively affect livestock farmers and their communities. Supply chain industries, such as butchers, could also be negatively affected if they do not adapt to the changing industry.

- If lab grown steaks become commercially viable and there is a shift in consumer preference to lab grown steaks over traditionally harvested meat, this would result in less livestock farming. Livestock farming is highly detrimental to the environment; it uses a significant amount of resources, such as land and water, and releases significant amounts of greenhouse gases into the atmosphere. The development of lab grown steaks could therefore have a positive influence on the environment by reducing land and water use and reducing greenhouse gas emissions, which contribute to global warming.

Question 3 – Influence (society on science)

- There is a growing need for more sustainable solutions to meat production. Many groups within society have been advocating for change and this message has been heard. Scientists have been influenced by this movement to research and develop clean meat as and this is close to becoming commercial. However, many people like steaks (not just a meat patty) and it is possible that a greater impact on sales could be achieved if this could be developed.
- Livestock farming is having a significant impact on land and water availability. Many climate change groups are advocating for reduced global carbon emissions. As livestock farming is a significant contributor to carbon emissions, society has influenced the development clean meat and lab grown steaks, which would reduce carbon emissions with further development and an upscaled production.

Science as A Human Endeavour 12 – 3D Printed Food

Question 1 – Applications

- The application of 3D food printers into space shuttles could allow astronauts to print themselves nutritious meals that can be eaten in the microgravity environments within space shuttles or the international space station. The ability to 3D print food could allow deeper space exploration. They could also be applied to the possible Mars exploration and settlement expeditions to provide sustainable food options for the humans involved.
- The application of 3D food printers in hospitals could allow their chefs to print nutritious meals for patients following surgery to supply vital nutrients. This could be especially useful for patients following dental surgery, such as surgery on a broken jaw, to print pureed nutritious meals that can be swallowed, as chewing is not an option for these individuals.

Question 2 – Development

- The development of food printers could replace current food preparation techniques at home. Cooking is very time consuming and not everybody has the nutritional and cooking knowledge to make healthy meals every night. In the future, 3D food printers could alleviate this problem. Researchers are aiming to develop 3D food printers that are simple to use and allow consumers to select meals that can be printed and cooked with the press of a button. If 3D food printers' development achieves this goal, it could result in less people cooking at home the traditional way because 3D printing it could be a more efficient use of time. Additionally, those individuals with poor nutritional and cooking knowledge could eat a greater variety of meals by 3D printing them.
- The development of 3D food printers to be used commercially could make the consumption of insects and algae more viable. The majority of the western world is not used to consuming insects and algae regularly, but their consumption may become necessary as the population increases. If 3D printers could be developed to 3D print pureed insects in an appealing pattern or meal, it could change the way the western world views the consumption of eating insects.

Topic 6: Nutrition and food safety during pregnancy and lactation

Science as A Human Endeavour 13 – Omega-3 Canola

Question 1 – Limitations

- Currently, the Office of Gene Technology Regulator (OGTR) has only approved the Omega-3 canola for a field trial and it hasn't been approved to be grown commercially. This obviously limits its potential use for society. Even if the OGTR does approve Omega-3 canola for commercial use, some states and territories such as South Australia and Tasmania have legislation banning farming of GM canola due to marketing concerns.

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- If commercial use is approved by the OGTR, it will still take Nuseed time to organise the crops growth and processing to release its human nutrition product, Nutriterra. This product still needs further testing for approval by the Food Standards Australia and New Zealand to be used in formula products.

Question 2 – Influence

- This technology could result in the production of a DHA supplement that has not caused harm to animals and is suitable for vegans concerned with the ethical treatment of animals to consume. This could result in better health outcomes for vegans, especially pregnant or lactating mothers (and their infants), who previously may not have been able to consume adequate DHA.
- The ability to produce DHA through GM crops instead of sourcing from deep sea fish could be more sustainable and have a positive influence on ocean ecosystems. There is currently unsustainable pressure being placed on our ocean ecosystems including sourcing omega-3 feed for salmon farmers from the oceans. If omega-3 harvested from canola can be fed to salmon instead, this would reduce pressure on the ocean ecosystems. Furthermore, fish would no longer be required to make omega-3 supplements further reducing the environmental impacts of farming the fish to make these supplements.

Science as A Human Endeavour 14 – Artificial Wombs

Question 1 – Applications

- Artificial wombs could alleviate the concern of women drinking alcohol during pregnancy and the associated negative health outcomes for the infant. Some members of society are genetically predisposed to being addicted to drugs and alcohol and it can be very hard to give up even if they want to. Having the option to have a baby externally would mean that mothers could still have their baby and not let their addiction directly affect the health of the baby.
- The application of artificial wombs could have a positive effect on the health system. If artificial wombs could deliver the precise amount of nutrients to the infants at critical growth periods, they would grow optimally and reduce the chance of developmental issues and the risk of developing certain diseases. This would relieve pressure on the health system and increase quality of life for the infants and their families. This could be of particular benefit for developing countries where malnutrition and famine is more common.
- The application of artificial wombs could allow mothers who cannot have a baby naturally to do so. There are many couples that have fertility problems and some mothers cannot carry children naturally for certain reasons such as forced removal of the uterus (hysterectomy) or ovaries (oophorectomy). This could be because of a cancer diagnosis.

Question 2 – Limitations

- At present the technology needs further research and development before it can be applied to humans for extremely premature babies and from conception. This requires time and money. There is also the potential that this research will not work for humans and may never be applied.
- It is unknown how artificial wombs will affect the development of a child's microbiome. The microbiome starts forming in the mother's womb and through the birthing process. It is unknown if artificial wombs could replicate this and if not, the adverse health outcomes for the infant.
- If the mother doesn't give birth, this could limit her ability to lactate and breastfeed her baby. It is well known that there are many benefits to the mother and baby from breastfeeding and if mothers couldn't breastfeed there could be adverse health outcomes for infants and mothers. One concern is that there could be an increased risk of infant deaths through the biological contamination of poorly sterilised formula bottles.
- If mothers choose to have their baby through artificial wombs it could limit the natural connection that develops throughout pregnancy. The developmental and emotional effects of this on the mother and child are unknown and could lead to increased anxiety and psychological issues for mother and child in the future.

Topic 7: Water and sustainable food supply

Science as A Human Endeavour 15 – Sex selection of egg laying chicks

Question 1 – Communication and Collaboration

- Egg farmers need to communicate with the CSIRO to discuss how the sex determination of pre-hatched eggs could be incorporated into their existing farming practices. Additional collaboration and communication with CSIRO may be needed to ensure technology required to select sex of pre-hatched eggs is installed onsite and working correctly.

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- They may also need to communicate with the Office of the Gene Technology Regulator (OGTR) to ensure that correct scientific procedures and safety measures have been adhered to.
- Furthermore, once the process is being applied, the egg farmers may need to communicate with pharmaceutical companies that manufacture vaccines and organise the donation or selling of their fertilised male chicken eggs to be used to create influenza vaccines.

Question 2 – Applications

- If pre-hatch sex selection could be applied to the egg farming industry, the unnecessary culling of male chicks would be prevented. As this is an ethical issue associated with the industry, people who have boycotted supporting the industry because of this may change their minds and return to eating eggs. This could increase sales for egg farmers but also add variety of food options and nutrients to these individuals' diets.
- The application of this technology could also lead to a more sustainable egg laying industry. Egg farmers would no longer have to incubate and hatch all eggs and can select the eggs that will develop into hen laying eggs. This increases the efficiency of the incubation process, requires less processing of eggs and chicks and would increase profits due to increased hen production.

Science as A Human Endeavour 16 – The Farm Robot

Question 1 – Development

- The development of RIPPA requires intensive testing and trials. RIPPA needs to be programmed to recognise individual crops. This requires onsite testing where programmers and farmers collaborate to improve the efficiency of the robot to detect insects and weeds. This requires trialling new machine learning algorithms to speed up the learning process. RIPPA could replace the old model of farmers walking along each crop row with a backpack vacuum to eliminate insects and collect rubbish from crops.
- Scientist are also developing an outdoor harvesting robot arm attachment with the ability to harvest produce. Harvesting produce is very labour intensive and if this harvesting robot arm can be developed and attached to RIPPA, this could replace the labour-intensive model with a more efficient robotic model. The development of this harvesting arm still has a long way to go because the arm needs to be able to identify the crop and if the fruit/vegetable is the right size to be picked, but it must also be developed to delicately pick the produce so that it doesn't damage it.

Question 2 – Application

- Organic farming does not use synthetic chemicals and can be very labour intensive. RIPPA the farm robot could reduce the amount of physical work required on organic farms by identifying insects and eliminating them from crops through its vacuum function. The robot could also be programmed to deliver certified natural herbicides and insecticides (instead of synthetic alternatives to individual crops) when necessary.
- RIPPA could also be programmed to scan crops to detect common insect infestations such as aphids, and alert farmers to problem areas so they can release natural predators, such as ladybugs, or spray with natural insecticide if required. The accurate scanning and detection of the number of insects could help organic farmers with their decision making as to which method is more appropriate.

Topic 8: Food processing

Science as A Human Endeavour 17 – Food Trust Platform

Question 1 – Applications

- The development of the edible barcode can be applied to many other food and drink industries including dairy, wine, spirits, seafood and other processed foods. This could allow consumers to authenticate more of their food purchases. This could also allow consumers to apply this technology to purchases when eating out at restaurants. Many restaurants have been caught serving counterfeit fish. The use of an app to detect the edible barcode could allow consumers to scan their food prior to eating and put greater pressure on restaurants to not cost cut and serve what they are advertising.
- This technology could also be applied to other industries such as tracking waste and recycling. Electronic waste and soft plastics (such as plastic bags) are often recycled at nominated drop-off points, but from here there is no oversight as to where these items end up. Research has shown that many plastic bags that have been 'recycled' end up at the dump and electronic waste that is to be recycled in Australia ends up overseas in developing countries. This technology could ensure greater oversight through the waste and recycling industry and increase consumer confidence that their efforts are not going to waste.

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Question 2 – Communication and Collaboration

- PwC is traditionally an accounting firm that has communicated and collaborated with SSAFE, multiple Universities and food industry leaders around the world to develop a food fraud vulnerability assessment tool. This communication was required to develop the assessment tool so that knowledge from various industries could be collated so that food companies could have a valid food fraud risk assessment for their individual businesses.
- Communication was required between PwC and TruTag technologies to apply the edible microchip combined with Blockchain technology to combat food fraud. PwC would also have had to communicate and collaborate with app developers to ensure the software's functionality serves the purpose for producers, processors and consumers alike, and it accessible to both iOS and Android platforms.
- Communication is also required with governing bodies such as the FDA, FSANZ and other local and international regulatory bodies to get approval for silicon dioxide chips to be used on perishable foods. This involves collating and supplying relevant information as per the requirements of each governing body. Once approved, this needs to be communicated to potential companies so they can implement, and to consumers so they can download and use the complementary app.

Question 3 – Limitations

- Although the silicon dioxide microchip has been approved for the tracking and consumption of pharmaceuticals by the FDA in America, it has not yet been approved for the use in food in Australia. Therefore, the 'edible microchip' needs to be approved by the regulatory bodies in Australia and the countries the foods are being exported to prior to its application.
- The cost of the technology is unknown and as with any new technology is likely to be expensive initially. This would mean that big companies would be able to get on board earlier and maintain their products reputation more easily in comparison to smaller companies who may not be able to afford this technology until it becomes more mainstream.

Science as A Human Endeavour 18 – New Haelen Milk Preservation Process

Question 1 – Influence

- This new process could also influence how camel, goats, sheep milk and fruit juices are preserved. This would increase the shelf life of a vast range of products reducing the amount of wastage across all levels of processing. This would have a beneficial effect on the environment with less food wastage ending up at the dump producing methane.
- This new process could also influence exports. At present there are many remote areas of China and other Asian countries that Australia exports fresh milk to by plane. This is very expensive. The new process could allow for the milk to be transported by refrigerated ships to these regions saving money and increasing profits.

Question 2 – Limitations

- Naturo released two milk products processed by the Haelen technology in 2023. However, it is not clear how long it will take for this tehnology to become mainstream and how much the Haelen processed milk will be. If it is very expensive, not everybody will be able to afford it.
- Even though the Haelen processed milk provides greater digestibility, consumer trials showed that one third of the subjects that normally experience adverse reactions to processed cow's milk, still had the adverse reactions when consuming Haelen processed milk. This means the nutritional benefits of milk can still not be accessed by everybody.

Science as a Human Endeavour 19 - Athlete Microbiome Project

Question 1 - Influence

- This discovery could influence elite sportsmen and women to have their faeces analysed for the presence of these beneficial species. If they are not present they could be encouraged to undergo a faecal transplant (poop doping) to obtain the performance benefits associated with these species residing in their guts.
- Additionally, this discovery could influence further research into the types of species that could increase endurance and performance for individuals at the elite level. This would promote more funding form sporting bodies to science, possibly creating additional jobs for scientists in this field.
- This discovery could also influence the medical field to research the benefits of these species for the general public. It could possibly provide a treatment for obesity and other diet-related disorders.

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Question 2 - Limitations

- As faecal matter does not consist of just the 'beneficial' species identified in the text, there is risk that other species that could provide disadvantages (such as increasing risk of specific disorders) are also transferred in the faeces from the particular donor. There are also other possible unknown risks and side effects that further studies may required to identify.
- As the species are limited to the intestines of elite sportsmen and women, they faecal matter for transplanting may be hard to obtain. Elite sport is very competitive, so these athlete's may not want to donate their faecal matter to reduce competition at the elite level. Additionally, as there may be limited supply, it could be very expensive for athlete's to undergo this procedure.

Science as a Human Endeavour 20 - Sweat sensors

Question 1 - Influence

- Sports science has had a big influence in the development of sweat sensors. Due to the amount of money involved in professional sport, sporting bodies are always looking for an edge to increase their performance. As hydration is important for performance, individualised real-time data is valuable information to athletes, coaches and team medics. This has influenced the research into sweat sensors.
- The increased sales of wearable health and fitness trackers has been very profitable. These companies have recognised that there is a demand for wearable devices that provide real-time health and fitness data. This combined with the potential profits, has infuenced further research into sweat sensors.

Question 2 - Applications

- Sweat sensors could be applied by athletes and coaches to in the world of sports to make better-informed decisions and improved athletic outcomes. This could be invaluable information during and after training sessions and in the lead up to events/competitions.
- These sweat sensors could be applied in the field of medicine. Because the sensor can detect many biomarkers in sweat, they could be programmed to detect specific biomarkers in the sweat that are associated with health disorders. This could be applied as a proactive approach to detect increased risk of disorders/disease and reduce the burden on an already overrun health system.

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