

SACE TWO

NUTRITION

WORKBOOK
EIGHTH EDITION

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Preface

This workbook has been written for students and educators undertaking Stage 2 Nutrition. The three topics in the This workbook has been written for students and educators undertaking Stage 2 Nutrition in 2024 and beyond. The three chapters in the book start with the Science Understandings prescribed in the new SACE Subject Outline, which was last released in late 2022. Each chapter includes a full description of the content the authors have interpreted from the SACE subject outline along with informative, coloured diagrams and links to relevant online resources to support the content. At the end of each sub chapter, the authors have also included exam style questions, case studies, science as a human endeavour questions, opportunities for students to build their science inquiry skills and extension activities where applicable. Key terms have been highlighted in bold and included as a glossary at the end of each sub chapter. Other terms are highlighted in a specific colour where their definition (orange), an interesting fact (green) or a reminder (blue) is provided in a separate box on the page.

The questions in the workbook allow students to build their confidence in addressing and applying their knowledge and understanding to a range of questions that target the SACE Performance Standards. A set of review questions have been included at the end of each sub chapter, which provide exam style questions that vary in length and difficulty. Each set of review questions equates to 60 marks, which is ideal for a single lesson. Each chapter is also supported with a 90-mark summary test, designed to support students with their revision and preparation for timed skills and application tasks and external SACE examinations. These questions ask students to recall, apply and describe their knowledge of the concepts addressed in the chapter to real world examples. An extensive set of solutions to all questions have been included in the back of the book, modelling the expected responses.

Students have been provided with patient case studies in which they are required to analyse and/or evaluate nutritional data to compare with nutrient reference values, the Australian dietary guidelines and/or the Australian Guide to Healthy Eating. This requires students to interpret data to identify undernutrition disorders, overnutrition disorders or malabsorption syndromes that the subject may be at risk of. This provides an opportunity for them to apply their knowledge and understanding of nutrition to suggest and justify modifications to the patient's food and beverage intake or lifestyle to meet their nutritional needs. Further case studies surround a focus of improving the sustainability of our food production. An exemplar response to all case study questions have been included in the solutions at the back of the book in their respective sub chapter.

The authors have presented the relevant content using real world examples through Science as a Human Endeavour (SHE). The authors have provided several SHE examples at the end of each sub chapter to demonstrate the links between science and society. These activities can be used as a strategy to get students familiar with identifying the key elements of science: communication and collaboration between scientists, governments and other agencies, the development of new technologies and theories, the influence of other areas and considerations, and the application and limitations in nutrition. Wherever possible, the authors have presented sources demonstrating nutrition from local and global perspectives. Solutions to all SHE questions have been included in the solutions at the back of the book in their respective sub chapter.

Science inquiry skills (SIS) have been provided to involve a range of practical activities where possible to allow students to develop testable hypotheses and use equipment appropriately to collect data. Students have been asked to represent and analyse this data through a range of discussion questions. Students have also been asked to evaluate procedures, describe limitations of the data, consider explanations for their observations and present and justify conclusions appropriate to their initial hypothesis. The authors hope these opportunities solidify nutrition concepts and enable students to critically consider the evidence they obtain so that they can present and justify conclusions, while applying their nutrition knowledge and understanding.

Extension activities have also been developed and supplied at the very end of each sub chapter to assist the educator in further extending their students and engaging them in the world of nutrition beyond the SACE subject outline.

We hope that you find this resource helpful, and that it demonstrates the significant role of Nutrition in the many aspects of our lives.

The authors and publisher wish you all the best for your studies in Stage 2 Nutrition.

Vicki Dent

Anastasia Toumpas

Topic 1: Principles of nutrition, physiology, and health

1

1.1 Determining Energy and Nutrient Requirements

Science understanding

- Macronutrients (proteins, carbohydrates, and lipids) are consumed daily and contribute to energy intake. Calculate total energy content of foods in kJ and percentage of energy from macronutrients, alcohol, and water, using the following energy values:
 - proteins, 16.7 kJ per gram
 - carbohydrates, 16.7 kJ per gram
 - lipids (fats), 37.7 kJ per gram
 - alcohol, 29.3 kJ per gram
 - water, 0 kJ per gram
- Compare energy intake from a macronutrient as a percentage of the total energy content with the Acceptable Macronutrient Distribution Range (AMDR).
 - 20 – 35% from fats
 - 45 – 65% from carbohydrates
 - 15 – 25% from proteins
- Daily energy needs are affected by a range of dietary, lifestyle and health factors.
- The energy required to maintain essential bodily functions when in a fasting and resting state is known as the basal metabolic rate (BMR).
 - Calculate the BMR for males using $\text{BMR (kJ)} = \text{Body weight (kg)} \times 1.0 \times 24 \text{ hours} \times 4.2$.
 - Calculate the BMR for females using $\text{BMR (kJ)} = \text{Body weight (kg)} \times 0.9 \times 24 \text{ hours} \times 4.2$.
 - Explain factors that can affect an individual's basal metabolic rate (BMR).
- Energy required by the body to digest, absorb and metabolise the nutrients consumed is estimated to be 10% of the daily energy intake, and is known as the thermic effect of food (TEF).
 - Calculate the thermic effect of food using energy intake values.
- The estimated energy expenditure (EEE) is the total amount of energy used in the body every day.
 - Calculate the EEE, using: $\text{EEE (kJ)} = \text{BMR (kJ)} + \text{TEF (kJ)} + \text{energy expended through physical activity (kJ)}$.
- A neutral energy balance is achieved when an individual's total energy intake is equal to their estimated energy expenditure.
 - Calculate the energy balance for an individual, using: $\text{Energy balance (kJ)} = \text{daily energy intake (kJ)} - \text{daily estimated energy expenditure (EEE) (kJ)}$.
 - Explain how a sustained change in energy balance could affect an individual's weight.
- Nutrient reference values (NRVs) provide recommendations of nutritional intake based on current nutrition research.
 - Explain how different nutrient reference values support a healthy nutrition intake:
 - Estimated Average Requirement (EAR)
 - Recommended Daily Intake (RDI)
 - Adequate Intake (AI)
 - Tolerable Upper Intake Level (UL)
 - Estimated Energy Requirement (EER)

SACE Subject Outline, 2024.

Energy yielding nutrients

In the human body, three nutrients can be used to provide energy: carbohydrates, proteins, and lipids. The other nutrients: vitamins, minerals and water do not provide energy to the body, and therefore are not **energy-yielding**. The energy released from carbohydrates, proteins and lipids is measured in **kilojoules** (kJ). However, in countries such as the United States, the term **calories** are still used as the preferred unit of food energy.



Fast fact

1 Calorie is equal to 4.2 kilojoules.

Most foods contain all three energy-yielding nutrients, as well as water, vitamins, and minerals. The energy stored within a food item is only released when its bonds are completely broken down in the body during metabolism. This energy is then used to fuel everyday activities, such as sending electrical impulses through the brain and nerves, moving muscles and synthesising body compounds.

The amount of energy provided depends on the quantity of carbohydrates, proteins, and lipids a food item contains. Each macronutrient yields a different number of kilojoules per gram. Carbohydrates yield approximately **16.7 kJ** per gram; protein yields **16.7 kJ** per gram and triglycerides yield the greatest amount of **37.7 kJ** per gram (as shown in Table 1.1.1). Therefore, a food item with a greater amount of lipids will provide a greater amount of energy; this food item would be energy dense.

Table 1.1.1: Energy provided by energy-yielding macronutrients.

Macronutrient	Energy (kJ/g)	Energy (calories/g)
Carbohydrate	16.7	4
Protein	16.7	4
Lipid	37.7	9

Alcohol contributes 29.3 kilojoules per gram (7 calories per gram). However, it is not considered a nutrient, as, due to its diuretic nature, it depletes the body of its nutrients and interferes with the growth, maintenance, and repair of the body. Water provides no kilojoules, contributing 0 kilojoules per gram and serves other benefits in the body (explained further in Topic 1.5: Water and Other Fluids).



Helpful online resources

Kilojoules on the menu | an introduction to kilojoules

<https://youtu.be/SsDPRP0XlqA?si=1uNSqn6nXBZyPIbs>



Calculating the composition of macronutrients in food

To calculate the energy composition from a food product, the quantity (grams) of carbohydrate, protein and lipid is multiplied by the energy provided by one gram of each of these macronutrients. These amounts are then added together. The total energy provided by a serving and 100g/ml is a legal requirement and must be displayed on all nutritional information panels (as highlighted on Figure 1.1.1).

The **energy distribution (%)** of each energy-yielding nutrient can be calculated using the following formula:

$$\text{Energy distribution} = \frac{\text{amount of energy provided per macronutrient}}{\text{total energy provided}} \times 100$$

NUTRITION INFORMATION		
Servings per package: 3		
Serving size: 150g		
	Quantity per serving	Quantity per 100 g
Energy	608 kJ	405 kJ
Protein	4.2 g	2.8 g
Fat, total	7.4 g	4.9 g
— saturated	4.5 g	3.0 g
Carbohydrate, total	18.6 g	12.4 g
— sugars	18.6 g	12.4 g
Sodium	90 mg	60 mg
Ingredients: Whole milk, concentrated skim milk, sugar, banana (8%), strawberry (6%), grape (4%), peach (2%), pineapple (2%), gelatine, culture, thickener (1442)		
All quantities above are averages		

Figure 1.1.1: The energy content per serving and per 100 g (or mL) is a legal requirement of all nutritional information panels on food products.

Example

A cup of fried rice contains 30g of carbohydrates, 5g of protein and 11g of lipids.

- (a) Calculate the total energy provided by a cup of fried rice. Show all your calculations and round your final answer to the nearest whole number.

$$30 \text{ g carbohydrate} \times 16.7 \text{ kJ/g} = 501 \text{ kJ}$$

$$5 \text{ g protein} \times 16.7 \text{ kJ/g} = 83.5 \text{ kJ}$$

$$11 \text{ g lipid} \times 37.7 \text{ kJ/g} = 414.7 \text{ kJ}$$

$$\text{Total} = 999.2 \text{ kJ} = 999 \text{ kJ}$$

- (b) Calculate the energy distribution of each macronutrient in the fried rice example above. Show all calculations and round your answers to the nearest whole number.

$$\text{Carbohydrate energy distribution} = \frac{501}{999.2} \times 100 = 50.1\% \approx 50\%$$

$$\text{Protein energy distribution} = \frac{83.5}{999.2} \times 100 = 8.4\% \approx 8\%$$

$$\text{Lipid energy distribution} = \frac{414.7}{999.2} \times 100 = 41.5\% \approx 42\%$$

1



Reminder

To confirm your calculations are correct, add up all your percentages. The total should equal 100.

Australian Acceptable Macronutrient Distribution Range (AMDR)

These percentages can then be compared to the acceptable macronutrient distribution ranges (AMDR) (Figure 1.1.2). These are recommendations for optimising the balance of macronutrient intake to reduce the risk of developing diet-related disorders, while also allowing for an adequate intake of nutrients. These ranges are set for healthy individuals who are maintaining their body weight and are not appropriate for weight loss or management of a specific health concern.

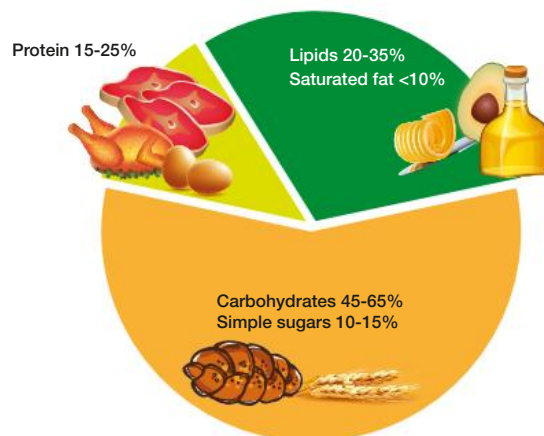


Figure 1.1.2: The acceptable macronutrient distribution ranges of each of the energy-yielding nutrients for individuals.

Example

- (c) Compare the energy distribution of each of the macronutrients in the fried rice example with those from the acceptable macronutrient distribution ranges and make suitable recommendations when necessary to ensure they meet these ranges.

Knowing that the fried rice provides 50% of its kilojoules as carbohydrates tells an individual that this is a suitable carbohydrate selection as it is within the recommended range of 45–65%. On the other hand, only 8% of the kilojoules are provided by protein, which tells an individual they need to make higher protein selections at other times of the day to meet the recommended range of 15–25%. The fried rice provides 42% of its kilojoules as lipids, which suggests that an individual should make lower lipid selections at other times of the day to keep with the recommended range of 20–35%.

Factors that Determine Energy Balance

We continuously expend energy and consume food periodically to refuel. Ideally, an individual's energy intake (energy in) should be equal to their energy expenditure (energy out), to achieve an **energy balance** and maintenance of their weight (as shown in figure 1.1.3). When the balance shifts, weight can fluctuate.

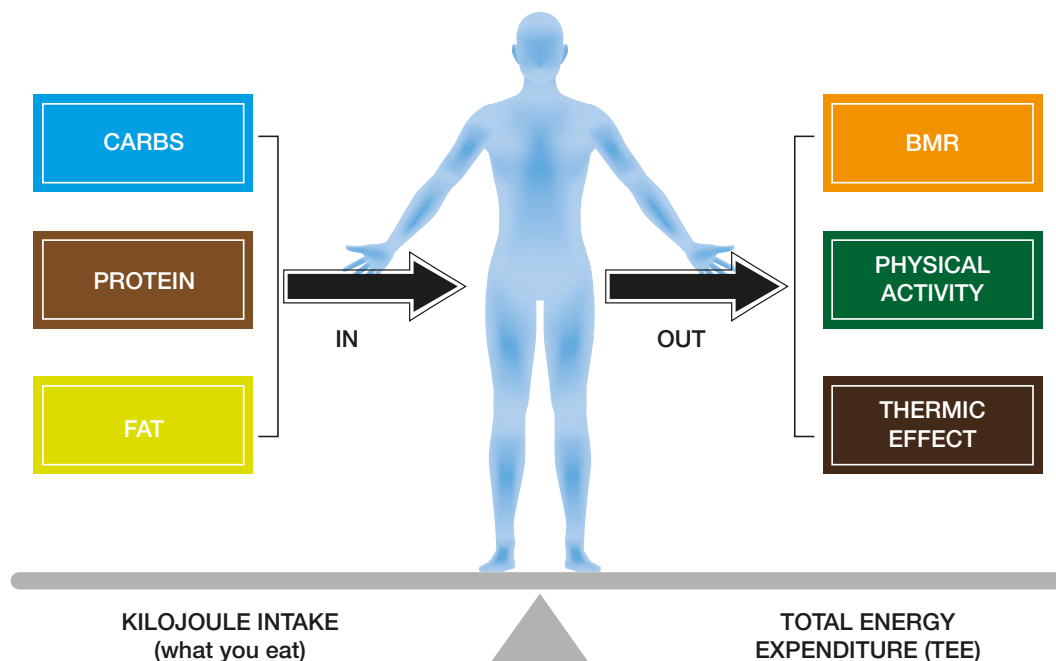


Figure 1.1.3: The energy balance, where the energy in is equal to the energy out.

A **positive energy balance** occurs when energy intake is greater than energy expenditure. That is, a person has consumed more kilojoules than the body needs. This leads to excess energy being stored as body fat, resulting in weight gain. Weight loss results from a **negative energy balance** when energy intake is less than energy used (as shown in Figure 1.1.4).

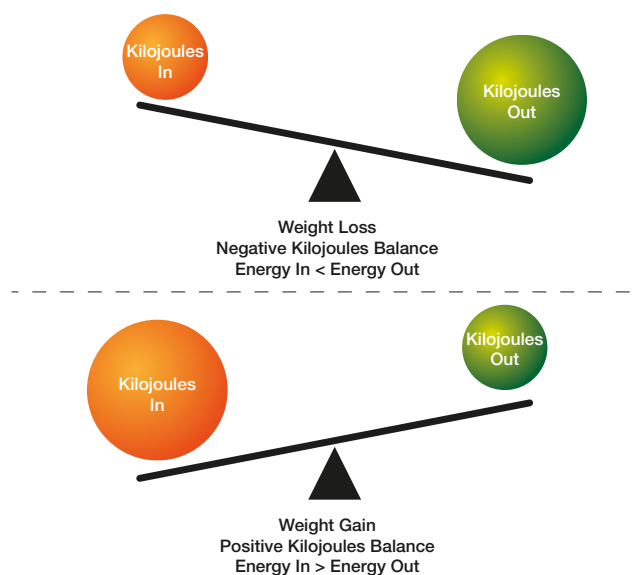


Figure 1.1.4: Positive and negative Energy Balance

Energy Intake (Energy In)

The consumption of food and beverages contributes to an individual's **energy intake**, which is dependent on the composition of food (number of kilojoules) and the amount that is eaten. The amount of food consumed must meet the nutritional needs without taking in too much or too little energy; however, a person's appetite prompts how much and how often to eat.

Energy Expenditure (Energy Out)

People expend energy when they are physically active, but they also expend energy when they are resting quietly. An individual's **energy expenditure** is determined by three main categories (as outlined below and shown in figure 1.1.5):

- Energy expended for basal metabolism (BMR)
- Energy expended for physical activities
- Energy expended for food digestion (thermic effect of food)

Basal Metabolic Rate (BMR)

Basal metabolic rate (BMR) can be defined as the rate at which the body expends energy for basal metabolic activities, which support all basic processes of life. Basal metabolic activities maintain the body temperature, keep the lungs inhaling and exhaling air, allows the bone marrow to continue producing red blood cells, keeps the heart beating 100,000 times a day and keeps the kidneys filtering the blood and removing wastes. Approximately two thirds of the energy an average person expends in a day supports these basal metabolic processes. However, the rate at which an individual expends this energy for these activities varies from person to person and may vary for the same individual with a change in circumstances of physical conditions (as shown in table 1.1.2)

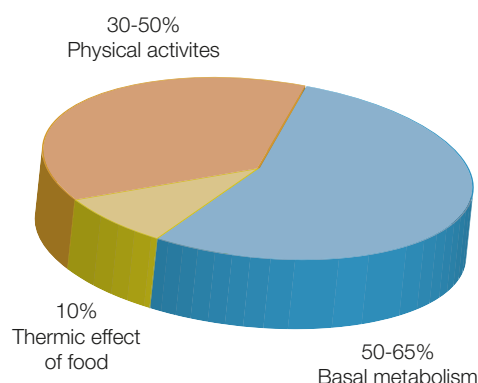


Figure 1.1.5: Components of energy expenditure

Table 1.1.2: Factors that influence an individual's BMR (the rate at which they expend energy)

Factor	Influence on BMR
Body Composition	A larger amount of lean body tissue increases BMR. This is because muscle tissue is a faster metabolising tissue (burns more kilojoules) than sluggish adipose tissue.
Growth	During childhood, adolescence and pregnancy energy demands are greater due to the growth experienced, increasing their BMR.
Age	Lean body mass diminishes after the age of 30, and the time available to complete physical activity declines, which can contribute to a decline in BMR.
Gender	Males generally have a higher BMR as their body is composed of greater lean body tissue than females. Males also expend more calories per kilogram per hour than females, where males burn 1.0 calorie and females burn 0.9.
Amount of Physical Activity	Regular physical activity increases lean body tissue, increasing BMR as muscle tissue burns more kilojoules than adipose tissue even at rest.
Fever, Infection, and Illness	The body expends more energy when recovering to develop an immune response and maintain normal body temperature. This increases BMR.
Environmental Temperature	High and low environmental temperatures increase BMR, as the body must work harder to maintain normal body temperature of 37°C.
Fasting, Starving, Malnutrition and Crash Dieting	Consuming fewer kilojoules than the body expends reduces BMR. This is because the body's basal metabolism slows down to conserve energy. BMR can drop up to 15%, and even further if lean body tissue is lost also.
Drugs	Drugs can increase or decrease an individual's BMR. For example, nicotine in smoking and caffeine can increase BMR; whilst some antidepressants and steroids can decrease BMR.
Genetics, Hormonal balance	Genetics and hormone levels can increase or decrease BMR, due to their influence on the rate at which the body expends energy.

There are several ways to calculate the BMR of an individual, however a simple method commonly used is to multiply the weight (kg) of an individual by 1.0 calorie per kilogram per hour for adult males and 0.9 calories per kilogram per hour for adult females. This is then multiplied by 24 to determine the kilojoules used for basal metabolic processes in a day, and finally multiplied by 4.2 to convert this value into kilojoules, which is the preferred energy unit used in Australia (as shown by the equations and example).

$$\text{BMR of a Male (kJ/day)} = \text{Bodyweight (kg)} \times 1 \text{ (calories)} \times 24 \text{ (hours)} \times 4.2 \text{ (kilojoules)}$$

$$\text{BMR of a Female (kJ/day)} = \text{Bodyweight (kg)} \times 0.9 \text{ (calories)} \times 24 \text{ (hours)} \times 4.2 \text{ (kilojoules)}$$

Example

Calculate the BMR for a 31-year-old female who weighs 73kg and is 165cm tall. Show all your calculations and round your final answer to the nearest whole number.

$$\text{BMR} = 73 \times 0.9 \times 24 \times 4.2$$

$$\text{BMR} = 6622.56 \approx 6623 \text{ kJ/day}$$

Physical Activity

Another component of an individual's energy expenditure is **physical activity**. This component is the most changeable, however, its influence on both weight gain and weight loss can be significant. During physical activity, the muscles require greater energy to move, and the heart and lungs need additional energy to deliver nutrients and oxygen and dispose of wastes. The amount of energy needed for any activity depends on muscle mass, body weight and activity. The larger the muscle mass and the heavier the body part being moved, the more energy that is expended. The activity's duration, frequency and intensity also influence energy expenditure. The longer, more frequent, and more intense the activity, the more kilojoules expended (as shown in table 1.1.3).

Table 1.1.3: Energy expended on various physical activities.

Activity	kJ/kg/min
Aerobics (vigorous)	0.571
Basketball (vigorous and full court)	0.895
Bicycling (21km/h)	0.416
Rowing (vigorous)	0.895
Running (12km/h)	0.869
Walking (6km/h)	0.345
Soccer (vigorous)	0.895
Swimming (20m/min)	0.322
Table Tennis (skilled)	0.416
Tennis (beginner)	0.294
Gardening	0.416
Vacuuming and other household tasks	0.277
Studying	0.100

Thermic Effect of Food

The **thermic effect of food** refers to the energy required, and the heat produced following the consumption of food. The additional energy required, and the heat produced is due to the increase in the contractions of the gastrointestinal tract, the manufacture and secretion of digestive juices and enzymes by different cells in the body and the active transport processes which absorb some nutrients. Therefore, the thermic effect of food can be defined as the energy required to eat and digest food, absorb nutrients, and move food through the gastrointestinal tract.

The thermic effect of food is proportional to the food energy consumed and is estimated at 10 percent of the energy intake. The proportions vary for different foods, as the thermic effect is greater for high protein foods than for high fat and carbohydrate foods. For example, lipids and carbohydrates, which are relatively easy to digest, raise energy needs by around 0-5% and 5-10% respectively, while proteins, which are more difficult to break down in digestion, require 20-30% of the energy consumed. The thermic effect can also be influenced by the meal size and frequency, as it is greater for a larger meal eaten at once rather than spread out over a couple of hours. However, with such a large variance in foods and their thermic effects, a figure of 10% of kilojoules consumed can be used to calculate energy needs required for the digestion of food (as shown in the example).

Example

Calculate the thermic effect of energy intake when a female's daily energy consumption is 8500kJ. Show all your calculations using: $0.10 \times$ kJ consumed/day.

$$0.10 \times 8500\text{kJ consumed/day} = 850\text{kJ}$$

1

Calculating Total Daily Energy Expenditure

The total energy expenditure (TEE) for a day can be simply calculated by adding an individual's BMR, the energy expended on physical activity that day and their thermic effect of food (as shown by the formula and example).

$$\text{Total Energy Expenditure} = \text{BMR} + \text{Energy Expended on Physical Activity} + \text{Thermic Effect of Food}$$

Example

Calculate the total energy expenditure for a female who has a BMR of 6623kJ/day, expends 1806kJ on physical activity (cycling and walking) and a thermic effect of 850kJ. Show all your calculations and round your final answer to the nearest whole number.

$$\text{Total Energy Expenditure} = 6623 + 1806 + 850$$

$$\text{Total Energy Expenditure} = 9279 \text{ kJ/day is expended}$$

Calculating Energy Balance

An individual's energy balance can be calculated by subtracting their total energy expenditure for a day from their energy intake from the foods and beverages consumed in that same day (as shown in the equation and example below).

$$\text{Energy Balance} = \text{Energy Intake} - \text{Total Energy Expenditure}$$

Energy balance is defined as the state achieved when energy intake is equal to energy expenditure. When the body is in energy balance, body mass is maintained. Differences in energy balance can cause changes in the body's mass. A positive energy balance will result when the energy balance is a positive value, due to the energy intake exceeding the total energy expenditure. This will result in weight gain if this pattern continues over a longer period. Whereas, a negative energy balance will result when the energy balance is a negative value, due to the total energy expenditure exceeding the energy intake. This will result in weight loss if this pattern continues over a longer period. The rate at which weight is gained or lost is determined by the magnitude of the difference between an individual's energy intake and their total energy expenditure. The different types of energy balance can be summarised as:

$$\text{Energy Balance (maintenance of weight): Energy Intake} = \text{Energy Expenditure}$$

$$\text{Positive Energy Balance (weight gain): Energy Intake} > \text{Energy Expenditure}$$

$$\text{Negative Energy Balance (weight loss): Energy Intake} < \text{Energy Expenditure}$$

Example

Calculate the energy balance of a female who consumes 8500kJ a day and has a total daily energy expenditure of 9279kJ. Show all your calculations and explain the impact this balance will have on her weight if this pattern continues.

$$\text{Energy Balance} = 8500 - 9279 \text{ Energy Balance} = -779\text{kJ}$$

This female's energy expenditure is greater than her energy intake, resulting in a negative energy balance (indicated by the minus sign). If this pattern were to continue, she would experience weight loss.

Nutrient Reference Values

Nutrient reference values (NRVs) are a set of recommendations for nutritional intake based on current available scientific knowledge that best support the health of individuals in Australia and New Zealand. These recommendations apply to healthy people and may not be appropriate for people with diseases that require an increase or decrease in nutrient needs. Each person's body is unique and has its own set of requirements. Men differ from women and needs change as people grow from infancy to old age. Therefore, nutrient recommendations are based on age, gender, and specific life stages. These values provide recommended intakes for energy (kilojoules), protein, carbohydrate, fibre, fats, water, vitamins, and minerals. The NRVs are made up of 5 different values (as discussed in Table 1.1.4):

Table 1.1.4: Description of NRVs used in Australia and New Zealand

NRV	Description
Estimated Average Requirement (EAR)	The average amount of a nutrient estimated to meet the nutrient requirements of half of a group of healthy individuals in a specific life stage and gender group.
Recommended Daily Intake (RDI)	The average daily dietary intake level is sufficient to meet the nutrient requirements of nearly all (approximately 98%) healthy individuals in a specific life stage and gender group. The RDI is set high enough above the EAR to meet the needs of most healthy people. When people's nutrient intakes are consistently below their daily requirements, they can become deficient, causing their nutrient stores to deplete, and leading to poor health and deficiency symptoms. Therefore, the RDI is set so much higher than the EAR, to ensure this value meets the nutrient needs of as many people as possible.
Adequate Intake (AI)	The AI reflects the average amount of a nutrient that a group of healthy individuals consumes. This NRV is used when an RDI or EAR cannot be determined due to insufficient scientific evidence. Therefore, AI relies heavily on scientific judgement.
Tolerable Upper Intake Level (UL)	The UL is the point at which an individual exceeds the recommended intake and where a nutrient is likely to become toxic. It is recommended that an individual not exceed these recommendations often or by much. The RDI should not be thought of as a minimum amount, and a more accurate view is to see an individual's requirements as a range, with a marginal and danger zone both below and above this range.
Estimated Energy Requirement (EER)	The EER represents the average dietary energy intake (kilojoules consumed per day) that will maintain an energy balance in a person who has a healthy body weight and level of physical activity. These values are determined to sustain a healthy and active life, as too much energy can lead to weight gain and its associated health consequences.



Key terms

Acceptable macronutrient distribution ranges (AMDR)	Estimated Energy Requirement (EER)
Adequate Intake (AI)	Kilojoule (kJ)
BMR	Lipids yield 37.7 kJ/g
Carbohydrates yield 16.7 kJ/g	Negative Energy Balance
Energy Balance	Nutrient Reference Value (NRV)
Energy distribution	Positive Energy Balance
Energy Expenditure	Proteins yield 16.7 kJ/g
Energy Intake	Recommended Dietary Intake (RDI)
Energy-yielding nutrient	Thermic Effect of Food
Estimated Average Requirement (EAR)	Tolerable Upper Intake Level (UL)

Review questions: 1.1 Determining Energy and Nutrient Requirements

1

1. Australian researchers found that children and adolescents consume more energy from energy dense foods than any other age group, with the average child receiving three packaged snack foods in their lunchbox each day. Parents should aim to provide only one energy dense snack food in their child's lunch box each day, and ideally it should be less than 600kJ.

Calculate the total energy provided by one serving of each of the following lunch box snacks and make a recommendation to which snack parents should choose to include in their child's lunch box. Show all your calculations and round your final answers to the nearest whole number.

	SNACK A Small packet (20g) of Original Popcorn	SNACK B Fruit & Nut Muesli Bar (45g)	SNACK C Mini Blueberry Muffin (40g)
Protein	1.8g	4.1g	1.7g
Fat, total	5.1g	6.7g	6.2g
Fat, saturated	1.0g	1.1g	1.0g
Carbohydrate, total	8.4g	25.1	17.0g
Carbohydrate, sugars	0.7g	7.8g	9.4g

(4 marks) (KA4, IAE3)

2. Refer to the ingredients list and nutritional information panel for one serving (100 g) of pasta carbonara.

	100 grams	Ingredients
Energy (kJ)	1246	250 g cooked pasta 20 g butter
Protein (g)	14	cup thickened cream 250 g bacon
Carbohydrates – total (g)	29	eggs
Carbohydrates – sugar (g)	4	2 egg yolks
Fat – total (g)	14	1 cup grated parmesan cheese 1 tablespoon rosemary
Fat – polyunsaturated (g)	2	Pinch of salt Pinch of pepper
Fat – monounsaturated (g)	3	
Fat – saturated (g)	9	
Dietary fibre (g)	1.5	
Sodium (mg)	200	

- (a) Calculate the energy distribution of each energy-yielding nutrient and make recommendations in comparison to the acceptable macronutrient distribution ranges (AMDR) for Australians. Show all calculations and round your answers to the nearest whole number.

(6 marks) (KA4, IAE3)

- (b) Suggest three specific modifications to the ingredients for the pasta carbonara recipe that would reduce the meal's energy density and increase its nutrient density.

(3 marks) (KA2)

3. Two 17-year-old adolescents – one male (Aaron) and one female (Emma) – are undertaking identical training programs for a national athletics competition.

- (a) State which adolescent is likely to have the higher basal metabolic rate (BMR).

(1 mark) (KA2)

- (b) Describe how one factor could account for the difference in the BMR of these two adolescents.

(2 marks) (KA2)

- (c) Refer to the following table, which provides additional information about Aaron:

weight	77 kg
daily energy intake	12300 kJ
energy expenditure from daily activity	2210 kJ

- (i) State the percentage (%) of Aaron's daily energy intake that contributes to the thermic effect of food.

(1 mark) (KA1)

- (ii) Calculate Aaron's energy expenditure. **Show all your working out.**

(4 marks) (KA4)

- (iii) Calculate Aaron's energy balance and identify the type of energy balance it is. **Show all your working out.**

(2 marks) (KA1, KA4)

- (iv) Describe the long-term effect on Aaron's weight and health if his energy balance remained the same for a long time.

(2 marks) (KA2)

4. Refer to the following nutritional information panel for a meal made by an elderly female aged 70 years old.

	Per serving
Energy (kJ)	
Protein (g)	15
Carbohydrates – total (g)	58
Carbohydrates – sugar (g)	36
Fat – total (g)	31
Fat – saturated (g)	18
Dietary fibre (g)	3
Sodium (mg)	320

- (a) Calculate the total energy content provided by one serving of this meal. Show all calculations and round to the nearest whole number.

(2 marks) (KA2, KA4)

- (b) The estimated energy requirement (EER) for an elderly female is 7600 kJ. What percentage of that recommended daily energy requirement is provided by this meal? Show all calculations and round your answer to the nearest whole number.

(2 marks) (KA2, KA4)

- (c) Using the NRV calculator on the following website: <https://www.nrv.gov.au/nutrients-energy-calc>, determine the NRVs of the following nutrients for this elderly woman.

	AI	EAR	RDI	UL
Calcium (mg)				
Iron (mg)				
Vitamin C (mg)				
Dietary Fibre (g)				

(3 marks) (IAE3)

5. Describe one advantage of using the RDI to evaluate an individual's diet and health.

(2 marks) (KA2)

6. A medical study was conducted on the basal metabolic rate (BMR) of 14 participants who went on a weight-loss diet for a short period of time. All participants lost a significant amount of weight while on the diet.

The average BMR of the participants prior to, during and after their weight loss journey is shown in the table below.

	Prior	During	After
Average BMR (kJ/day)	10950	8400	7980

- (a) Calculate the change in the average BMR over the time of the participant's weight loss journey in kJ/day.

(1 mark) (KA4)

- (b) The study found that, after their weight loss journey had finished, the participants' BMR had changed. Explain how weight loss may have contributed to the decrease in average BMR.

(2 marks) (IAE3)

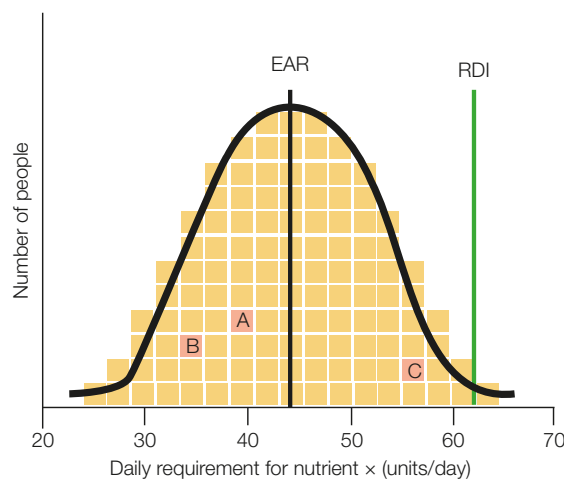
- (c) Explain why some participants experience weight gain if they return to their original diet and lifestyle.

(2 marks) (KA2)

7. A glass of wine contains 2.6g of carbohydrates and 1g of protein and provides 520kJ. Calculate the amount of energy provided by the alcohol only in a glass of wine. Show all your calculations and round your final answer to the nearest whole number.

(2 marks) (KA2, KA4)

8. The EAR and RDI of a specific nutrient are shown in the graph below. Each square in the graph below represents an individual with unique nutritional requirements, however three different individuals are shown: A, B and C.



- (a) With reference to the graph above, state the daily requirement for nutrient X for the following individuals:

A:

(1 mark) (AE3)

C:

(1 mark) (AE3)

- (b) Suggest one reason why individual C has a higher daily requirement of nutrient X than individual A.

(1 mark) (KA2)

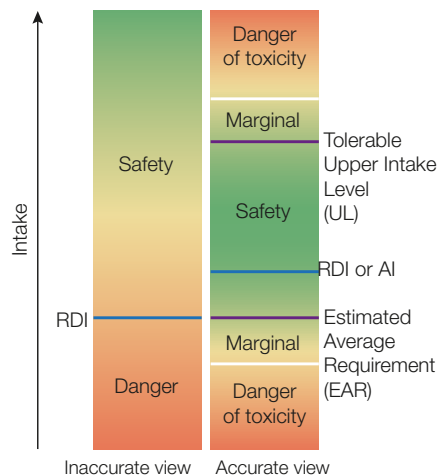
- (c) True or False: An RDI for a nutrient is the amount that everyone needs to consume each day. Provide reasoning to explain your answer.

(2 marks) (KA2)

- (d) Explain why the RDI value is much higher than the EAR value on the graph.

(2 marks) (KA2)

9. The image below demonstrates an inaccurate view vs accurate view of the nutrient intakes of individuals.



- (a) With reference to the image above (accurate view), identify when an individual's intake of a nutrient would be inadequate.

(1 mark) (IAE3)

- (b) Explain why the view for nutrient intakes on the right in the image above is regarded as the accurate representation.

(2 marks) (KA2)

10. An adolescent's diet is composed of the following distribution for each macronutrient.

THE MACRONUTRIENT DISTRIBUTION RANGES OF AN ADOLESCENT'S DAILY DIET

Carbohydrates Protein Lipids



Compare the energy distribution of each macronutrient displayed in the graph above with those from the acceptable macronutrient distribution ranges and make suitable recommendations for this adolescent.

(3 marks) (IAE3)

11. Giuseppe's recommended daily energy intake is 8820 kJ, which allows him to maintain his current weight. It is also recommended that 55% of his energy intake is provided by carbohydrates, 25% provided by protein and 20% provided by lipids.

Use this information to determine the quantity of each macronutrient in grams that he would need to consume to maintain his weight by meeting the recommended energy intake and macronutrient distributions. Show all your calculations and round your final answers to the nearest whole number.

1

(6 marks) (KA2, KA4)

Total: ____ / 60 marks

Case Study

Samantha is a 16-year-old female from a low socioeconomic background. She currently weighs 58kg and is 159cm tall and is moderately active. Her average daily diet is shown in the table on the left:

Download *My Fitness Pal* or *FoodWorks* and enter Samantha's diet to determine her energy intake (kJ), macronutrient energy distribution (%) and intake of the nutrients (dietary fibre, sodium, calcium, and iron) listed in the table on the right.

Meal	Food	Quantity	Macronutrient	Energy Distribution of her Current Diet (%)
Breakfast	Pikelets	4	Carbohydrates	
	Orange Juice (sweetened)	250 ml	Protein	
Snack	Tiny teddies (chocolate)	50 g	Lipids	
	Potato Chip (smiths original)	100 g		
Lunch	Sausage Roll	1		
	Sauce	20 g		
	Chocolate Milk	250 ml		
Snack	Banana	1 medium		
	Pizza Shapes	50 g		
	Milk Chocolate	50 g		
Dinner	Chicken Nuggets	6		
	Vanilla thick shake	250 ml		
	Instant Mashed potato	80 g		
Snack	Milo	10 g		
	Full cream milk	250 ml		

Nutrient	Current Intake
Dietary Fibre (g)	
Sodium (mg)	
Calcium (mg)	
Iron (mg)	

Using the acceptable macronutrient distribution ranges (AMDR) and the NHRMC website: <https://www.nrv.gov.au/nutrients>, identify any key differences between her current intake and the recommendations for an individual of her age and gender. Use data in your response when identifying these differences and identify which diet related disorders she may be at risk of if her current eating habits continue into adulthood.

(10 marks) (IAE3, KA2, KA4)



Science as a human endeavour

How to count macros for weight loss and why registered dietitians often consider it a better method than calorie counting

<https://www.businessinsider.com.au/how-to-count-macros-2020-12>

Macronutrients (or macros) are the kinds of nutrients that your body needs in large amounts to provide energy. Think carbohydrates, fat, and protein. Some people prefer to track their macros, rather than calorie intake, when improving their diet.

“Macronutrients contribute calories, so by tracking macronutrients, you are essentially counting total calories intake as well,” says Emily Field, MPH, RD, a registered dietitian with a private practice in New York City. Macro counting (sometimes called “flexible dieting”) is often considered more beneficial than calorie counting because it considers where the calories are coming from.

For example, small servings of a chocolate chip muffin and a fillet of steamed salmon are both roughly 275 calories, but they’re not equally healthy and they don’t have the same amount of nutrients. Macro counting helps you make that distinction whereas calorie counting does not.

“Counting macros means that you are simply adding up the total number of grams of carbohydrates, fats, and proteins of the food items that you are consuming per meal or per day,” says Andrea Marincovich, RD, registered dietitian, and founder of The Realistic Dietitian.

It’s a broad range, so you can adjust the macro ratio depending on your dietary preferences. For example, a strength-training athlete can increase their protein and carbohydrates, while a person monitoring their blood sugar might want to reduce their carbohydrate percentage and increase their fat intake instead.

Calculating macros is often confusing at first and it may take some time to adjust, even for experienced calorie counters. Here is a sample computation for an individual intending to consume 1,500 calories a day composed of 45% carbohydrates, 20% protein, and 35% fat:

Carbohydrate: $45\% \times 1,500 \text{ calories} / 4 \text{ calories} = 168.75 \text{ grams per day}$

Protein: $25\% \times 1,500 \text{ calories} / 4 \text{ calories} = 93.75 \text{ grams per day}$

Fat: $30\% \times 1,500 \text{ calories} / 9 \text{ calories} = 50 \text{ grams per day}$

To count macros, you calculate the number of calories that you burn per day (or your total daily energy expenditure) and then set a macro ratio that works with your lifestyle and dietary preferences. If you want to lose weight, you need to eat fewer calories than you burn every day.

“It’s not hard to count macros, but it does take effort and energy, which can make it hard for some people. Learning to count macros is a behaviour change,” says Marincovich. It can be overwhelming to establish a whole new way of looking at food and putting together meals, but there is a learning curve to it, she says.

1. Discuss a **limitation** of counting ‘macros’ that is described in the above passage.

(2 marks) (KA3)

2. Discuss how counting ‘macros’ could **be applied to** society.

(4 marks) (KA3)

? Science Inquiry Skills

Testing the Energy Content in Food

Introduction:

Foods contain varying amounts of energy, which is dependent on the distribution of macronutrients within the food. For example, fats yield a greater amount of energy per gram than carbohydrates and protein, therefore a food with a greater fat content will contain a greater amount of energy.

Calories are defined as the amount of energy needed to raise the temperature of 1kg of water by 1 degree Celsius. The amount of energy released can be measured using a piece of equipment known as a calorimeter. A calorimeter can measure the total amount of energy by burning the food and measuring the amount of heat produced. Foods that release greater heat contain a larger amount of energy and are therefore labelled as energy dense. This piece of equipment uses the Law of Conservation, which states that energy is never created or destroyed but transferred.

Hypothesis:

If the food item contains a greater content of fat, then a greater amount of heat will be released increasing the temperature of the water inside the calorimeter, indicating it contains the most energy.

Materials:

- 1 x marshmallow*
- 1 x cheese and bacon ball*
- 1 x popcorn (popped)*
- 3 x calorimeters (or 3 soft drink cans with tab on)
- 1 x cork wrapped in aluminium foil
- 3 x metal paper clips (or needle)
- 1 x metal tongs
- 1 x heat proof mat
- 1 x alcohol thermometer
- 1 x electronic scale
- 1 retort stand with clamp
- 1 x 50ml measuring cylinder
- Matches

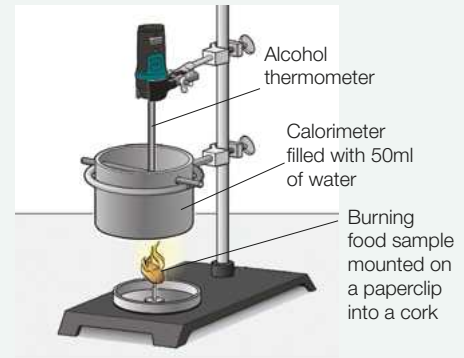
*Other foods can be used such as a potato chip, Twisties, pasta, tiny teddies, shortbread, burger rings, or nutri grain.

Method:

1. Measure 50ml of cold water and then pour into the calorimeter (or soft drink can).
2. Determine the mass of the 50ml of water only and record this in the first row of the first results table of the results section for each food item.
3. Fold out a metal paperclip (or use a needle) and pierce one end of the paperclip through the first food item: marshmallow.
4. Use the electronic scales to measure the mass of the marshmallow and paperclip and record this in the first results table of the results section.
5. Pierce the other end of the paper clip (or needle) into the cork covered with aluminum foil and place on a heat proof mat.
6. Suspend the calorimeter filled with water (or soft drink can) using the retort stand and clamp, as shown in figure 1.1.3.
7. Adjust the height of the clamp on the retort stand so that the top of the food sample is approximately 2cm below the bottom of the calorimeter (or soft drink can) (as shown in the image after the method).
8. Place the alcohol thermometer into the calorimeter (or soft drink can) ensuring that it doesn't touch the bottom but is below the water line. This can be achieved by a group member holding it or for added safety another clamp to hold it in place (as shown in the image after the image).
9. Record the initial temperature of the water and record in the first results table of the results section.
10. Using the matches, light the food sample from the bottom and make sure it is directly under the centre of the calorimeter.
11. Allow the water inside the calorimeter to be heated until the food sample stops burning.
12. Stir the water gently with the thermometer and record the highest water temperature observed and record the final temperature in the first results table of the results section.
13. Using the metal tongs, remove the paperclip from the cork and determine the final mass of the food residue and paperclip using the electronic scales. Record the final mass in the first results table of the results section.

? Science Inquiry Skills

14. Remove the calorimeter from the clamp and replace it with a new one filled with 50ml of water.
15. Repeat steps 2-14 with the other food samples.
16. Once finished, place all matches and burnt residue in a container filled with water supplied by the teacher and clean up the workbench.
17. Calculate the difference in mass of food and water temperature and complete the first results table of the analysis section. Complete the remainder of the results, analysis, and discussion sections.



Results

1. Complete the following table by recording the results from the experiment conducted.

	Food Combusted		
	Marshmallow	Cheese and Bacon Ball	Popcorn
Mass of water (g)			
Initial mass of food sample and paper clip (g)			
Final mass of food sample and paper clip (g)			
Difference in mass of food (food combusted) (g)			
Initial water temperature (°C)			
Final water temperature (°C)			
Difference in water temperature (ΔT) (°C)			

2. Using the data from the results table above and the formula below, calculate the energy (kJ) released by each of the food samples tested.

$$\text{Energy (kJ) per 100g} = \frac{(m_{\text{water (g)}} \times \text{Change in Temperature } (\Delta T) \times \text{Heat Capacity } (C_p = 4.185))}{[\text{mass of food sample combusted (g)} \times 10]}$$

Food Combusted	Energy released per 100g (kJ)
Marshmallow	
Cheese and Bacon Ball	
Popcorn	

Analysis and Discussion

3. With reference to the nutritional information panel, rank the food samples regarding their energy content (kJ). Ensure you evaluate the macronutrient content, especially the total fat, and include this in your answer.

4. Rank the foods from highest energy containing food to the lowest energy containing food based on your results. Explain if this was expected or not.

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5. Compare your group's data for each food sample with the data of another group and comment on the precision of the results. Use data in your response.

6. Identify two random errors that may have occurred and explain the effect they would have had on the results of the experiment.

7. Compare the accuracy of your group's results for each food sample with the energy content per 100g on the nutritional information panel on the food packaging.

8. Identify **two** systematic errors that may have been present and explain how they would have affected the accuracy of the results.

9. Identify two improvements that could improve the reliability and validity of the results.

10. Write a conclusion for this experiment, explaining if the hypothesis was supported or not supported.

Extension Activities

1

1. Refer to the following nutrition information panel from a packet of breakfast cereal.

	Per serving	Per 100 g
Protein (g)	2.2	8.8
Fat – total (g)	0.6	2.5
Fat – saturated (g)	0.2	0.8
Carbohydrate – total (g)	21.1	84.5
Carbohydrate – sugars (g)	6.3	25

- (a) Calculate the total energy provided from one 100 g serving of the breakfast cereal. Show all your calculations and round your final answer to the nearest whole number.

- (b) Using the NRV calculator on the following website: <https://www.nrv.gov.au/nutrients-energy-calc>, determine your estimated energy requirement (EER). Then calculate the proportion (%) of energy that this breakfast cereal would account for, in comparison to your EER. Show all calculations and round your final answer to the nearest whole number.

To calculate your EER, determine your physical activity level (PAL) and then multiply that value by 1000 to get it into kJ.

Your EER:

- (c) Using the NRV calculator on the NHRMC website: <https://www.nrv.gov.au/nutrients>, determine your NRVs of the following five nutrients.

	AI	EAR	RDI	UL
Calcium				
Iron				
Vitamin C				
Dietary Fibre				
Water				

2. The average adult needs to consume an energy intake of 8,700kJ a day. An adult is attempting to 'macro' count and achieve an energy distribution of 55% carbohydrates, 20% protein and 25% lipids. Determine how many grams of each macronutrient they would need to consume each day to achieve this ratio. Use the formulas below, show your working out and round your answers to the nearest whole number.

As further extension, you can determine the average kilojoule intake you need to consume and determine the number of grams of each macronutrient you should be consuming to match the acceptable macronutrient distribution ranges.

$$\text{Carbohydrate Intake} = \frac{55}{100} \times \text{Energy Intake (kJ)} \div 16.7\text{kJ/g}$$

$$\text{Protein Intake} = \frac{20}{100} \times \text{Energy Intake (kJ)} \div 16.7\text{kJ/g}$$

$$\text{Lipid Intake} = \frac{25}{100} \times \text{Energy Intake (kJ)} \div 33.7\text{kJ/g}$$

3. 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'. Alternatively, some foods are described as energy dense. Energy density is a measure of the number of kilojoules per gram. Both the nutrient density and energy density can be calculated using the following formulas:

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

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

- (a) One cup of orange juice provides 463kJ and 125mg of Vitamin C, whereas one medium sized orange provides 285kJ and 86mg of Vitamin C. Which of the two sources is more Vitamin C dense? *Show all your working out.*
- (b) One cup (250g) of orange juice provides 463kJ of energy, whereas a medium sized orange (163g) provides 285kJ of energy. Which of the two foods is more energy dense? *Show all your working out.*

4. There are several methods that can be used to determine an individual's BMR.

Use the two methods: Harris-Benedict and Schofield outlined below to calculate the BMR of a 31-year-old female who weighs 73kg and is 165cm tall and a 47-year-old male who weighs 88kg and is 166cm tall and compare your answers. *Show all your working out.*

The **Harris-Benedict** method to estimate an individual's BMR (kJ/day) uses weight, height, age, and gender as outlined in the formulas below.

Male:

$$\text{BMR} = 66 + (13.7 \times \text{weight in kg}) + (5 \times \text{height in cm}) - (6.8 \times \text{age in years})$$

$$\text{BMR} = \text{calories/day} \times 4.2$$

$$\text{BMR} = \text{kJ/day}$$

Female:

$$\text{BMR} = 655 + (9.6 \times \text{weight in kg}) + (1.8 \times \text{height in cm}) - (4.7 \times \text{age in years})$$

$$\text{BMR} = \text{calories/day} \times 4.2$$

$$\text{BMR} = \text{kJ/day}$$

The **Schofield** method to estimate an individual's BMR (kJ/day) uses weight, age, and gender as outlined in the formulas below.

Age (years)	Male	Female
< 3	$249 \times \text{weight in kg} - 127$	$244 \times \text{weight in kg} - 130$
3-10	$95 \times \text{weight in kg} + 2110$	$85 \times \text{weight in kg} + 2033$
10-18	$74 \times \text{weight in kg} + 2754$	$56 \times \text{weight in kg} + 2898$
18-30	$63 \times \text{weight in kg} + 2896$	$62 \times \text{weight in kg} + 2036$
30-60	$48 \times \text{weight in kg} + 3653$	$34 \times \text{weight in kg} + 3538$
> 60	$49 \times \text{weight in kg} + 2459$	$38 \times \text{weight in kg} + 2755$

5. There are several ways to estimate an individual's total energy expenditure for the day. The Schofield method used to calculate an individual's BMR can also be used to determine the number of kilojoules expended in a day. This is determined by multiplying their BMR using the Schofield equation (as seen on the previous page) with an estimate of physical activity levels (PAL) from the table below. The total energy expenditure can be calculated using the following equation:

$$\text{Total Energy Expenditure} = \text{BMR (using Schofield equation)} \times \text{PAL}$$

Description of Lifestyle	Examples of Occupations / Individuals	Physical Activity Levels (PAL)
At rest, exclusively sedentary or lying (chair-bound or bed-bound).	Old individuals. Unable to move around freely or earn a living.	1.2
Very sedentary with seated work with little or no strenuous leisure activity	Office employees, precision mechanics	1.4-1.5*
Light active with seated work with some requirement for occasional walking and standing but little or no strenuous leisure activity	Laboratory assistants, drivers, students, assembly line workers	1.6-1.7*
Moderately active with predominantly standing or walking work	Domestic duties, salespersons, waiters, mechanics, traders	1.8-1.9*
Heavy to vigorously active with heavy occupational work or highly active leisure	Construction workers, farmers, forest workers, miners, high performance athletes	2.0-2.4

*Significant amounts of strenuous leisure activities (30-60 minutes, 4-5 times a week) should add 0.3 PAL units per day.

Calculate the total energy expenditure of a 55-year-old male who weighs 90 kg and works in an office environment and performs no strenuous leisure activity. Use the BMR Schofield equation provided on the previous page to calculate his BMR and then determine his total energy expenditure by using the PAL units in the table above.

6. Write the name of a food or beverage item recently consumed, and then draw the item in the box below (or find a picture). Find the nutrient content of that food item and record below, and then calculate the amount of physical activity (using Table 1.8.4) needed to be completed to use the energy consumed from this food or beverage item.



Fast fact

To calculate the kilojoules spent per minute of activity for your own body weight, multiply the kJ/kg/ min by your weight and then multiply that number by the number of minutes spent in the activity.

Food or beverage item:

Picture or drawing of food or beverage item	Your Serving Size (g or ml)	
	Energy (kJ)	
	Protein (g)	
	Fat, total (g)	
	Fat, saturated (g)	
	Carbohydrates (g)	
	Sugars (g)	

One serving of _____ which contains _____ kilojoules per serving is equivalent to _____ minutes of _____.

7. Create an AMDR approved meal.

- (a) Select and identify a recipe that is a personal favourite or a recipe that you can cook for breakfast, lunch, dinner, or as a snack.
- (b) Research your recipe and include a list of the ingredients below.

- (c) Access the following Food Standards website and create a nutrition information panel for your recipe by entering each individual ingredient, and then enter the data in the nutrition information panel.

<https://www.foodstandards.gov.au/industry/npc/Pages/Manage-Recipes.aspx>

NUTRITION INFORMATION		
Servings per package:		Serving Size:
	Average Quantity per serving	Average Quantity per 100g
Energy (kJ)		
Protein (g)		
Fat, total (g)		
- saturated (g)		
Carbohydrates (g)		
- Sugars (g)		
Sodium (mg)		

- (d) Calculate the amount of energy that is provided by each macronutrient per serving of the recipe above.
- (e) Calculate the energy distribution (%) of the three macronutrients per serving. Provide your answers as rounded to the nearest whole number.
- (f) Compare the energy distribution of the three macronutrients per serving of your recipe to the acceptable macronutrient distribution ranges (AMDR).

- (g) Make modifications to the ingredients of your original recipe and include the new ingredients below. Remember the goal is that the energy distribution of your recipe matches with the AMDR.

- (h) Access the Food Standards website: <https://www.foodstandards.gov.au/industry/npc/Pages/Manage-Recipes.aspx> and create another nutrition information panel for your modified recipe and then enter the data in the nutrition information panel.

NUTRITION INFORMATION		
Servings per package:		Serving Size:
	Average Quantity per serving	Average Quantity per 100g
Energy (kJ)		
Protein (g)		
Fat, total (g)		
- saturated (g)		
Carbohydrates (g)		
- Sugars (g)		
Sodium (mg)		

- (i) Calculate the amount of energy that is provided by each macronutrient per serving of the modified recipe in question (h).

- (j) Calculate the energy distribution (%) of the three macronutrients per serving of the modified recipe. Provide your answers as rounded to the nearest whole number.

- (k) Compare the energy distribution of the three macronutrients per serving of your modified recipe to the original recipe. Are they closer to the acceptable macronutrient distribution ranges (AMDR)?

- (l) Cook your AMDR approved meal!

Macronutrients

Macronutrients can be defined as the nutrients humans consume, and need, in the largest quantities. Macro, meaning 'large', alludes to this. Their requirements are prescribed in grams per day, whilst other nutrients have only milli or microgram needs. Not only are macronutrients defined by being needed in large quantities each day, but they also give humans energy. Each macronutrient provides a differing amount of energy. While water does make up a large proportion of what we consume each day, and need, it does not provide any energy and is therefore not considered a true macronutrient. The true macronutrients that are needed in large amounts each day, and provide energy, are carbohydrates, lipids, and protein.

1.2 Carbohydrates

Science understanding

Macronutrients have a specific function and structure.

- Identify the general structure and sources of the following carbohydrates:
 - polysaccharides (starch, glycogen, and cellulose)
 - disaccharides (maltose, lactose, and sucrose)
 - monosaccharides (glucose, galactose, and fructose)
- Explain the effects of different carbohydrates on blood glucose (blood sugar) levels.
- Identify sources of soluble and insoluble fibre
- Explain the role of soluble and insoluble fibre in the body and their roles in the prevention of some diet-related diseases.

SAGE Subject Outline, 2024

Structure and Classification of Carbohydrates

Carbohydrates are made from combinations of the elements carbon (C), hydrogen (H) and oxygen (O). You may see carbohydrates referred to as CHO. Atoms of these elements arrange into a variety of structures called saccharides. The carbohydrate saccharides we consume include:

- **monosaccharides** (single unit)
- **disaccharides** (double unit of two joined monosaccharides)
- **oligosaccharides** (small number of joined monosaccharides, typically three to ten)
- **polysaccharides** (long linear or highly branched chains of many joined monosaccharides).

Simple Carbohydrates

The monosaccharides and disaccharides can be collectively termed simple **carbohydrates (sugars)**. They consist of one or two sugar units (saccharides), which contributes to them being easily absorbed by the body and can cause increased spikes in blood glucose levels.

Monosaccharides

There are three monosaccharides, which consist of one singular sugar unit. Each of these sugar units contains 6 carbon atoms, 12 hydrogen atoms and 6 oxygen atoms, which can be written in shorthand as C₆H₁₂O₆. Although they contain the same number of atoms, they are arranged differently (as shown in figure 1.2.1), which contributes to their different levels of sweetness. As this type of carbohydrate is made up of one singular sugar unit, they cannot be broken down further into a simpler form contributing to its quick release into the bloodstream. Monosaccharides serve as the building block for all other sugars and carbohydrates.

The three monosaccharides include:

- glucose 
- galactose 
- fructose 

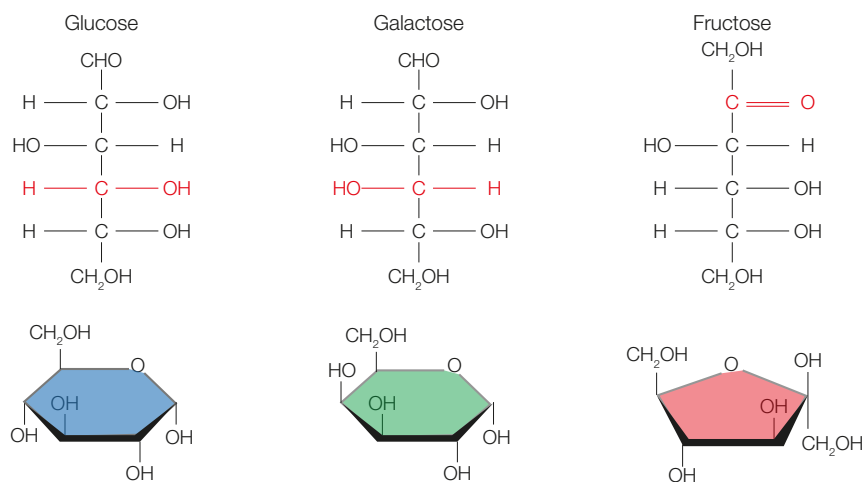


Figure 1.2.1: The structure of the monosaccharides: glucose, galactose, and fructose, where the difference in their arrangement is highlighted in red.

Disaccharides

Disaccharides are simple sugars that are made up of two monosaccharides (singular sugar units) joined together (as shown in figure 1.2.2). Digestion requires only one bond between the two sugar units or monosaccharides to be broken, allowing for quick absorption and release into the bloodstream.

There are three disaccharides which include:

- maltose (glucose + glucose)
- sucrose (glucose + fructose)
- lactose (glucose + galactose)



Fast fact

To make a disaccharide, a chemical reaction known as condensation links two monosaccharides together. A hydroxyl (OH) group from one monosaccharide and a hydrogen (H) atom from the other combine to create a molecule of water (H₂O). The two originally separate monosaccharides link together with single oxygen (O).

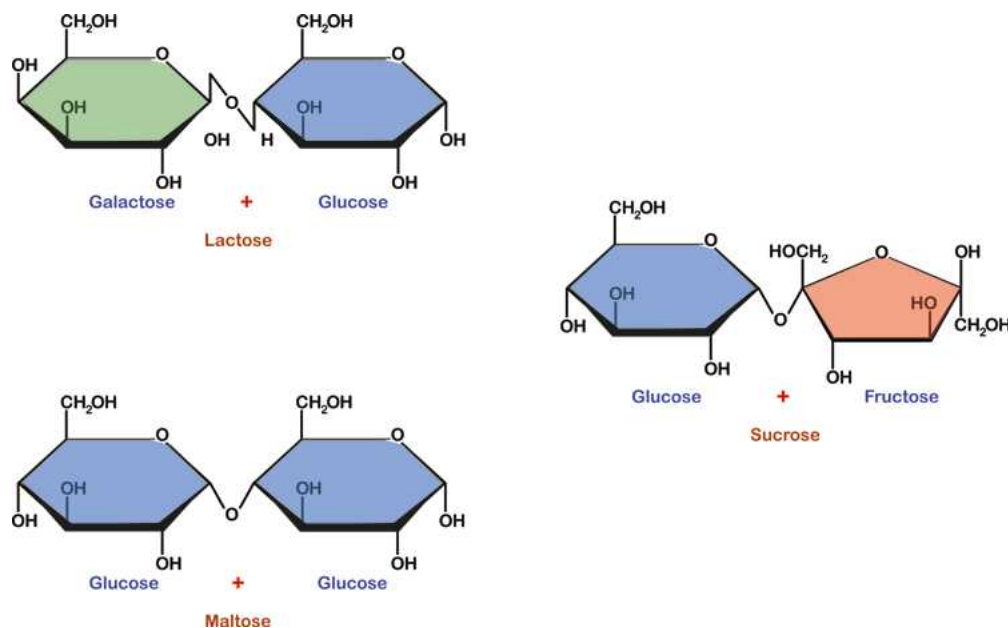


Figure 1.2.2: The structure of disaccharides, maltose, sucrose, and lactose

Complex Carbohydrates

The remaining saccharide classifications, namely the oligosaccharides and polysaccharides, can be collectively known as the **complex carbohydrates**. They can be 'larger' in size and consist of three or more singular sugar units (monosaccharides) bonded together to form chains, especially the polysaccharides, which may be composed of several hundred thousand joined glucose molecules! The breakdown of these carbohydrates into monosaccharides takes much longer and is dependent on the number of sugar units it is composed of. Therefore, these carbohydrates are absorbed into the bloodstream a lot slower, contributing to a steady rise in blood glucose levels.

Oligosaccharides

Oligosaccharides are complex carbohydrates which are composed of three to ten singular sugar units (as shown in Figure 1.2.3). The prefix '**oligo**' means '**just a few**'. These carbohydrates are not relatively abundant in the diet when compared to the other classifications of carbohydrates.

Examples of oligosaccharides include:

- Galacto-oligosaccharides: Raffinose and Stachyose
- Fructo-oligosaccharides: ketose and nystose

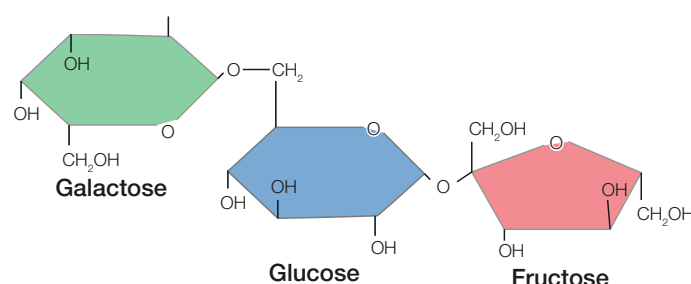


Figure 1.2.3: The structure of an Oligosaccharide: Raffinose, consisting of three singular sugar units.

Polysaccharides

Polysaccharides are complex carbohydrates which consist of more than ten singular sugar units (as shown in Figure 1.2.4). The prefix '**poly**' means '**many**'. These are the most complex carbohydrates due to their length and are the most abundant carbohydrates found in food.

The most abundant Polysaccharides include:

- Starch
- Resistant Starch
- Glycogen
- Soluble (e.g., pectin and gums) and Insoluble Fibre (e.g., cellulose and lignin)

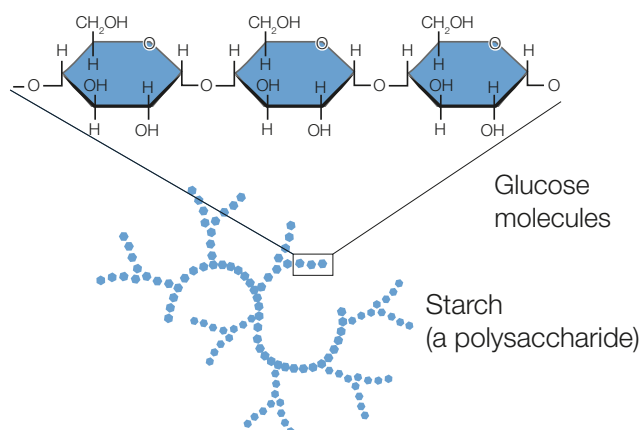


Figure 1.2.4: The structure of a Polysaccharide, Starch consisting of many singular sugar units

Sources of Carbohydrates in the Diet

Food and/or beverages that are good sources of each of the examples of saccharides are displayed on the following continuum. The continuum lists the saccharide examples from the most to least sweet, with the sweeter sugars coinciding with those we crave most.

Very sweet	Fructose	Found naturally in honey and sweet fruits, e.g., grapes. Can be added as high-fructose corn syrup in foods and beverages, such as confectionery and soft drink.
	Sucrose	Found naturally in sweet fruits. Added as granulated sugar (table sugar, e.g., raw sugar) from sugar-cane processing (called refined sugar) in many foods, such as cakes and dried fruit.
	Glucose	Found naturally in honey and fruit. Added in foods such as sauces and cereals.
	Galactose	Not found naturally in high amounts in its monosaccharide form. When galactose is found in foods, it is usually present in its disaccharide form, i.e., joined to glucose to form lactose.
	Maltose	Not found naturally in high amounts in any foods. However, when foods high in starch undergo processing (such as cooking), the starch can end up being broken down into maltose. This may be the case in breads, cereals, sweet potatoes, etc. Can be added in foods with a malt flavour, e.g., malt milkshake, malt biscuits, confectionery.
	Oligosaccharides	Found naturally in the onion group (onions, garlic, etc.) and legumes. Can be added to foods such as cereals and yoghurts as inulin; its creamy texture is used to replace oils, and its sweet taste is used to replace sucrose.
	Lactose	Found naturally in the dairy group (milk, cheese, etc.), making it the only carbohydrate that doesn't come from plants.
	Starch	Can be added to bread and bread products. Found naturally in foods such as oats, rice, legumes, corn and root vegetables. It is used as a primary ingredient in cereals, breads, pasta, etc. Corn starch/potato starch (called refined starch) can be added as a thickener to many processed foods, such as custard.
	Soluble fibre	Found naturally in the pith (flesh) of fruits and the flesh of vegetables, plus in foods such as oats, legumes, and soy products. Citrus fruits including apples, plums, grapes, oranges, lemons and grapefruits are a great source of pectin.
	Insoluble fibre	Can be added to many fibre-enriched/fortified foods, such as bread. Found naturally in foods such as bran, nuts, seeds, the skins of fruit and vegetables; also used as an ingredient in whole meal/whole wheat products, such as whole meal bread. Cellulose is specifically found in root and leafy vegetables, such as beetroot, carrot, celery, and rhubarb. Lignin is highest in fruits, particularly strawberries and peaches. Can be added to many fibre-enriched/fortified foods, such as bread.
Least sweet		



Definition

Sugar added to food is termed refined sugar.

Functions and Nutritional Significance of Simple Carbohydrates and Starch

Source of Energy

The primary function of simple carbohydrates and starch is to provide energy (16.7 kJ/g).

Simple carbohydrates and starch are broken down and converted into monosaccharides, and if necessary, converted into glucose and glucose derivatives after consumption in preparation for absorption. Once glucose is absorbed into the bloodstream, it is transported to cells (especially muscle cells) and broken down further to create energy in the form of **adenosine triphosphate (ATP)** through a process of **cellular respiration**.

Definitions

Cellular respiration is a metabolic pathway that breaks down glucose into carbon dioxide and water and produces ATP also during this reaction.

Fast fact

The brain can only use glucose to produce ATP to provide energy; therefore, glucose is the body's preferred source of energy.

Simple Carbohydrates

Monosaccharides are already small enough to enter the bloodstream, while disaccharides need only one bond broken between the two joined monosaccharides before they can be absorbed into the bloodstream. Both monosaccharides and disaccharides can therefore enter the bloodstream quickly and are associated with a rapid rise in blood glucose levels and consequential rapid energy release (as shown in Figure 1.2.5). Foods or beverages consumed that produce this blood glucose response are known to have a high **glycaemic index (high GI)**.

Definition

Glycaemic Index (GI) is a measure of how a food or beverage will affect blood glucose levels after consumption. Foods with minimal or no carbohydrate content do not have a GI value, nor would they significantly affect blood glucose levels post meal.

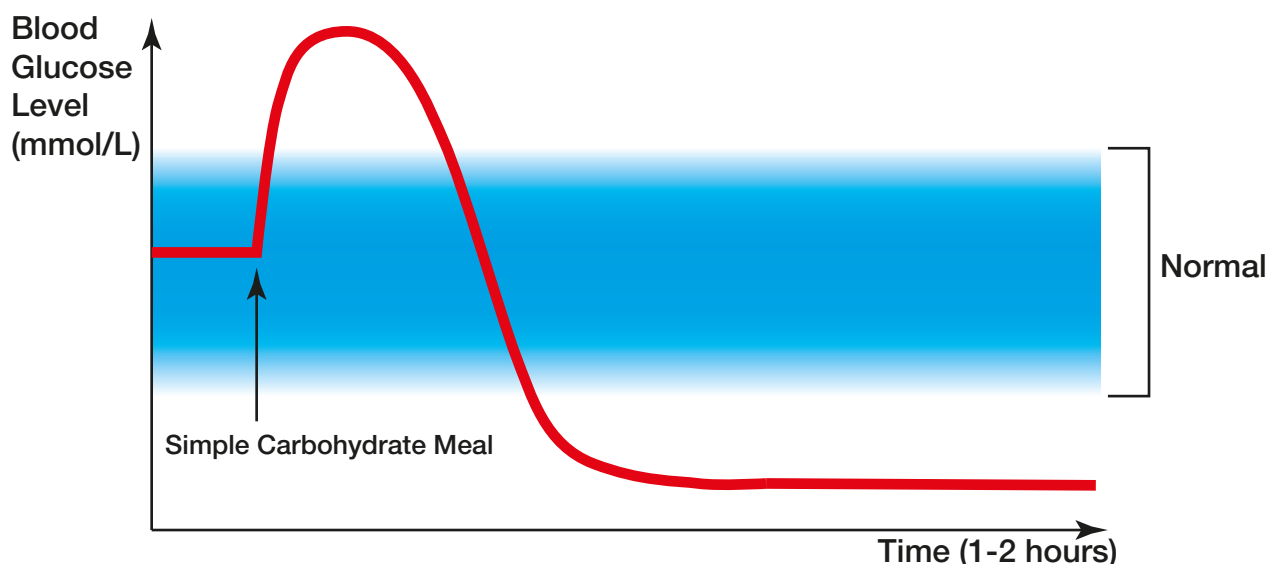


Figure 1.2.5: Effect of simple sugars on blood glucose levels (high GI).

Complex Carbohydrates

Starch, on the other hand, is a much larger molecule, made of hundreds of glucose units bonded together. Therefore, it breaks down into glucose slowly and takes longer to be absorbed into the bloodstream. This results in a lower and more gradual elevation in blood glucose levels and, consequentially, sustained energy (as shown in Figure 1.2.6). Foods or beverages that produce this blood glucose response are known to have a **low glycaemic index (low GI)**.

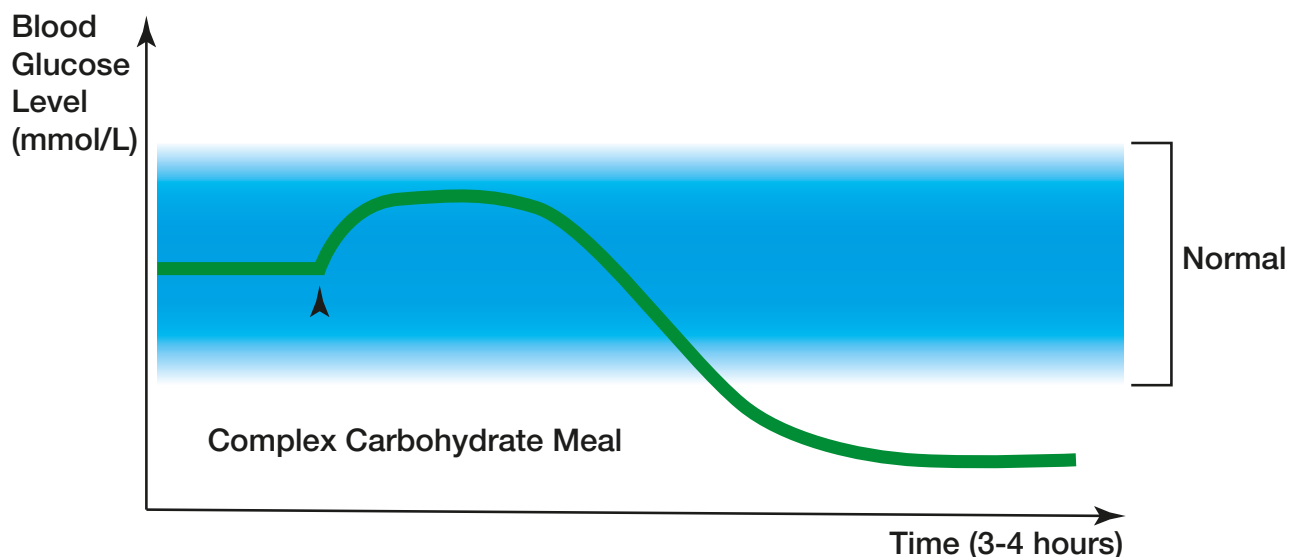


Figure 1.2.6: Effect of starch on blood glucose levels (low GI).

A component of the Cell Membrane

Blood glucose can also be used for a structural role, as part of the cell membrane. Glucose molecules will bond together and form short-chain oligosaccharides on the exterior of the cell membranes (Figure 1.2.7). The role of these oligosaccharides is in cell recognition: how our body recognises our own cells in contrast to those that are foreign, such as bacteria or viruses.



Reminder

Oligosaccharides are 3 to 10 glucose molecules joined together.

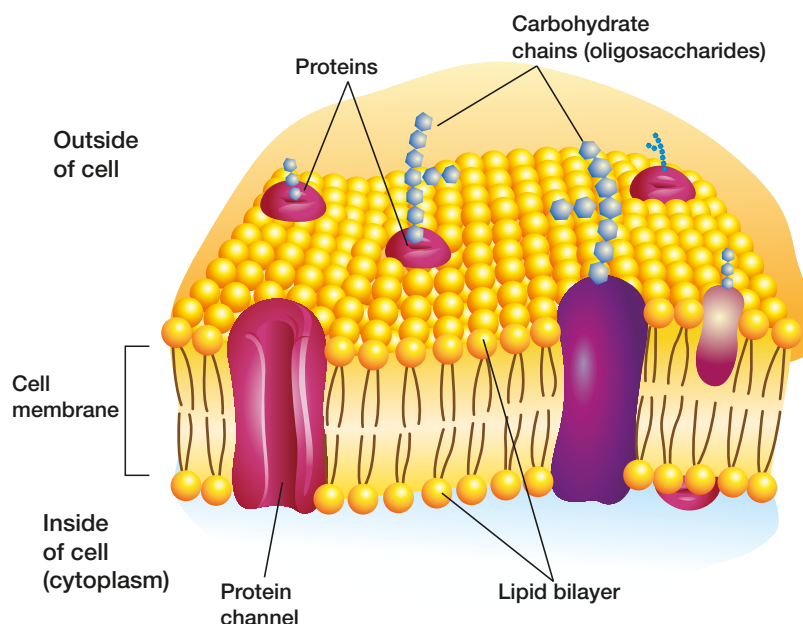


Figure 1.2.7: Oligosaccharides on the exterior of the cell membrane used in cell recognition.

Functions and Nutritional Significance of Oligosaccharides and Soluble and Insoluble Fibre

Achieving efficient nutrient absorption and satiety

Oligosaccharides, **resistant starch**, and soluble fibre cannot be broken down into glucose and absorbed into the bloodstream. Instead, most of these carbohydrates bind water and partly dissolve to become 'gel-like' in the stomach. The addition of water to the carbohydrate food consumed can also cause expansion of the stomach. The gel-like consistency of the carbohydrate food, plus the increase in volume from the addition of water, causes food to empty from the stomach into the small intestine at a slower rate. The slower rate of stomach emptying has two roles:

1. It slows initial digestion in the first part of the small intestine called the duodenum to slow down and maximise the absorption of nutrients (including monosaccharides)
2. It keeps the body feeling fuller for longer (this feeling is called **satiety**), via two means:
 - i. expansion of the stomach triggers the feeling of satiety, which prevents overeating and the development of obesity.
 - ii. slow absorption of monosaccharides gives a gradual blood glucose rise, providing sustained or longer-lasting energy. This can also help to regulate blood glucose levels, preventing the onset of type 2 diabetes.



Definitions

Many foods high in starch, particularly when eaten raw, without any processing (for example bananas with some green to them, and beans), will not be completely digested into glucose. The starch that isn't digested is called resistant starch.

Maintaining a healthy digestive tract

The ability of the oligosaccharides, resistant starch, and soluble fibre to continue to bind water along the digestive tract helps to produce soft and bulky faeces, allowing easier passage through the large intestine.

Unlike simple sugars and starch, these carbohydrates are mostly indigestible. The human body lacks the enzymes to break these down into monosaccharides, which is the only saccharide molecule small enough to be absorbed into the bloodstream from the small intestine. Oligosaccharides, resistant starch, and soluble fibre will therefore move onto the large intestine. This is where many **beneficial bacteria** are found.



Definitions

Beneficial or non-harmful bacteria (microorganisms) are termed non-pathogenic; harmful microbes are termed pathogenic.

The bacteria use oligosaccharides, resistant starch, and soluble fibre as sources of food and can break them down in a process called **fermentation**. When these carbohydrates are broken down via fermentation, the products are flatulence-causing gas and short-chain fatty acids, which can even provide some energy to intestinal cells lining the colon (around 8–13 kJ/g, depending on the type of carbohydrate broken down) (as shown in figure 1.2.8). Bacteria that die during the fermentation process then provide additional bulk to stools. This can prevent constipation and the development of diverticular disease.

The bacteria in the large intestine also aids in our immune system, serving a function of hindering the growth of harmful microorganisms that may enter the large intestine.

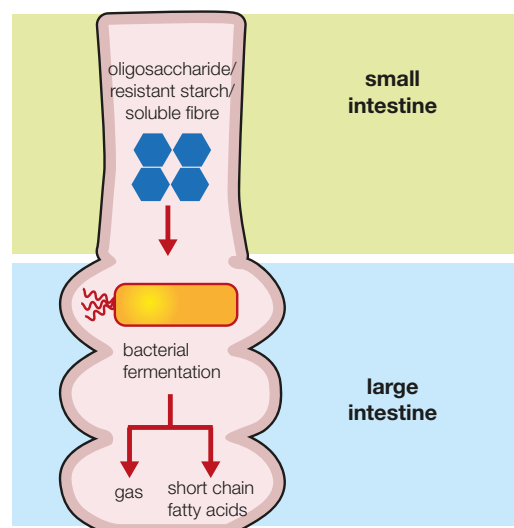


Figure 1.2.8: Bacterial fermentation of oligosaccharides, resistant starch, and soluble fibre in the large intestines, producing gas and short chain fatty acids.

Lowering blood cholesterol levels

Soluble fibre is known to reduce cholesterol. It does this by binding to bile acids that are excreted into the small intestine from the liver (Figure 1.2.9). Bile acids are made of cholesterol and will re-enter the bloodstream from the small intestine, potentially raising blood cholesterol levels. However, if soluble fibre binds to the bile acids, it reduces the amount of cholesterol re-entering the bloodstream, because soluble fibre is too large to be absorbed into the bloodstream. This reduces the risk of cholesterol depositing in artery walls, which can contribute to the development of atherosclerosis. The bile acids (cholesterol) are transported by soluble fibre along the digestive tract and finally removed from the body as waste, excreted as part of our faeces.

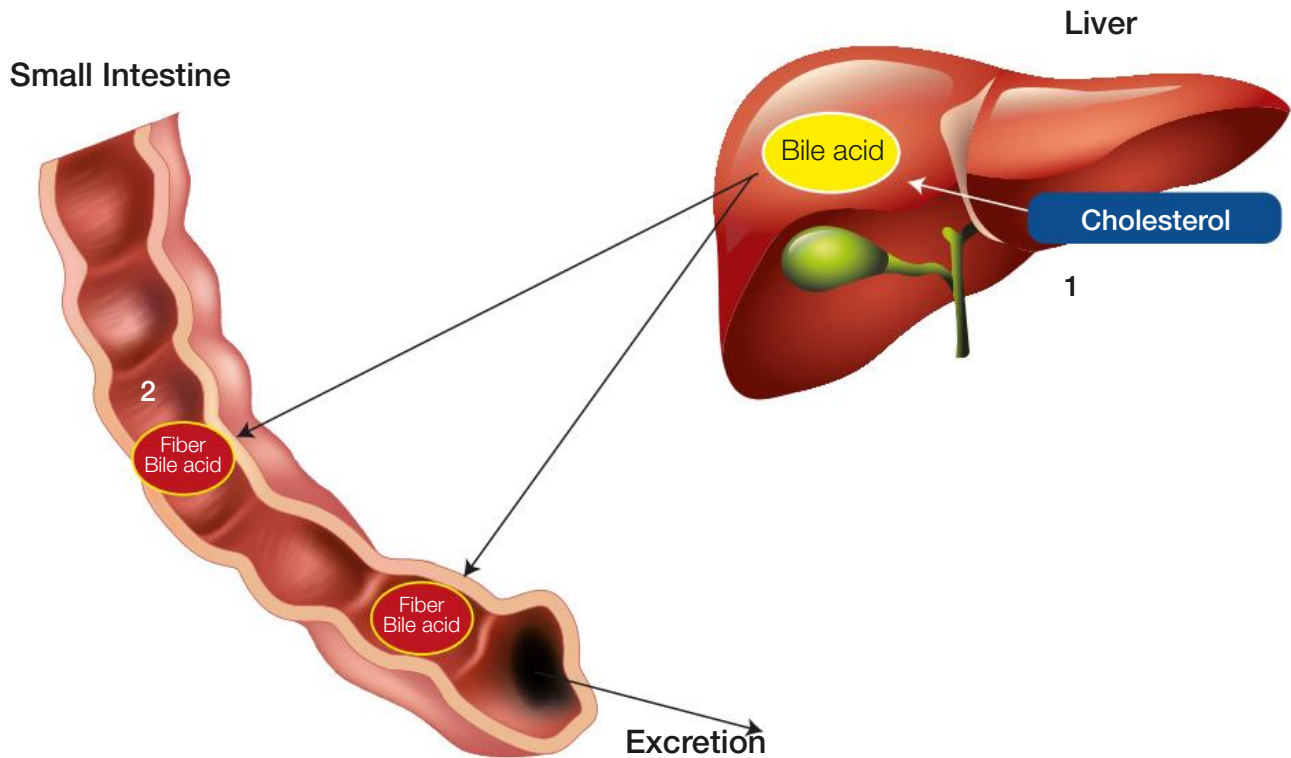


Figure 1.2.9: Soluble fibre binding to bile acids (made of cholesterol), preventing them from entering the bloodstream and causing them to be excreted as waste.

Supporting healthy digestive movement

Insoluble fibre is generally not dissolvable in water, or able to be fermented (broken down by bacteria) in the large intestine. Its role is to provide bulk to faeces or to increase stool weight, which allows easier passage of stools, thereby reducing constipation and diverticular disease.

Key terms

Complex Carbohydrates	High GI	Polysaccharides
Disaccharides	Insoluble fibre (cellulose & lignin)	Resistant starch
Fermentation	Low GI	Simple Carbohydrates
Glucose	Monosaccharides	Soluble fibre (pectin & gums)
Glycaemic index (GI)	Oligosaccharides	Starch
Glycogen		

Review questions: 1.2 Carbohydrates

1

1. Identify each molecule's saccharide grouping:

- (a) Starch:
(b) Fructose:
(c) Maltose:

(3 marks) (KA1)

2. Name two disaccharides that glucose is a part of.

Disaccharide 1:

Disaccharide 2:

(2 marks) (KA1)

3. Explain the structural difference between a monosaccharide and disaccharide.

(2 marks) (KA1)

4. The Glycaemic Index (GI) ranks carbohydrates in food according to how their consumption would affect a person's blood glucose levels. The majority of sports drinks have a high GI, explain how this would affect an individual's energy levels for the first few hours after consumption.

(2 marks) (KA2)

5. For the foods below, match the carbohydrate to the speed of breakdown and absorption into the bloodstream. Choose between **starch, glucose, and sucrose**.

	Food A	Food B	Food C
Time from consumption to blood glucose peak	18 minutes	90 minutes	20 minutes
Type of carbohydrate			

(3 marks) (IAE3)

6. Fill in the empty column of the table below using the following types of carbohydrates (more than one type of carbohydrate can be used for the following functions and may be used more than once).

Simple Carbohydrates (SC)

Glucose (G)

Soluble Fibre (SF)

Insoluble Fibre (IF)

Oligosaccharides (O)

Starch (S)

Resistant Starch (RS)

Function	Type of Carbohydrate
Provides bulk to stools due to not being broken down	
Slows stomach emptying	
Binds to water, producing soft and bulky stools	
Foods high in this carbohydrate create a low GI response	
These carbohydrates undergo fermentation in the colon, providing energy and a food source to beneficial bacteria	
Foods high in this carbohydrate create a high GI response	
Assists in the functioning of the immune system	
Carbohydrates that provide the body with energy	

Function	Type of Carbohydrate
Simple carbohydrates and starch are broken down into this molecule	
Slows down initial digestion, maximizing nutrient absorption	
The only type of carbohydrate the brain can utilize to create energy	
Creates satiety	
Reduces cholesterol levels, by binding to bile acids	
Provides bulk to stools through the bacteria that die during fermentation	

(14 marks) (KA1)

7. Below is a table listing some of the ingredients in a bowl of cereal. Identify which saccharide group three ingredients would be classified as.

Ingredient	Saccharide grouping
Whole wheat flakes	
Corn flakes	
Apricots	
Almonds	
Raw sugar	
Milk	

(3 marks) (KA2)

8. (a) Explain where and how soluble fibre is broken down in the body.

(2 marks) (KA1)

- (b) Explain one way that soluble fibre can help prevent constipation.

(2 marks) (KA2)

- (c) Provide two specific examples of foods that are high in soluble fibre.

1.

(1 mark) (KA1)

2.

(1 mark) (KA1)

9. Many foods high in starch, such as white bread, baked potatoes and white rice are processed (e.g., cooked) having had their starch partly broken down into smaller chains including maltose. Explain the effect these foods would have on blood glucose levels, and why.

(3 marks) (KA2)

10. Explain why simple carbohydrates and starch have different roles in the body to fibre, resistant starch, and oligosaccharides.

(2 marks) (KA2)

11. Refer to the following nutritional information panel, demonstrating the carbohydrate and sugar content of three different food sources.

Content per 100g	FOOD A	FOOD B	FOOD C
Carbohydrate (g)	77	44.3	44.4
Sugar (g)	51.3	2.7	40.5

- (a) With reference to the nutritional information panel above, which food source has the highest carbohydrate content.

(1 mark) (IAE3)

- (b) With reference to the nutritional information panel above, which food source has the highest complex carbohydrate content.

(1 mark) (IAE3)

- (c) With reference to the nutritional information above, identify the food source which would have the highest glycaemic index. Make sure to use evidence, such as data, to justify your response.

(3 marks) (IAE3)

- (d) Foods can be classified based on their primary nutrient. With reference to the nutritional information above, what type of saccharide would food B be considered as and explain the effect the consumption of this food source would have on blood glucose levels.

(3 marks) (KA2, IAE3)

12. The glycaemic index (GI) is used to rank carbohydrate foods. The classification levels are shown in the left table.

The results of an investigation by scientists who tested the effect of different cooking methods on the GI of a white potato are shown in the right table.

Table 1: Glycaemic index (GI) classification

Low GI	<55
Medium GI	55-70
High GI	>70

Table 2: The effect of cooking methods on the glycaemic index (GI) of a white potato

Method of cooking a potato	GI
Boiled (10 minutes)	49
Boiled (19 minutes)	56
Boiled (19 minutes) and mashed*	73

*Beaten to a creamy consistency

- (a) Explain the effect of low GI foods on blood glucose levels.

(2 marks) (KA2)

(b) Use the data in Table 2 from the investigation above to answer the following questions.

(i) State the independent variable.

(1 mark) (1AE3)

(ii) Identify one variable that must be controlled and explain the effect on the GI if the variable is not controlled.

(3 marks) (1AE3)

(iii) Explain how cooking the potato for longer results in different GI classifications.

(2 marks) (1AE3)

(c) Refer to the graph below, which shows a graph constructed by a student using the data from the investigation. State *two* errors that the student made when constructing their graph.



(2 marks) (1AE3)

(d) When the investigation was repeated later, a systematic error was discovered.

(i) Identify *one* possible systematic error in the investigation.

(1 mark) (1AE3)

(ii) State *one* impact of a systematic error on the data.

(1 mark) (1AE3)

Total: / 60 marks



Science as a human endeavour

What is Kombucha and does its hype stand up to Scientific Scrutiny?

<https://www.sciencealert.com/science-behind-kombucha-fermented-tea-health-claims>

Kombucha is made from either a green or black tea base. Added to that is white sugar, which has been fermented with a type of “tea fungus” called a symbiotic culture of acetic acid (vinegar) bacteria and yeast, or SCOBY, for one to two weeks.

Lightly fermented foods, made from bacteria, contain healthy bacteria. The theory is that these bacteria help colonise our gut, which early research suggests may improve a range of bodily functions from our mood and stress levels to our weight and cravings for food. To gain any long-term health benefits from foods containing live bacteria, known as probiotics, the current research suggests you would need to take them continuously.

The jury is still out on whether probiotics are beneficial to the wider population. So kombucha – or yoghurt, for that matter – won’t necessarily improve the health of your gut. To maintain good gut health, the best thing you can do is eat a wide variety of healthy foods.

A quick Google search will produce many exciting health claims about kombucha. These include detoxifying the blood, reducing cholesterol levels, reducing blood pressure, protecting against diabetes, antibacterial effects, and counteracting ageing.

When scientists want to evaluate the effect of a nutrient on health, we like to see that the studies have been done in humans, rather than animals. Many “lab bench” studies may begin by looking at isolated cells and then animals. This provides us with limited evidence, as human biological systems typically work differently. For kombucha, there is only evidence from lab bench studies and animal studies. No published studies come from human clinical trials of drinking kombucha. Two reviews of the lab bench and animal studies on kombucha from 2014 and 2000 suggest the drink may have antimicrobial, antioxidant, anti-cancer, and anti-diabetic properties. The reviews also note some exciting mechanisms by which kombucha could potentially be used to treat gastric ulcers and high cholesterol and improve the body’s immune response and liver detoxification. But they do not yet tell us if they translate to humans.

A chemical called DSL (D-Saccharic acid-1,4-lactone) is potentially the most beneficial component in kombucha. DSL has the potential to inhibit an important enzyme, β -glucuronidase, which may be linked to cancer growth. But once again, this has not been shown in humans.

Based on the current evidence, we can say the health properties of kombucha are likely to be like drinking tea or other fermented foods. If you enjoy kombucha, continue drinking it, but if you favour the traditional black and green tea, there are good health reasons to continue drinking those. While some exciting properties have been shown from lab bench and animal studies, it doesn’t necessarily follow that we will see these benefits in humans.

Keep in mind that some of the kombuchas on the market have fruit juice added after the fermentation process, which will contribute to your overall sugar intake. The amount of sugar in these varieties can range from 10-15g per serve (two to three teaspoons), so if you have regular tea without sugar, drinking kombucha will increase your sugar intake.

1. Explain how the continual consumption of Kombucha or other foods containing bacteria can improve gut health, and therefore immunity.

(2 marks) (KA2)

2. Discuss one **limitation** of Kombucha mentioned in the passage above.

(2 marks) (KA3)

? Science Inquiry Skills

The Absorbability of Soluble Fibre

Introduction

Dietary fibre includes the parts of plant-based foods that your body cannot digest or absorb via the villi in the small intestine. Unlike other food components, such as simple carbohydrates, starch, lipids, and protein – which your body breaks down and absorbs – dietary fibre isn't digested by your body. Instead, it passes relatively intact through your stomach, small and large intestines and then excreted out of the body. However, fibre can be categorised as soluble or insoluble. Insoluble fibre does not dissolve in water, whereas soluble fibre does dissolve in water, where it becomes 'gel-like' in the stomach. This gel-like consistency of soluble fibre can assist in providing a feeling of satiety and slowing down the emptying of chyme in the stomach into the small intestine. These roles can assist in preventing diet related disorders, including obesity and nutrient deficiencies, such as Anaemia.

Hypothesis:

If the food source contains a greater content of soluble fibre, then it will absorb a greater volume of water and become more gel-like.

Materials:

- 8 x 50ml beakers
- 2 x 50ml measuring cylinder
- Distilled Water
- Electronic Scales
- Stirring Rod
- Funnel & Chux
- Stopwatch
- 5g All-Bran Wheat Flakes
- 5g Quinoa Flakes
- 5g Raw Buckwheat
- 5g Rolled Oats
- 5g Flaxseed Meal
- 5g Black Chia seeds
- 5g Psyllium Husks
- 5g Pearl barley

Method:

1. Research the amount of soluble fibre that each of the food sources contain and enter this in second column of the results table below.
2. Measure 5g of All-Bran Wheat Flakes into a 50ml beaker using electronic scales.
3. Measure 30ml of distilled water using a measuring cylinder.
4. Place the 30ml of distilled water into the beaker containing the All-Bran Wheat Flakes and start the stopwatch as soon as the distilled water has been added. Allow the All-Bran to sit for 5 minutes.
5. Stir the All-Bran and water occasionally with the stirring rod.
6. Stop the stopwatch once 5 minutes have passed.
7. Place the funnel with chux into the opening of the second measuring cylinder.
8. Pour the excess water from the beaker containing the All-Bran through the funnel and chux and into the second measuring cylinder (the chux may need to be squeezed to ensure all excess water has been released).
9. Measure the amount of water that has been added into the second measuring cylinder.
10. Subtract the amount of water that has been added into the second measuring cylinder from 30ml (this is the amount of water that has been absorbed by the soluble fibre in each of the food sources tested). Enter this value in the third column of the results table below.
11. Repeat steps 2-10 using the other 7 food sources.

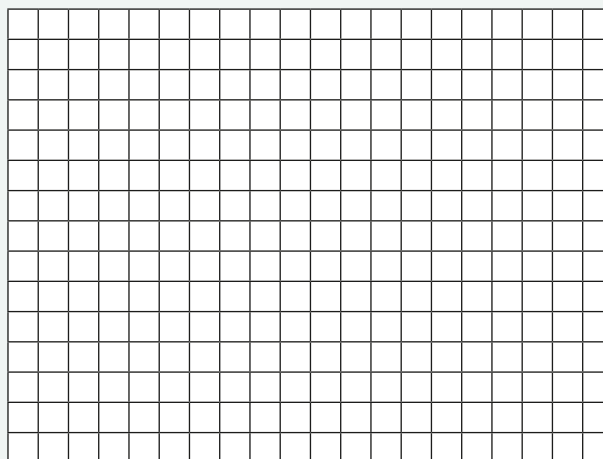
? Science Inquiry Skills

Raw Data:

Food Source	Soluble Fibre Content (per 100g)	Volume of Water Absorbed (ml)
All-Bran Wheat Flakes		
Quinoa Flakes		
Raw Buckwheat		
Rolled Oats		
Flaxseed Meal		
Black Chia seeds		
Psyllium Husks		
Pearl barley		

Presentation of Data:

1. Represent the raw data as a scatter graph, plotting the Soluble Fibre content (g/100g) on the x axis and the volume of water absorbed (mL) on the y axis. Ensure to add the suitable features on the graph below, including a title, even scale, labelled axes, and trend line.



Analysis & Discussion:

2. With reference to the graph above and using data in your response, describe the trend of results.

3. Describe how you could increase your intake of soluble fibre, and the importance of consuming this type of carbohydrate.

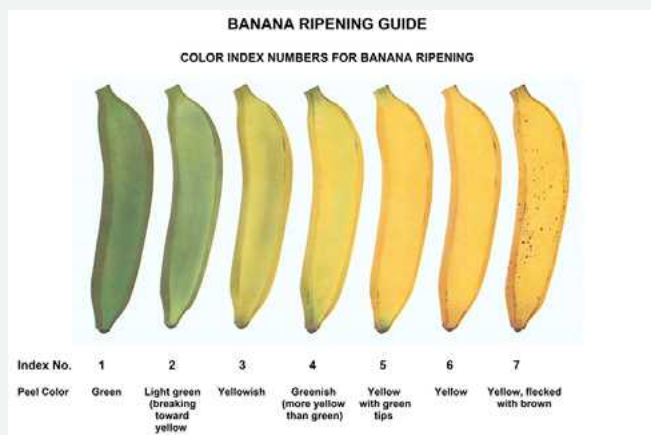
4. Write a conclusion for this experiment, explaining if the hypothesis was supported or not supported.

? Science Inquiry Skills

The Effect of Ripening on Glycaemic Index

Introduction

Australians consume approximately 5,000,000 bananas each day! They are a rich source of carbohydrates and have a short life span caused by their fast-ripening process. During ripening, the visual appearance of bananas degrades from a greenish yellow peel to a yellow peel with brown spots. The ripeness of the banana can be determined by comparing the colour of the peel to a standardized colour chart, which has evolved to seven stages (as shown in the Figure below).



During the ripening process, the enzyme amylase catalyses the breakdown of starch to simple sugars; first to maltose and then to glucose. The simple sugar levels are high as a banana reaches a ripening index number of 3 until the overripe stage (index 7), where most of the starch has been converted into glucose, which the banana continues to use for cellular respiration.

Hypothesis:

If the ripening index number of the banana increases from 1, then the starch content decreases and simple sugar content increases.

Materials:

- Bananas of varying ripeness
- Iodine Solutions (2% potassium iodide with 1% iodine in water)
- Kitchen knife
- Chopping board
- Brush
- Mortar and Pestle
- Distilled Water
- 50ml beaker
- Stirring rod
- Benedict's reagent
- Test Tube
- Test Tube Rack
- 5ml Measuring Cylinder
- Water bath set at 90 degrees Celsius

Method:

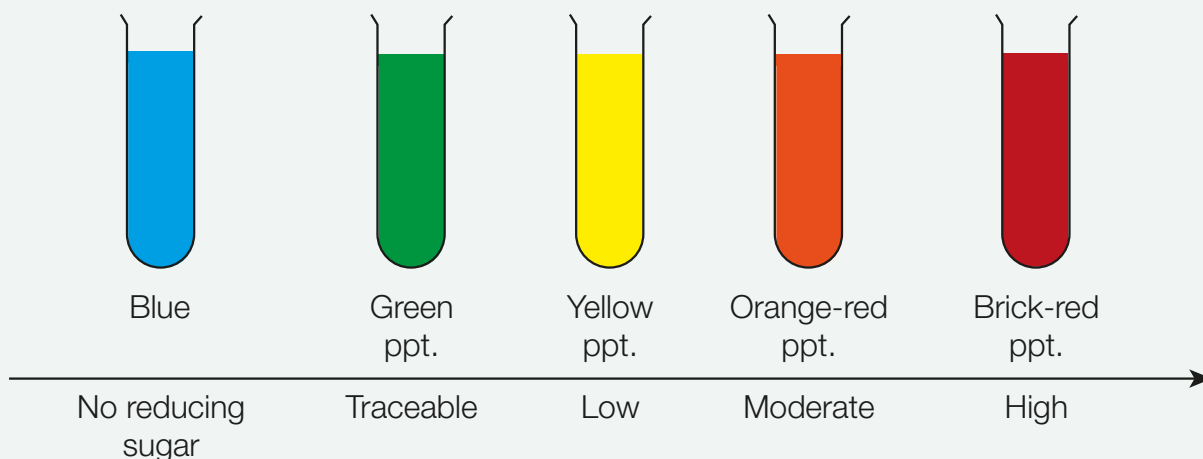
Part 1: Iodine - Starch Test

1. Cut each banana in half lengthwise using the kitchen knife and chopping board.
2. With a brush, cover the surface of each banana with the Iodine solution.
3. Wait one minute and compare the colour of each of the banana samples.
4. Describe the colour of each banana sample and record this in Part 1 of the results table.
5. Determine if starch is present in the banana sample. If starch is present, then the surface of the banana will turn a blue-black colour. If starch is not present, then the surface of the banana will remain yellow/orange (the colour of the Iodine solution).

? Science Inquiry Skills

Part 2: Benedict Test for Simple Sugars (such as Glucose and Fructose)

1. Mash the banana sample with a mortar and pestle until it is in a liquid form (as liquid as you can get it), and place in a small beaker.
2. Add a small amount of distilled water to the ground banana in the beaker and stir with a stirring rod to ensure it is a liquid consistency.
3. Add the banana sample to a test tube, until it is quarter filled.
4. Measure 2ml of Benedicts solution with a measuring cylinder, and place in the test tube with the banana.
5. Place the test tube in a water bath set at 90 degrees Celsius for 5 minutes, while occasionally shaking it.
6. Carefully take out the test tube from the water bath and place it in a test tube rack to observe.
7. Describe the colour of the solution in the test tube, if no sugar is present the solution will remain blue, but if simple sugars are detected, it will change colour – green if a traceable amount of sugar is present, yellow if a low amount is present, orange if a moderate amount is present and red if a high amount of sugar is detected (as shown in the figure below demonstrating Benedict's Test Results for the Presence of Simple Sugars, such as Glucose and Fructose).



Raw Data:

	Part 1: Iodine Starch Test		Part 2: Benedict Sugar Test	
Banana Ripeness and colour	Colour of Banana after the application of Iodine Solution	Presence of Starch (✓ or X)	Colour of Banana after the application of Benedict's reagent	Presence of Glucose & Fructose (X, traceable, low, moderate or high)
1. Green				
2. Light Green				
3. Yellowish (more green than yellow)				
4. Greenish (more yellow than green)				
5. Yellow with green tips				
6. Yellow				
7. Yellow with brown				

? Science Inquiry Skills

Analysis & Discussion:

1. Classify the following carbohydrates according to their saccharide grouping.

Starch:

Maltose:

Glucose:

2. With reference to the results obtained, describe the effect of ripening on:

(a) The starch content in bananas

(b) The Glucose and Fructose content in bananas

3. Justify why there is a difference in the starch and simple sugar content in the bananas as they ripen.

4. Identify the glycaemic index (high or low) of bananas with a ripening index of 1 and 3 and explain the effect of ripening on the glycaemic index of bananas.

5. Explain how the precision and validity of the experiment could be improved.

Extension Activities

1

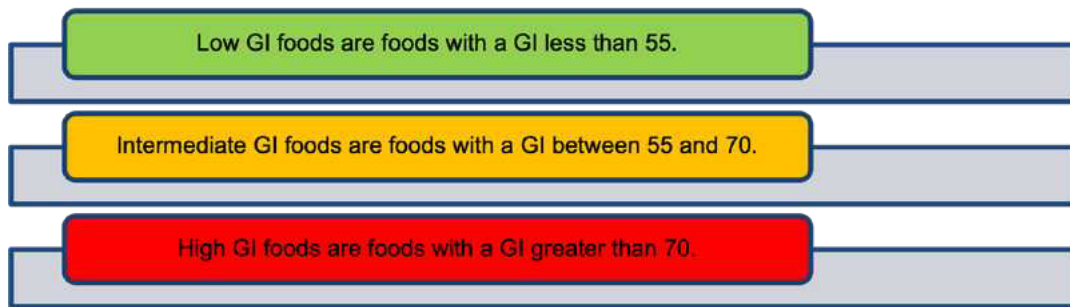
1. Explain the storage when excessive simple carbohydrates and starch are consumed in the human body.

2. According to Nutrition Australia, it is recommended that between 25-30g of fibre is an adequate daily intake for Australians. Compile a list of the foods consumed in a typical day and research their fibre content to determine if you meet this daily recommendation.

Food	Fibre per serve (g)	Food	Fibre per serve (g)
		Total Daily Fibre Consumption (g)	

3. Research and explain the impact of consuming excess sugar, which can be found in products such as Kombucha or fruit juices on the health of an individual's teeth, especially children.

4. Access the following website: <https://glycemicindex.com/gi-search/> and look up the foods listed in the table below to determine their GI Value. Once their GI value has been determined, explain the effect these foods would have on blood glucose levels after consumption using the GI ranges as shown below.

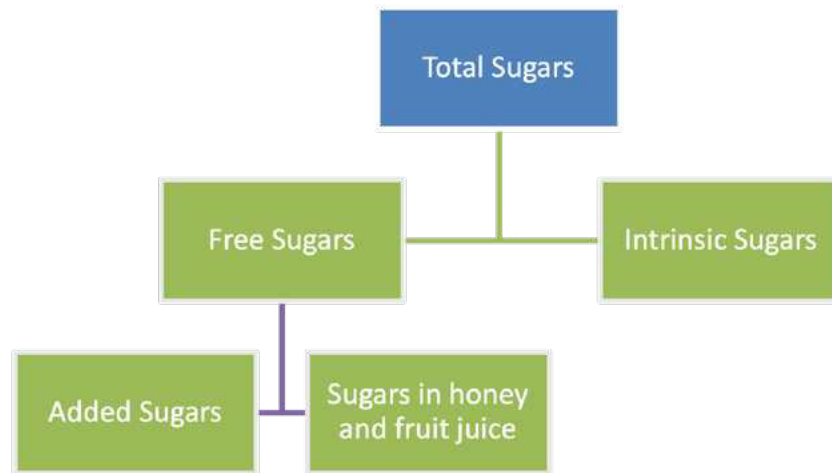


Food Item	GI Value	Effect on Blood Glucose Levels
Watermelon, raw, red-fleshed, seeded		
Basmati, easy cook white rice		
All-Bran Soy 'n Fibre (Kellogg's)		
Nutella, chocolate hazelnut spread		
Sweet potato, peeled, cut into 25mm slices, and boiled in water for 20 mins		
Sweet potato, baked with skin on at 175°C for 45 mins		
Tamar Valley Natural Yoghurt, no added sugar		
Soy Yoghurt, peach, and mango		

5. The World Health Organisation recommends our 'free' sugar consumption should only make up 10% of our total daily energy intake, which equates to approximately 50g or 12 teaspoons a day.

The Australian Health Survey found that in 2011-2012, Australians were consuming an average of 105 grams of total sugars per day, with just over half of this being free sugars (60g each day, or the equivalent of 14 teaspoons of white sugar), with the balance (45 grams) being the naturally occurring sugars.

- (a) Research and use the image below to explain the difference between total sugars, intrinsic sugars, free sugars and added sugars.



- (b) Look up and state the name of common sugars that are added to our foods in Australia.
- (c) The amount of sugar on the Nutritional Information Panel (NIP) of food products includes the naturally occurring sugar, as well as the free sugars. Avoiding sugar completely is not necessary, but to try and avoid large amounts of added sugar look to see if there is more than 15g of sugar per 100g, and then check the ingredients list for added sugar or alternate names that are listed high.

Look up the sugar content per 100g of commonly consumed carbohydrates or perceived “healthy” carbohydrates and record in the table below.

Food	Sugar per 100g	Food	Sugar per 100g

1.3 Lipids

Science understanding

Triglycerides and sterols are two types of lipids. Triglycerides (fats) are made up of glycerol and three fatty acid chains.

- Identify and compare the general structure and sources of the following fatty acids:
 - Saturated
 - Unsaturated
 - Monounsaturated
 - Polyunsaturated (omega-3 & omega-6 essential fatty acids)
 - Trans-fatty acids
- Explain the functional roles of triglycerides as a nutrient.
- Identify sources of omega-3 and omega-6 essential fatty acids in the diet.
- Explain the importance of omega-3 and omega-6 essential fatty acids for health.

Cholesterol is a type of sterol that is transported by lipoproteins in the bloodstream.

- Identify sources of cholesterol.
- Explain the role of cholesterol and lipoproteins (LDL & HDL) in the body.

SACE Subject Outline, 2024.

Structure and Classification of Lipids

The **lipid** family includes triglycerides (fats and oils), phospholipids and sterols (including cholesterol). The structure of lipids is like carbohydrates in that they consist of carbon (C), hydrogen (H) and oxygen (O).

Triglycerides

Triglycerides are the most abundant lipids, both in foods and the body. Every **triglyceride** is composed of one molecule of **glycerol**, which acts as a backbone to three attached **fatty acid chains** (as shown in Figure 1.3.1).

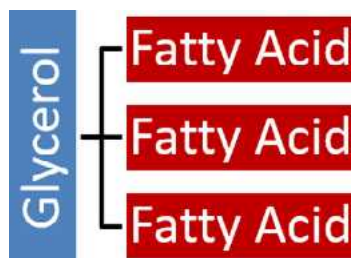


Figure 1.3.1: The basic structure of a triglyceride, composed of a glycerol backbone attached to three fatty acid chains.

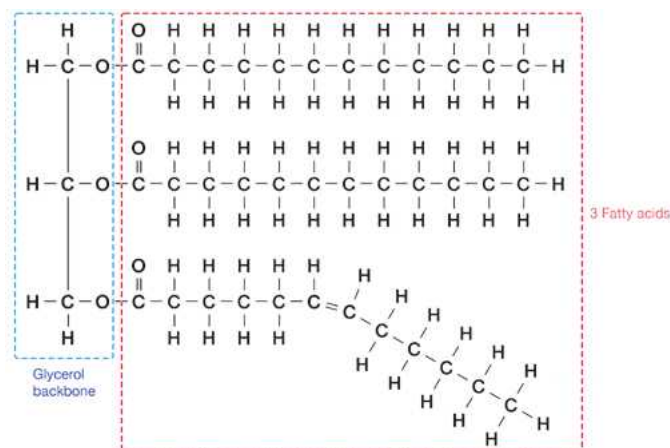


Figure 1.3.2: The chemical structure of a triglyceride, composed of a glycerol backbone attached to three fatty acid chains.

All fatty acids have the same basic structure consisting of a chain of carbon and hydrogen atoms. On one end of the fatty acid chain is a **carboxylic acid group (COOH)** which is known as the alpha (α) end and is the attachment point to the glycerol backbone via an ester bond through the oxygen atom. The other end of the chain is exposed and known as the omega (ω) end, consisting of a **methyl group (CH₃)** (as shown in figure 1.3.3 and 1.3.4). Fatty acids differ from one another, by the length of their carbon chains and in the number and location of their double bonds. Most naturally occurring fatty acids contain an even number of carbon atoms in their chains, which may be between 4-24 carbons long. The longer chain (12 to 24 carbons) fatty acids of meats, fish and vegetable oils are most common in the diet. Smaller chain fatty acids (fewer than ten carbons) are primarily found in dairy products.

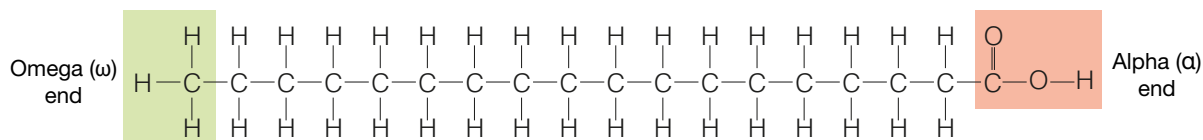


Figure 1.3.3: The structure of stearic acid, an 18-carbon saturated fatty acid.

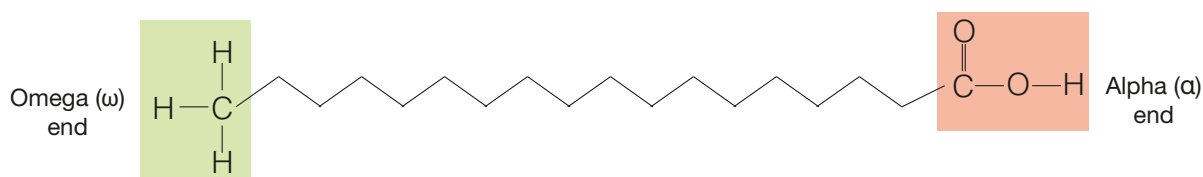


Figure 1.3.4: The structure of stearic acid, an 18-carbon saturated fatty acid (simplified version, with each corner on the zigzag line representing a carbon atom with two attached hydrogens).

Saturated Fatty Acids

Fatty acids may be saturated or unsaturated. A **saturated** fatty acid is completely loaded with all its hydrogen atoms and contains only single bonds between its carbon atoms (as shown in Figure 1.3.3). These types of triglycerides are generally solid at room temperature and have a higher melting point.

Unsaturated Fatty Acids

An **unsaturated** fatty acid does not contain the full quota of hydrogen atoms, due to containing at least one double bond between the carbon atoms. An unsaturated fatty acid that contains one double bond between the carbon atoms is a **monounsaturated** fatty acid (as shown in Figure 1.3.5 and 1.3.6), which are generally liquid at room temperature and have a lower melting point than saturated fats. An unsaturated fatty acid that contains more than two double bonds between the carbon atoms is a **polyunsaturated** fatty acid (as shown in Figure 1.3.7 and 1.3.8). These types of triglycerides are also generally liquid at room temperature and have a lower melting point than saturated fats and monounsaturated fats. Although drawn straight in Figure 1.3.5, 1.3.6, 1.3.7 and 1.3.8, unsaturated fatty acid chains bend at the double bond, which is regarded as a point of unsaturation as two hydrogen atoms are missing in this part of the carbon chain.



Fast fact

The three types of atoms found in triglycerides: hydrogen (H), oxygen (O) and carbon (C) have a characteristic number of bonds it can form with other atoms, which determines the saturation of hydrogens of each fatty acid. Hydrogen can only form one bond; oxygen can only form 2 bonds and carbon can only form 4 bonds.

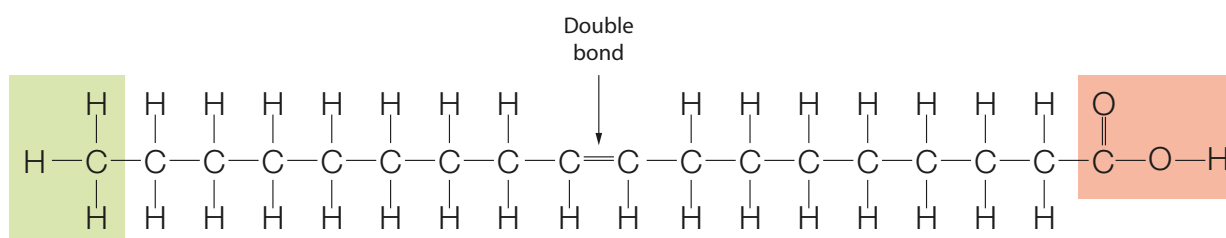


Figure 1.3.5: The structure of oleic acid, an 18-carbon monounsaturated fatty acid containing one double bond between the carbon atoms.

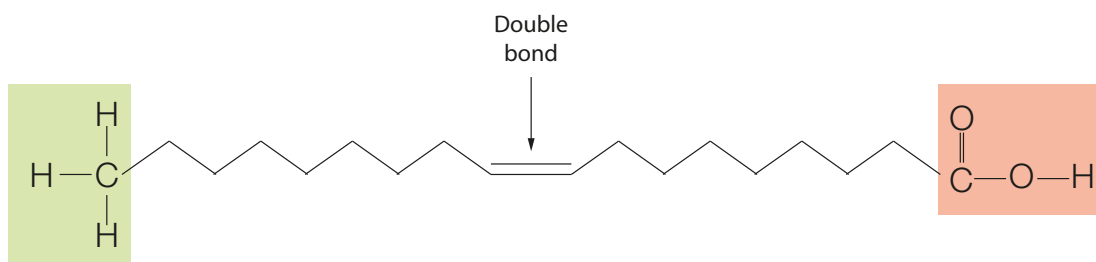


Figure 1.3.6: The structure of oleic acid, an 18-carbon monounsaturated fatty acid (simplified version).

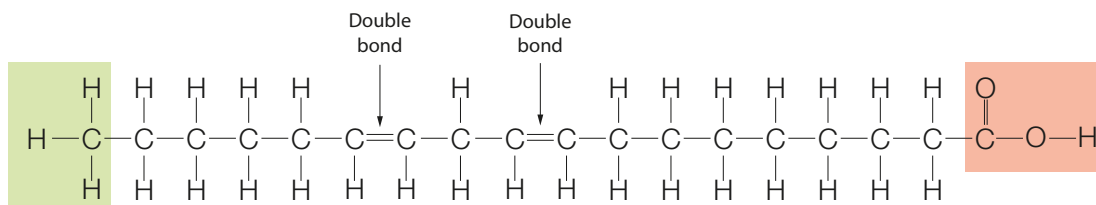


Figure 1.3.7: The structure of Linoleic acid, an 18-carbon polyunsaturated fatty acid containing two double bonds between the carbon atoms.

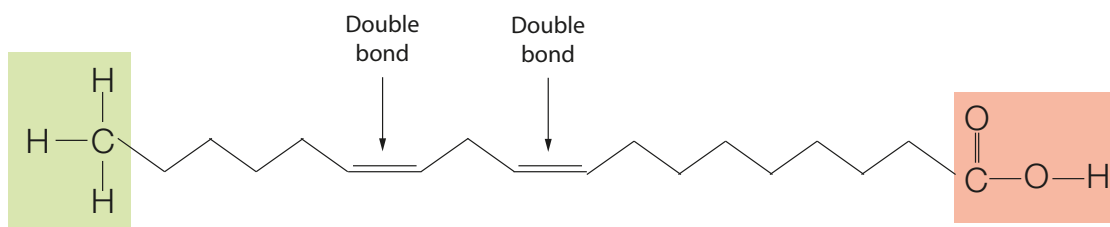
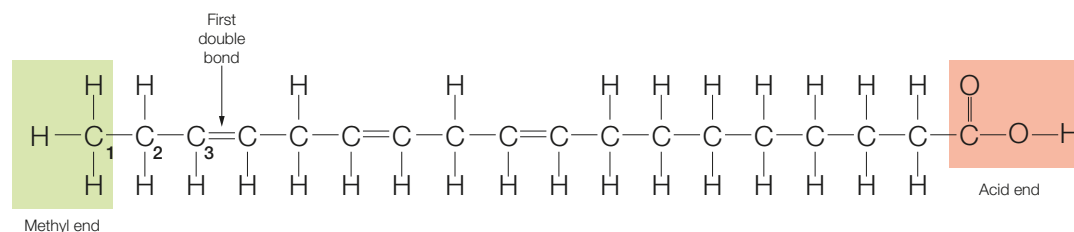


Figure 1.3.8: The structure of Linoleic acid, an 18-carbon polyunsaturated fatty acid (simplified version).

Essential Fatty Acids

Fatty acids also differ in the location of their double bond. Polyunsaturated fatty acids are identified by the position of the double bond in relation to the methyl group (CH_3) or omega (ω) end of the carbon chain. This is described by an omega number. A polyunsaturated fatty acid with its first double bond three carbons away from the methyl end is known as **omega-3** fatty acid, whereas a fatty acid with its first double bond six carbons away from the methyl end is known as **omega-6** (the main omega 3 and omega 6 fatty acids are shown in Figure 1.3.9). These fatty acids cannot be synthesised by the body, and therefore must be consumed through the diet. This is why they are considered **essential fatty acids**.

Alpha-Linolenic acid (ALA), the main type of omega-3 fatty acid



Linolenic acid (LA), the main type of omega-6 fatty acid

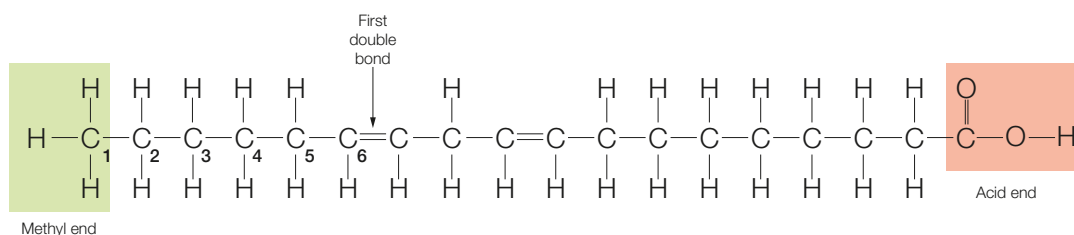


Figure 1.3.9: The omega number of polyunsaturated fatty acids: Omega-3 (top) and Omega-6 (bottom).

Trans Fatty Acids

Naturally occurring unsaturated fatty acids have double bonds that are known as **cis**, which means that the hydrogen atoms attached to the carbon atoms with a double bond are on the same side of the carbon chain and take on a more bent shape (as shown in Figure 1.3.10). Naturally occurring **trans-fatty acids**, have double bonds with hydrogens attached to the carbon atoms on opposite sides of a straighter carbon chain (as shown in Figure 1.3.11). These types of fats act more like a saturated fat due to being more solid at room temperature, than an unsaturated fat regardless of their structure and presence of a double bond.

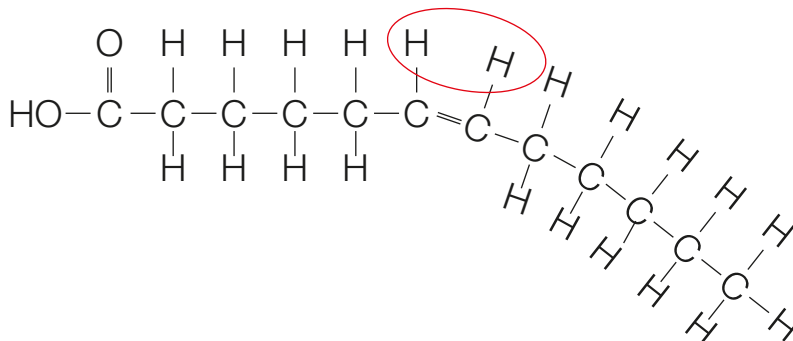


Figure 1.3.10: A cis monounsaturated fatty acid, with both hydrogen atoms at the double bond on same side of the carbon chain.

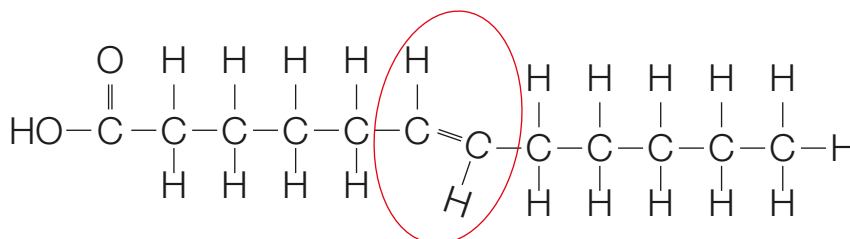


Figure 1.3.11: A naturally occurring trans-fatty acid, with its hydrogen atoms at the double bond on the opposite side of the carbon chain.

Trans fatty acids are predominately made through a process known as **hydrogenation**, which is why these fatty acids are also known as hydrogenated fats. During hydrogenation, some or all the points of unsaturation (double bonds) are made saturated by breaking the double bonds and adding hydrogen atoms. Most often, polyunsaturated fatty acids are partially hydrogenated, meaning only some of their double bonds are broken by the addition of hydrogen atoms, creating a trans-fatty acid. However, the double bonds that remain after processing change their configuration from cis to trans, where the hydrogen atoms at the double bond are now on opposite sides of the carbon chain. During complete hydrogenation, all the double bonds are broken and are saturated with hydrogen atoms. This process effectively converts unsaturated fatty acids to saturated fatty acids. The benefit of hydrogenation is it can improve the texture of foods by making them more solid and protects fats against oxidation, which causes these products to turn **rancid**. The process of complete and partial hydrogenation is shown in Figure 1.3.12 below.

Definition

Rancid refers to foods containing fat or oil, which causes them to smell or taste unpleasant because of being old, stale and exposed to oxygen.

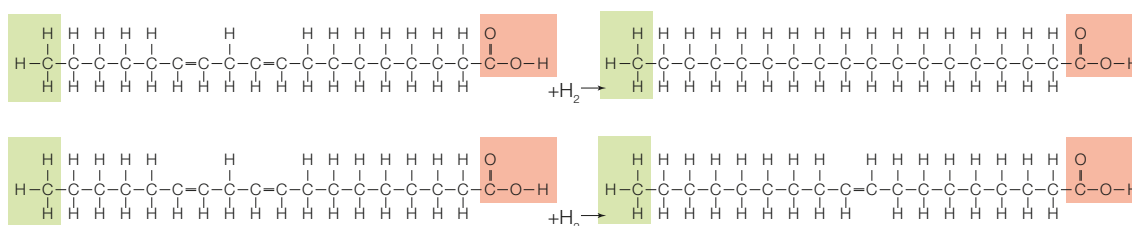


Figure 1.3.12: The process of complete (top) and partial (bottom) hydrogenation, where hydrogen atoms are added to an unsaturated fatty acid to remove all double bonds or where some remain to extend shelf life and improve texture.



Helpful online resources

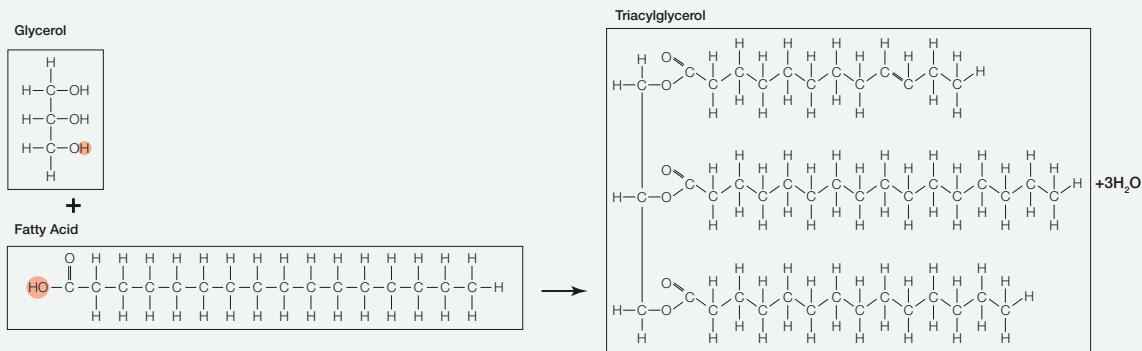
What are Fatty Acids - Structure of Fatty Acids - Types of Fatty Acids

https://youtu.be/5FIEcQ9-XQA?si=NDa_vPfHkauklkzc



Fast fact

Fatty acids rarely occur free in food or in the body and are most often attached to a glycerol molecule via their acid end, making a triglyceride. To make a triglyceride, a series of condensation reactions combine a hydrogen atom (H) from the glycerol and a hydroxyl group (OH) from a fatty acid, forming a molecule of water (H₂O). A triglyceride may be composed of a mixture of more than one type of fatty acid, as shown below where 2 fatty acids are saturated, and one is monounsaturated.



Cholesterol

In addition to triglycerides, lipids also include sterols. The most well-known sterol is **cholesterol**, which is also composed of carbon, hydrogen, and oxygen. The structure of cholesterol features glycerol and fatty acid chains, like that found in triglycerides. However, in cholesterol, the fatty acid chains are fused as rings, giving it a steroid section and its classification as a **sterol** (as shown in Figure 1.3.13).

Cholesterol is a waxy substance that is only very slightly soluble in water and blood, making it mostly **hydrophobic**. Therefore, cholesterol must be transported in association with **hydrophilic** proteins, called **lipoproteins** when circulating in the blood. This is the same transport triglycerides require.



Definition

Hydrophilic molecules tend to mix with and dissolve in water, and therefore can be transported in the blood, which is predominantly composed of water. Hydrophobic molecules tend to repel water, which is why they require a hydrophilic molecule to support their transport in the blood.

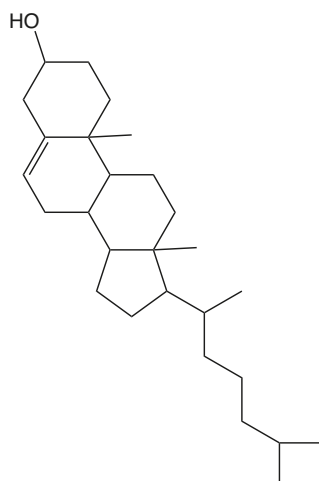


Figure 1.3.13: Structure of cholesterol.

Lipoproteins assist in transporting lipids throughout the bloodstream. They are complex particles that have a central hydrophobic core of cholesterol and triglycerides. This hydrophobic core is surrounded by a hydrophilic membrane consisting of phospholipids, free cholesterol, and protein. The body makes four types of lipoproteins, including chylomicrons, very-low density lipoprotein (VLDL), low-density lipoprotein (LDL) and high-density lipoprotein (HDL). These lipoproteins are distinguished by their size and density, which is determined by their composition (as shown in Figure 1.3.14). The more lipid present, the lipoprotein density decreases; the more protein present, the denser the lipoprotein molecule is. It is also important to note that the type of cholesterol does not change amongst the different classifications of lipoproteins, it is the proportion of cholesterol which changes.

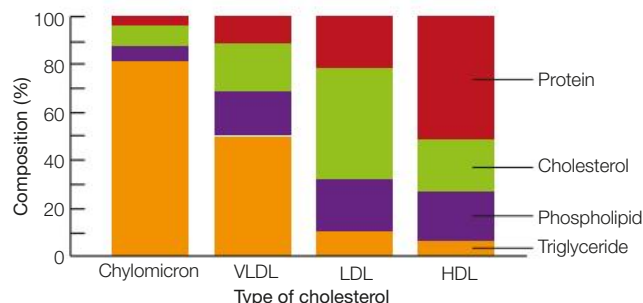


Figure 1.3.14: The composition of Chylomicron, VLDL, LDL and HDL, which determines its size and density.

Chylomicrons

Chylomicrons are the largest and least dense of the lipoproteins, which are made by the intestines. They are involved in the transport of dietary triglycerides and cholesterol to the body's tissues and liver and become smaller in size as their contents get depleted. However, the size of chylomicrons varies depending on the amount of fat ingested. A high fat intake leads to the formation of large chylomicron particles due to the increased amount of triglyceride being transported in comparison to a fasting state where little fat is consumed.

Very-low Density Lipoprotein (VLDL)

Very-low density lipoproteins (VLDL) are produced by the liver and are triglyceride rich. VLDL particles are smaller than chylomicrons but can vary in size depending on the quantity of triglyceride carried in the particle. When triglyceride production in the liver is increased, the secreted VLDL particles are larger. As VLDL travels throughout the body, muscle and adipose tissue removes triglycerides, causing VLDL to shrink in size. As a VLDL loses triglycerides, the proportion of lipids shifts, and the lipoprotein density increases. Therefore, the VLDL eventually becomes a low-density lipoprotein (LDL).

Low-density Lipoprotein (LDL)

A **low-density lipoprotein** (LDL) is derived from VLDL and is further enriched in cholesterol. LDL carries most of the cholesterol in circulation, delivering it to the body's cells. The high proportion of cholesterol can lead to the depositing of LDL on artery walls becoming entrapped and leading to the formation of plaque. This is why LDL is labelled as 'bad' cholesterol.

High-density Lipoprotein (HDL)

The liver makes **high-density lipoprotein** (HDL) to remove excess cholesterol from the blood and carries it back to the liver for recycling and disposal. This is why HDL is referred to as 'good' cholesterol. HDL contains the lowest proportion of lipids, and highest quantity of proteins making it the smallest in size with the greatest lipoprotein density.

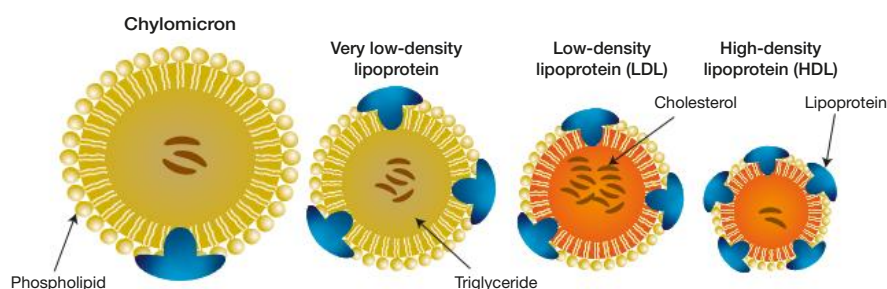


Figure 1.3.15: Structural differences of Chylomicron, VLDL, LDL and HDL.

Sources of Lipids in the Diet

Foods high in lipids will typically have proportions of each type of fatty acid. Therefore, food sources will differ depending on the primary proportion and classification of fatty acid in each food.

Saturated fat

Foods high in saturated fat mostly come from animals (as shown in Figure 1.3.16) and are mostly solid at room temperature. Most dairy products, especially cream, cheese and butter contain a substantial quantity of saturated fats, as do most meats and meat products, including beef, sausages, and pork. The fat from pork, called lard (as shown in Figure 1.3.17), is sometimes used as a cooking fat in fast food outlets (turns to oil when heated). Any food deep-fried in lard soaks up the oil and becomes a source of saturated fat. Non-animal sources of saturated fat include coconut oil, palm oil and cocoa butter (as shown in Figure 1.3.17). Palm oil is commonly used as an ingredient in foods such as ice cream, margarine, instant noodles, chocolate and bread or bread products. Coconut oil is commonly used as a dairy replacement in pastries and desserts. Cocoa butter is a key ingredient in chocolate.

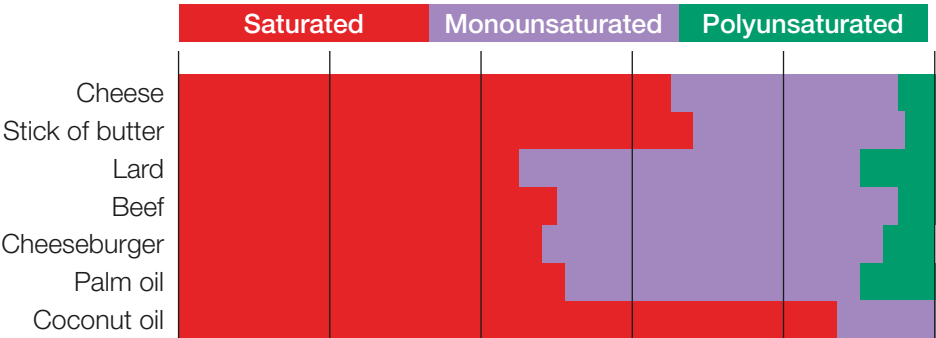


Figure 1.3.16: The percentage of fatty acids in foods high in saturated fat.



Figure 1.3.17: Common sources of saturated fat (from left to right: lard from pork used in cooking, coconut oil, palm oil from fruit of oil palms and cocoa butter from cocoa beans).

Monounsaturated fats

Monounsaturated fats are found predominantly in plant-based foods and are liquid at room temperature. The most abundant monounsaturated fatty acid is oleic acid (refer to Figure 1.3.5), which is found in foods such as avocados and nuts (cashews, macadamias, and almonds). Cooking oils including canola, olive, and peanut, also contain high quantities of this fatty acid (as shown in figure 1.3.18).

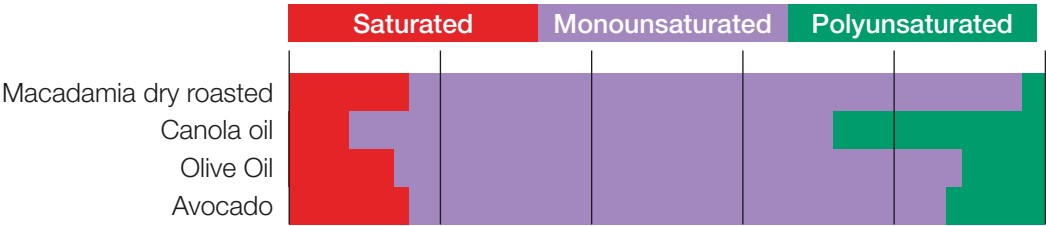


Figure 1.3.18: The estimated percentage of different fatty acids in foods high in monounsaturated fats.

Polyunsaturated fats

Essential Fatty Acids - Omega 3

Omega 3 is known as an essential fatty acid, as the body is unable to synthesise it and therefore needs to be consumed through the diet. Foods high in omega 3 include oily fish, such as salmon, mackerel, and sardines. Other good sources include flaxseed, chia seeds, and soybean oils and spreads (Figure 1.3.19).



Figure 1.3.19: Common sources of Omega 3, from left to right: Sardines, soybeans, chia seeds in bread and a smoothie.

Essential Fatty Acids - Omega 6

Omega 6 is also considered an essential fatty acid, which can be sourced from oils (soybean, sunflower, cottonseed), seeds (sunflower, sesame, and pumpkin), and nuts (walnuts, pine, brazil, pecans) (see Figure 1.3.20 and 1.3.21).

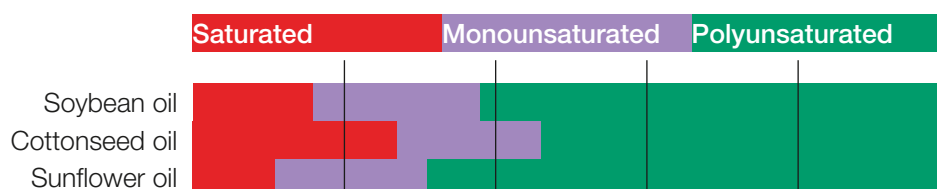


Figure 1.3.20: The estimated percentage of different fatty acids in foods high in polyunsaturated fats.



Figure 1.3.21 Cottonseed oil extracted from seeds of cotton plant, brazil nuts and pumpkin seeds in bread.

Trans-fatty acids

Most trans-fatty acids are artificially made and not found naturally in high quantities in foods. Trans fats can be naturally found in milk and some meat products, but in very low levels. Artificially produced trans fats, including hydrogenated oils are commonly used in baked foods such as biscuits, cakes, and pastries to extend the shelf life of these products (Figure 1.3.22). Fast food outlets may also use partially hydrogenated vegetable fats (mostly trans-fat) for deep-frying, thereby rendering any food that soaks up the fat high in trans fats.



Figure 1.3.22: Copha is a hydrogenated coconut oil used in cooking (for example, in chocolate crackles).

Cholesterol

The average individual synthesises all the cholesterol the body needs in the liver but can be consumed via the diet also. Cholesterol is predominantly found in animal products, including meat (beef, poultry), fish, eggs, and dairy (cheese). Most cholesterol is stored in the body's cells, with the remaining cholesterol transported in the blood with the assistance of lipoproteins. As the body produces all the cholesterol it needs, consuming foods naturally high in cholesterol will increase the quantity of cholesterol being circulated in the blood.



Reminder

Consumers commonly ask which foods contain 'good cholesterol' (HDL) or 'bad cholesterol' (LDL). However, good, or bad cholesterol are not types of cholesterol, which is found in foods, but refers to the way the body transports cholesterol in the blood.

Functions of Lipids

Triglycerides

Triglycerides tend to function similarly, irrespective of their triglyceride classification, while omega 3 and omega 6 have additional roles.

Transportation and storage of fat-soluble vitamins

The fat-soluble contents of the diet are cholesterol, and vitamins A, D, E and K. These molecules will conglomerate with triglycerides during digestion and move with them into the bloodstream. Triglycerides, and fat-soluble molecules (cholesterol and vitamins) travelling with them, must be joined to proteins to be able to travel into the bloodstream. The complex of triglycerides, cholesterol, fat-soluble vitamins, and protein is called a lipoprotein. Once circulating the bloodstream, the lipoproteins will travel primarily to sites of **adipose tissue** (body fat) where the fatty acid chains of triglycerides and fat-soluble vitamins will move from the lipoproteins into fat cells (adipocytes) and be stored until needed. Therefore, triglycerides provide storage for fat-soluble vitamins.

A source of energy

The main function of triglycerides is energy storage. When energy is required, triglycerides are broken down into glycerol and fatty acid chains from the fat cells (adipocytes) within adipose tissue and released into the bloodstream. Due to the hydrophobic nature of triglycerides, they are carried in the bloodstream via a blood protein (albumin) to the working cells which require energy. Triglycerides are carried to the working cells (except the brain, which exclusively relies on glucose) where they are broken down further to create energy in the form of adenosine triphosphate (ATP). Triglycerides are the most energy dense macronutrient providing the body with a substantial amount of energy of 37kJ/g. Approximately 30% of our daily energy should come from fats and oils, mostly from unsaturated fats with no more than 10% from saturated fat and no more than 1% from trans fats.

Cushioning and insulation of vital organs

Sites of adipose tissue, where triglycerides are stored in the fat cells, are mostly found around internal organs and under the skin (as shown in Figure 1.3.23). Adipose tissue around vital organs and joints, known as visceral fat, provides protective cushioning and padding. This padding absorbs any pressure placed on important organs and joints, preventing any physical impact to these body parts. Adipose tissue under the skin is known as subcutaneous fat, which is involved in thermoregulation, specifically insulation due to its ability in generating heat. It does not conduct heat as readily as other tissues, thereby reducing heat loss through the skin and keeping us warm.

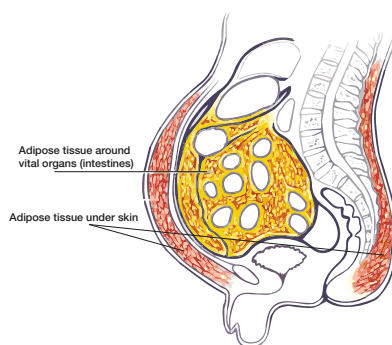


Figure 1.3.23: Adipose tissue around vital organs providing cushioning and under the skin providing insulation.

Essential Fatty Acids – Omega 3 and Omega 6

Assisting the circulatory and immune systems

Omega 3 and omega 6 are **essential fatty acids**, which play a part in the successful functioning of circulatory and immune systems. Both essential fatty acids are useful in normal fetal/infant brain development and in the reduction of low-density lipoproteins (LDL cholesterol), reducing the risk of plaque build-up on artery walls.

Omega 3 seems to have further roles including: keeping the heart beating regularly, thereby reducing the risk of an abnormal heartbeat (arrhythmia); thinning the blood, thereby reducing the risk of clotting; and supporting the immune system by reducing inflammation which contributes to chronic diseases such as rheumatoid arthritis.

Omega 6 has been found to regulate and promote blood-clotting processes to reduce blood loss, reduce the risk of infection, and regulate inflammation in response to injury or infection.

Cholesterol

Most cells, particularly in the liver, can synthesise cholesterol when its functions are needed. It is LDL that transports cholesterol from the liver to where it is required in the body, making LDL the main cholesterol transporter in the body.



Fast fact

The liver will produce between 800-1500mg of cholesterol each day, thus contributing much more to the body's total than does the diet. The chemical structure is the same, but cholesterol that is made in the body is known as endogenous, whereas cholesterol from outside of the body (from food) is referred to as exogenous.

Component of the cell membrane

Cholesterol is embedded in the phospholipid bilayer of the cell membrane (as shown in figure 1.3.24), which is required for its structural role, creating stability, and enhancing fluidity. This allows the movement of substances across the membrane to be more efficient.

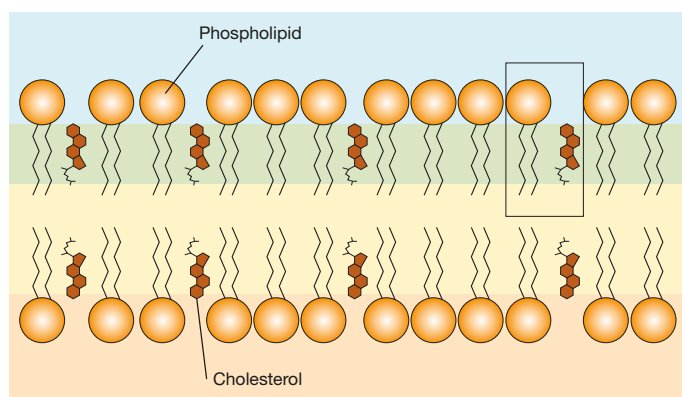


Figure 1.3.24: Cholesterol in the phospholipid bilayer of the cell membrane.

Synthesis of body compounds

Many vitally important body compounds are composed of cholesterol, including bile involved in the digestion of lipids, hormones (including the sex hormones: estrogen and testosterone) and vitamin D (as shown in Figure 1.3.25).

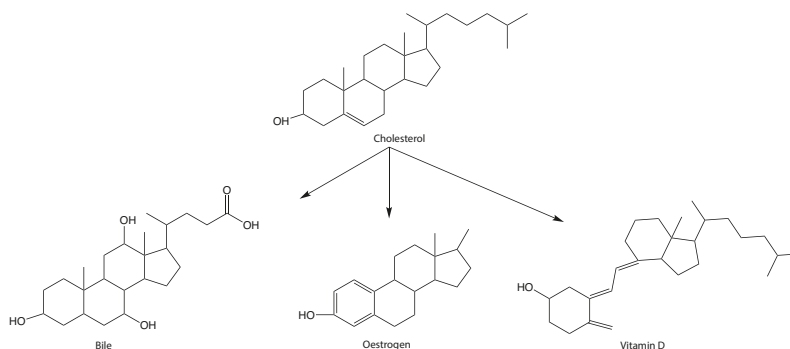


Figure 1.3.25: Cholesterol is used to make bile, sex hormones like estrogen and vitamin D.



Key terms

Adipose tissue	Hydrogenation	Saturated
Cholesterol Chylomicrons	Lipids Lipoprotein	Sterol
Cis fatty acid	Low density lipoprotein (LDL)	Subcutaneous Fat
Essential Fatty acids	Monounsaturated	Trans-fatty acid Triglyceride
Fatty Acid	Omega-3	Unsaturated
Glycerol	Omega-6	Very-low density lipoprotein (VLDL)
High-density lipoprotein (HDL)	Polyunsaturated	Visceral Fat

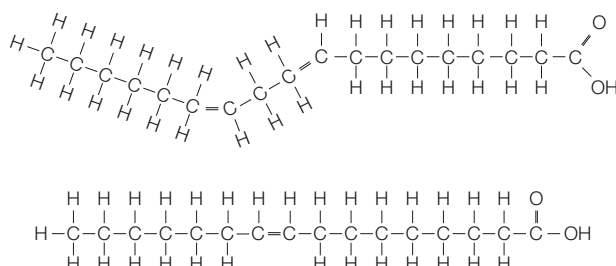
Review questions: 1.3 Lipids

1. Fill in the blank spaces in the table below.

Triglyceride Classification	Structural Property	Physical Property
Saturated		
Monounsaturated		Liquid at room temperature
Polyunsaturated	More than one double bond between the carbon atoms	

(4 marks) (KA1)

2. Classify the following triglycerides according to their structure.



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5. Trans fatty acids can be found naturally in very small amounts in some foods, or they can be created artificially by food manufacturers. The industrial process partially hydrogenates vegetable oils to produce trans fatty acids.
- (a) Describe how trans fatty acid properties are like both saturated fat and unsaturated fat.
- (i) Property like a saturated fat:
- (1 mark) (KA2)
- (ii) Property like a unsaturated fat:
- (1 mark) (KA2)
- (b) Provide one reason why manufacturers may artificially create trans fats to add to food products.

(2 marks) (KA1)

6. Essential fatty acids are an important nutrient in the body.

(a) State an essential fatty acid.

(1 mark) (KA1)

(b) Describe what an essential fatty acid is.

(2 marks) (KA1)

7. Identify four good sources of monounsaturated and polyunsaturated fats from the following recipe for zucchini, cheese, and smoked salmon salad.

Ingredients	Triglyceride category
1 zucchini (about 12–15 cm long)	
2½ tbsp olive oil	
2 tbsp sesame seeds	
4 slices avocado	
1 tbsp finely chopped basil	
200 g cherry tomatoes	
90 g (about 6 slices) smoked salmon	
125 g soy cheese cut into small cubes	

(4 marks) (KA2)

8. Describe the difference between visceral and subcutaneous fat and explain one functional role that each of them has in the human body.

(4 marks) (KA2)

9. Cholesterol is an insoluble and waxy substance, which is carried around the body through the blood.

(a) Describe how cholesterol is carried around in the blood, providing justification.

(2 marks) (KA2)

(b) State two functions of cholesterol in the body.

(2 marks) (KA1)

(c) Eating too much saturated fat can increase the level of LDL cholesterol in your blood, whereas eating polyunsaturated fats can decrease the level of LDL cholesterol in your blood and increase the level of HDL cholesterol in your blood.

(i) Describe the difference in the structure of LDL and HDL cholesterol.

(2 marks) (KA2)

(ii) With reference to the table below, identify the type of oil which would increase the level of LDL cholesterol in the blood the most and the type of oil which would increase the level of HDL cholesterol in the blood the most.

Fatty Acid Name	Carbon Chain Length	Degree of saturation (number of double bonds)	Melting point (°C)
Myristate	14	0	54.4
Palmitoleate	16	1	-0.1
Linoleate	18	2	-5
Arachidonate	20	4	-49

Oil which would increase the level of LDL cholesterol the most:

Oil which would increase the level of HDL cholesterol the most:

(2 marks) (IAE3)

10. Unsaturated fats have double bonds between the carbon atoms, explain the difference between a double bond that is **cis**, and **trans**. Draw a diagram to support your response.

(3 marks) (KA2)

11. Triglycerides provide the most energy of any of the macronutrients.

(a) Name the two molecules all triglycerides are composed of.

(1 mark) (KA1)

(b) State the energy value per gram.

(1 mark) (KA1)

(c) Describe a concern about the excessive consumption of fat, due to its high kilojoule content.

(2 marks) (KA2)

12. The properties (melting point) of fatty acids are dependent on the length of the carbon chain and degree of saturation (number of double bonds). The results of this investigation are shown in the table below.

Fatty Acid Name	Carbon Chain Length	Degree of saturation (number of double bonds)	Melting point (°C)
Myristate	14	0	54.4
Palmitoleate	16	1	-0.1
Linoleate	18	2	-5
Arachidonate	20	4	-49

(a) Identify the following fatty acids as saturated, monounsaturated, and polyunsaturated.

Myristate:

Palmitoleate:

Linoleate:

Arachidonate:

(4 marks) (KA2)

(b) Predict the state of the following fatty acid at room temperature.

Myristate:

(1 mark) (IAE3)

(c) Using data from the table above, explain the link between the carbon chain length and the degree of saturation and how this impacts the melting point of fatty acids.

(3 marks) (IAE3)

(d) The following table lists the content of saturated, monounsaturated, and polyunsaturated fats in one tablespoon of various oils.

Oil	Total Fat Content (g)	Saturated Fat Content (g)	Monounsaturated Fat Content (g)	Polyunsaturated Fat Content (g)
Flaxseed	14	1	3	10
Coconut	14	12	1	1
Olive	14	2	10	2
Canola	14	1	8	4

Which oil would have a similar melting point to the following fatty acids:

Myristate:

Palmitoleate:

(2 marks) (IAE3)

Total: / 60 marks



Science as a human endeavour

Is coconut oil actually good for you?

: <https://www.sbs.com.au/food/article/2020/02/21/coconut-oil-actually-good-you>

Coconut oil has become the darling of the wellness scene. Beyond its use in traditional cuisines like Indian, Thai and Sri Lankan cooking, the tropical oil has inspired countless raw dessert recipes, as suggestions we add it to coffee or even eat it by the tablespoon. Proponents claim it can strengthen immunity, assist weight loss, boost brain function, promote heart health and regulate blood sugar levels.

On the other hand, major health heavyweights, including the Dietitians Association of Australia, the Heart Foundation, the World Health Organisation, and the American Heart Association aren't so enthusiastic, advising that we only use the saturated-fat laden oil occasionally, that we choose unsaturated vegetable oils instead, or that we avoid it altogether. To make matters more confusing, some high-profile health experts and scientists have argued that saturated fat isn't the heart disease villain we once thought, which puts a question mark over coconut oil.

As it turns out, the answer isn't clear-cut, and that's largely because the folks in white lab coats still have some investigating to do. "There is not enough scientific evidence to state categorically that coconut oil is good for us, nor bad for us, as definitive clinical trials assessing the effects of coconut oil on health benefits are lacking," Professor Barbara Meyer, director of the University of Wollongong's Lipid Research Centre, tells SBS.

Melanie McGrice, accredited practising dietitian and spokesperson for the Dietitians Association of Australia, agrees. "I don't think there's enough research yet to say it's an amazing superfood that everybody should consume, but there's also not enough research to put it in the same category as potato chips and say it's something we definitely shouldn't be consuming," she says.

Then there's the debate around the impact of coconut oil on blood lipids, and by extension, heart disease risk. We know that coconut oil is packed with saturated fat (92 per cent to be exact), which we've long been told raises LDL (bad) cholesterol, hence why the Heart Foundation recommends saturated fat be only 7 per cent of our total energy intake and the Australian Dietary Guidelines recommend limiting intake of foods high in saturated fat. For Peter Clifton, a professor of nutrition at the University of South Australia, there's no doubt that LDL cholesterol is a heart risk. "The overwhelming weight of evidence from genetic, observational and intervention studies is that LDL cholesterol is strongly related to heart disease," he says. "It's one of the most well-established medical facts we have."

While we may not have a black and white answer as to whether coconut oil is good or bad for us (or even, neutral, as Dr Yutang Wang, senior lecturer in biomedical science at Federation University suspects) anytime soon, we don't need to avoid it entirely in the interim. "If it's called for as part of a dish, it probably doesn't hurt to include a bit of coconut oil, maybe once a week or fortnight," advises McGrice.

According to Clifton, coconut oil only really becomes a concern, cholesterol-wise if you're consuming it regularly. "If you're taking 30mls a day, six days out of seven because you believe it's going to do something beneficial, then you're probably doing yourself some harm," he says.

The type of coconut oil you consume also matters. Wang recommends choosing virgin coconut oil, as the hydrogenation process that other oils go through can generate harmful trans fats.

1. Discuss how this example above demonstrates the key concept of **Communication and Collaboration**. Provide two clear examples from the example above.

(3 marks) (KA3)

2. Explain how the process of hydrogenation can result in the production of trans fats.

(2 marks) (KA2)

? Science Inquiry Skills

The Melting Point of Triglycerides

Introduction:

The melting point of a substance is the temperature at which a solid will melt and becomes a liquid. The melting point of a triglyceride is dependent on two factors: the length of the carbon chain and the shape of a fat molecule, which is determined by its degree of saturation.

The length of the carbon chain can differ in a fatty acid, where it can contain between 4-24 carbon atoms. Fatty acids are classified as short chain fatty acids, medium chain fatty acids and long chain fatty acids based on their carbon chain length (as shown in the table below). As the number of carbon atoms in the chain increases, so does the melting point. Therefore, the shorter the fatty acid chain, the more likely it will be liquid at room temperature, while longer fatty acid chains have higher melting points and are likely to be solid at room temperature.

Fatty Acid Classification	Number of Carbon Atoms
Short Chain Fatty Acid	<6
Medium Chain Fatty Acid	6-12
Long Chain Fatty Acid	>12

The degree of saturation is determined by the number of double bonds present within the carbon chain, which determines the shape of a fat molecule (as shown in the table below). A saturated fatty acid is extremely flexible due to containing no double bonds, allowing it to bend and pivot around the carbon bonds permitting them to stretch out into a straight line that easily stacks together to form a solid. An unsaturated fatty acid cannot pivot due to the presence of at least one double bond, making them more bent out of shape which makes it harder for them to pack together and more likely to be liquid at room temperature. Therefore, as the number of double bonds in the carbon chain increases, its saturation decreases causing the melting point to decrease. The melting point is also dependent on whether the double bond is cis or trans. The melting point of a cis double bond is lower than a trans double bond, due to the hydrogen atoms being on the same side of the carbon chain causing a bend and meaning the atoms are not packed as tightly together.

Degree of Saturation	Number of Double Bonds Present within the Carbon Chain	Maximum Number of Hydrogen Atoms	Shape
Saturated	0	Yes	Straight line that can easily stack together
Monounsaturated	1	No	Bent out of shape that cannot easily stack together
Polyunsaturated	>1	No	Bent out of shape that cannot easily stack together

Hypothesis:

If the carbon chain and degree of saturation decreases, then the melting point of the fatty acid decreases.

Materials:

- Olive Oil
- Sunflower Oil
- Coconut Oil
- Avocado Oil
- Safflower Oil
- Butter
- 6x melting point capillary tubes
- Thermometer
- Sticky Tape
- 6x 250ml Beaker
- Water
- Retort Stand and Clamp
- Hot plate (or Bunsen burner)
- Stirring Rod
- Hot Hands

? Science Inquiry Skills

Helpful online resources

A similar Experiment Determining the Melting Point of Fat

<https://youtu.be/60EQUae6XD8?si=rAZzrHLBeh6lfV03>



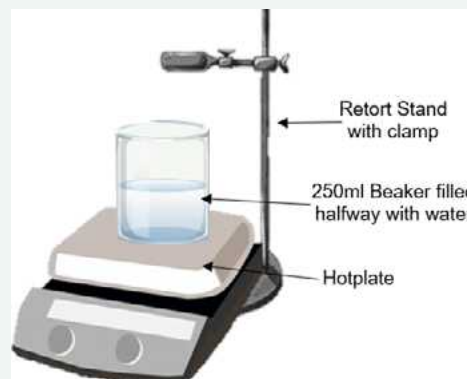
Method:

Pre-Experiment Preparation:

1. Place approximately 1ml of olive oil in a capillary tube, and immediately place in the freezer horizontally overnight for it to become a solid.
2. Repeat step 1 with the remaining lipids (including the solids).

After at least 24 hours:

3. Classify the triglycerides in the second to last column of the results table with reference to their compositions.
4. Set up the apparatus as shown in the diagram below (do not turn the hot plate on yet).
5. Collect one of the capillary tubes from the freezer at a time and break off the closed end, so both ends are open. **Act quickly as the lipid may melt.**
6. Stick the capillary tube to the bottom and one side of the thermometer with sticky tape (be sure not to block out the values on the thermometer). **Act quickly.**
7. Place the thermometer with attached capillary tube into the beaker filled with water without touching the bottom. Use the clamp on the retort stand to hold it up, while making sure to have the values on the thermometer facing forward. **Act quickly.**
8. Turn on the hot plate and monitor the temperature and the lipid in the capillary tube, while occasionally stirring the water with a stirring rod.
9. Record the temperature in the last column of the results table once a bubble of the lipid is released from the capillary tube and floats on top of the water in the beaker. This temperature is the recorded melting point.
10. Turn off the hot plate.
11. Replace the water in the beaker. **Use hot hands in case the beaker is hot.**
12. Repeat steps 5-11 with cooled hot plate and new beaker with the other lipids in the capillary tubes. **Only take one capillary tube from the freezer at a time.**



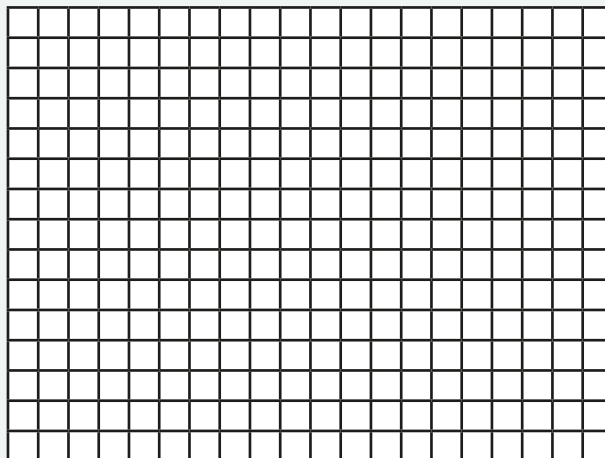
Raw Data:

Fat	Composition (%)			Triglyceride Classification	Melting Point (°C)
	Saturated	Monounsaturated	Polyunsaturated		
Olive Oil	14.0	69.7	11.2		
Sunflower Oil	11.9	20.2	63.0		
Coconut Oil	85.2	6.6	1.7		
Avocado Oil	20	65.4	15.5		
Safflower Oil	10.2	12.6	72.1		
Butter	54.0	19.8	2.6		

? Science Inquiry Skills

Presentation of Data:

Represent the raw data as a column graph, plotting the Triglyceride Classification on the x axis and the Melting Point ($^{\circ}\text{C}$) on the y axis. Ensure to add the suitable features on the graph below, including a title, even scale, labelled axes, and legend.



Analysis & Discussion:

- With reference to the results, which oil is more unsaturated, safflower or olive oil? Explain your answer.
 - Which should have a higher melting point, safflower oil or olive oil? Provide reasoning.

- The melting point of stearic acid is 70°C , and the melting point of oleic acid is 4°C . Explain in detail why their melting points are so different.

- Write a conclusion for this experiment, explaining if the hypothesis was supported or not supported.

1.4 Proteins

Science understanding

Triglycerides and sterols are two types of lipids. Triglycerides (fats) are made up of glycerol and three fatty acid. Proteins are made up of long chains of amino acids.

- Identify the general structure of amino acids.
- Explain the functional roles of protein as a nutrient.
- Explain the difference between essential, non-essential, and conditionally essential (e.g., due to infancy, illness, or a vegan diet) amino acids.
- Identify plant, animal, and novel sources of protein in the diet.
- Compare the biological value of protein sources, including complete and incomplete proteins.

SACE Subject Outline, 2024.

Structure of Proteins and Amino Acids

Proteins chemically consist of the same elements as carbohydrates and lipids: carbon (C), hydrogen (H) and oxygen (O); however, proteins also consist of nitrogen (N). Therefore, protein-containing foods are the only source of nitrogen for the body. Carbon, hydrogen, oxygen, and nitrogen link together to form different **amino acids**, which means 'contains nitrogen'. These amino acids are the building blocks of proteins, where each protein has a unique sequence of amino acids.

Amino acids have the same structural formula: a central carbon atom bonded to one **hydrogen (H)** atom, an **amino group (NH₂)** and a **carboxylic acid group (COOH)**. However, it is the **fourth attachment** that distinguishes the difference between each amino acid, changing the acid's shape, size, electrical charge, or other characteristics. This fourth attachment is known as a **side group**, which may involve a single atom or group of atoms (as shown Figure 1.4.1). This is why proteins are more complex in structure than the other two macronutrients: carbohydrates and lipids, as each side group varies from one amino acid to the next (Figure 1.4.2 shows examples of different amino acids).

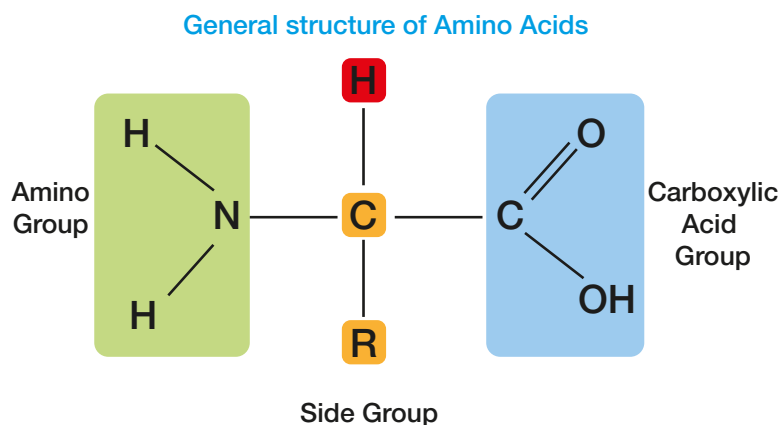


Figure 1.4.1: The general chemical structure of an amino acid.

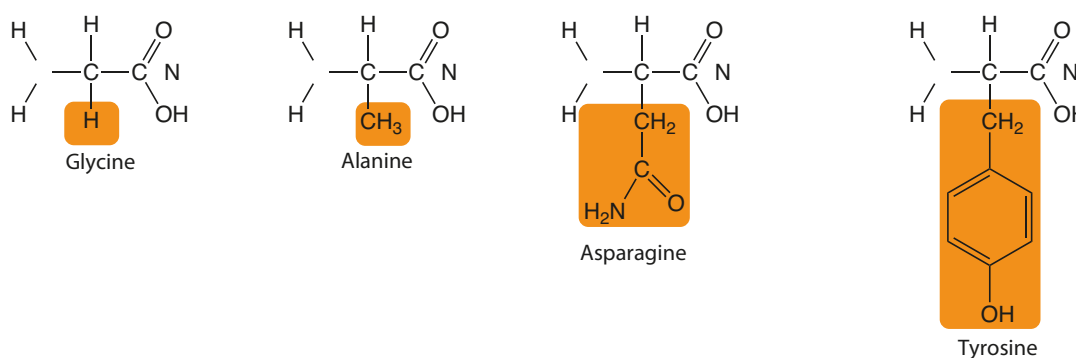


Figure 1.4.2: Different examples of amino acids. Each of them has the same chemical structure, differing only in each fourth attachment – the side group.

Essential, Non-essential and Conditional Amino Acids

There are 20 amino acids required by the body. These amino acids are categorised as being essential or non-essential (Figure 1.4.3). **Essential amino acids** must be provided by diet, as the body cannot synthesise these at all or cannot produce them in amounts sufficient for meeting the body's requirements. **Non-essential amino acids** can be synthesised by the body in sufficient amounts. The amino group of these amino acids is formed using nitrogen from the breakdown of excess amino acids, while the remainder of its structure is produced using carbon, hydrogen and oxygen provided by carbohydrates and lipids. Therefore, it is not vital to consume non-essential amino acids as these can be synthesised by the body, however protein food sources provide both these types of amino acids.

Non-essential amino acids may become essential under certain circumstances, such as illness, injury, stress, or rapid growing stages. In these cases, they are referred to as **conditionally essential** (refer to Figure 1.4.3; conditionally essential amino acids are asterisked). For example, in children, arginine is a conditionally essential amino acid for optimal growth and development, and it must therefore be provided by the diet. However, in adults, arginine is a conditionally essential amino acid that is only required in the diet in certain circumstances, such as after trauma, injury, or renal failure.

Essential Amino Acids <i>Must be provided by the diet</i>	Conditional Amino Acids <i>Essential under certain circumstances only</i>	Non-Essential Amino Acids <i>Can be made by the body</i>
• Histidine (His) • Isoleucine (Ile) • Leucine (Leu) • Lysine (Lys) • Methionine (Met) • Phenylalanine (Phe) • Threonine (Thr) • Tryptophan (Trp) • Valine (Val)	• Arginine (Arg) • Cysteine (Cys) • Glutamine (Gln) • Glycine (Gly) • Proline (Pro) • Serine (Ser) • Tyrosine (Tyr)	• Alanine (Ala) • Asparagine (Asn) • Aspartic Acid (Asp) • Glutamic Acid (Glu)

Figure 1.4.3: The 20 different amino acids required by the body, categorised as essential, conditional, and non-essential. Their abbreviated names are in brackets.

Biological Value of Proteins

Proteins can be classed as complete, incomplete, or complementary. Their classification is determined by the type of amino acids in their structure. A **complete protein** contains all essential amino acids required by the body in the correct proportion; however, they may or may not contain all the non-essential amino acids. These proteins are considered to have a **high biological value (HBV)** (refer to Figure 1.4.4). Proteins that are missing or have a limited supply of one or more essential amino acids are labelled as **incomplete** and having a **low biological value (LBV)** (refer to Figure 1.4.4). Therefore, incomplete proteins cannot support the structural and functional roles of proteins in the body solely. The combination of incomplete proteins to obtain all essential amino acids, produces a **complementary protein**.

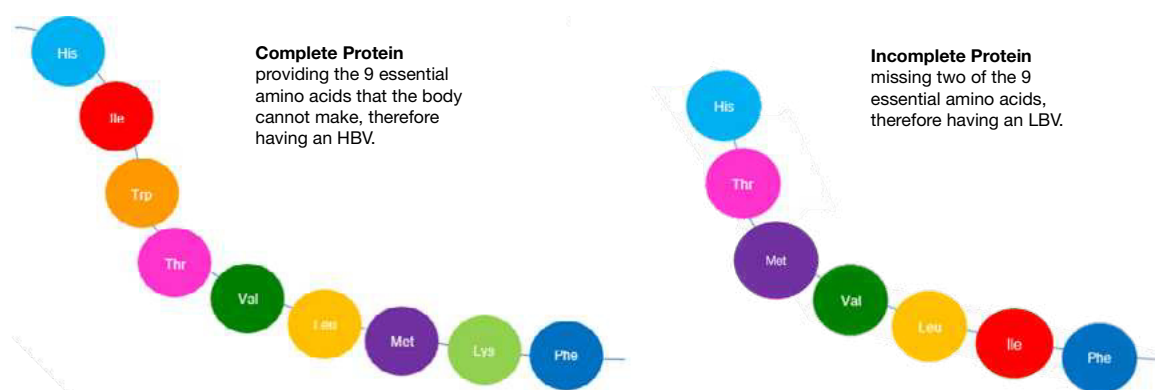


Figure 1.4.4: A visual representation of a complete and incomplete protein.

Sources of Protein in the Diet

The body is unable to store excess amino acids; therefore, dietary protein is vital to consume daily. Protein food sources are required to provide the essential amino acids and nitrogen, which is used to build non-essential amino acids and other nitrogen containing compounds the body needs.

Complete Proteins

Protein food sources derived from animal sources are generally known as **complete proteins** because they contain all nine essential amino acids that the body cannot make (refer to Table 1.4.1). These protein sources have a high bioavailability with approximately 90-99% of the animal protein consumed being digested, and then absorbed and made available to the body.

Examples of complete proteins include meats (beef, chicken, pork, lamb), seafood (fish, prawns), dairy products (milk, cheese, yoghurt), eggs and egg products (mayonnaise, cakes, pancakes). However, gelatine is an exception and regarded as an incomplete protein even though it is sourced from collagen in animals, as it does not contain the essential amino acid tryptophan.

Incomplete Proteins

Protein food sources derived from plant sources are generally known as **incomplete proteins**, due to being limited in one or more of the nine essential amino acids (refer to Table 1.4.1). The essential amino acid which is not provided in adequate amounts in the diet, is known as the **limiting amino acid**, which limits protein synthesis to the rate at which the essential amino acid is available. The most likely limiting amino acids include Lysine, Methionine, Threonine and Tryptophan (as shown in Table 1.4.2). Plant-based protein sources have a lower bioavailability than animal proteins, with approximately 70-90% of the plant protein consumed being digested. Therefore, plant-based protein sources provide less amino acids to the body in comparison to animal-based proteins.

Examples of incomplete proteins include nuts (almonds, cashews, peanuts), seeds (pumpkin seeds, flaxseeds, sesame seeds), grains and grain products (wheat, oats, flour, cereals), fruits (bananas, grapes, apples), vegetables (spinach, kale, carrots, capsicum) and legumes (kidney beans, chickpeas, lentils). Soy products (tofu, soybeans, soy milk), quinoa and chia seeds are an exception, as they contain all essential amino acids making them complete proteins.

Table 1.4.1: The essential amino acid composition of beef (a complete protein) and grains (an incomplete protein).

Essential amino acids	His	Ile	Leu	Lys	Met	Phe	Thr	Trp	Val
Beef	✓	✓	✓	✓	✓	✓	✓	✓	✓
Grains	✓	✓	✓		✓	✓		✓	✓

Table 1.4.2: Plant-based proteins and the essential amino acids that they tend to be limited in.

Plant Based Protein	The limiting Essential Amino Acid/s
Nuts	Lysine
Seeds	Lysine
Grains and Grain Products	Lysine, Threonine or Tryptophan
Fruits	Methionine
Vegetables	Methionine
Legumes	Methionine

Complementary Proteins

Proteins derived from plant sources have a lower biological value than animal sources as they are limited in one or more essential amino acids, making them incomplete proteins. For these reasons, vegetarians and vegans must ensure they consume a wide variety of plant-based proteins to prevent becoming deficient in any essential amino acid. A **complementary protein** is the consumption of different plant-based proteins which have different limiting amino acids to ensure all nine essential amino acids are obtained from the diet. For example, Methionine is the limiting amino acid in peanut butter, whereas Lysine is the limiting amino acid in wholegrain bread (as shown in Table 1.4.3). Therefore, when consumed together, all essential amino acids are supplied by this meal. However, it is not necessary to obtain all essential amino acids at every meal. A variety of nuts, seeds, grains and grain products, fruits, vegetables, and legumes consumed throughout the course of the day can provide all essential amino acids.

Table 1.4.3: Two incomplete proteins combine to produce a complementary protein that provides all essential amino acids.

Essential amino acids	His	Ile	Leu	Lys	Met	Phe	Thr	Trp	Val
Peanut butter	✓	✓	✓	✓		✓	✓	✓	✓
Wholegrain bread	✓	✓	✓		✓	✓	✓	✓	✓
Together	✓	✓	✓	✓	✓	✓	✓	✓	✓

Novel Proteins

Novel protein foods (NPFs) are any type of protein that does not come from the sources which have dominated our diets for generations, including beef, lamb, chicken, fish, eggs, and dairy products. Novel sources are based on vegetable protein and micro-organisms and are produced from sources that are widely available but not commonly consumed. A wide variety of vegetarian alternatives are already available on the market, including seitan, tofu, soy meat, tempeh and quorn (refer to Table 1.4.4). Some novel protein sources such as insects, algae, duckweed, microbial protein, leaf protein and rapeseed are expected to enter the market as replacements for current animal derived protein sources (refer to Table 1.4.4). These sources are being explored due to the increasing demand for protein as the growth of the population continues to increase and due to their environmental benefits.

Table 1.4.4: Novel Protein Sources and what they are generally derived from.

Novel Protein Source	Generally Derived From
Seitan	Wheat gluten, after rinsing the starch from wheat dough
Tofu & Soy Meat	Soybeans
Tempeh	Cooked and slightly fermented soybeans
Quorn	A natural fungus found in soil, making it a mycoprotein
Insects	Crickets, mealworms, ants, grasshoppers etc.
Algae	Aquatic plants, known as edible seaweed
Duckweed	Water plants with small leaves
Microbial protein	Microorganisms, including fungi, bacteria, or algae
Leaf Protein	Proteinaceous (protein) mass extracted from leaves
Rapeseed	Rapeseed meal, a by-product from the extraction of oil from rapeseed, a bright yellow flowering plant

Functional Role of Proteins

Amino acids – whether essential and gained via consumption, or non-essential and synthesised by the body – are linked together in a variety of sequences to make different proteins required by the body. A **peptide bond** links each amino acid, forming a **polypeptide chain** (as shown in Figure 1.4.5). This is completed through a **condensation** reaction, the same type of reaction that combines monosaccharides to form a disaccharide or polysaccharide and fatty acids and glycerol to form a triglyceride.

Definitions

Condensation is the combination of two molecules to form a larger molecule; by producing water as a by-product.

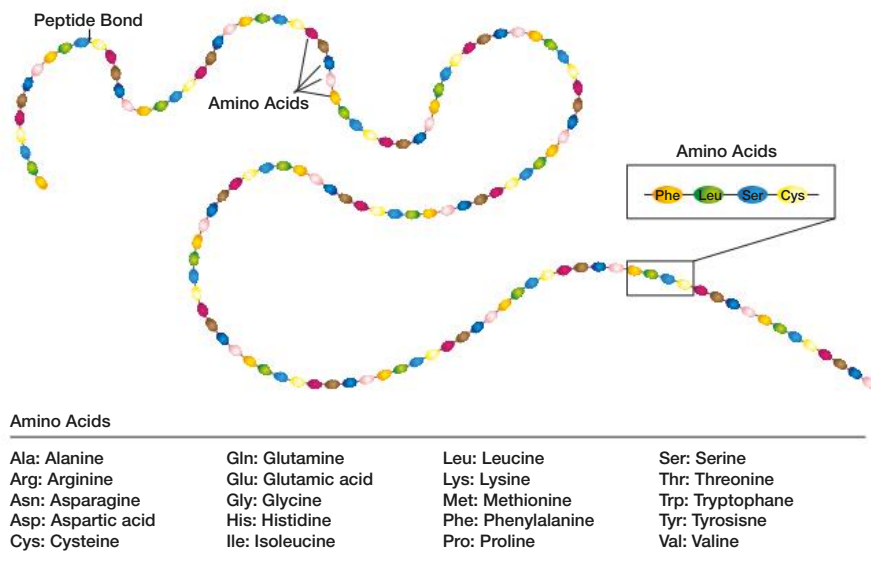


Figure 1.4.5: A sequence of amino acids linked together forming a polypeptide bond.

Proteins can be a few dozen to several hundred amino acids long. The length and sequence of amino acids determines a protein's unique shape, which enables them to perform their various functions in the body. The sequence of amino acids is determined by the order of the bases on **genes** provided to the foetus by the genetic information received at conception. This code of instructions is held in every cell; however, each cell uses a different combination of genes to build the specific protein it needs to perform its specialised functional roles in the body (Figure 1.4.6).

Definition

A gene is a segment of DNA

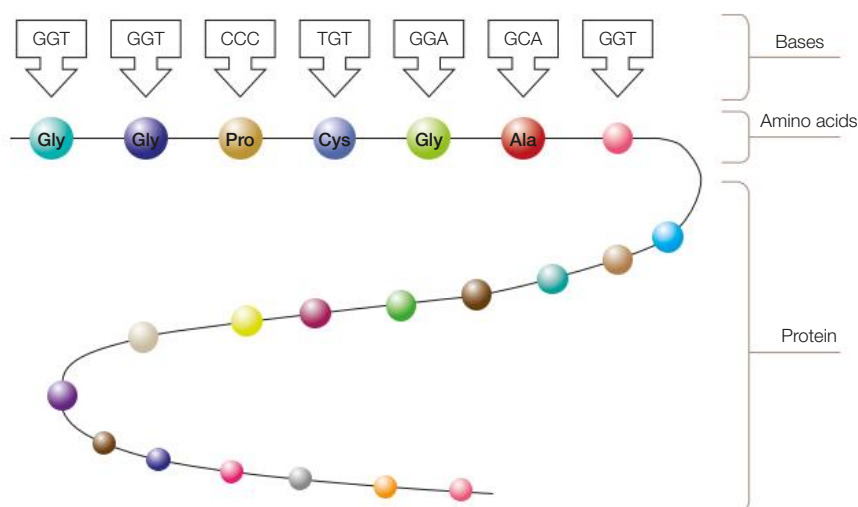


Figure 1.4.6: The creation of proteins in the body is determined by the order of bases on our genes, which are specialised to perform its structural and functional roles.

Growing, maintaining, and repairing body tissues

Proteins are the building blocks of life, which is why our body requires a constant supply of amino acids for the **growth, maintenance, and repair** of body tissues. When protein is consumed, they are broken down to amino acids, which are then transported to the cells to make specific proteins the body requires. From the moment of conception, proteins are required for growth and development of the initial matrix of bones, muscles, nerves, blood, glands, skin, hair, fingernails, teeth, ligaments, tendons, and artery walls. In addition to this, our body is continuously replacing cells in the body to maintain their performance and function, with approximately 330 billion cells replaced daily. Finally, our body also requires protein to repair body tissues, such as a cut to the skin, a broken bone, or a fatigued muscle after exercise.

Synthesising enzymes

An **enzyme** is a catalyst that speeds up biochemical reactions in the body, including the breakdown of materials in digestion, the building of bodily tissues, and the transformation of substances in the body such as the conversion of glucose into energy. An enzyme has a specific shape to perform its role, including its active site that attracts a particular substrate, or molecule that an enzyme acts on. This substrate has a complementary shape to the enzyme's active site to form an enzyme-substrate complex, allowing the enzyme to carry out its function more effectively (as shown in Figure 1.4.7).

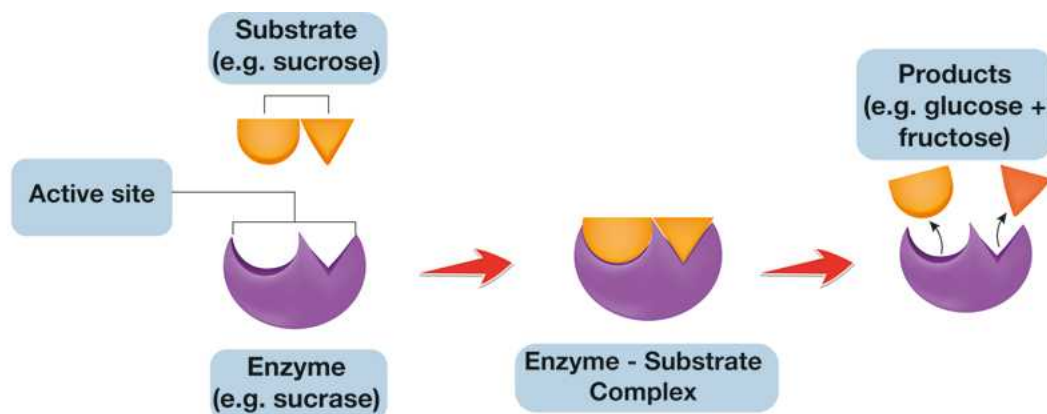


Figure 1.4.7: An enzyme's active site allows the substrate to bind, forming an enzyme-substrate complex which is then able to perform its function of breaking down a molecule in this example.

Synthesising hormones

Hormones are the body's chemical messengers, which allow the body's cells to communicate with each other. This communication tells your body what to do and when to do it. Hormones are made by the endocrine glands, which release these hormones directly into the bloodstream. The blood carries these hormones to their complementary receptor on the cell, where they bind together and communicate the message, they are carrying to implement the appropriate response (refer to Table 1.4.5 for examples of hormones and their actions).

Table 1.4.5: Examples of hormones, where they are produced and their functions.

Hormone	Endocrine Gland that Produces Hormone	Function
Insulin	Pancreas	Lowers blood glucose levels by signaling glucose to enter the cells to be used or stored as energy
Growth hormone	Pituitary Gland	Stimulates growth and the reproduction of cells
Thyroxine	Thyroid Gland	Regulates body metabolism, the function of the heart, bone and brain development and muscle health
Dopamine	Adrenal Gland	Regulates mood, motivation, memory, learning, behaviour, and attention

Synthesising antibodies

An **antibody** defends the body against invading pathogens that may cause disease or a virus, such as the flu, smallpox, measles, or the common cold. Special white blood cells detect these pathogens, which leads to the body producing an antibody with a complementary shape to a specific protein on the pathogen, known as an antigen (as shown in Figure 1.4.8). The antibody binds to the antigen which signals specialised white blood cells to engulf it. This significantly speeds up the removal of these pathogens, preventing or reducing the symptoms of the disease or virus. Once the body has produced a specific antibody in response to a particular invading pathogen, the body remembers how to manufacture it. This allows the body to produce the antibody more quickly the next time the same pathogen invades the body, assisting the development of the body's immunity.

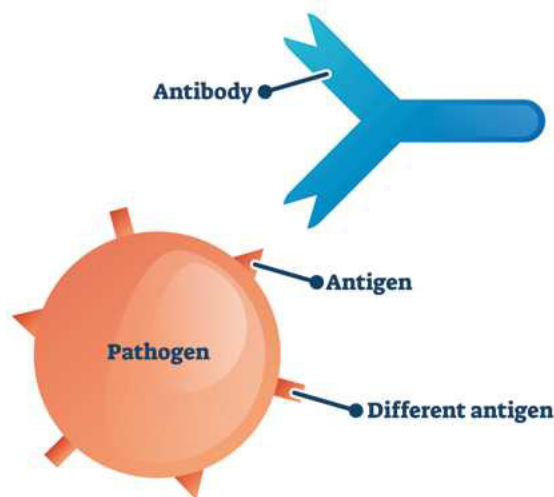


Figure 1.4.8: Each antibody is manufactured to destroy a specific antigen on the pathogen invading the body. The antigen binds to the specific binding site on the antibody.

Providing a secondary source of energy

The body requires a constant supply of energy for efficient cell and brain function. Protein supplies 16.7kJ/g and of the energy we consume, it is recommended that 15 to 25 per cent be sourced from protein. However, proteins are tasked with many other specific roles, so they are not designed to be the body's primary supplier of energy. Therefore, this percentage is to ensure individuals are obtaining adequate protein for its functional needs in the body. However, during times of starvation and insufficient carbohydrate and lipid consumption, proteins' main functions are sacrificed. The body will break down body tissue proteins to make amino acids that can be converted into glucose (through the process of gluconeogenesis) and used as a secondary energy source to maintain vital functions in the body.

Regulating fluid and acid–base balance

An important protein, albumin, produced by the liver, maintains homeostasis (equilibrium state) in the body by attracting water and controlling the movement of liquids into and out of the cell.



Fast fact

The liquid in a cell is known as intracellular fluid, whereas the liquid outside of the cell is known as the extracellular fluid

Proteins can also control the acid–base balance in the blood due to their amino and carboxylic acid groups. These groups allow them to bind to positively charged hydrogen ions (H^+), which can make the blood too acidic or negatively charged hydroxide ions (OH^-), which can make the blood too basic. Protein can discharge them from the body if required, which maintains the pH of the blood.

Assisting in muscle contraction and relaxation

A muscle fibre is composed of two types of proteins – actin (thin) and myosin (thick) filaments – which assist in transforming chemical energy in the form of ATP into mechanical energy. This transformation causes the muscle to contract as the actin and myosin filaments slide past one another (as seen in Figure 1.4.9).

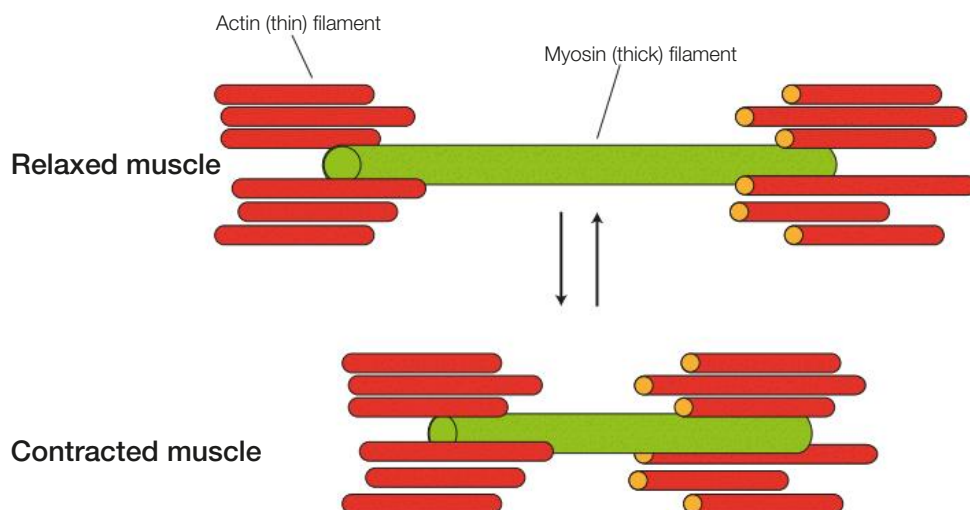


Figure 1.4.9: Sliding proteins (actin filaments and myosin filaments) allow muscle contraction and relaxation to occur.

Acting as transporters

Proteins in the body are **hydrophilic** and travel throughout bodily fluids, delivering nutrients and other molecules for cellular use. For example, haemoglobin is a protein in red blood cells which binds and carries oxygen from the lungs to the body's cells to create energy. Proteins also enable the safe transportation of fats through the blood, including lipoproteins which transport triglycerides, cholesterol, and fat-soluble vitamins to the cells for cellular use.



Reminder

Hydrophilic molecules have an affinity to water and tendency to mix with it, whereas hydrophobic molecules tend to repel water and are unable to mix with it.

Other proteins can be found embedded in the cell membrane, such as channel and carrier proteins. These allow specific compounds to enter the cell when required (as shown in Figure 1.4.10). Each transport protein is specific to a certain nutrient or group of compounds.

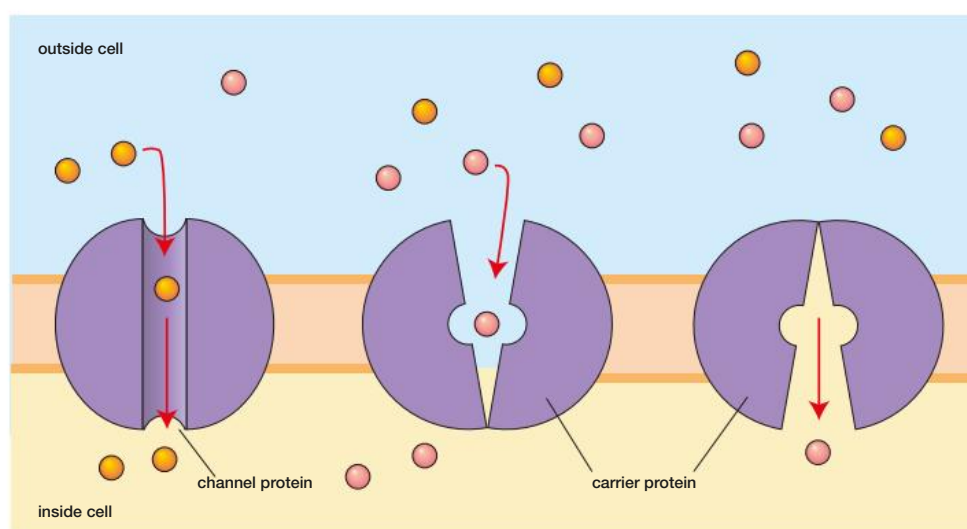


Figure 1.4.10: Channel and carrier proteins can be found in the cell membrane, which allows specific nutrients or compounds to enter the cell when required.

Key terms

Amino Acid	Essential amino acid	Non-essential amino acid
Antibody	High biological value (HBV)	Novel Protein Foods (NPFs)
Body tissues	Hormone	Peptide bond
Complementary protein	Incomplete protein	Polypeptide chain
Complete protein	Limiting amino acid	Secondary source of energy
Conditionally essential amino acid	Low biological value (LBV)	Transporter proteins
Enzyme		

Review questions: 1.4 Proteins

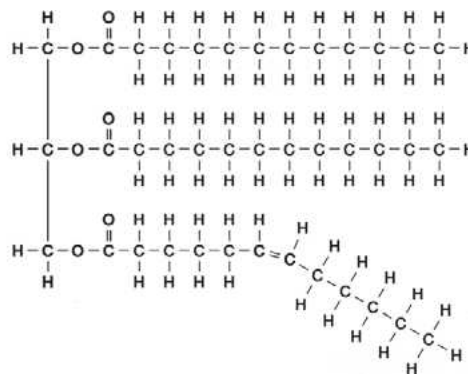
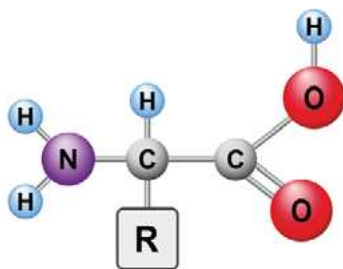
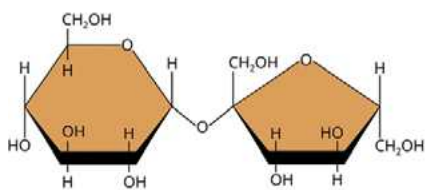
1. Protein is a macronutrient that should be consumed daily.

(a) Identify the element which Protein only provides the body.

(1 mark) (KA1)

(b) Amino acids are the building blocks of protein.

(i) Identify which of the following diagrams represents an amino acid. Circle your answer.



(1 mark) (KA1)

(ii) Explain the difference between an essential and a non-essential amino acid.

(2 marks) (KA1)

2. Describe what determines the shape and function of a protein.

(2 marks) (KA2)

3. The following image shows common sources of protein in the diet:



- (a) With reference to the image above, identify three sources which would have a high biological value and three sources which would have a low biological value.

High biological value:

Low Biological Value:

(3 marks) (KA2)

- (b) Explain what is meant by a protein having a high biological value, and state what these proteins are classified as.

(2 marks) (KA2)

4. Explain why using protein as the predominant energy source may be a concern to an individual's health.

(2 marks) (KA2)

5. Describe the difference between an enzyme and a hormone and use an example of each type of protein to support your explanation.

(4 marks) (KA2)

6. The following table shows the limiting amino acids (indicated by an X) in different plant-based proteins.

Plant-Based Protein	Limiting Amino Acids			
	Methionine	Lysine	Tryptophan	Threonine
Black Beans	X			
Cashews		X		
Wheat based Noodles		X		X
Brown Rice		X		
Pita Bread		X		
Capsicum Dip	X			
Sesame Seeds		X		
Hummus	X			
Popcorn		X	X	
Crackers		X		X
Vegetables	X			

(a) Describe what a limiting amino acid is.

(1 mark) (KA1)

(b) If capsicum dip is consumed with crackers, identify what type of protein this would be classified as.

(1 mark) (KA1)

(c) Identify a group of individuals that should have a sound knowledge of the protein classification identified in question 6(b) and explain its importance.

(3 marks) (KA2)

(d) With reference to the table above, provide two more specific food examples of the protein classification identified in question 6(b).

(2 marks) (KA2)

(e) Explain why consuming popcorn and cashews is not an example of the protein identified in question 6(b).

(2 marks) (KA2)

7. Excess amino acids cannot be stored in the body. Explain how an individual can obtain all essential amino acids.

(2 marks) (KA2)

8. Although, a deficiency in protein is not very common in Australia, groups at greater risk may develop the following symptoms in the table below. Explain why the following symptoms may occur in an individual with a deficiency in protein, (*hint: a deficiency in a nutrient is the opposite to its function*).

Symptom of Protein Deficiency	Explanation
Oedema (fluid retention) and difficulty with correct fluid balance	
Poor skin, nail, and hair development	
Stunted growth in children	
Greater susceptibility to bacterial and viral infections	
Anaemia (lack of quality red blood cells) & Fatigue	
Depletion in muscle mass	
Muscle pain	

(14 marks) (KA2)

9. Refer to the following table, which displays one significant physiological change and the approximate recommended daily intake (RDI) of protein for different stages of the human life cycle.

Stage in Human Life Cycle	Physiological Change	Protein RDI (grams)
Infancy (0–12 months)	Rapid growth rate in length and mass of body tissues.	10–14
Childhood (1–8 years)	Activity levels increase due to learning how to walk, run, talk, concentrate, jump, and climb.	14–20
Childhood (9–13 years)	Hormone levels start to increase due to the onset of puberty experienced towards the end of this life stage.	35–40
Adolescence (13–18 years)	Blood volume increases due to rapid growth spurt in height.	45–65
Adulthood (18–70 years)	Growth is completed.	45–65
Elderly	Functioning of the immune system declines.	55–80
Pregnancy	Times of intense development and rapid cell division.	60

- (a) With reference to the data table above, describe the trend in the RDI of protein from the ages 0 to 18 years.

(2 marks) (AE3)

- (b) Arginine is generally a non-essential amino acid that can become a conditionally essential amino acid during periods of rapid growth and development.
- (i) Explain what is meant when an amino acid is classified as being conditionally essential.

(2 marks) (KA2)

- (ii) With reference to the table above, identify a life stage where Arginine may be conditionally essential.

(1 mark) (KA2)

- (c) With reference to the table above, select two different life stages and explain how protein can support the physiological change listed in the table.

Life Stage:

Explanation:

Life Stage:

Explanation:

(4 marks) (KA2)

10. The table below indicates the general protein recommendations per kilogram based on activity levels.

Level of Activity	Definition	Recommended Daily Protein Intake (g/kg)
Sedentary	Seated or lying down all day with little to no intentional exercise per day.	0.8
Lightly Active	Seated work with intentional exercise for at least 30 minutes per day.	1.1
Moderately Active	Most of the day spent sitting with occasional standing and walking, with intentional exercise between 45 minutes to 1 hour per day.	1.4
Very Active	Standing or walking for most of the day, along with intentional exercise for over an hour per day.	1.7
Vigorously Active	Strenuous work, such as construction along with high intensity exercise most days.	2.0

- (a) Using data from the table above, describe the trend in the protein recommendation as the level of activity increases. Provide justification to support this trend.

(3 marks) (IAE3, KA2)

- (b) Use the following formula to calculate the amount of protein (g) a 68kg individual should consume if they have a job which requires them to stand most of the day, and regularly attends the gym after work by completing a class for one hour each day. *Show your calculations and round off to the nearest whole number.*

Amount of Protein (g) = Recommended Daily Protein Requirement (g/kg) x Body weight (kg)

(2 marks) (KA4)

- (c) Use the following table, which shows the protein content in common food sources to plan a daily diet (inclusive of breakfast, lunch, dinner, and snacks) to meet the protein requirements of the individual calculated in question 10(b). Enter the food items in the table below and ensure to calculate the total protein quantity.

Food Source and Quantity	Protein Content (g)
170g of Tofu	20.40
1 cup (150g) of cooked Chickpeas	11.85
200g of Lentil and Couscous salad (lentils, chickpeas, couscous, tomato, cucumber)	14.20
240g of Green Salad (broccoli, cabbage, corn, kale, sunflower seeds)	13.4
¼ cup (30g) of Raw Almonds	5.85
¼ cup (30g) of Raw Cashews	5.10
2 tsp (20g) of Peanut Butter, no added salt or sugar	4.86
½ cup of cooked Quinoa	3.90
½ cup of cooked Brown Rice	2.77
2 slices (94g) of wholegrain sliced bread	7.9
80g of cooked Lean Chicken Breast	23.84
100g of cooked Barramundi	22.80
65g of cooked Lean Beef Steak	20.74
2 Large (120g) hard boiled eggs	14.88
¾ cup (200g) of Low Fat, natural dairy Yoghurt	12.75
1 cup (250ml) of Low-Fat Dairy Milk	9.50

Meal	Food Items	Protein Quantity (g)
Breakfast		
Lunch		
Dinner		
Snacks		
	Total Protein Quantity	g

(4 marks) (KA2)

Total: / 60 marks



Science as a human endeavour

Considering insects as food

Source: <https://medicalxpress.com/news/2020-02-insects-seaweed-lab-grown-meat-foods.html>

Insects form a significant part of diets across the globe and are increasingly discussed as a sustainable protein source for the future. The largest farm in North America is less than two hours outside of Toronto and produces an array of cricket and mealworm powders and whole-roasted snacks. Insects are a front-runner in the quest for sustainable protein sources, producing the same amount of protein as conventional poultry, beef, and pork with far fewer feed requirements. Studies estimate that insects require 25 times less land resources to raise than conventional beef, half the energy and one-third of the water resources. From a nutritional standpoint, numerous species of insects are rich in key proteins, micronutrients, and minerals, although nutritional profiles change significantly during the different life stages of various insects.

1. With reference to the science as a human endeavour above, describe what is **influencing** the introduction of insects as a protein food source.

(6 marks) (KA3)

? Science Inquiry Skills

Testing for Protein

Introduction

There are different tests which can be used to detect the presence of carbohydrates, lipids, and proteins. These tests involve adding a reagent to a food sample which changes colour depending on what macronutrients are present. Biuret solution is made up of Sodium Hydroxide and Copper Sulfate and is used to identify the presence of protein. This solution starts blue and changes colour to purple when protein is detected. The formation of a purple colour indicates the presence of peptide bonds between amino acids in the sample. The intensity of the developed purple colour is directly proportional to the concentration of peptide bonds present in the solution.

Hypothesis:

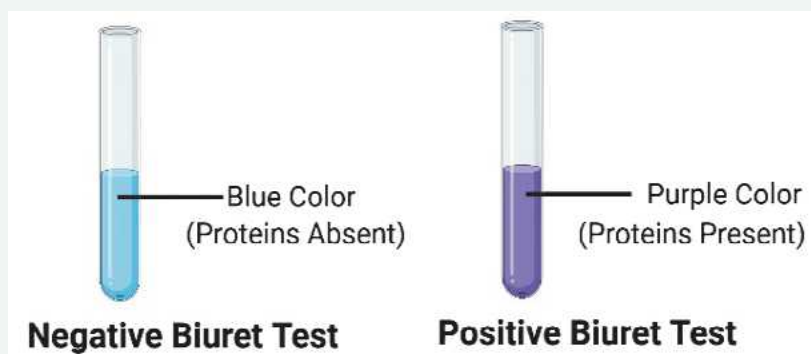
If protein is present in the food item, then the colour of the solution will change to a purple end point.

Materials:

- Foods that can be tested:
 - White Rice
 - Shredded Cooked Chicken
 - Egg Whites
 - Milk
 - Chickpeas
 - Potato
 - Cheese Slices
 - Butter
 - White Beans
 - Vegetable Oil
 - Oats
 - Quinoa
- Biuret Solution (1M Sodium Hydroxide and 0.1M Copper Sulfate)
- Mortar and Pestle
- Knife
- Cutting Board
- Small Beaker
- Stirring Rod
- Large Test Tubes
- Test Tube Rack
- Distilled Water
- 5ml Measuring Cylinder
- Test Tube Labels

Method:

1. If required, break down the food sample using a mortar and pestle until it is in a liquid form and add to small beaker (cut the food sample with a knife and chopping board if required first).
2. Add a small amount of distilled water to the food sample in the beaker and stir with a stirring rod to ensure it is a liquid consistency (aqueous solution).
3. Add the food sample to a large test tube, until it is a quarter filled.
4. Label the test tube with the food sample being tested.
5. Measure 2ml of Biuret's Solution with a measuring cylinder, and place in the test tube with the food sample, while shaking gently to mix.
6. Describe the colour of the solution in the test tube after letting it stand at room temperature for 5 minutes and record this in the results table below, if no protein is present the solution will remain light blue, but if a small concentration of protein is detected the solution will change to dark blue and if a high concentration of protein is detected the solution will turn purple (as shown in the figure below).



? Science Inquiry Skills

Raw Data:

Food Source:	Colour of the Solution after the Biuret Test	Presence of Protein (✓ or ✗)	Complete or Incomplete Protein (if protein is detected)

Analysis & Discussion:

1. Identify what proteins are made up of and the name of the bond that joins these monomers together.

2. Describe what could be used as a control and explain the importance of having a control test in this investigation.

3. Explain how the reliability of the results could be enhanced and the importance of improving this.

4. This test is commonly used to assess individual's urine samples to detect for the presence of protein. Research and explain why the presence of protein in an individual's urine would be a concern.

Extension Activities

1. Research a specific situation when a non-essential amino acid becomes conditionally essential.
2. Research and describe the restrictions of the following diets, which commonly restrict some if not all animal-based protein sources.

Vegan	
Lacto vegetarian	
Ovo vegetarian	
Lacto-ovo vegetarian	
Pescatarian	
Pollotarian	
Flexitarian	

3. Novel protein sources are protein sources, which do not come from traditional foods that have dominated our diets for generations. Insects are an example of a novel protein, which are expected to enter the market due to being nutrient dense, their environmental benefits and significant supply to meet the growing populations' protein demand.

Edible insects can be sourced from several websites including the Edible Bug Shop: <https://ediblebugshop.com.au/> can be added to common baked good recipes (as shown on the next page) to enhance their protein content, texture and flavour!

CHOCOLATE CHIP CRICKET POWDER COOKIES RECIPE

(Makes approximately 12 large cookies)



Ingredients	Method
• 55g softened butter • 53g brown sugar • 55g caster sugar • 1 large egg • 5g vanilla extract • 95g plain flour • 40g milk chocolate chips • 40g dark chocolate chips • 20g Cricket Protein powder (or 20g of crickets chopped up for additional crunch) WARNING: Individuals with allergies to crustaceans may experience allergies to edible insects also.	1. Pre heat your oven to 180°C. 2. Prepare a baking tray by lining it with baking paper. 3. Beat your butter and sugar for 1-2 minutes or until smooth and fluffy. You can mix by hand or use a kitchen aid or thermomix. 4. Beat in the egg and vanilla into the butter and sugar mixture until combined. 5. Add the flour and cricket powder and mix this on a low speed until well combined and the dough starts to form a ball. 6. Mix in the milk and dark chocolate chips. 7. Using a tablespoon, scoop out balls of the dough and roll them between your hands to make them an even shape. 8. Place the balls onto your lined baking tray, making sure to leave a 3cm gap between the balls (this will allow the cookies to spread evenly). 9. Bake the cookies for 15-18 minutes until golden brown.

CHOCOLATE RASPBERRY CRICKET BROWNIES RECIPE

(Makes approximately 10 individual brownies)



Ingredients	Method
• 32g Dark Chocolate buttons • 32g Salted Butter • 1/3 Cup Caster Sugar • 1 Egg • 1mL Vanilla Extract • 1/4 Cup Plain Flour • 32g Dark Chocolate Chips • 1 Tablespoon of Cricket Protein Powder • 8g Cocoa • 1/8 teaspoon Baking Powder • 25g Fresh or frozen Raspberries (or Blueberries) • Handful of crickets (for crunch) WARNING: Individuals with allergies to crustaceans may experience allergies to edible insects also.	1. Melt Butter and dark chocolate buttons in the microwave or on a low heat on the stove and mix until smooth. Let this cool to room temperature before using. 2. Pre heat your oven to 165°C. 3. Beat the eggs, vanilla, and sugar together by hand or with an electronic mixer until the sugar dissolves. 4. Add cooled, melted butter and chocolate mixture to the egg, vanilla, sugar mixture and mix until combined. 5. In a separate bowl, combine all the dry ingredients, including the chocolate chips, making sure they are all evenly mixed. 6. Add the wet ingredients into the bowl full of dry ingredients, and fold in until just combined (do not over mix!) 7. Now fold in the raspberries and crickets without breaking them up too much. 8. Spoon the mixture evenly between in a shallow baking tray or cupcake tray. 9. Place your brownies into the oven at 165°C (fan forced) for approximately 22 minutes. It is OK if they are still a bit gooey in the centre. 10. Wait until they are fully cooled before removing them from the baking tray.

1.5 Water and Other Fluids

Science understanding

Identify sources of water and other fluids in the diet and explain its function in maintaining good health.

- Describe the benefits derived from consuming fluids other than water.
- Explain the factors that affect hydration levels, including fluid intake, salt intake, exercise, illness, caffeine, and alcohol.
- Describe the effects of dehydration.

SACE Subject Outline, 2024.

Sources of Water in the Diet

The recommended daily intake of water is dependent on diet, body size, activity levels, environmental temperatures, and humidity; therefore, it is difficult to establish one water requirement value. However, according to the nutrient reference values for Australia and New Zealand, a male should consume 3.4 litres and a female should consume 2.8 litres of total water content a day. The total water content includes not only consuming water but other beverages and food items, which almost all contain some water. The body’s metabolic processes (e.g., digestion) are also sources of water, as they produce approximately 200 to 300 mL of water each day that can then be used by the body for other functions.

Fluid sources

Water is undoubtedly the best drink for hydration, as it contains no kilojoules. However, consumers do not only drink water for hydration. After water, other fluid sources of water include coffee, tea, full fat or reduced fat milk, flavoured milks, fruit juices, cordial, regular or diet soft drinks, energy or sports drinks and alcoholic drinks. The consumption of these sources not only provides a source of water but other nutrients too, which serve a function in the body. However, caffeinated beverages (tea, coffee, and soft drinks) and alcohol promote greater water loss through urine as they act as a **diuretic** – especially if more than 3 cups are consumed in a day.

 **Definition**

A diuretic is a source which causes increased urination.

Solid food sources

Solid foods contribute approximately 20% of total daily water intake or about 700-800mL. Most foods contain water, with most fruits and vegetables having around 90 per cent water, and most meats and cheeses containing almost 50 per cent water (refer to Table 1.5.1 for other food sources containing water).

Table 1.5.1: Water-content range of selected foods and beverages.

Water content (%)	Food
100	Water
99 – 90	Milk, watermelon, strawberries, lettuce, cabbage, celery, spinach
89 – 80	Fruit juice, yoghurt, apples, grapes, oranges, carrots, broccoli, pears, pineapple
79 – 70	Bananas, avocado, cottage cheese, ricotta cheese, corn, prawns, baked potato
69 – 60	Pasta, legumes, salmon, ice-cream, chicken breast
59 – 50	Hot dogs, feta cheese, minced beef, steak
49 – 40	Pizza
39 – 30	Bread, cheddar cheese, bagels
29 – 20	Salami, cake, biscuits
19 – 10	Butter, margarine, raisins
9 – 1	Walnuts, peanuts, chocolate chip cookies, crackers, cereals, pretzels, peanut butter
0	Oils, sugars

Drawn from Popkin, BM, D’Anci, KE & Rosenberg IH 2010, ‘Water, hydration, and health’, Nutrition Reviews, vol. 68, no. 8, pp. 439–458. <https://doi.org/10.1111/j.1753-4887.2010.00304.x>

Functions of Water

Approximately 60 per cent of the average adult body and 70 per cent of an average child's body is composed of water (as shown in Figure 1.5.1). Water makes up 75 per cent of lean body tissue, 25 per cent of adipose tissue and 90 per cent of blood volume. The bodily proportion of water is smaller in female, obese and/or elderly people, as they have a lower percentage of lean body tissue. It is essential for an individual to stay well hydrated as water is the fluid in which all life processes occur in the body.

Definition

To stay well hydrated is having absorbed enough water or other liquid to perform its bodily processes.

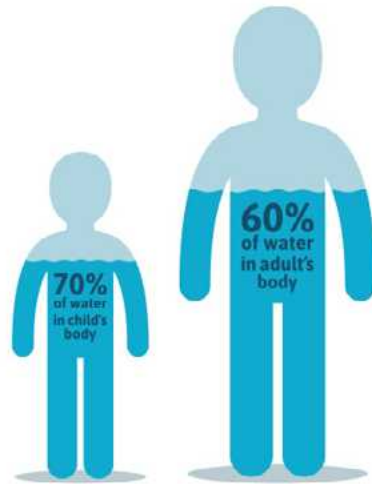


Figure 1.5.1: The water composition in an average child (left) and adult's (right) body.

Transportation of nutrients and waste products

The water constituting our blood volume acts as a **solvent**, allowing a variety of different nutrients to dissolve within its contents including minerals, vitamins, amino acids and glucose, and substances such as hormones. Water assists in the effective transportation of these nutrients and substances around the body via the bloodstream to enable metabolic processes or chemical reactions.

The chemical reactions in our body produce waste products, including carbon dioxide and urea. The water in the blood also assists in transporting carbon dioxide to the lungs to be exhaled and urea to the kidneys for excretion via urine. If these waste products build up in the body, they can cause complications, which is why their removal is essential.

Maintaining blood volume

Blood volume is determined by the amount of water ingested (along with other factors). The average volume of blood in an adult is 5.5L. The kidneys can adjust blood volume by expelling excess water via urine or conserving water if an individual is dehydrated. This assists in maintaining blood pressure, which has a proportional relationship with blood volume. For example, if the volume of blood is increased, this means the heart must pump additional blood around the body, which increases blood pressure. Maintaining an ideal blood pressure ensures all parts of the body receive the oxygen and nutrients they need to function optimally.

Definition

Blood volume refers to the total amount of fluid circulating within the arteries, capillaries, veins, venules, and chambers of the heart at any time.

Regulating body temperature

Water assists in maintaining our internal body temperature of 37°C by releasing heat from the body via sweat. When the body's temperature increases above 37°C, the body begins to sweat (perspire), which is mainly comprised of water and salts. Sweat evaporates from the surface of the skin, which takes heat with it and allows for a cooling sensation to be experienced.

Supporting digestion

Digestion starts with saliva, the basis of which is water. Saliva moistens food for easy movement throughout the remainder of the digestive tract. Water also produces soft stools, preventing them from drying out and getting stuck in the large intestines. This promotes easy evacuation from the bowels, preventing the risk of constipation.

Lubricating and moistening body joints and tissues

Water acts as a **lubricant and shock absorber** for joints, the eyes, the brain, the spinal cord, and the foetus during pregnancy. There are names for the different types of lubricating and shock absorbing fluids; for example, amniotic fluid protects the foetus and synovial fluid protects joints (as shown in Figure 1.5.2). This fluid protects the body's sensitive structures against shock.

The water (synovial fluid) between a knee joint reduces friction and allows for a smooth gliding motion between the bones. This prevents the bones from rubbing against each other, which would cause stiffness and pain during movement (as shown in Figure 1.5.2).

As air passes through the nasal cavity and mouth it is warmed, filtered, and humidified by mucous secretions containing water. Air entering the mouth is warmed but not filtered. This increases the amount of water vapour in the air entering the lungs, which in turn reduces risks to the respiratory system. Without the moist air, the respiratory system could dry out and cause damage to the delicate tissues.

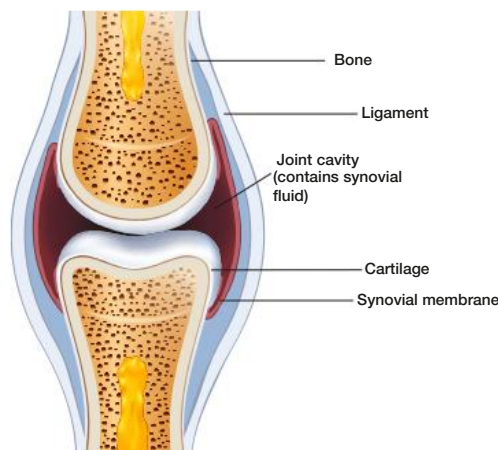


Figure 1.5.2: Fluid cushions joints to protect them from damage.

The Causes and Effects of Dehydration

The body loses water each day through fluids in sweat, faeces, urine, breath, blood, vomit, and tears. The average amount of water lost from the body is approximately 2.2 litres per day, with the greatest loss of water experienced through urine, which accounts for approximately 0.5 to 1.4 litres per day. If an individual consumes more water, the kidneys excrete more urine, which makes it more dilute. On the other hand, if an individual does not consume enough water, the kidneys conserve as much water as possible, making urine more concentrated to avoid dehydration.

The Causes of Dehydration

Water balance is achieved when the amount of water lost from the body is equal to the amount of water consumed through water sources or produced by the body via metabolic processes (as shown in Table 1.5.2). Dehydration is caused by an imbalance where not enough fluid is consumed to replace the water lost from the body. The amount of water lost from the body can be increased due to several factors, which affect hydration levels. Exposure to hot and humid environmental conditions and the completion of strenuous physical activity increases the amount of water lost via sweat, which removes heat from the body. Illness can also affect hydration levels, as individuals are less likely to feel like eating or drinking when sick. Illness can also cause symptoms of fever, vomiting and diarrhea, which can promote water loss and lead to dehydration. The excessive consumption of diuretics, such as caffeine and alcohol, trigger the kidneys to increase urine production which increases the volume of water lost from the body. Salt is primarily composed of sodium chloride, where sodium can attract and hold onto water by reducing the kidneys' ability to remove water via urine. Therefore, a diet low in salt can increase the risk of dehydration.

Table 1.5.2: An equal water balance where the amount of water gained from different sources and the amount of water lost via different bodily fluids is equal.

Water sources	Amount (mL)	Water loss	Amount (mL)
Beverages	550–1500	Kidneys (urine)	500–1400
Food	700–1000	Skin (sweat)	450–900
Metabolic processes	200–300	Lungs (breath)	350
		GI tract (faeces)	150
Total	1450 – 2800	Total	1450 – 2800

How do you know if you are drinking enough water?

The easiest way to determine if an individual is dehydrated is to check the colour and volume of urine produced. This can be checked and monitored every few hours and compared to a **dehydration urine chart** (as shown in Figure 1.5.3). If a person's urine is light in colour and has a high volume, this is an indication that that person is drinking enough water and is well hydrated. However, if the urine colour is dark and low in volume, then not enough water is consumed and an indication of dehydration.



Urine Sample	Colour of Urine	Level of Hydration	Recommendation
1	Colourless	Over Hydrated	See doctor
2	Pale Straw Yellow	Well Hydrated	Keeping drinking at the same rate
3	Translucent Yellow	Hydrated	Keeping drinking at the same rate
4	Yellow	Fairly Hydrated	Drink a glass of water now
5	Dark Yellow	Mildly Dehydrated	Drink a glass of water now
6	Amber	Dehydrated	Drink 2-3 glasses of water now
7	Burnt Orange	Very Dehydrated	Drink 2-3 glasses of water now
8	Red	Severely Dehydrated	See doctor

Figure 1.5.3: Urine dehydration chart.

The Effects of Dehydration

Dehydration may develop through water deprivation or excessive **water loss**. Thirst is the first sign of dehydration, causing the mouth to become dry and initiating drinking behaviour. If an individual is not able to replenish bodily fluids, the symptoms of dehydration may progress rapidly from thirst to weakness, fatigue, headaches, fevers, delirium, and kidney damage. Dehydration may even lead to death if bodily fluids are not replenished (refer to Table 1.5.3 for specific symptoms and signs of dehydration).

Table 1.5.3: Signs and symptoms of different stages of dehydration.

Stage of dehydration	Body weight loss (%)	Symptoms
Mild	1–2	Thirst, fatigue, weakness, vague discomfort, loss of appetite, dizziness, dry mouth, dark-coloured urine.
Moderate	3–6	Increased heart rate, decreased sweating and urination, headaches, nausea, difficulty concentrating, irritability, impaired temperature regulation.
Severe	7–10	Muscle spasms, vomiting, seizures, exhaustion, delirium, increased risk of collapsing.

Key terms

Blood Volume Dehydration	Hydrated	Urine
Dehydration Urine Chart	Lubricant & shock absorber	Water Balance
Diuretic	Solvent	Water loss
	Sweat (perspire)	Water source

Review questions: 1.5 Water

1. Evaluate the following statements as True or False and provide reasoning behind your choice.

- (a) Muscle tissue contains less water than fat tissue.
- (b) Bodily water content is dependent on age and body weight.
- (c) Diarrhoea and vomiting can cause dehydration.
- (d) Water deficiency will not cause kidney damage.
- (e) Constipation cannot be prevented by an increased water intake.
- (f) People who are more active require more water.
- (g) Water is not necessary for the digestive process.
- (h) Males generally require more water than females.
- (i) Water is the vehicle for transportation of nutrients around the body.
- (j) Water contains 20 kJ per 100 mL.

(20 marks) (KA1)

2. Explain why males generally require a greater amount of water than females.

(2 marks) (KA2)

3. Name three foods (not beverages) from separate food groups that have high water-content.

(3 marks) (KA1)

4. Approximately 82% of Australians do not meet the Adequate Intake for total water intake, putting them at risk of dehydration.
- (a) With reference to the urine dehydration chart (Figure 1.5.3), if an individual produces the following urine sample, identify what stage of dehydration they would be at.



(1 mark) (IAE3)

- (b) Identify the first sign of dehydration, which may indicate an individual needs to consume water.

(1 mark) (KA2)

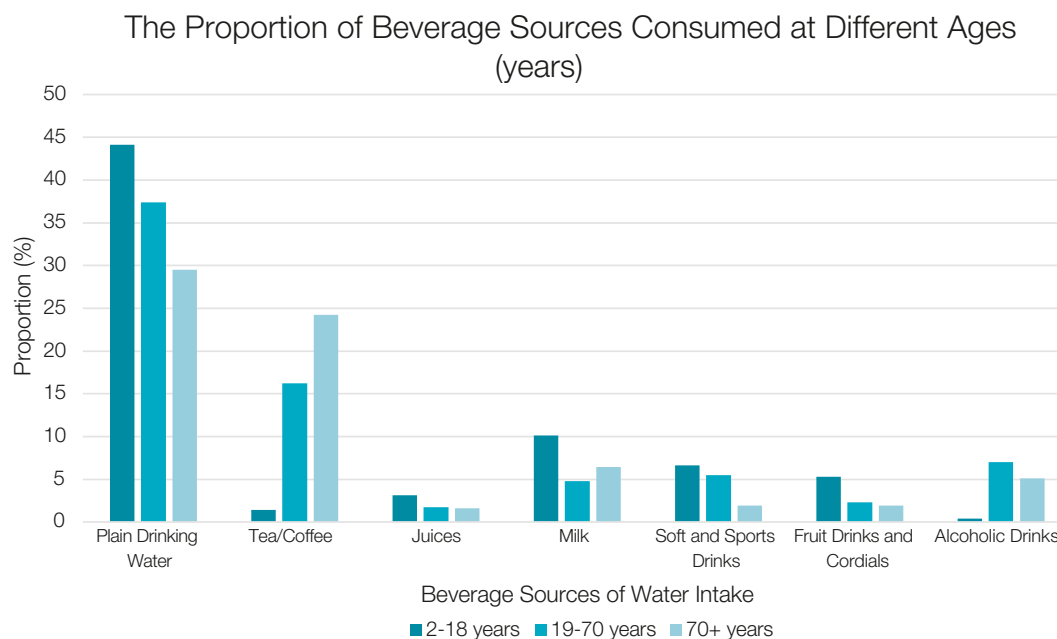
- (c) If an individual produces the urine sample above, suggest a suitable recommendation.

(1 mark) (KA2)

5. Dehydration can lead to a low blood pressure reading of less than 90/60mmHg. Explain how dehydration can reduce an individual's blood pressure.

(3 marks) (KA2)

6. The following graph demonstrates the proportion (%) of beverages consumed that individuals obtain their water intake from across different age groups.



- (a) With reference to the graph above, describe the trend in relation to drinking plain water across the different age groups, and propose one reason for this trend.

(3 marks) (IAE3, KA2)

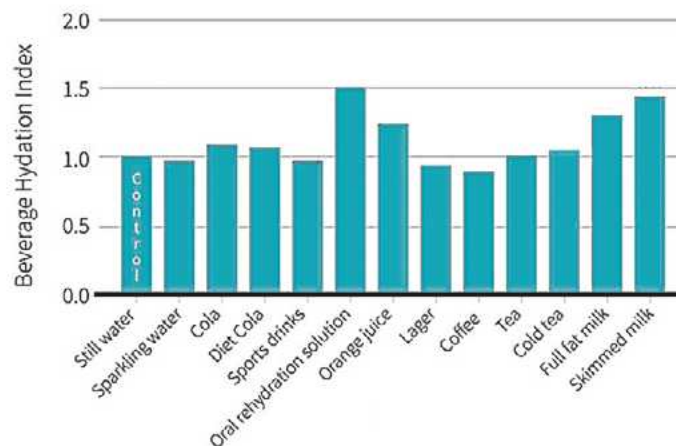
- (b) As can be seen on the graph above, the consumption of tea and coffee increases as the age of individuals increases. Explain how the excessive consumption of these beverages can increase an individual's risk of dehydration.

(2 marks) (KA2)

- (c) Approximately 87% of cow's milk is composed of water. With reference to the graph above, identify the age group in which milk consumption is at its greatest and explain an additional benefit of consuming milk at this age.

(3 marks) (IAE3, KA2)

7. Beverages can be given a hydration index, which is determined by dividing the volume of urine produced after drinking water by the volume of urine produced after drinking the test beverage. A study involving 72 active participants was conducted where 13 different beverages were tested. The beverage hydration index of different beverages is shown in the graph below, where a higher hydration index indicates more water is retained in the body than if the consumer had drunk an equal volume of plain water (control).



- (a) With reference to the graph above, identify a test beverage which has a lower hydration index than still water.

(1 mark) (IAE3)

- (b) Explain the importance of using a large sample size of 72 participants.

(2 marks) (KA2)

- (c) Explain the purpose of including a control when establishing the beverage hydration index of the tested beverages.

(2 marks) (KA2)

- (d) With reference to the graph above, identify which test beverage provides the greatest hydration and how the consumption of this beverage could prevent constipation.

(2 marks) (IAE3, KA2)

- (e) The consumption of coconut water claims to be *as hydrating as plain water*. After the consumption of 500ml of coconut water 132ml of urine was measured after 2 hours, in comparison to 106ml of urine measured after the consumption of 500ml of plain water. Using the formula below, calculate the beverage hydration index of coconut water and identify if the claim is supported or not supported. *Show your working out.*

$$\text{Beverage Hydration Index} = \frac{\text{Urine Volume post Water Consumption}}{\text{Urine Volume post Test Beverage Consumption}}$$

(3 marks) (KA4)

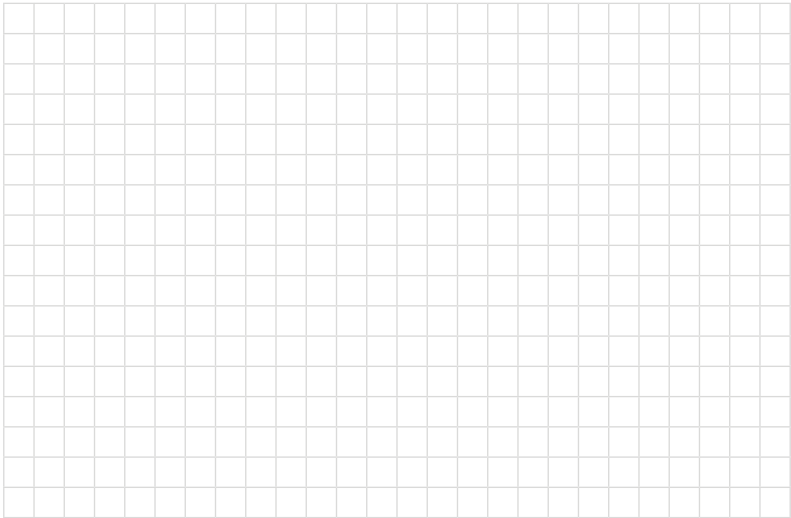
8. An experiment was conducted investigating the amount of water (L) lost via sweat from athletes in different environmental temperatures. The amount of water lost via sweat was recorded every 15 minutes throughout two different football games and the results are shown in the table below.

The amount of Water Lost (Litres)									
Temperature (°C)	0min	15min	30min	45min	60min	75min	90min	105min	120min
22	0	0.2	0.3	0.7	1	1.3	1.5	1.8	2.2
31	0	0.5	1.2	1.7	2.4	2.9	3.4	4.0	4.5

- (a) State the dependent variable of this investigation.

(1 mark) (IAE1)
- (b) Graph both sets of data from the table above on the same set of axes in the space provided below.

Title: The Effect of Temperature on the Amount of Water Lost via Sweat in Football Athletes



- (c) Using data from the table or graph, explain why there is a difference in the amount of water lost via sweat in the two football games.

(4 marks) (IAE2)
- (d) The recommended water intake for an individual is dependent on several factors. Describe two other factors that can lead to an increased need for water.

(2 marks) (IAE3)

(4 marks) (KA2)

Total / 60 marks



Science as a human endeavour

Which drink is best for hydration? Hint: It isn't Water

Source: <https://edition.cnn.com/2019/09/25/health/best-drinks-for-hydration-wellness/index.html>

Sure, you can always reach for a glass of water — but plain H₂O isn't the most hydrating beverage around, according to a study from Scotland's St. Andrews University that compared the hydration responses of several different drinks. The researchers found that while water — both still and sparkling — does a pretty good job of quickly hydrating the body, beverages with a little bit of sugar, fat or protein do an even better job of keeping us hydrated for longer. The reason has to do with how our bodies respond to beverages, according to Ronald Maughan, a professor at St. Andrews' School of Medicine and the study's author. One factor is the volume of a given drink: The more you drink, the faster the drink empties from your stomach and gets absorbed into the bloodstream, where it can dilute the body's fluids and hydrate you. The other factor affecting how well a beverage hydrates relates to a drink's nutrient composition. For example, milk was found to be even more hydrating than plain water because it contains the sugar lactose, some protein and some fat, all of which help to slow the emptying of fluid from the stomach and keep hydration happening over a longer period of time. Milk also has sodium, which acts like a sponge and holds onto water in the body and results in less urine produced. This study tells us much of what we already knew: Electrolytes — like sodium and potassium — contribute to better hydration, while calories in beverages result in slower gastric emptying and therefore slower release of urination," said Melissa Majumdar, a registered dietitian, personal trainer and spokeswoman for the Academy of Nutrition and Dietetics who was not involved in the study.

1. Explain how the finding of this study could be **applied** to an endurance athlete (an athlete who completes physical activity over a long period of time without exhaustion) regarding the recommended hydration fluid before and after a marathon event.

(4 marks) (KA3)

? Science Inquiry Skills

Water Content in Fruits and Vegetables

Introduction:

Most solid foods contain water, with many fruits and vegetables containing 90 per cent water. The amount of water in fruits and vegetables can be determined by removing its water content and calculating the percentage difference in mass. One method of removing its water content is using a dehydrator, which is an appliance that uses heating elements along with fans to direct hot air over the food, which releases moisture from the food's interior and accelerates surface evaporation. Sun drying is another method that can be used, which involves the evaporation of water from food with direct sunlight or solar heating, along with the assistance of surrounding air. A light covering of cheesecloth fabric can be used to protect food from insects. Both these methods can be used to preserve fruits and vegetables, by reducing the water availability in these foods which is a requirement for bacterial growth.

Materials:

- 5x large plastic plates
- Cheesecloth fabric
- Electronic balance
- 2x oranges
- 2x bananas
- 2x zucchini
- 2x sweet potatoes
- 1x vegetable peeler
- Chopping board
- Knife
- Food dehydrator

*Other fruits and vegetables can be used including apples, strawberries, mangoes, pineapple, tomatoes, bell peppers, snap peas, watermelon, broccoli.

Method:

1. Place a plastic plate on the electronic scales and reset the weight to zero.
2. Place the entire orange onto the electronic scales and measure its initial mass (g) and record this in the first raw data table below.
3. Measure the initial mass (g) of the remaining fruits and vegetables and record these in the first raw data table below. *Ensure to peel the banana and sweet potato with the vegetable peeler first. Reset the weight of the scales to zero each time.*
4. Using the chopping board and knife, cut all fruit and vegetables into thin slices and place all slices into the food dehydrator. *You may need to dehydrate each food item separately, however, be sure that you dehydrate all the pieces of the same fruit and vegetable together.*
5. Repeat steps 2-3 and record the initial mass (g) of the second pieces of fruit and vegetables and record this into the second raw data table.
6. Using the chopping board and knife, cut all fruit and vegetables into thin slices and place all slices spread out on individual plastic plates.
7. Place cheesecloth fabric over the fruit and vegetables on their individual plastic plates to protect from insects and rodents.
8. Place all four plastic plates in a safe area with plenty of access to direct sunlight.
9. Leave the fruits and vegetables in their respective areas for 24 hours (*this time may need to be extended depending on the number of food dehydrators available and the level of direct sunlight*).
10. After the time has passed, collect all fruit and vegetable samples.
11. Place all orange slices that were air dried using the food dehydrator on the electronic scales and record their final mass (g) in the raw data table below. *Ensure the weight of the scales has been reset to zero each time.*
12. Repeat step 11 and measure the final mass of the remaining fruits and vegetables from their respective treatments.
13. Calculate the difference in mass of each fruit and vegetable from their respective treatments using the following formula: *Initial Mass (g) – Final Mass (g)* and record in the results tables below.
14. Calculate the percentage of water in the fruits and vegetables that were air dried using the food dehydrator and sun dried using the formula below and record in the results tables:

$$\text{percentage of water in food} = \frac{\text{difference in mass}}{\text{initial mass}} \times 100$$

? Science Inquiry Skills

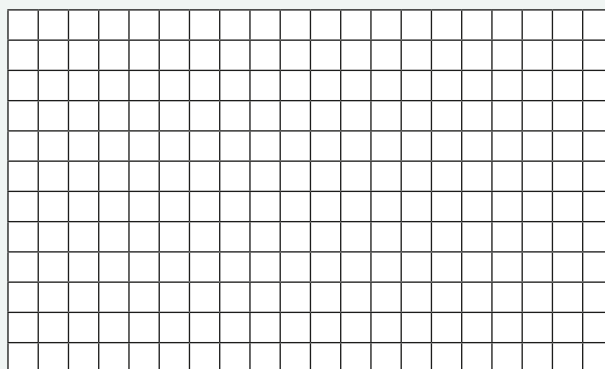
Raw Data:

FOOD DEHYDRATION (AIR DRYING)	Fruit and Vegetables			
	Orange	Banana	Zucchini	Sweet Potato
Initial Mass (g)				
Final Mass (g)				
Difference in Mass (g)				
Percentage of Water (%)				

SUN DRYING	Fruit and Vegetables			
	Orange	Banana	Zucchini	Sweet Potato
Initial Mass (g)				
Final Mass (g)				
Difference in Mass (g)				
Percentage of Water (%)				

Presentation of Data:

Represent the percentage of water in the fruits and vegetables tested (%) as a column graph. Ensure to add the suitable features on the graph, including a title, even scale, labelled axes, and legend.



Analysis & Discussion:

- With reference to the data tables and graph above, identify which fruit or vegetable had the greatest and lowest percentage of water with each respective treatment. If a different fruit or vegetable was identified for each respective treatment, propose a reason why.

	Air Drying	Sun Drying
Greatest Percentage of Water		
Lowest Percentage of Water		

? Science Inquiry Skills

2. Research the percentage of water in each of the fruits and vegetables tested, and comment on the accuracy of your results.

3. Identify two random errors that may be present and discuss how these could have impacted the reliability of the data.

4. Discuss how the reliability of the data could be enhanced.

Extension Activities

Helpful online resources

Nutrient Reference Values from [eatforhealth.gov.au](https://www.eatforhealth.gov.au)

<https://www.eatforhealth.gov.au/nutrient-reference-values/nutrients/water>



1. Using the following website link above; identify the total daily water intake (food and beverages) and fluid intake required for you, based on your gender and age. Are you meeting this recommendation? If not, suggest some possible modifications to your diet that may assist in increasing your total water consumption.

Total Daily Water Intake (Food and Beverages) Required:

Total Daily Fluid Intake (including plain water, milk, and other beverages):

Recommendations (if required):

2. Water is the best recommended source of water, due to containing no kilojoules or sugar. However, other fluids can be a great source of water and other nutrients which can provide another function in the body. Research two other nutrients that may be provided by these other fluid sources and their benefits in the body.

Fluid Source	Other Nutrients Present and their Benefit
Milk	
Black Coffee and Tea	
Fruit Juice	
Sports or Energy Drink	
Smoothie	

Micronutrients

Micronutrients can be defined as the nutrients humans consume, and need, in small amounts. Micro, meaning ‘extremely small’ alludes to this. They tend to have recommended daily intakes of less than 100 milligrams, compared to macronutrients which have much larger daily demands in grams. Micronutrients include vitamins and minerals. Vitamins are organic substances, which means they can be made by plants or animals (including humans). Whereas minerals are inorganic elements that are sourced from soil and water and absorbed by plants or eaten by animals (humans).

1.6 Vitamins

Science understanding

Micronutrients (vitamins and minerals) are required by the body for good health and the prevention of many diet related disorders.

- Identify sources of fat-soluble and water-soluble vitamins.
- Explain the effect of cooking techniques on fat-soluble and water-soluble vitamins.
- Compare fat-soluble and water-soluble vitamins with respect to transport in the body, absorption, storage in the body and excretion, probability of toxicity, and stability.
- Explain the functions of vitamins B1, B2, and B3, for metabolism of macronutrients, vitamin B9 (folate), vitamin B12, vitamin C, and vitamin D, which are all associated with deficiencies and health issues in Australia and vitamin K.

Describe the consequences of undernutrition, including anaemia, rickets, scurvy, and spina bifida.

SACE Subject Outline, 2024.

Vitamin Classification

Vitamins are organic substances which can be classified as water soluble or fat soluble. Water soluble vitamins dissolve in water upon entering the body, whereas fat soluble vitamins are absorbed along with fats in the diet and stored in the body’s adipose tissue and liver. The classification of vitamins determines several characteristics (as shown in Table 1.6.1).

Table 1.6.1: Characteristics or properties of fat-soluble and water-soluble vitamins.

	Water-soluble vitamins	Fat-soluble vitamins
Transportation in the body	Dissolve in water, therefore transported freely and easily in the blood.	Dissolve in fat/oil, therefore, require transport in the bloodstream via triglycerides in lipoproteins.
Absorption	Move directly into the blood, due to being able to dissolve in water	Enter the lymphatic system with fats, before making their way into the bloodstream
Storage in the body & Excretion	Body cannot store most of them, therefore any excess quantities of water-soluble vitamins are excreted from the body via bodily fluids, including urine, faeces, perspiration, tears, blood, or vomit.	Body stores excess fat-soluble vitamins in adipose tissue and the liver.
Requirements	Required in frequent amounts, every 1-3 days as they are not typically stored in the body and frequently excreted.	Not required as frequently and can be consumed between weeks and months as the body stores these vitamins.
Probability of deficiencies	Deficiencies are possible (hypovitaminosis), while excess is rare, due to the body’s inability to store most water-soluble vitamins.	With storage in the body possible, deficiencies are less common. However, fat- soluble vitamins are more likely to accumulate in the body leading to dangerously high levels and toxicity (hypervitaminosis).
Stability	Less stable and can be destroyed through processing (e.g., cooking and exposure to heat) and lost with poor storage (e.g., food left uncovered on a bench top exposed to oxygen and light). These vitamins can also leach into the surrounding water when these food sources are cooked in water, such as in boiling.	More stable and not readily lost through processing and poor storage. These vitamins can leach into fats, such as oil and butter which may be used when cooking, such as in deep-frying.

There are 13 essential vitamins in total. Their classification as either water or fat soluble is displayed in Figure 1.6.1. Of the 13 vitamins listed below, the vitamins discussed in this topic are vitamin B₁ (Thiamin), B₂ (Riboflavin) & B₃ (Niacin), B₉ (Folate), B₁₂ (Cobalamin) C (Ascorbic Acid), D (Calciferol) and K (Phylloquinone).

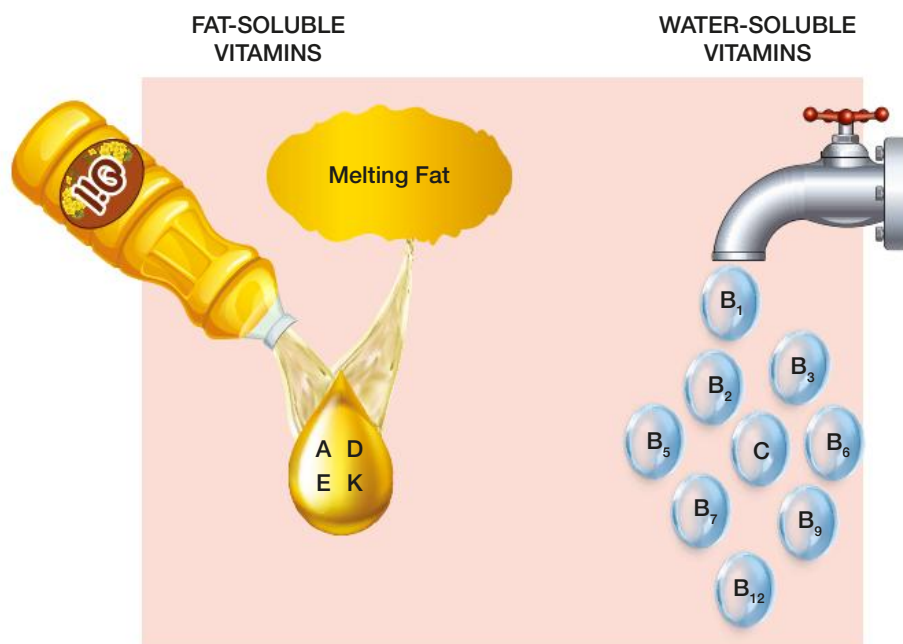


Figure 1.6.1: Vitamins and their groupings as either water or fat soluble.

Vitamins B₁, B₂ & B₃ (Thiamin, Riboflavin & Niacin)

The chemical names for vitamins B₁, B₂ and B₃ are Thiamin, Riboflavin and Niacin respectively. These vitamins are part of the B group and are water soluble.

Sources of Vitamins B₁, B₂ & B₃

Vitamins B₁, B₂ and B₃ occur in small quantities in many nutritious foods. Wholegrain or fortified bread and cereal products, meat, poultry, legumes, dark green leafy vegetables (such as broccoli, turnip greens, asparagus, and spinach), yeast and vegemite are all great sources of these vitamins.



Fast fact

The greatest source of Vitamin B₂ are milk and milk products, which is why these products are sold in cardboard or opaque plastic containers as these vitamins are water soluble and sensitive to ultraviolet light.

Functions of Vitamins B₁, B₂ & B₃

Metabolism of Macronutrients

Vitamins B₁, B₂ and B₃ act as a **coenzyme** in the metabolism of macronutrients and release of their energy. Vitamin B₁ acts as a coenzyme factor that assists enzymes in the breakdown of carbohydrates for energy production. Vitamin B₂ specifically acts as a coenzyme involved in the metabolism of carbohydrates, lipids, and protein; and thus, the production of energy in the form of ATP. And finally, vitamin B₃ acts as a coenzyme in the catabolism and anabolism of carbohydrates, lipids, and protein. Therefore, these vitamins do not provide any energy, they bind to enzymes which activate them to metabolise macronutrients (substrate) which provide the body with energy.



Definition

A coenzyme is a non-protein compound that is necessary for the functioning of an enzyme.

Vitamin B₉ (Folate)

The chemical names for vitamin B₉ are **folate** or **folic acid**. Folic acid is the synthetic form, which is used in supplements and to fortify foods, while folate is the naturally occurring form found in our foods.

Sources of Vitamin B₉

As the vitamin's name suggests foliage, green leafy vegetables (such as broccoli, spinach, and kale) are an excellent source of folate, whereas animal products generally aren't. Folate is also abundant in legumes (such as chickpeas, kidney beans and lentils), some fruits (including strawberries and citrus fruits), yeast extracts (such as Vegemite) and nuts and seeds (such as walnuts and flaxseeds). Its artificial form, folic acid, must be added (fortified) to flour used in making bread and grain products (for example rolls and pizza bases) in Australia. The bioavailability of folic acid is almost double than the amount of folate absorbed from foods.

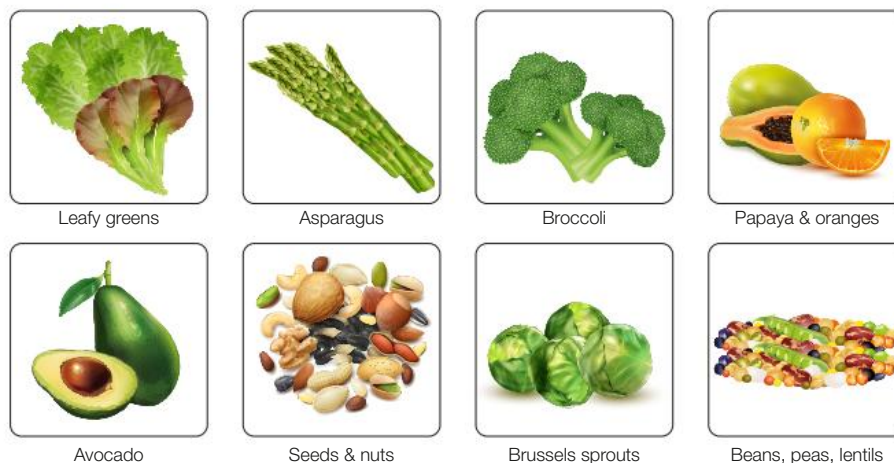


Figure 1.6.2 Sources of folate.

Functions of Vitamin B₉

Acting as a Coenzyme

Like most other water-soluble B vitamins, folate helps metabolise or break down the macronutrients to produce energy. B₉ specifically metabolises amino acids (protein) and works as a coenzyme to carry out this function (as shown in figure 1.6.3). A coenzyme's role is to bind to an enzyme to activate the enzyme, which then catalyses body reactions – in this case, the breakdown of amino acids. Folate also operates as a coenzyme in the synthesis of deoxyribonucleic acid (DNA) required to make new cells for growth and cell replacement.

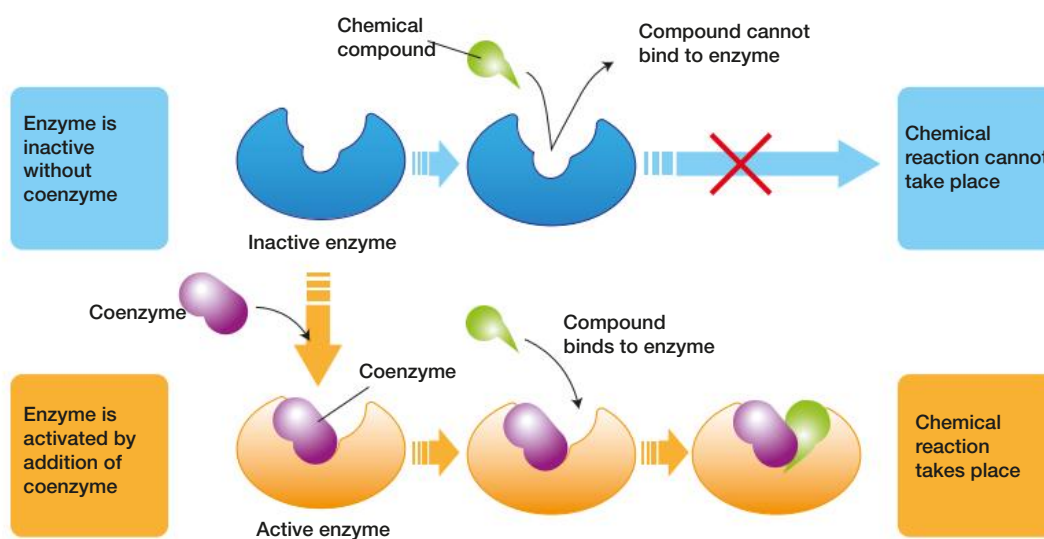


Figure 1.6.3: Coenzyme attachment activating an enzyme to carry out a body reaction.

Development of red blood cells and the neural tube

Folate is required for the formation of red blood cells (RBCs) and is particularly important during pregnancy for the growth and formation of the foetus' **neural tube**. The neural tube becomes the baby's brain and spinal cord.

Deficiency of Vitamin B₉

Megaloblastic Anaemia

Folate deficiency is linked to a type of anaemia called megaloblastic anaemia. The underlying problem is that DNA synthesis, which requires folate as a coenzyme, is disrupted in RBC formation when folate is deficient. Without folate, DNA damage destroys many of the RBCs as they attempt to divide and mature. Therefore, the result is immature and abnormally large RBCs (as shown in Figure 1.6.4). This results in fewer, but larger RBCs that are unable to travel through the capillaries as efficiently as normal red blood cells, or carry sufficient oxygen, which is needed to create energy. Fatigue from lack of energy is the main symptom indicating this condition.



Figure 1.6.4: Normal red blood cells compared to a red blood cell with folate deficiency.

Neural Tube Defects

Folate requirements increase substantially during pregnancy, increasing the risk of deficiency. Inadequate folate a month prior to conception and during pregnancy, especially in the first trimester (first three months) is linked to **neural tube defects**, where the tube doesn't fuse properly. The different types of disabilities are all termed as neural tube defects, with the two most common types being **anencephaly** and **spina bifida**. In anencephaly the neural tube fails to close, resulting in the brain missing or failing to develop. This type of neural tube defect often results in miscarriage or the infant dying shortly after birth. Spina bifida is more common and characterised by the incomplete closure of the spinal cord, where the spinal cord protrudes as a sac (as shown in figure 1.6.5). This sac may rupture and lead to meningitis, a life-threatening infection. Spina bifida can also be accompanied by varying degrees of paralysis and other problems including kidney disorders, curvature of the spine, muscle weakness and motor and sensory losses. There are several causes of neural tube defects, which are still being researched; however, folate supplementation has been confirmed to reduce the risk.



Fast fact

Each year, 300 to 350 pregnancies in Australia are affected by neural tube defects, where approximately 45-50 of every 100,000 newborns are born with a neural tube defect.

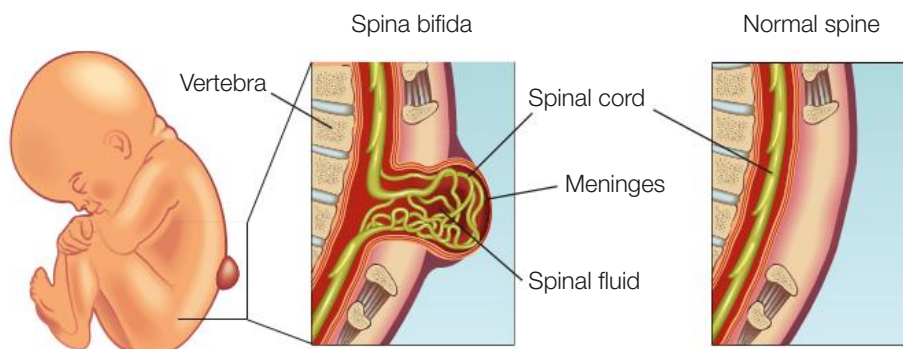


Figure 1.6.5: The spinal cord in Spina bifida, where the neural tube fails to close around the spine leaving it unprotected.

Vitamin B₁₂ (Cobalamin)

Vitamin B₁₂ has the chemical name **cobalamin** when found naturally in foods. Its synthetic counterpart is called cyanocobalamin.

Sources of Vitamin B₁₂

Vitamin B₁₂ is unique among the vitamins found almost exclusively in foods derived from animals. It is also one of the few water-soluble vitamins that can be stored in the body. It is stored in the liver and muscles of animals, thereby making liver, fish, poultry, and other meats a good source. Other sources holding substantial cobalamin levels are eggs and dairy products, such as milk (as shown in figure 1.6.6). Therefore, consumers who eat a reasonable amount of meat and vegetarians who consume milk products or eggs are also protected from a deficiency of this vitamin. Vitamin B₁₂ supplements and fortified products, such as soymilk and cereals are sources that can be consumed that are not derived from animals.



Figure 1.6.6: Foods high in vitamin B12.

Functions of Vitamin B12

Acting as a coenzyme

Like folate, vitamin B₁₂ works as a coenzyme in DNA synthesis in RBC formation and in metabolism of macronutrients to produce energy (specifically amino acids - protein). Folate and Vitamin B₁₂ work together in activating each other; and are dependent on the other to function properly.

Deficiency of Vitamin B12

Anaemia – Pernicious and Megaloblastic

A deficiency in vitamin B₁₂ is generally caused from poor absorption of this nutrient, rather than poor intake. If Vitamin B₁₂ is not released from its protein sources appropriately in the stomach and therefore not absorbed in the small intestines into the bloodstream, **pernicious anaemia** can occur (which is a type of megaloblastic anaemia). As well as this, a prolonged inadequate intake, as can occur with a vegan diet, can result in megaloblastic anaemia. This is because Vitamin B₁₂ is required to convert folate into its active form. Therefore, a deficiency in this vitamin slows down DNA synthesis producing large and immature RBCs, via the same processes as folate deficiency.

Vitamin C (Ascorbic Acid)

Vitamin C is a water-soluble vitamin and is highly susceptible to being destroyed. Its chemical name is **ascorbic acid**.

Sources of Vitamin C

Vitamin C is found in most fruits and vegetables. Kiwifruit, strawberries, and citrus fruits such as oranges and limes are some of the fruits that hold substantial quantities of ascorbic acid. The vegetables that are good sources of vitamin C are green leafy vegetables like kale, spinach, and broccoli.



Figure 1.6.7: Common sources of Vitamin C.

Functions of Vitamin C

Synthesis of Collagen

Vitamin C is important in the formation of collagen. Collagen is the main component in **connective tissues** and serves as the matrix on which bones and teeth form. It is also abundant in tissues such as blood vessels and capillaries, which must expand and contract with each beat of the heart. Beyond its structural role, collagen has a functional role in the skin of healing wounds. Collagen assists in gluing separated tissues together, forming scars and therefore helping wounds heal.



Definitions

Body tissues such as tendons, ligaments, skin, cartilage, etc. are called connective tissue. The term is derived by its ability to connect, support or separate tissues or organs. For example, tendons connect muscles to bone.

Antioxidant

Vitamin C acts as an antioxidant, which defends against free radicals. A free radical is an unstable atom that can cause **oxidative stress** to cells and body tissues. This oxidative stress can cause damage to cells in the body and accelerate the aging process. By causing damage to cells and their DNA, proteins, and cell membranes, this prevents the cell from functioning normally and potentially causing the development of some cancers in the body. However, Vitamin C can react with these free radicals, making them more stable and protecting other substances in the body from their damage.



Definitions

Oxidative stress is when there is an imbalance of free radicals and antioxidants in the body, and when there is a greater number of free radicals than antioxidants.

Absorption of Iron

Another of Vitamin C's many roles is to enhance the absorption of iron from food by protecting this mineral from oxidation by free radicals. When consumed in the same meal, vitamin C will improve the absorption of iron from digested food into the bloodstream, specifically non-haem iron from plant sources (see chapter 1.7 for more information).

Deficiency of Vitamin C

Scurvy

Scurvy is the deficiency disease associated with hypovitaminosis of vitamin C. Initial symptoms include fatigue, inflammation of the gums and generally feeling unwell. If ascorbic acid deficiency progresses, symptoms progress to small red or purple spots and bruising on the skin from broken and bleeding capillary blood vessels, joint pain, swollen bleeding gums and loosening teeth, and many other symptoms (as shown in figure 1.6.8). These symptoms are directly correlated to impairment of collagen synthesis, as this process is driven by vitamin C. When the collagen synthesis fails, connective tissues become weak causing them to break down. Poor wound-healing can also result, as collagen has a key role in the formation of scar tissue.

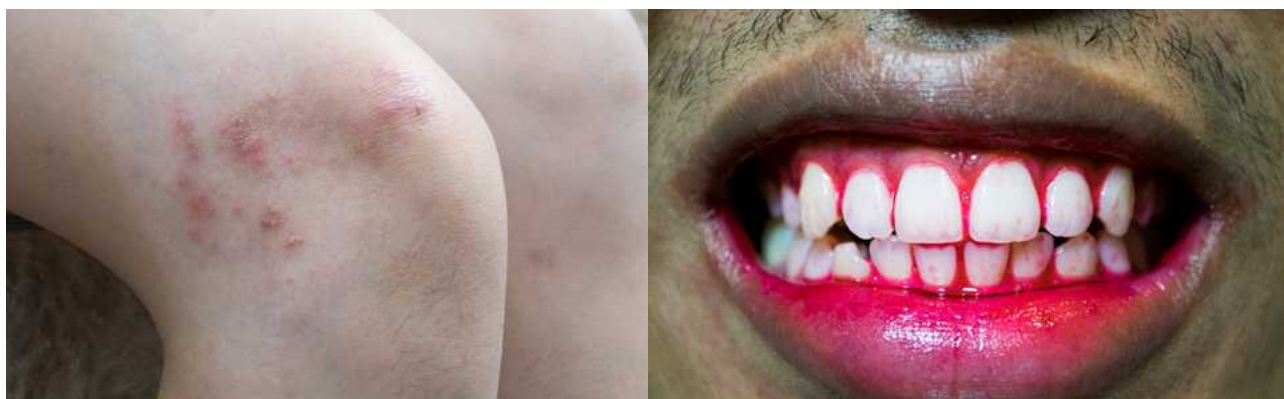


Figure 1.6.8: Symptoms of scurvy (red/purple spots and swollen gums, loosening teeth).

Vitamin D (Calciferol)

Vitamin D is different from all the other nutrients in that the body can synthesise it, with the help of sunlight and from a precursor that the body makes from cholesterol. A series of reactions (via enzymes of the liver and then kidney) turn vitamin D into its active form.

Sources of Vitamin D

Most of the world's population relies on natural exposure to sunlight to maintain adequate vitamin D levels. This is because the body makes a vitamin D precursor from cholesterol in our diet. When exposed to ultraviolet radiation (UV) from the sun, it is converted to an active form of vitamin D via a series of reactions relying on enzymes of the liver and then kidney. Although, most people don't need to make a special effort to consume Vitamin D from food, it is advised that people who don't spend much time in the sun or live in northern/southern regions of the world consume sources of Vitamin D. Unfortunately, very few foods contain Vitamin D; however great sources include fortified margarines, oily fish (such as salmon, herring, and mackerel), liver and eggs. However, it is difficult to get all the required vitamin D from consumption.



Fast fact

The body can only produce a limited amount of vitamin D at a time. So, additional time in the sun will not increase vitamin D levels but will increase the risk of prematurely wrinkled skin and skin cancer. For most people, exposing hands, face, and arms on a clear summer day for 5-10 minutes during the peak UV periods 10am and 2pm on most days of the week should be sufficient to achieve adequate Vitamin D levels.

Functions of Vitamin D

Absorption of Minerals

Vitamin D is important for increasing the blood concentrations of Calcium and phosphate (phosphorus). Vitamin D increases the blood concentration of these minerals by enhancing their absorption from the small intestines into the blood (as shown in Figure 1.6.9), and reducing the amount lost via urine by enhancing their reabsorption by the kidneys and enhancing their movement into the bones. This allows the bones to grow denser and stronger, as they absorb and deposit these minerals.

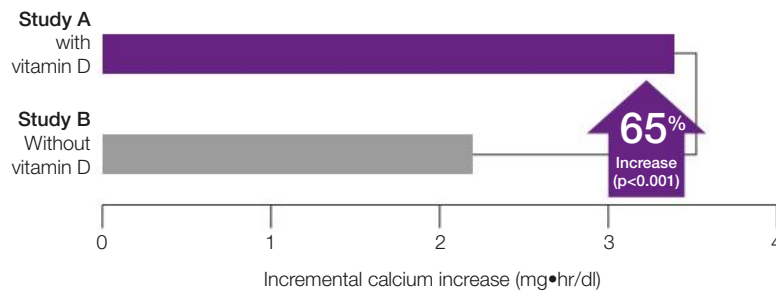


Figure 1.6.9: Absorption of calcium with and without vitamin D in the same meal.

Deficiency of Vitamin D

Rickets and Osteomalacia

As vitamin D has a vital role in the absorption of nutrients responsible for muscle movement and bone development, a person who does not get enough of this vitamin may experience muscle weakness or pain, or bone (joint) pain. Chronic hypovitaminosis impairs calcium and phosphorus absorption. This can lead to rickets in children, adolescents not reaching peak bone mass, osteomalacia in adults and an earlier onset of osteoporosis in the elderly. **Rickets** is a disease where the bones fail to develop properly, resulting in skeletal abnormalities such as bowed legs (as shown in figure 1.6.10). **Osteomalacia** generally occurs in adults caused by the poor mineralization of bones, leading to soft, flexible, and brittle bones.



Fast fact

In Australia, rickets is emerging where approximately 5 children per 100,000 under the age of 15 are diagnosed each year.

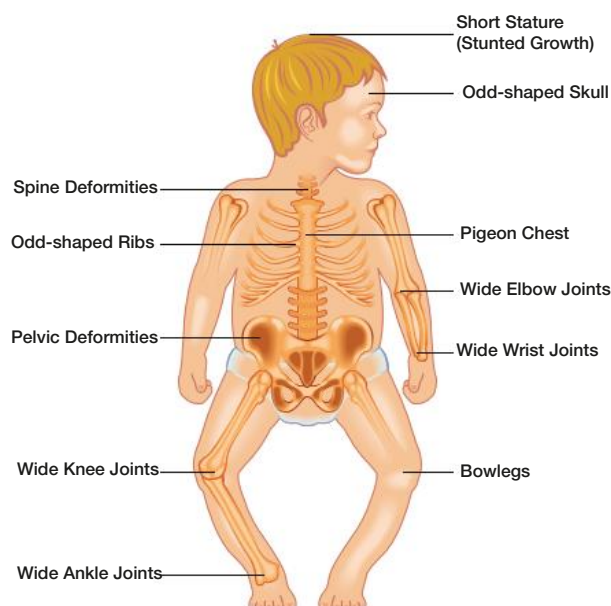


Figure 1.6.10: Skeletal deformities associated with rickets.

Vitamin K (Phylloquinone)

Vitamin K a fat-soluble vitamin that comes in two forms: the main type being phylloquinone and the other type, menaquinone.

Sources of Vitamin K

The main form of Vitamin K, phylloquinone, is found in green leafy vegetables (such as kale, broccoli, spinach), cabbage and brussels sprouts. The other form of vitamin K, menaquinones, is mainly produced by bacteria during fermentation in the large intestines. However, this form of Vitamin K can also be sourced from fermented foods produced by bacteria, such as sauerkraut, natto (Japanese fermented soybeans) and various cheeses.



Fast fact

Newborns are born with very small amounts of vitamin K in their bodies, due to not having a fully functioning microbiome yet. This is why newborns are given a shot of vitamin K at birth. This protects the baby from developing dangerous bleeding which can lead to brain damage and even death.

Functions of Vitamin K

Blood Clotting

Vitamin K assists with normal blood clotting when damage occurs to a blood vessel. When damage occurs causing bleeding, the blood needs to clot to prevent significant blood loss. Vitamin K is required for the synthesis of blood clotting proteins, including prothrombin in the liver. When injury occurs to the tissues or circulatory system, clotting factors are released which convert prothrombin into the activated enzyme thrombin. Thrombin then acts to transform fibrinogen present in plasma into an insoluble form of fibrin, which in combination with platelets from the blood, forms a blood clot (as shown in figure 1.6.11). Therefore, an individual with a deficiency of Vitamin K, means the body cannot produce enough of prothrombin and is at risk of excessive bleeding.

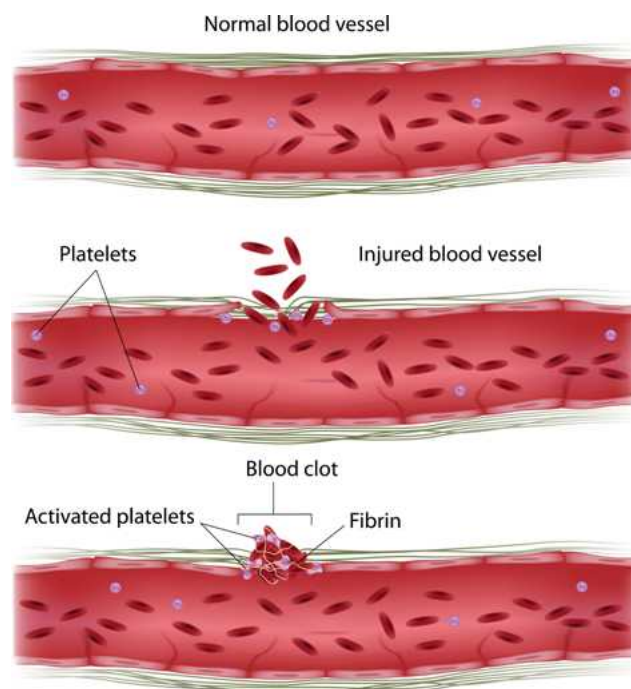


Figure 1.6.11: The blood clotting process



Helpful online resources

Blood clots: Plugging the breaks

<https://www.msmanuals.com/en-au/home/blood-disorders/blood-clotting-process/how-blood-clots>



Key terms

Anencephaly	Pernicious Anaemia	Vitamin B ₉
Coenzyme	Rickets	Vitamin B ₁₂
Fat soluble	Scurvy	Vitamin C
Megaloblastic Anaemia	Spina Bifida	Vitamin D
Neural tube defects	Vitamins	Vitamin K
Osteomalacia.	Vitamins B ₁ , B ₂ , B ₃	Water Soluble

Review questions: 1.6 Vitamins

1. Match the following information with its correctly associated vitamin:

1.	A deficiency of vitamin C	a. Sunlight and oily fish					
2.	Sources of vitamin D	b. Folate & Vitamin B12					
3.	Assists in red blood cell production	c. Vitamin A, D, E, K					
4.	Produced by bacteria in the large intestine	d. Water soluble vitamins					
5.	Deficiency of vitamin D in children	e. Vitamins B1, B2 & B3					
6.	Stored in adipose tissue	f. Vitamin K					
7.	Assists with the release of energy	g. Rickets					
8.	Sensitive to heat, light, and oxygen	h. Scurvy					
1 =	2 =	3 =	4 =	5 =	6 =	7 =	8 =

(8 marks) (KA1)

2. Explain what type of vitamin-high foods are required more often in the diet, those containing fat-soluble or water-soluble vitamins?

(3 marks) (KA2)

3. Complete the following table.

Vitamin Characteristic	Fat Soluble	Water Soluble
Transportation in the body		Dissolves in water, transports easily in the blood
Storage in the body	Excess is stored in adipose tissue and the liver	
Absorption		Absorbed directly into the blood
Probability of deficiencies	Deficiencies are less common, and a greater risk of hypervitaminosis	
Stability in food processing	More stable and not readily lost through processing	

(5 marks) (KA1)

4. Data from the 2015 Longitudinal Study of Australian Children (LSAC) annual statistical report show that more than 40% of Australian children aged 4-5 years, compared with around 25% of children aged 6-7 years, exceed the recommended 2-hour daily limit for screen time (e.g., watching television, using computers, and playing electronic games).

(a) Explain one possible reason for this difference.

(2 marks) (KA2)

(b) Vitamin D is essential to children's development. Discuss:

- The physiological need for children to have an adequate vitamin D intake during childhood.
- Two food sources that would improve a child's vitamin D intake.
- One diet related health disorder that may develop in a child who has a vitamin D deficiency.
- Why children who exceed recommended daily limit for screen time have an increased risk of vitamin D deficiency.

(8 marks) (KA2)

5. Refer to the following table:

Vitamin	Life stage (years)				
	0 – 1	1 – 12	12 – 18	18+	Pregnancy
Folate RDI (µg)	100	150	200	200	400
Folate actual intake (µg)	100	150	180	170	300

(a) Using data from the table above, describe the trend in the RDI of Folate across the different life stages.

(2 marks) (IAE3)

(b) State a health concern for a foetus and a pregnant female if the actual intake of Folate is consumed, compared to the RDI at pregnancy.

Foetus:

Pregnant Female:

(2 marks) (KA2)

(c) State a food source that a pregnant female could consume to meet her daily Folate RDI.

(1 mark) (KA1)

6. Vitamin B12 is a micronutrient that is naturally present in some foods and is added to others. It is also available as a dietary supplement and prescription medication.

(a) State whether Vitamin B12 is water-soluble or fat soluble.

(1 mark) (KA1)

(b) State one function of Vitamin B12 in the body.

(1 mark) (KA1)

(c) Name one specific food that is naturally high in Vitamin B12.

(1 mark) (KA1)

(d) Vitamin B12 deficiency is a relatively common disorder.

(i) Identify the name of the deficiency an individual would develop if they failed to consume enough Vitamin B12.

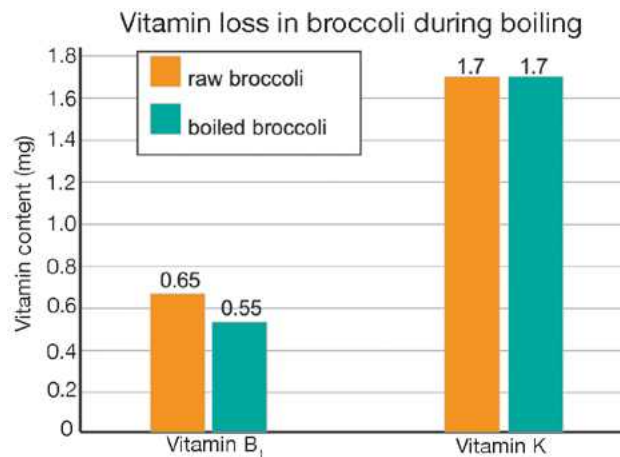
(1 mark) (KA1)

(ii) Identify a symptom that an individual may experience if they develop a Vitamin B12 deficiency and explain why this symptom may develop.

(4 marks) (KA2)

7. Students investigated the effects of boiling vegetables. They compared the vitamin content of raw broccoli with that of the broccoli that was boiled.

Refer to the following graph, which shows the amount of vitamin B₁ and vitamin K lost from broccoli during boiling.



(a) State the dependent variable of this investigation.

(1 mark) (IAE1)

(b) Identify two factors that must remain constant during the investigation and explain why.

(4 marks) (IAE1)

(c) Using data from the graph, describe the effect of boiling on the:

(i) Vitamin B1 content of broccoli.

(2 marks) (IAE3)

(ii) Vitamin K content of broccoli

(2 marks) (IAE3)

(d) Explain why there is a difference between the amount of Vitamin B1 lost and Vitamin K lost from broccoli during boiling.

(2 marks) (KA2, IAE3)

(e) Explain the storage of Vitamin B1 and Vitamin K in the human body if consumed in excess.

(3 marks) (KA2)

(f) State one function of both Vitamin B1 and Vitamin K in the human body.

Vitamin B1:

(1 mark) (KA1)

Vitamin K:

(1 mark) (KA1)

(g) State one specific food source other than broccoli, for both vitamin B1 and Vitamin K.

Vitamin B1:

(1 mark) (KA1)

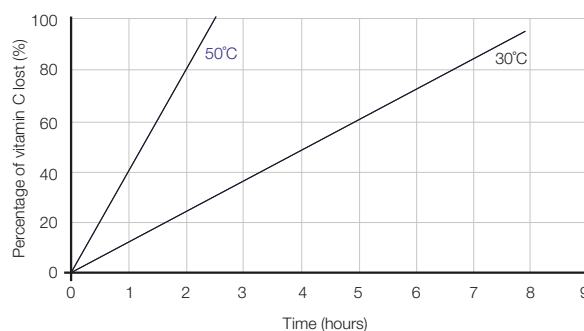
Vitamin K:

(1 mark) (KA1)

8. Fresh juice should be stored at 4°C and consumed within 3 days. Students conducted an experiment to investigate the effect of poor storage on the Vitamin C content of orange juice.

Two samples of orange juice were heated at different temperatures, one being heated at 30°C and the other heated at 50 °C. The amount of vitamin C lost was measured every hour for 8 hours.

Refer to the following graph, which shows the percentage of vitamin C lost over time in orange juice.



Using data from the graph, compare the percentage of Vitamin C lost after 2 hours of heating the orange juice at 30°C and at 50°C, and justify the difference.

(3 marks) (KA2, IAE3)

Total: / 60 marks



Science as a human endeavour (Influence)

Folate Fortification Reduces Neural Tube Defects

Source: <https://researchimpact.uwa.edu.au/research-impact-stories/folate-fortification-reduces-neural-tube-defects/>

Maternal dietary folate deficiency in the first weeks of life carries a higher risk that the fetus' neural tube will not fuse, leading to the development of either spina bifida or anencephaly. For two decades Bower et al. followed a dedicated pathway to impact by lobbying the Australian Government's Health portfolio's statutory authority, Food Standards Australia New Zealand (FSANZ), to introduce mandatory fortification of wheat flour. In 1995 voluntary fortification was allowed and in 2009 fortification of wheat flour with folate became mandatory. From 2011 to 2016, NTD births dropped, regardless of mother's culture, age, educational attainment or choice of hospital system.

Folate is essential to the healthy development of babies in early pregnancy. Maternal dietary folate deficiency in the first weeks of life carries a higher risk that the fetus' neural tube will not fuse, leading to the development of either spina bifida or anencephaly. Spina bifida results in significant lifelong physical disability and early death. Anencephaly almost always results in death before or within a few days of birth. Both conditions are known as Neural Tube Defects (NTD).

Bower et al identified the importance of folate in the 1980's resulting in widespread promotion of the benefits of folic acid supplements to Western Australian women considering pregnancy. However, campaigns to encourage folic acid supplements were not effective in reducing NTD in the Indigenous population. Other factors such as the mother's age, educational attainment, being pregnant for the first time, and the birthing using the public health system were found to increase risk of NTD, even though heavy promotional campaigning was undertaken. Additionally, the Indigenous population was found to be at higher risk of NTD compared to the non-Indigenous population. While health promotion was moderately successful in reducing the overall risk of NTD, it wasn't effective for Indigenous children, of whom a higher proportion were vulnerable. The result was an increasing disparity in NTD between Indigenous and non-Indigenous children.

A 2016 review by the Australian Institute of Health and Welfare found that since the flour fortification program's introduction, levels of NTDs had dropped by 14.4 per cent. Pre-fortification, the cost of spina bifida was calculated as \$13,535 for the first four years and \$4354 for every year after, up to the age of 43 or 84 years. Children with spina bifida are hospitalised 19.4 times more than the general population and have 2.9 times more outpatient visits. Children with spina bifida have pharmaceutical use that is 3.1 times that of the general population and often require assistive technology. Loss of work productivity in carers of people with spina bifida has been estimated at 9.2 hours a week. People with spina bifida in the workforce lose an average of 10 days due to their disability and have reduced earning capacity (\$21,000 less than the general population). The Commonwealth of Australian Governments Health Council Report estimated that mandatory folic acid fortification resulted in 1) \$350,000 per year more value in terms of a combination of increased productivity and reduced health costs than the alternative of no mandatory fortification; 2) fewer NTD-affected pregnancies, translating into gains of 135 life years and 130 Quality Adjusted Life Years.

Pre-fortification (2007-2009) there were 2.43 cases of spina bifida per 1000 births in the Indigenous population. The disparity in mortality and morbidity between Indigenous and non-Indigenous Australians is a stark example of the inequity that exists in Australia. Mandatory fortification of wheat flour with bread is an example of a research led change in government policy that was designed to address the health needs of less socially privileged members of our society. Post-fortification (2010-2014) rates had dropped to 0.82 cases of spina bifida per 1000 births in the Indigenous population..

1. Discuss how this example demonstrates the key concept of **Influence**. Provide two clear examples from the example above of how it demonstrates this key concept.

(4 marks) (KA3)

? Science Inquiry Skills

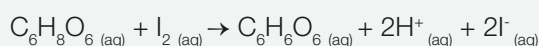
The Effect of Boiling on Vitamin C in Broccoli

Introduction:

Vitamin C (ascorbic acid) is a water-soluble vitamin found predominantly in citrus fruits and vegetables including leafy greens, such as broccoli. Water soluble vitamins are unstable and can be destroyed when exposed to heat, oxygen and light and can leach into the surrounding water used to cook food. Boiling is a common cooking method used, which involves the full immersion of food in water that has been heated to its boiling point (100°C). Therefore, boiling foods results in the denaturing of water-soluble vitamins, such as vitamin C due to exposure to high temperatures and a long cooking time. As well as this, boiling results in the leaching of water-soluble vitamins into the surrounding water, due to the high volume of water used in this cooking method.

A simple titration can be completed to determine the presence of Vitamin C in the surrounding water used in the boiling process. Iodine and starch are added to a sample of the surrounding water used to boil broccoli, which can be assumed contains vitamin C due to its water solubility causing it to leach from the broccoli. When iodine is added to the solution, ascorbic acid (vitamin C) is oxidised to dehydroascorbic acid, while the iodine is reduced to iodide ions (as shown in the equation below). Once all the ascorbic acid has been oxidised, iodine then reacts with starch. Starch is used as an indicator, which determines the end point and turns the solution a purple/black colour in the presence of iodine. Once the solution has reached the desired end point, this indicates that there is no Vitamin C left in the solution as it has all been oxidised. Therefore, the more iodine added to reach the desired end point indicates more vitamin C was present.

Ascorbic Acid + Iodine → Dehydroascorbic Acid + Iodide Ions



Hypothesis:

If the boiling time increases, then the amount of vitamin C that leaches from the broccoli into the surrounding water will increase, requiring more iodine to oxidise it.

Materials:

- Vitamin C Solution (1 Vitamin C tablet with 1000ml of distilled water)
- 500ml of Starch solution (1 teaspoon of corn flour with cup and ¾ of hot water)
- 350g Broccoli
- 5x 100ml beaker
- 8x 1000ml Beaker
- 1x 10ml measuring cylinder (for starch)
- 1x Pipette (or eye dropper) (for iodine)
- Distilled Water
- Iodine (aqueous)
- Stirring rod
- Electronic scales
- knife
- chopping board
- Hotplate
- Stopwatch
- Sieve
- Hot hands

Method:

1. Measure and place 2ml of the Vitamin C solution in a clean 100ml beaker.
2. Add distilled water to the Vitamin C solution until the beaker is just over halfway full.
3. Measure and add 5ml of starch solution to the Vitamin C solution in the beaker and then stir with a stirring rod.
4. Carefully add iodine drop by drop with a pipette to the beaker and count every individual drop. Stir the solution with a stirring rod gently after each drop.
5. Stop adding iodine drops once the solution turns a deep purple/black colour. Stir the solution with a stirring rod for a further 30 seconds to ensure the colour change remains.
6. Put this beaker to the side, as this will act as your colour comparison for the remainder of the experiment.
7. Cut and measure 80grams of broccoli (attempt to measure 40grams of both the stem and florets) using electronic scales.
8. Measure 800ml of Water using a 1000ml Beaker.
9. Place the broccoli into the beaker filled with water, ensuring it is completely immersed for 1 minute.
10. Stir the broccoli with a stirring rod every 30 seconds.
11. Filter the raw broccoli mixture through a sieve to remove all broccoli parts and decant the liquid off into another 1000ml beaker once the 1-minute time has elapsed.

? Science Inquiry Skills

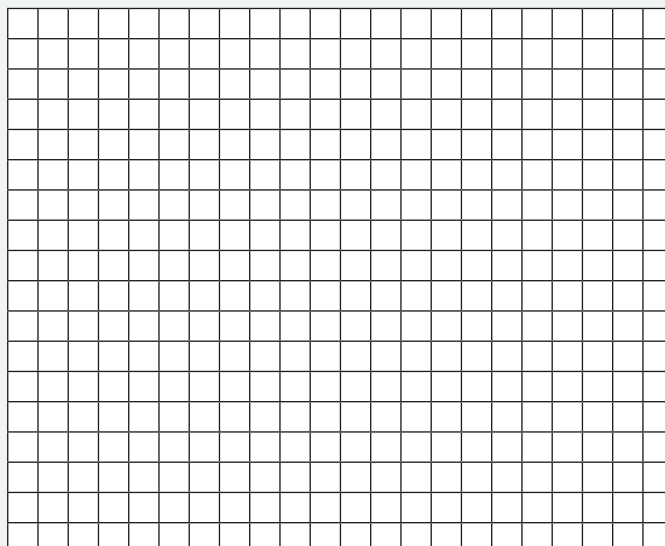
12. Measure out 50ml of the raw Broccoli mixture into a 100ml Beaker (the remainder can be used by other groups or repeated trials).
13. Measure 5ml of the starch solution and add to the raw broccoli mixture and stir with a stirring rod.
14. Carefully add iodine drop by drop to the solution. Count the number of drops as you add them and ensure to stir the solution after each drop is added. Stop when the solution turns a deep purple/black colour (the same shade as the initial vitamin C solution). Stir the solution for a further 30 seconds to ensure the colour change is permanent.
15. Record the number of drops added in the results table.
16. Repeat steps 7-8 but place the beaker onto the hotplate.
17. Turn the hotplate on and heat the water until it boils.
18. Place the broccoli into the boiling water, ensuring it is completely immersed and cook for 1 minute. **A sieve with a long handle can be used to carefully place the broccoli into the boiling water.**
19. Stir the broccoli with a stirring rod every 30 seconds.
20. Remove the beaker from the hotplate once the cooking time has elapsed. **Use hot hands in case the beaker is hot.**
21. Repeat steps 11-15.
22. Repeat steps 16-21 but cook the broccoli for 5 minutes.
23. Repeat steps 16-21 but cook the broccoli for 10 minutes.
24. Determine the class average and record in the results table.

Raw Data:

Cooking Time (minutes)	Number of Iodine Drops	
	Group	Class
0		
1		
5		
10		

Presentation of Data:

Represent the raw group and class data as a line graph, plotting the Cooking Time on the x axis and the Number of Iodine drops on the y axis, which represents the level of vitamin C in the water. Ensure to add the suitable features on the graph below, including a title, even scale, labelled axes, and legend.



? Science Inquiry Skills

Analysis & Discussion:

1. With reference to the graph and using group data in your response, describe the trend of the results.

2. With reference to the graph,

- (a) Predict the number of iodine drops that would be required if a cooking time of 7.5 minutes was tested (linear interpolation) and a cooking time of 15 minutes was tested (linear extrapolation).
(b) Describe the expected trend of Vitamin C leaching from the broccoli as the cooking time increases beyond the tested 10 minutes.

3. Compare the group data with the class data and discuss which data set is more reliable and why.

4. Identify two random errors that may be present and discuss how these could have impacted the reliability of the data.

5. Explain how the validity of the results could be enhanced.

6. Write a conclusion for this experiment, explaining if the hypothesis was supported or not supported. Suggest an alternative cooking method that would result in less nutrient loss.

1.7 Minerals

Science understanding

Micronutrients (vitamins and minerals) are required by the body for good health and the prevention of many diet related disorders.

- Identify rich sources of the following minerals and explain their functions in the body:
 - Calcium
 - Iron (haem and non-haem)
 - Iodine
 - Sodium
 - Potassium
- Explain how a deficiency in iodine can result in health issues.
- Explain factors affecting bioavailability and absorption of minerals
 - Haem iron vs non-haem iron
 - Caffeine and alcohol consumption
- Describe the interrelationship of different micronutrients:
 - Vitamin C promotes absorption of non-haem iron.
 - Calcium inhibits iron absorption.

SACE Subject Outline, 2024.

Minerals

Minerals are inorganic compounds that do not contain carbon. They are water soluble and must be obtained from the diet. Minerals are not destroyed easily through poor storage and food processing like vitamins are, therefore, the content of minerals is maintained in our food. They retain their chemical structure until excretion from the body. Minerals can be categorised as major or trace (refer to Table 1.7.1). **Major minerals** are required in larger amounts and are found in the body in amounts greater than five grams. **Trace minerals** are required in smaller amounts and are found in the body in amounts less than 5 grams. This does not indicate that one group is more important than the other, as all minerals are vital for body function.

Table 1.7.1: Common major and trace minerals required and present in the body.

Major minerals	Trace minerals
Calcium	Iron
Phosphorus	Zinc
Sodium	Copper
Potassium	Iodine
Magnesium	Manganese
Sulfur	Selenium
Chloride	Fluoride
	Chromium
	Molybdenum
	Nickel
	Silicon
	Vanadium
	Cobalt
	Boron

Of the minerals listed in Table 1.7.1, those that are most found to be an imbalance in Australian diets are calcium, iron, iodine, sodium, and potassium. These are therefore of priority and discussed in detail in this topic.

Calcium

Sources of Calcium

Calcium is lost from the body every day through bodily fluids, primarily urine. Therefore, the body requires calcium to be replaced each day through diet. Bones act as a calcium bank, offering a source of this mineral to the body if the levels of calcium in the blood drop. Approximately 99% of calcium is stored in the bones and teeth, and 1% in our blood. This is why recommendations are based on the amount needed to retain as much calcium in the bones as possible (as shown in Table 1.7.2). This allows bones to develop to their fullest potential in size and density. An individual should achieve their peak bone mass by their mid to late twenties.

Table 1.7.2: The recommended daily intake (RDI) of calcium at different ages for males and females.

Age (years)	Calcium RDI (mg)
1 – 3	500
4 – 8	700
9 – 11	1000
12 – 18	1300
19 – 50/70	1000
50+ (women)	1300
70+ (men)	1300

Calcium is found most abundantly in a single food group: dairy products. These include milk, cheese, and yoghurt. However, if an individual is unable to consume dairy products due to personal likes and dislikes, religious or ethical beliefs, or malabsorption syndromes, such as lactose intolerance, they can include non-dairy sources of calcium to reach their recommended daily intake. Tofu, almonds, sesame seeds, green leafy vegetables (such as broccoli, kale, bok choy), and fortified products (e.g., juices, cereals, and soy milk) can supply calcium to a person who does not consume dairy products (see figure 1.7.1).



Figure 1.7.1: Sources of Calcium

Functions of Calcium

Calcium has several functions; however, its main role is its involvement in the development of our bone’s structure.

Strengthening bones

Calcium plays an integral part in the development of bones, providing a rigid structure that supports the body and serves as an attachment point for muscles, making movement possible. Calcium combines with phosphorus and forms Calcium Phosphate crystals on a matrix of the protein, collagen during bone formation. During mineralisation, the crystals become denser providing strength and rigidity to the bones. This process is continuous throughout an individual’s life cycle, where bone is constantly being maintained and produced during an ongoing process of remodeling. This process ensures that bones remain strong and dense, preventing them from becoming fragile and porous (as shown in figure 1.7.2).

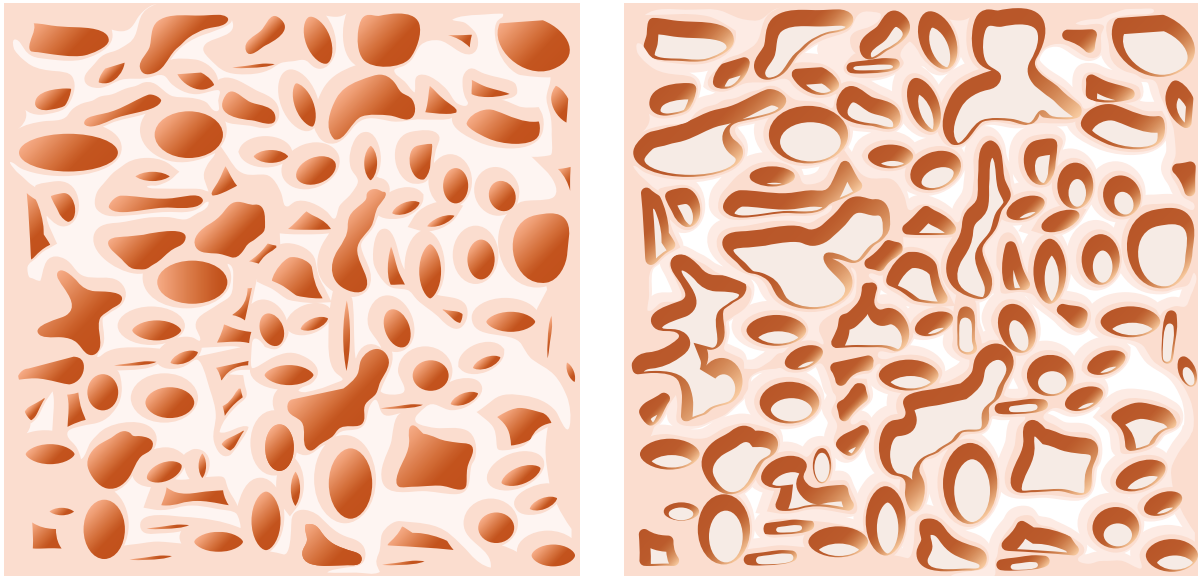


Figure 1.7.2: A comparison between strong, dense bone (left) and fragile, porous bone (right).

Assisting in the transmission of nerve impulses, along with muscle contractions and relaxations

The muscle and nerves work together to use calcium. The nerve tissues use calcium to stimulate nerve impulses to trigger muscle contraction. These contractions produce muscle movement. Since the heart is composed of muscle tissue, calcium also assists in keeping the heart beating and contracting.

Factors affecting the Bioavailability of Calcium

For the average adult, approximately 30% of the calcium consumed is absorbed. However, vitamin D acts as an absorption enhancer where it increases the absorption of calcium from the small intestines into the blood and reduces the amount lost via urine by enhancing the reabsorption of calcium by the kidneys.

On the other hand, some dietary foods, and beverages (as shown in Table 1.7.3) can inhibit the absorption of calcium by binding to the mineral when consumed at the same time, forming insoluble salts. Excessive sodium, alcohol and caffeine intakes can reduce calcium **bioavailability** by promoting greater calcium urinary excretion. Therefore, consuming a high intake of calcium absorption inhibitors and having conditions that can impair calcium absorption and can prevent the development of a strong and dense bone matrix.

Definition

Bioavailability is the degree to which a nutrient is absorbed and utilised by the body.

Table 1.7.3: Calcium absorption inhibitor food sources and their responsible components.

Food sources	Component
Processed foods, cured meats, salted nuts, cold cuts, sauces, canned products	Sodium (only when consumed in excess)
Soft drinks	Phosphoric Acid
Tea, spinach, kale, nuts, chocolate, strawberries, herbs	Oxalates
Cocoa, coffee, apples, herbal teas, blackberries, raspberries, blueberries	Polyphenols
Walnuts, lentils, wholegrains, cereals, dried beans, almonds, rice	Phytates

Iron

Sources of Iron

The average red blood cell has a life span of approximately 115 days (four months), before it is taken apart in preparation for recycling and excretion. The iron component of a red blood cell can be recycled and taken to the bone marrow to be reused in new red blood cells. This is one of the reasons why iron is only required in small amounts, as the body is good at retaining and recycling its iron, especially from the recycling of red blood cells.

Iron is not very well absorbed by the body. In fact, the average male only requires 1mg and the average female only requires 1.5mg of iron per day. However, the recommended daily intake of iron is 8mg per day for the average male and 18mg per day for the average female. This higher recommendation is to accommodate for the poor absorption of iron by the body. As well as this, growing children and adolescents have higher iron demands due to rapid growth that causes an increase in their blood volume. Menstruating, lactating, and pregnant females have the greatest demands of iron, due to the loss of iron to monthly periods, growing fetuses, or breastfeeding babies respectively (as shown in Table 1.7.4).

Table 1.7.4: The recommended daily intake (RDI) of iron at different life stages for males and females.

Life stage	Iron RDI (mg)
Children and adolescents	10 – 13
Menstruating females	12 –18
Lactating females	12 – 18
Pregnant females	22 – 36
Males	8

Iron occurs in two forms: haem iron and non-haem iron. **Haem iron** is only found in the flesh of foods derived from animal sources, such as meat, poultry, and seafood. **Non-haem iron** is found in food derived from plant sources, such as lentils, beans, tofu, nuts, seeds and grains and animal sources, such as eggs, milk, and dairy (as shown in figure 1.7.3). Therefore, foods derived from animal sources are a combination of haem and non-haem iron. Haem iron is also more readily absorbed by the body at a rate of 7–35%, whereas non-haem iron is absorbed at a rate of 2–20%. This is dependent on an individual's dietary factors and the body's iron stores.



Figure 1.7.3: Sources of Haem and Non-Haem Iron

Functions of Iron

Most of the body's iron is found in two proteins: haemoglobin and myoglobin.

Producing haemoglobin in red blood cells

Iron is a significant component of haemoglobin, which is found in red blood cells. **Haemoglobin** is the component of red blood that picks up oxygen when blood passes through the lungs. This oxygen is then transported throughout the body and delivered to the cells for the process of **aerobic respiration** to occur. Oxygen is one of the requirements of this reaction, for ATP (energy) to be produced (as shown by the equation below in Figure 1.7.4). In addition, the red blood cell can pick up the waste product, carbon dioxide, some of which is carried by haemoglobin to be exhaled by the lungs. It is also the haemoglobin component that provides the colour of a red blood cell. When haemoglobin is attached to oxygen molecules, this adds a red colour to these cells and therefore provides colour to the skin also. However, when oxygen has been delivered to the cells, the red blood cell has a blue-red appearance.

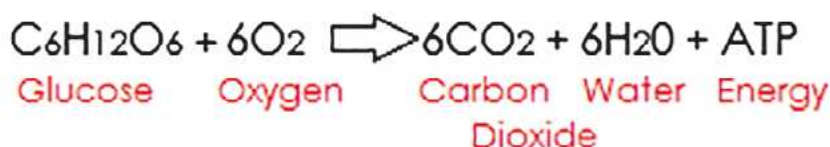


Figure 1.7.4: The aerobic respiration reaction, where glucose obtained from ingested food and oxygen inhaled are requirements to produce ATP (energy) the body requires for bodily processes.

Producing myoglobin

Iron is a component of the oxygen-binding protein **myoglobin**, which is found in the body's muscle tissue. Myoglobin has a strong affinity for oxygen, which allows it to store oxygen in the muscle efficiently. This is important when the body is lacking oxygen, such as during anaerobic (short-lasting and high intensity) exercise when the body's demand of oxygen is greater than the supply. This is when myoglobin can release its oxygen and make it available to the muscle tissue, preventing it from becoming damaged under these harsh conditions.

Factors affecting the Bioavailability of Iron

Iron is poorly absorbed by the body, as exposure to oxygen causes iron to form highly insoluble oxides, which are unavailable for absorption in the human gastrointestinal tract. However, foods that are high in vitamin C act as an absorption enhancer. Vitamin C will protect iron, especially non-haem, from oxidation and will enhance its absorption from digested food into the bloodstream if consumed in the same meal.

A diet low in iron and nutrients that aid in its absorption can reduce the bioavailability and absorption of Iron. Some components of dietary choices can bind with non-haem iron, inhibiting its absorption (as shown in table 1.7.5).

Table 1.7.5: Iron absorption inhibitor food sources and their responsible components.

Food sources	Component
Eggs	Phosvitin
Dairy	Calcium
Tea, spinach, kale, nuts, chocolate, strawberries, herbs	Oxalates
Cocoa, coffee, apples, herbal teas, blackberries, raspberries, blueberries	Polyphenols
Walnuts, lentils, wholegrains, cereals, dried beans, almonds, rice	Phytates

Iodine

Sources of Iodine

Iodine is a trace mineral and so we only need very small amounts. Most adults require up to 150 micrograms a day (a millionth of a gram). Although only small amounts are needed, we need iodine on a regular basis as we cannot store large amounts in the body. The recommended daily intake of iodine is dependent on your age and life stage (as shown in table 1.7.6).

Table 1.7.6: The recommended daily intake (RDI) of iodine at different ages for males and females.

Age (years) / Life stage	Iron Adequate Intake (mg)
1-8	90
9-13	120
14+	150
Pregnancy	220
Breastfeeding	270

Iodine is in many foods, but much of the Australian food supply is now low in iodine due to low levels in soils and changes in the sanitation processes in the dairy industry, which once used sanitizers which contained iodophors (an iodine containing solution). However, oceans still hold sufficient iodine, therefore, shellfish, such as shrimp and oysters, fish, such as cod, salmon and tuna, and seaweed are good sources of iodine. Soils that are close to the ocean or were once covered by ocean waters can also hold iodine. Therefore, the amount of iodine in fruits and vegetables is dependent on the quality of the soil it is grown in, and the fertilizer used. However, due to the reemergence of iodine deficiency, known as goitre, salt used for bread making, except organic bread, was fortified with iodine. This salt is known as iodised salt and can be purchased to use at home also. However, Australians are using less iodised salt when cooking at home and in restaurants, which is another contributing factor to the reemergence of iodine deficiency.



Figure 1.7.5: Food sources of iodine

Functions of Iodine

Production of Thyroxine

Iodine is required to produce a hormone in the **thyroid gland**, known as **thyroxine**. This hormone is responsible for regulating the growth and development of tissues, metabolism, and thermoregulation. Once thyroxine is released into the blood, it communicates with the cells to increase metabolism. As well as this, elevated levels of thyroxine cause the cells to increase chemical reactions such as aerobic respiration, which burns energy and increases heat production. This helps to maintain resting body temperature, which is why a deficiency in iodine results in feeling cold. A deficiency in iodine can also cause symptoms of weight gain and fatigue as less energy is being burnt, causing it to be stored instead. It can also cause the enlargement of the thyroid gland, which is referred to as **goitre**. This is due to less thyroxine being produced signally the thyroid gland to enlarge in preparation to produce more hormones to correct the deficiency. Stunted growth and impaired neurological function in babies and young children can also develop if females of childbearing age or breastfeeding mothers are deficient in this mineral.

Sodium

Sources of sodium

The Australian and New Zealand government recommends that adults consume approximately 2000mg of sodium per day, which is equivalent to about 5000mg (5g) or one teaspoon of salt. Due to their smaller body sizes and more sensitive taste buds, children and infants have lower recommended sodium intakes: infants (0 to 1 year of age) should not exceed 580 mg and children (1 to 7 years of age) should not exceed 1730 mg. According to Food Standards of Australia and New Zealand, approximately one third of Australians consume a greater amount of sodium than the upper limit, which exceeds the adequate intake (as shown in table 1.7.7).

Table 1.7.7: The adequate intake (AI) of sodium at different ages for males and females.

Age (years)	Iron Adequate Intake (mg)
1-3	200-400
4-8	300-600
9-13	400-800
14+	460-920

Sodium is mainly consumed as sodium chloride (table salt) and separates to sodium (Na^+) and chloride (Cl^-) when dissolved in water. In general, processed foods have a greater amount of sodium present than fresh produce, as sodium is intentionally added as a preservative and flavour enhancer. In fact, most of the sodium consumed in people's diets comes from the salt added to foods during manufacturing. The second greatest source is the table salt added to cooking and at the table. Other examples of sources rich in sodium are processed meats, such as ham, bacon and salami, pizza, canned vegetables, beef stock, sauces, salted nuts, pretzels, and biscuits.

Functions of sodium

Regulating the volume of extracellular fluid

Sodium is mainly located in the extracellular fluid, which is the body's fluid not contained in the cells, including blood. Sodium can attract and hold onto water by reducing the kidneys' ability to remove water via urine. Therefore, when an individual consumes foods high in salt and it enters (or absorbs into) our bloodstream, greater water is attracted and held. This increases blood volume, which ensures constant blood flow to the body's cells. An increased blood volume will elevate blood pressure, until sodium is not needed and excreted via urine.

Assisting with the contraction of muscles and the transmission of nerve impulses

Muscle and nerve cells generate electrical impulses by controlling the flow of electrically charged molecules, including sodium. This is part of the **sodium-potassium pump** found in the membranes of cells. When a muscle needs to contract, the sodium-potassium pump will open, allowing sodium to rush into the cell which creates an electrical impulse that causes the muscle to contract. Potassium will follow which turns the signal off and allows muscle relaxation. Both micronutrients will be re-pumped in or out of cells (generally sodium out and potassium in) to re-establish former levels before the next impulse or muscle movement is needed (as shown in figure 1.7.6). The re-establishment of former levels also helps prevent muscle twitches and cramps. For the electrical impulse to travel to the muscle to trigger its contraction, or for any electrically transmitted message to travel to or from the brain and/or spinal cord along nerves, the same principle applies. The sodium-potassium pump on nerve cell membranes will open to allow sodium to flow in. This will trigger an electrical impulse that is carried from nerve cell to nerve cell until it reaches the brain or a muscle for action.

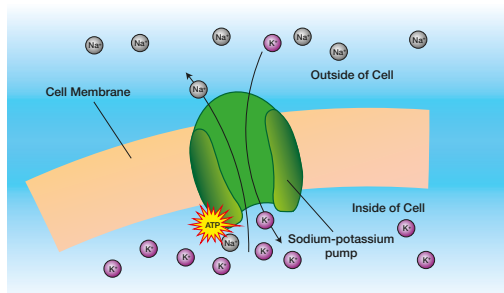


Figure 1.7.6: The sodium-potassium pump found in the membrane of the cell. Sodium is pumped out of the cell and potassium into the cell to re-establish the former levels.

Potassium

Sources of potassium

The richest sources of potassium are whole foods which have not been processed. Examples of whole foods include fresh fruit (such as watermelon, bananas, avocado), vegetables (such as spinach, broccoli, pumpkin, sweet potato), legumes (such as white and black beans) and meat. It is recommended that people increase their intake of fresh produce to meet the recommended daily intake of potassium, which is 3800 mg for the average adult male and 2800 mg for the average adult female.

Functions of potassium

Potassium works in conjunction with sodium to regulate fluid balance and assist in muscle contraction and relaxation.

Regulating the volume of extracellular fluid

Potassium regulates the amount of sodium that enters and exits the cell. If there is greater sodium on the outside of the cell, the kidneys will retain more water to maintain the sodium–water ratio in the body.

Assisting the contraction of muscles and the transmission of nerve impulses

For electrical impulses to travel along nerves, potassium is required. Potassium is also vital for muscle movement, as it works with sodium to create an electrical charge. This is achieved with the assistance of the sodium–potassium pump in the cell membrane (refer to Figure 1.7.6). This exchange of sodium and potassium across the cell membrane assists in maintaining a steady heartbeat.



Key terms

Absorption enhancer	Goitre	Potassium
Absorption inhibitor	Haem iron	Sodium
Aerobic respiration	Haemoglobin	Sodium–potassium pump
Bioavailability	Iodine	Thyroid gland
Calcium	Major mineral	Thyroxine
Extracellular fl	Myoglobin	Trace mineral
	Non-haem iron	

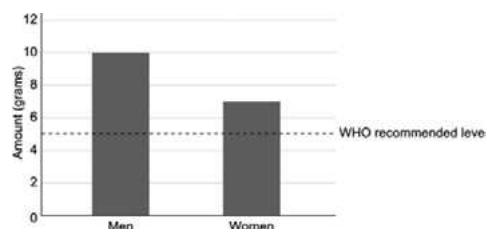
Review questions: 1.7 Minerals

1. Explain the difference between a major and a trace mineral.

(2 marks) (KA1)

2. The graph below shows the average salt intake of Australian men and women per day.

- (a) Using data from the graph below, compare the amount of salt that Australian men and women are consuming daily with the amount that the World Health Organisation (WHO) recommends.



(2 marks) (AE3)

- (b) Salt is composed of sodium chloride. Explain two benefits of sodium consumption in the human body.

(4 marks) (KA2)

- (c) State a nutrient that sodium works in conjunction with, in the human body.

(1 mark) (KA1)

3. Complete the following table by identifying if an individual diagnosed with a deficiency of Iron or Calcium should increase or decrease their intake of the following foods and beverages to assist with the management of their nutrient deficiency.

- (a) Iron Deficiency:

Food or beverage source	Increase or decrease intake
Orange juice	
Excessive milk and yoghurt	
English Breakfast Tea	
Lamb	
Fresh salmon	
Eggs	
Fortified cereals	

- (b) Calcium Deficiency:

Food or beverage source	Increase or decrease intake
Cow's milk	
Salmon	
Pepsi	
Coffee	
Yoghurt	
Wholegrains	
Processed foods	

(14 marks) (KA2)

4. Iron is vital to produce haemoglobin, the oxygen-binding component of a red blood cell. Explain two symptoms that an individual would experience if they were deficient in iron, reducing the concentration of haemoglobin in their red blood cells.

(4 marks) (KA2)

5. The table below shows the recommended daily intake (RDI) of iron for females.

Age (years)	RDI of iron (mg/day)
9-13	8
14-18	15

- (a) Explain the importance of one function of iron in the body.

(2 marks) (KA2)

- (b) Explain why the RDI of iron is greater for females aged 14-18 years than for younger females aged 9-13 years.

(2 marks) (KA2)

- (c) Explain how a combination of certain foods will ensure that a meal meets the RDI of iron for a female who is vegetarian and aged 14-18 years.

(2 marks) (KA2)

- (d) There are two types of iron: haem and non-haem.

- (i) Identify one food source for haem iron and non-haem iron.

Haem iron:

(1 mark) (KA1)

Non-haem iron:

(1 mark) (KA1)

- (ii) State which type of iron is more readily absorbed by the human body.

(1 mark) (KA1)

6. Students conducted an experiment to determine the calcium concentration in four different types of milk. The results of the experiment and the true values given on the containers for each type of milk are shown in the table below.

Types of Milk	Calculated calcium concentration (mg/100mL)				True values (mg/100mL)
	Trial 1	Trial 2	Trial 3	Average	
Cow's milk (whole)	118	104	132	118	118
Cow's milk (skim)	43	130	139	104	130
Almond milk	82	78	80	80	80
Soy milk (fortified)	143	146	149	146	160

- (a) Using the data in the table above, identify and explain which type of milk has data displaying low precision and high accuracy.

(4 marks) (IAE3)

- (b) The students identified an outlier in the data for one milk type that was caused by experimental error.

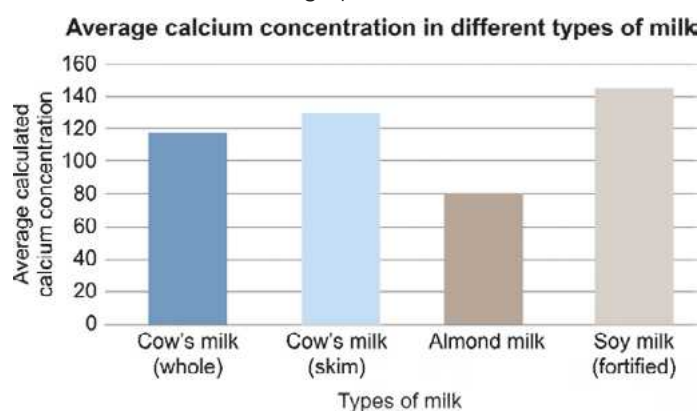
- (i) State the outlier.

(1 mark) (IAE3)

- (ii) Recalculate the average calcium concentration for this type of milk after removing the outlier and describe the effect on the data.

(2 marks) (IAE3, KA4)

- (c) The students made a graph of the results of the experiment, as shown below. Identify two errors that the students made in the construction of their graph.



(2 marks) (IAE3)

- (d) Soy milk is a commonly used alternative to cow's milk. Identify one group within the community that is more likely to consume soy milk than cow's milk and provide a reason why.

(2 marks) (KA2)

- (e) Research suggests that calcium from cow's milk is more bioavailable than calcium in soy milk.
- (i) Identify and explain one factor that interferes with the absorption or reabsorption of calcium in the body.

(2 marks) (KA2)

- (ii) Describe one possible consequence of long-term reduced bioavailability of calcium in an individual.

(2 marks) (KA2)

7. To address mild iodine deficiency in Australia, a mandatory fortification program was implemented in 2009 with the addition of iodine to salt (iodised salt), used in bread making.

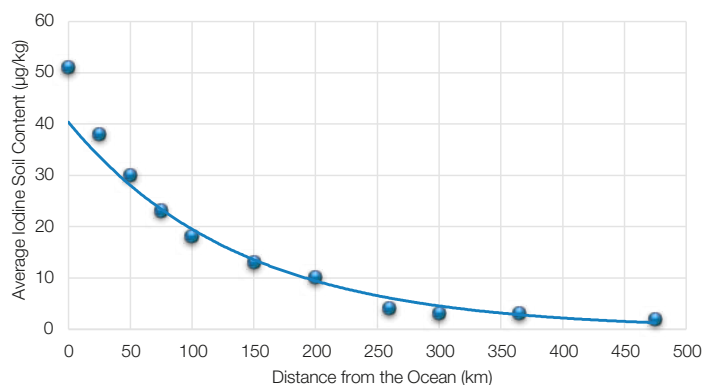
- (a) State one function of iodine in the human body.

(1 mark) (KA1)

- (b) Identify a food source that is naturally high in iodine.

(1 mark) (KA1)

- (c) Iodine is naturally found in our soils. The average content of iodine ($\mu\text{g}/\text{kg}$) in our soils was measured at different sites with varying distances (km) from the ocean. The results are shown in the graph below.



- (i) Using data from the graph above, describe the trend in the iodine content in the soil as the distance from the ocean increases.

(2 marks) (IAE3)

- (ii) Three towns are displayed in the table below, along with their distance from the ocean.

Town	Kadina	Waikerie	Eudunda
Distance from the ocean (km)	10.7	111	63

- With reference to the table and graph above, identify which town would have the poorest iodine levels in their soil.
- Discuss the potential effects on the iodine content of vegetables grown in the soil of the town identified in question 7(c)ii1, and the symptoms that may be experienced by consumers of these vegetables.

(1 mark) (IAE3)

(4 marks) (KA2)

Total: / 60 marks

Case Study

Jimmy is a 13-year-old boy who enjoys gaming and watching TV in his free time. Some of the micronutrient levels in the foods Jimmy typically eats in a day are recorded by a dietician in the table below.

Food	Calcium (mg)	Iron (mg)	Potassium (mg)	Vitamin C (mg)	Vitamin D (µg)	Vitamin B12 (µg)
2 pieces of toast with sugar and cinnamon	137	3	118	—	—	1.6
Banana	6	0.3	422	10	—	—
Hot dog on a bun	120	2	230	11.6	0.1	0.5
Juice box	—	—	220	72	—	—
Roast chicken quarter	28	3	596	—	—	0.6
Hot chips	32	1.5	935	19	0.2	—

His micronutrient levels were compared to the recommended daily intakes (RDI), or Adequate Intakes (AI) prescribed by Eatforhealth.gov.au as the Nutrient reference values for Australia and New Zealand.

Age (years)	Gender	Calcium RDI (mg/day)	Iron RDI (mg/day)	Potassium AI (mg/day)	Vitamin C RDI (mg/day)	Vitamin D AI (µg/day)	Vitamin B12 RDI (µg/day)
9-11	Male	1000	8	3000	40	5	1.8
	Female	1000	8	2500	40	5	1.8
12-13	Male	1300	8	3000	40	5	1.8
	Female	1300	8	2500	40	5	1.8
14-18	Male	1300	11	3600	40	5	2.4
	Female	1300	15	2600	40	5	2.4

Case Study

With reference to the data in the previous tables:

- Identify two micronutrients that are lacking in Jimmy's typical diet. Show your calculations to justify your findings.
- Some vitamins and minerals work in conjunction. Identify a pair of micronutrients whose conjunctive role may be impaired and describe the effects of this impairment on the bioavailability of the mineral.
- Provide modifications to Jimmy's typical food intake and/or his lifestyle to help improve his micronutrient intake of inadequate micronutrients. Indicate the appropriate nutrient for each modification.

(10 marks) (AE3, KA2 KA4)

1.8 Digestion, the Microbiome & Malabsorption

Science understanding

Digestion and Metabolism of food influences the absorption and use of nutrients.

- Identify organs involved in the ingestion and digestion of food/fluids along the gastrointestinal tract and describe their function, including mouth, salivary glands, oesophagus, stomach, liver, gall bladder, pancreas, small intestine, large intestine, rectum, and anus.
- Explain the chemical digestion of macronutrients into their products by specific enzymes, including salivary amylase, gastric pepsin, pancreatic amylase, trypsin, and lipase, and intestinal sucrase, maltase and lactase.
- Explain the role of the following processes in mechanical digestion, including mastication in the mouth, peristalsis along the gastrointestinal tract, and the emulsification of lipids in the small intestine.
- Describe the absorption of the products of macronutrient digestion in the villi, including monosaccharides and amino acids into the blood and fatty acids and glycerol into lacteal (lymph) system.

The Microbiome of the large intestines is critical to digestion and health.

- Describe the importance of the gut microbiome synthesis of vitamin K and short chain fatty acids (SCFAs).
- Discuss factors that affect gut microbiome diversity, including prebiotics, probiotics, infections including food poisoning and antibiotics.

Lactose intolerance and coeliac disease are factors that can interfere with the absorption of nutrients.

- Describe the nature, causes, symptoms, management and health consequences of coeliac disease and lactose intolerance.

SACE Subject Outline, 2024.

The gastrointestinal tract

The gastrointestinal tract (GI) tract is a flexible muscular tube that extends from the mouth, through the oesophagus, stomach, small intestine, large intestine (also called the colon) and rectum to the anus (Figure 1.8.1). The salivary gland, pancreas, liver, and gallbladder are accessory or secondary organs, which release their secretions into the GI tract when required.

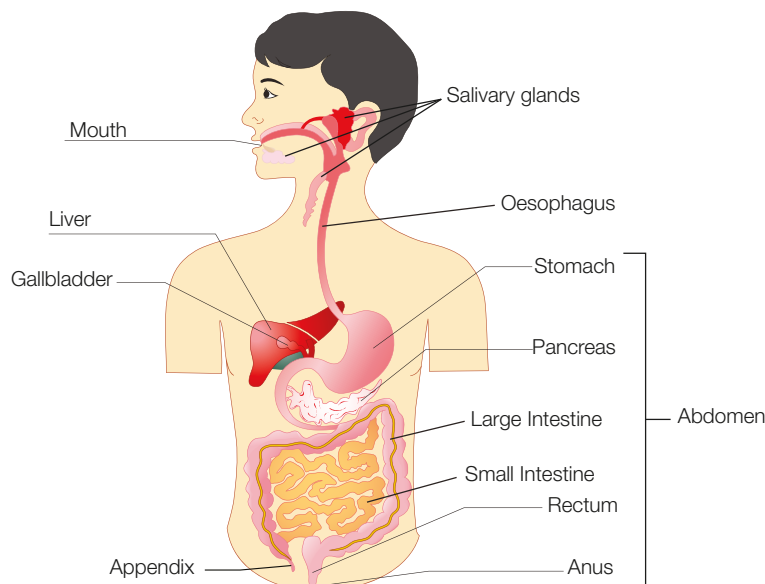


Figure 1.8.1: The gastrointestinal tract organs, starting from the mouth and ending at the rectum and anus.



Fast fact

The abdomen, also more commonly known as the 'belly', is the part of the body that starts from the stomach and ends at the anus.

The bowel is another term used to describe the small intestines, large intestines, rectum, and anus.

Mouth

The process of digestion begins in the mouth or oral cavity. After food enters the mouth, teeth mechanically break down large pieces of food into smaller ones through the process of chewing, also known as **mastication**. This process involves the grinding and chopping action of the teeth, which physically break down ingested food into smaller pieces. This prepares food for swallowing and movement into the oesophagus. This also increases the surface area of ingested food, for efficient chemical digestion further in the gastrointestinal tract.

During mastication, food is mixed with saliva released by the **salivary glands**, which are located behind or below the tongue. Saliva consists of digestive enzymes, including **salivary amylase** and **lingual lipase**. Salivary amylase initiates the chemical digestion of starch (complex carbohydrates) into shorter polysaccharides and disaccharides, specifically maltose. Lingual lipase initiates the chemical digestion of triglycerides into shorter fatty acid chains. Very little carbohydrate and triglyceride digestion takes place here, due to food spending little time in the oral cavity.

Saliva also consists of water, salts, and mucus, which enables food to be moistened for easy swallowing and assists in dissolving the food so that the taste buds on the tongue can detect any of the five basic sensations: sweet, salty, sour, bitter and umami.



Fast fact

Umami corresponds to the flavour of glutamates, especially monosodium glutamate, which is a compound that naturally occurs in the breakdown of proteins.

When a mouthful of food is shaped into a ball by the tongue and swallowed, it is then referred to as a bolus. The bolus passes through the pharynx, a short tube connecting the oral cavity to the oesophagus. The pharynx also serves the respiratory system as it connects the nasal and oral cavity to the larynx; however, the epiglottis, a small flap of moveable cartilage, closes off the air passage when swallowing to avoid choking.

Oesophagus

The oesophagus is a muscular tube connecting the oral cavity to the stomach. Once the bolus enters the oesophagus from the mouth, it takes 5 to 10 seconds for it to reach the stomach. The oesophagus is ringed with circular muscles, which are surrounded by longitudinal muscles. When the rings tighten and the longitudinal muscles relax, the oesophageal tube contracts. When the rings relax and the longitudinal muscles tighten, the tube bulges and relaxes. These mechanical actions are known as **peristalsis**, which occur involuntarily and continuously to push the bolus further along the oesophagus in one direction (Figure 1.8.2).

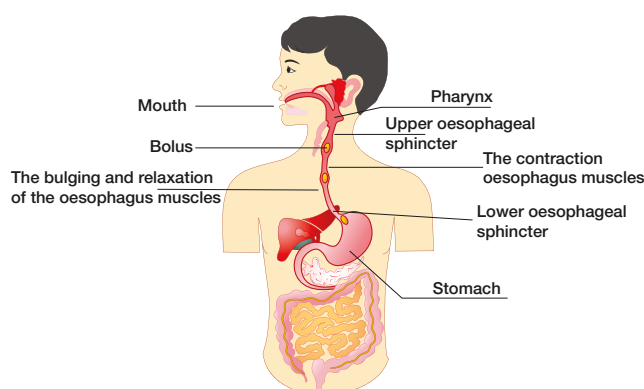


Figure 1.8.2: The involuntary contractions and relaxations (peristalsis) of the oesophagus muscles pushing the bolus along the tube into the stomach.

The oesophagus also has a sphincter muscle at each end (Figure 1.8.2). During swallowing, the **upper oesophageal sphincter** opens, allowing the bolus to enter the oesophagus from the pharynx. The bolus is then pushed down the oesophagus, passing through the **lower oesophageal sphincter** into the stomach. Once the bolus enters the upper portion of the stomach, the lower oesophageal sphincter closes (Figure 1.8.3) to prevent the stomach contents and gastric juices from travelling backward.



Fast fact

The lower oesophageal sphincter is also known as the cardiac sphincter.

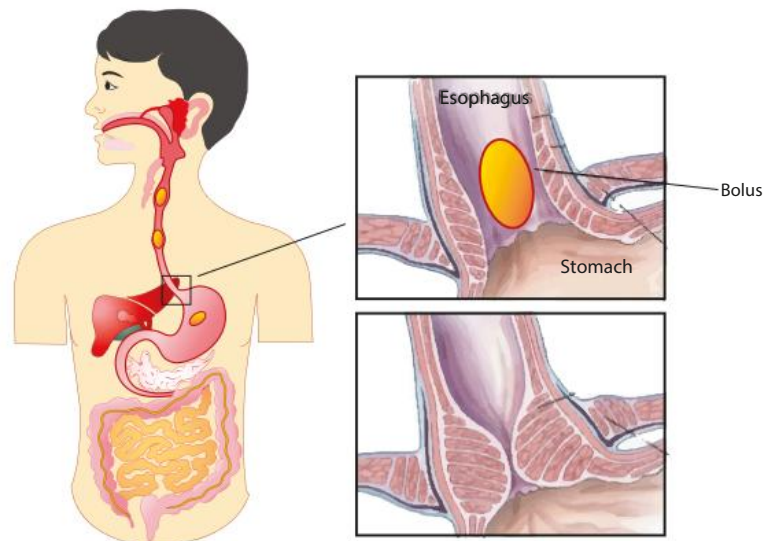


Figure 1.8.3: The lower oesophageal sphincter, which opens to allow the bolus to enter the stomach and closes to prevent the gastric contents from moving backward.

Stomach

The stomach has the thickest and strongest muscles of all the GI tract organs. The stomach has three types of muscles – circular, longitudinal, and diagonal – that alternately contract and relax (Figure 1.8.4). These actions assist in the mechanical **mixing and churning** of the bolus with **gastric juices** to produce a semiliquid paste called **chyme**. The gastric glands secrete gastric juices, which are a mixture of water, enzymes, and hydrochloric acid, which has a strong acidic pH of 2. The strong acidity of the stomach prevents bacterial growth and kills most bacteria that have been ingested with food consumption. This is the only site in the digestive system that can withstand a strong acidic nature. The cells of the stomach secrete a thick, slippery white mucus that covers and protects them from acid, enzymes, and pathogenic bacteria.

Hydrochloric acid also assists in the chemical digestion of protein. Hydrochloric acid uncoils and denatures each protein strand to allow digestive enzymes to break the peptide bonds between the amino acids. The hydrochloric acid converts the inactive form of the enzyme pepsinogen into its active form: **pepsin**. Gastric pepsin is then able to break larger polypeptide chains into smaller ones by breaking the peptide bonds between them. The stomach enzymes work most efficiently in the stomach's strong acidic environment, but the salivary enzymes become inactive, therefore ceasing the breakdown of carbohydrates and lipids. Once the actions of the stomach are complete, the stomach releases a small amount of chyme at a time through the **pyloric sphincter** into the first part of the small intestine: the duodenum.

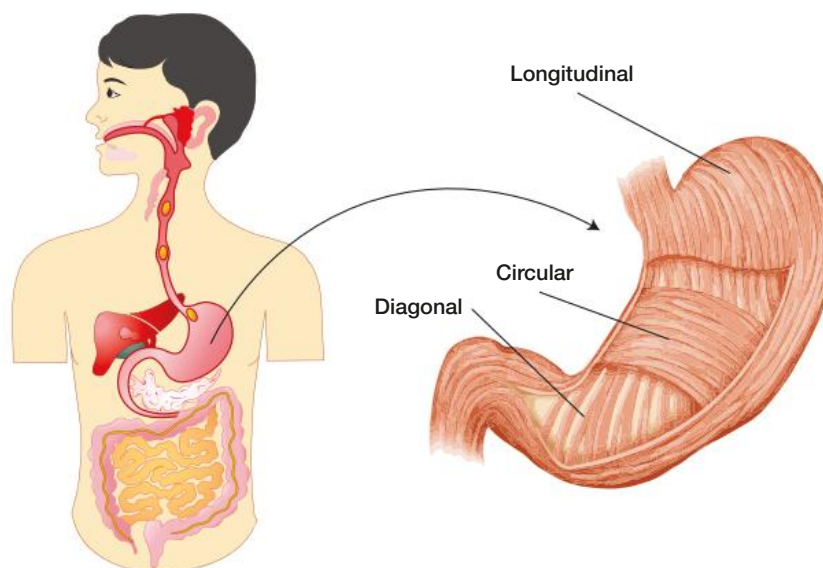


Figure 1.8.4: The circular, longitudinal and diagonal muscles of the stomach, which alternately contract and relax to mix and churn the bolus with gastric juices to make a semiliquid called chyme.

Small Intestine

The small intestine is made up of three segments: the **duodenum**, the **jejunum**, and the **ileum** (as shown in Figure 1.8.5), which make up approximately 6 metres of tubing coiled up within the abdomen. This is the site where the chemical digestion of macronutrients is completed. Nutrient and water absorption takes place here too.

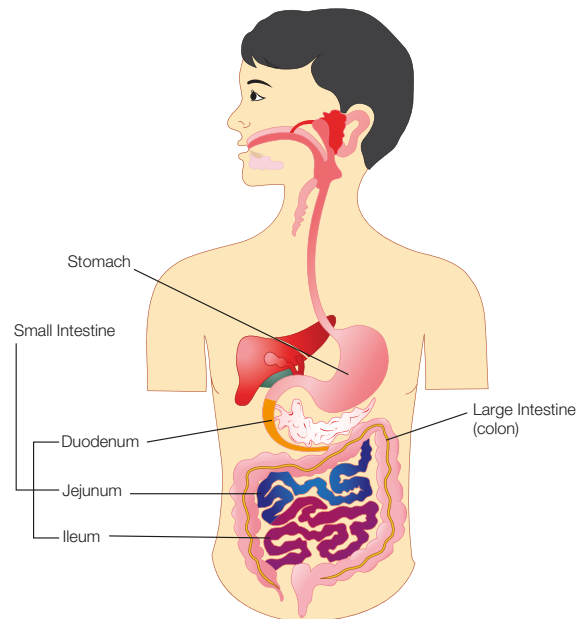


Figure 1.8.5: The three segments of the small intestine: duodenum, jejunum, and ileum.

Mechanical digestion

The mechanical contractions and relaxations of the circular intestinal wall muscles assist with chyme movement along the gastrointestinal tract, or peristalsis, and mixing the stomach's chyme with the digestive juices and enzymes involved in the chemical digestion, called **segmentation**. Segmentation also assists with the absorption of nutrients by promoting close contact with intestinal cells and causing the contents to move slowly through the tract for maximum digestion and absorption.

Chemical digestion

For chemical digestion to be completed, the pancreas, liver, and gallbladder release their secretions into the small intestines via the common bile duct and pancreatic duct (as shown in Figure 1.8.6). These secretions are composed of enzymes, bile, and sodium bicarbonate. The sodium bicarbonate secreted by the pancreas is alkaline (the opposite of the gastric contents), to neutralise the acidic nature of the chyme that has come from the stomach. This allows the pancreatic enzymes to efficiently complete the chemical digestion of all macronutrients.

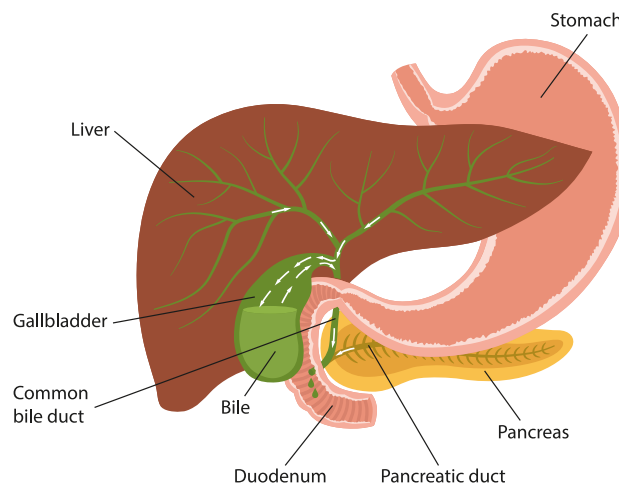


Figure 1.8.6: The common bile and pancreatic duct, which release their secretions into the small intestines.

Chemical digestion of carbohydrates

The chemical digestion of simple sugars, namely disaccharides, from food consumed begins in the small intestine whilst that of polysaccharides, specifically starch is completed. **Pancreatic amylase** enters the small intestine via the pancreatic duct. This enzyme continues to break down polysaccharides into disaccharides and shorter chain glucose molecules, which are also eventually broken down into maltose (as shown in figure 1.8.7).

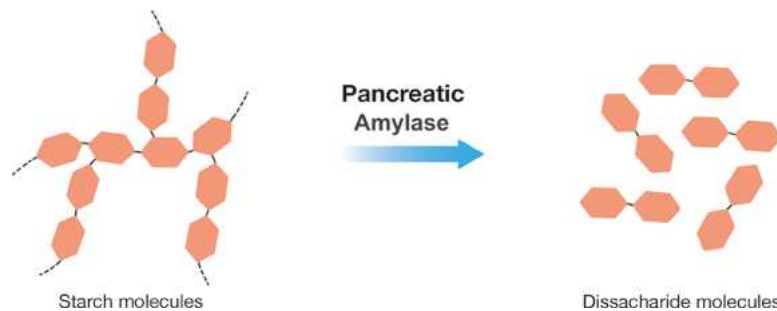


Figure 1.8.7: The chemical digestion of polysaccharides (e.g., starch) by pancreatic amylase into disaccharides

The final steps are completed by specific enzymes secreted by the intestinal cells, which break down disaccharides into monosaccharides (as shown in figure 1.8.8):

- **Maltase** breaks maltose into two glucose molecules.
- **Sucrase** breaks sucrose into one glucose and one fructose molecule.
- **Lactase** breaks lactose into one glucose and one galactose molecule.

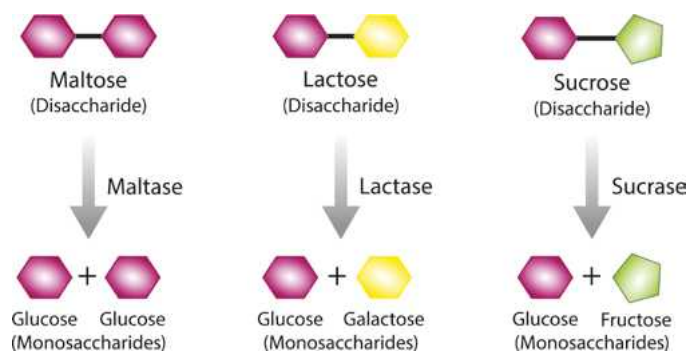


Figure 1.8.8: The chemical digestion of disaccharides into their respective monosaccharides.

At this stage, all polysaccharides and disaccharides have been broken down into monosaccharides, ready for absorption into the bloodstream. Glucose travels throughout the bloodstream ready for cellular use (producing energy during a process of respiration). Fructose and galactose are taken to the liver, where they are converted into other compounds similar to glucose.

Chemical digestion of proteins

The shorter polypeptide chains (produced from the chemical digestion in the stomach by pepsin) enter the small intestine where their digestion is completed. Several pancreatic and intestinal protease enzymes, including **trypsin** and **chymotrypsin**, break them down into singular amino acids or shorter peptide chains consisting of two (dipeptides) or three amino acids. An enzyme found on the surface of the intestinal cells, **peptidase**, completes the digestion of these shorter peptides into singular amino acids (as shown in figure 1.8.9). Singular amino acids are then absorbed into the bloodstream ready for their functional and structural roles in the body.

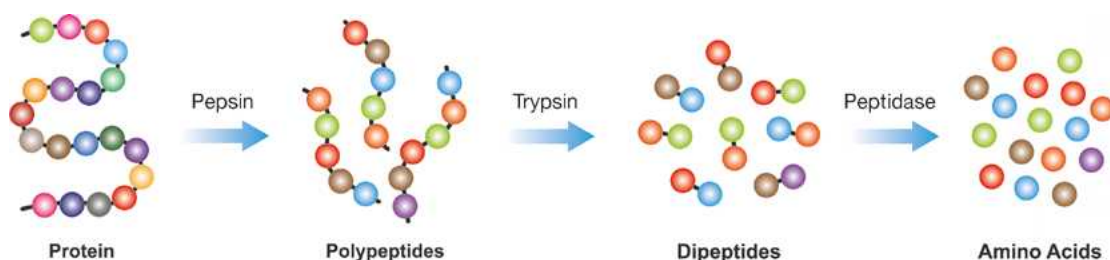


Figure 1.8.9: The chemical digestion (simplified version) of protein into singular amino acids

Chemical digestion of lipids

Most of lipid digestion takes place in the small intestine, where it is completed. Once the small intestine detects lipid is present, the gallbladder releases its stores of **bile** via the common bile duct. The liver produces bile, but the gallbladder concentrates, stores and releases it when required.

Bile is composed of bile acids and cholesterol, and it has an affinity for both fat and water. Bile **emulsifies** larger fat molecules and converts them into small fat droplets, allowing them to be immersed in the surrounding water fluid. The emulsification of fat aids in the mechanical digestion of lipids, by increasing the surface area available for **pancreatic lipase** to complete its chemical digestion (as shown in figure 1.8.10).

Pancreatic lipase can either remove each of the triglyceride's outer fatty acids one at a time (leaving a monoglyceride) or break apart all three fatty acids (leaving a free molecule of glycerol). These are then packaged as a lipoprotein, ready for absorption and transportation through the lacteal (lymph) system, before entering the bloodstream near the heart. The blood carries these lipids to the rest of the body for immediate use and storage.

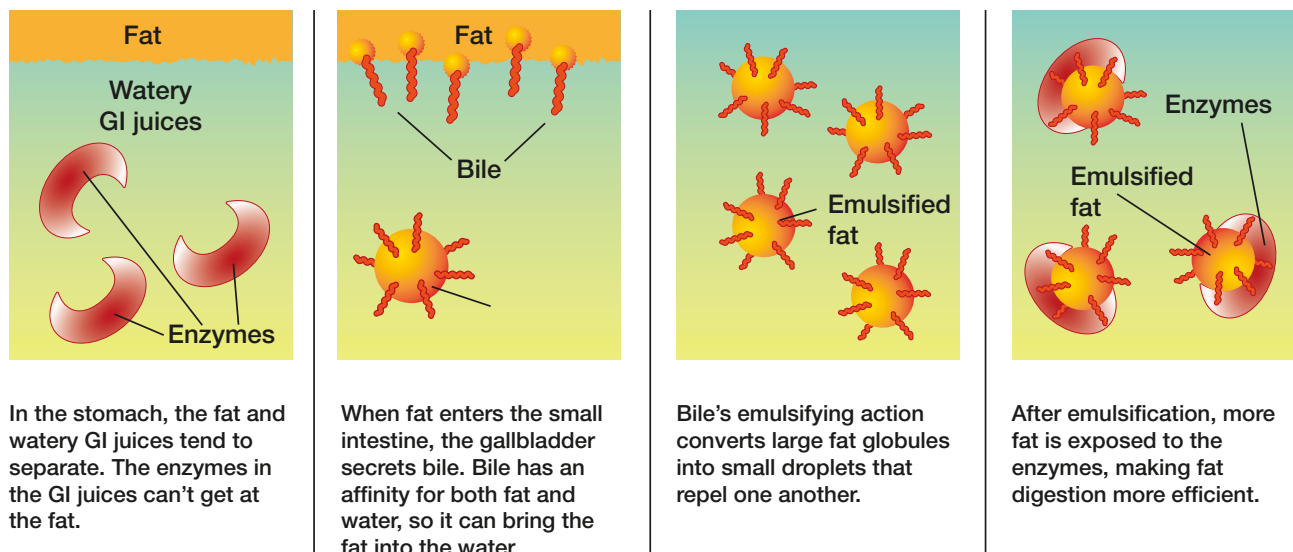


Figure 1.8.10: The emulsification of larger fat molecules produces small fat droplets, which increase the surface area available for pancreatic lipase to efficiently complete the chemical digestion of lipids into fatty acid chains, glycerol and monoglycerides.

Absorption of macronutrient digestion

Once chemical and mechanical digestion have completed the breakdown of food into molecules small enough, the body absorbs the nutrients and water derived from the food consumed. Almost all ingested food, 80% of micronutrients and 90% of water are absorbed in the small intestines.

The inner surface of the small intestine appears to be smooth; however, when looked at closely, it has a wrinkled appearance and is covered with hundreds of folds. Each fold has thousands of finger-like projections, known as **villi**. Each villus is composed of thousands of cells, which are covered in **microvilli** on their surface (Figure 1.8.8). These villi and microvilli increase the surface area available, maximising the absorption of macronutrients, micronutrients, and water. The cells covering each villus can identify and select the nutrients the body requires. These cells then absorb the nutrients through a process of diffusion, facilitated diffusion or active transport.

The absorption of nutrients occurs throughout the small intestines; however, nutrients that are ready for absorption early are absorbed near the top of the small intestine (duodenum), whereas nutrients that take longer to digest are absorbed further down (in the jejunum and ileum).

Once a nutrient passes through the cell of a villus, it enters the transport systems (the bloodstream or the lymphatic system). Both systems supply vessels to each villus (as shown in Figure 1.8.11). The products of carbohydrate digestion (monosaccharides) and protein digestion (amino acids) are absorbed into the bloodstream. Most triglycerides are absorbed into the lacteal (lymph) system before making their way into the bloodstream closer to the heart. Once nutrients have been absorbed, they are transported throughout the body for immediate use and storage or to the liver for further metabolism.

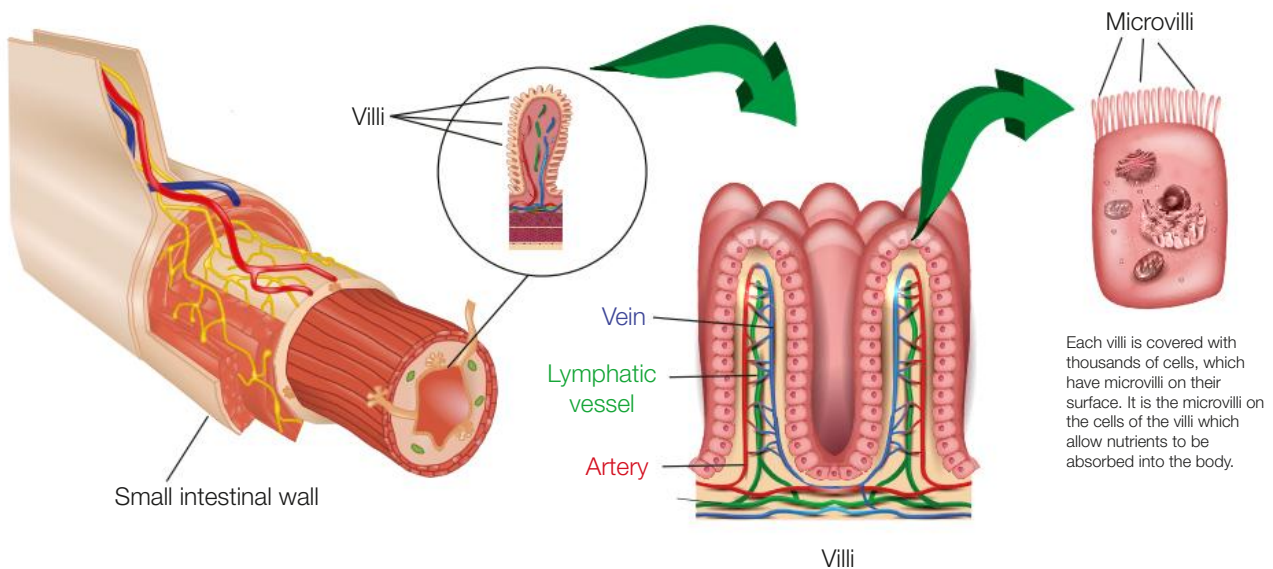


Figure 1.8.11: The small intestinal wall, composed of thousands of villi and microvilli.

Large Intestine

The nutrients that have not been digested or absorbed make their way to one of the final parts of the gastrointestinal tract. The large intestine is four times thicker than the small intestines and is made up of three sections: ascending colon, transverse colon, and descending colon (as shown in Figure 1.8.12). The contents that reach the large intestine are composed of water, a few dissolved salts, excess body secretions, and undigested materials including dietary fibre.

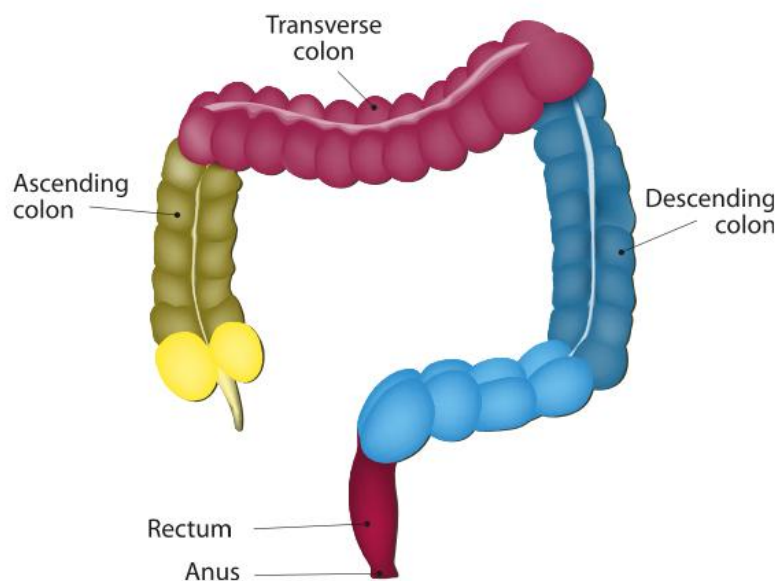


Figure 1.8.12: The sections of the large intestine.

In the large intestine, bacteria **ferment** soluble fibre, producing water and gas. The products of fermentation make stools soft through the addition of water and stimulate movement of the colon, assisting in the excretion of stools. This process can also add bulk to stools through the addition of bacteria that may have died during the fermentation process.

Insoluble fibre passes through the large intestine unchanged, which assists in adding bulk to stools, preventing diarrhoea, and eliminating waste. Finally, all the materials, including water, salts, and minerals (sodium and potassium) that the body can use are reabsorbed, leaving the waste that is excreted from the body with little to no nutritional value in it.

Rectum and anus

Once the food reaches the rectum, the digestion and absorption of nutrients is complete, leaving semisolid waste ready to be excreted from the body. The strong muscles of the rectum and anus expand to hold this waste until ready to defecate. Once ready, the muscles of the rectum and the anus relax, opening the passage for waste to be excreted.

Secondary organs of the digestive tract

The breakdown of food into nutrients requires secretions from five different organs: the salivary gland, gastric glands, pancreas, liver, and gallbladder. These secretions enter the GI tract at various points, providing water and different **enzymes** that assist in the chemical breakdown of nutrients. The enzymes involved in digestion facilitate the chemical process of hydrolysis, where the addition of water breaks down larger molecules into smaller ones ready for absorption.



Reminder

An enzyme is a type of protein that speeds up a chemical reaction in the body, including the breakdown of materials during digestion.

Overview of the gastrointestinal tract

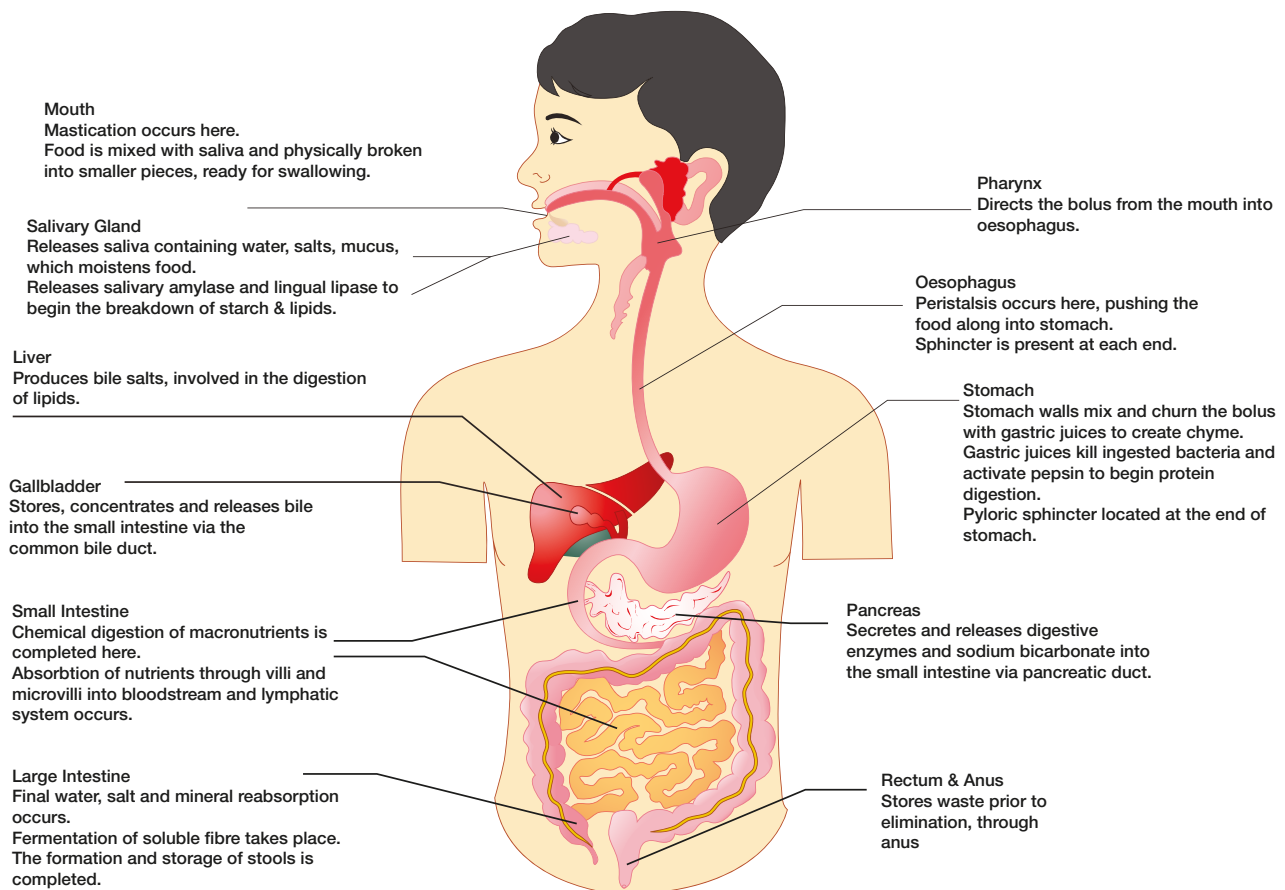


Figure 1.8.13: The functions of primary and secondary organs in the gastrointestinal tract.

Overview of mechanical digestion

In mechanical digestion, food is pushed along and physically broken down into smaller fragments via the acts of mastication in the mouth, peristalsis of the oesophagus, the mixing and churning of the stomach walls, the emulsification of fats in the small intestines, and the segmentation of the intestinal walls (as outlined in table 1.8.1).

Table 1.8.1: The mechanical digestion of each macronutrient

Mechanical process	Site where it occurs	Definition
Mastication	Mouth	Mastication is the grinding and chewing action by teeth in the mouth, which physically break down ingested food into smaller pieces.
Peristalsis	Oesophagus	Peristalsis is the alternate and involuntary contractions and relaxations of the circular and longitudinal muscles of the oesophageal walls.
Mixing and churning	Stomach	The circular, longitudinal and diagonal muscles of the stomach walls contract and relax, mixing and churning the bolus with gastric juices to produce a semifluid paste called chyme.
Emulsification of Fats	Small Intestines	Bile emulsifies larger fat molecules and physically breaks them into small fat droplets, allowing them to be immersed in the surrounding water fluid and increasing the surface area available for the chemical digestion to be completed.
Segmentation	Intestines	Segmentation involves the contractions and relaxations of the circular muscles of the intestinal walls.

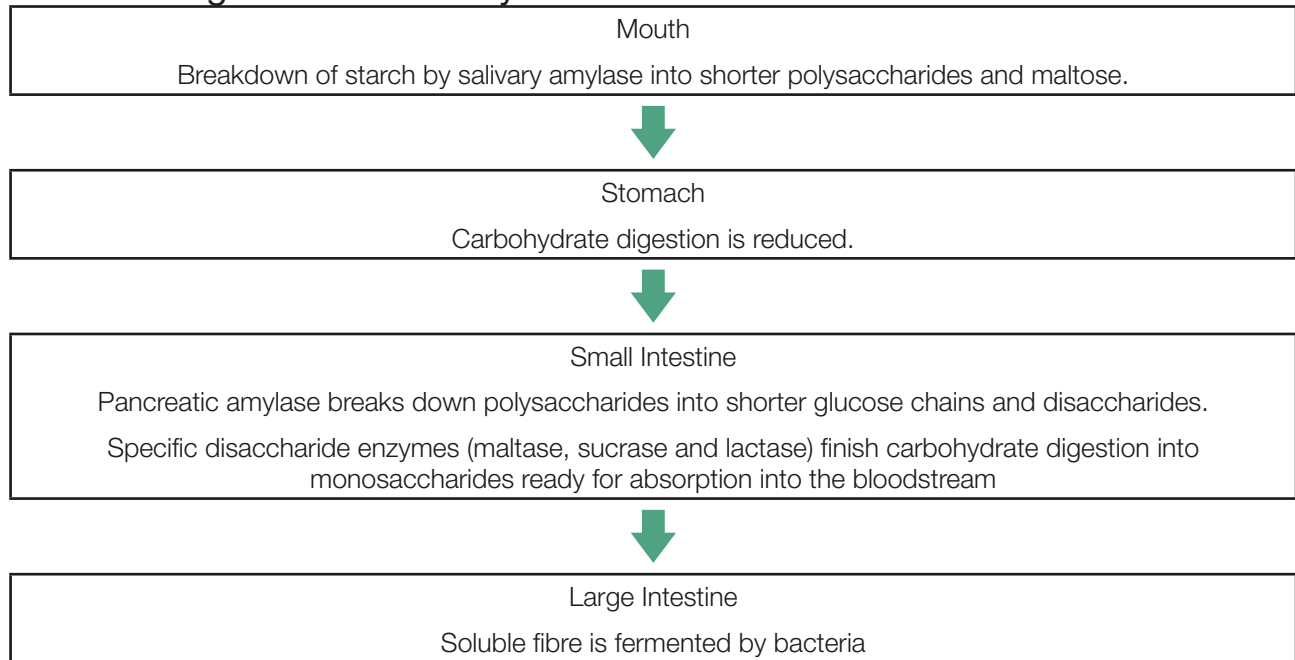
Overview of chemical digestion

Chemical digestion results in the breakdown of all three macronutrients into their basic chemical structures, with the assistance of digestive enzymes and juices. This takes place throughout the gastrointestinal tract; however, it predominantly occurs in the small intestine where this process is completed. The chemical digestion of each macronutrient is summarised in Table 1.8.2 below.

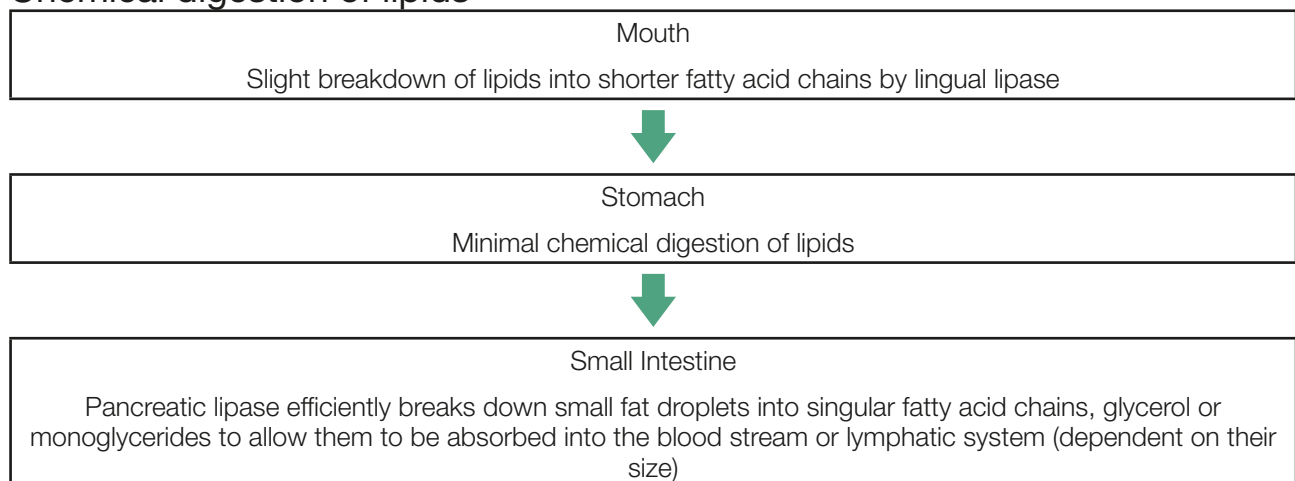
Table 1.8.2: The chemical digestion of each macronutrient

Macronutrient	Site of digestion	Digestive enzymes and juices involved	Products of digestion	Absorbed into
Carbohydrates	Mouth	Salivary amylase	Shorter polysaccharides and disaccharides	N/A
	Small intestine	Pancreatic amylase	Shorter polysaccharides and disaccharides	
		Maltase, sucrase, lactase	Monosaccharides	Bloodstream
Proteins	Stomach	Hydrochloric acid and gastric pepsin	Shorter polypeptide chains	N/A
	Small intestine	Pancreatic trypsin and chymotrypsin	Singular amino acids and short peptide chains	Bloodstream
		Intestinal peptidase	Singular amino acids	
Lipids	Mouth	Lingual lipase	Shorter fatty acid chains	N/A
	Small intestine	Bile	Small fat droplets	N/A
		Pancreatic lipase	Glycerol and short fatty acids	Bloodstream
			Monoglycerides and long fatty acids	Lacteal system

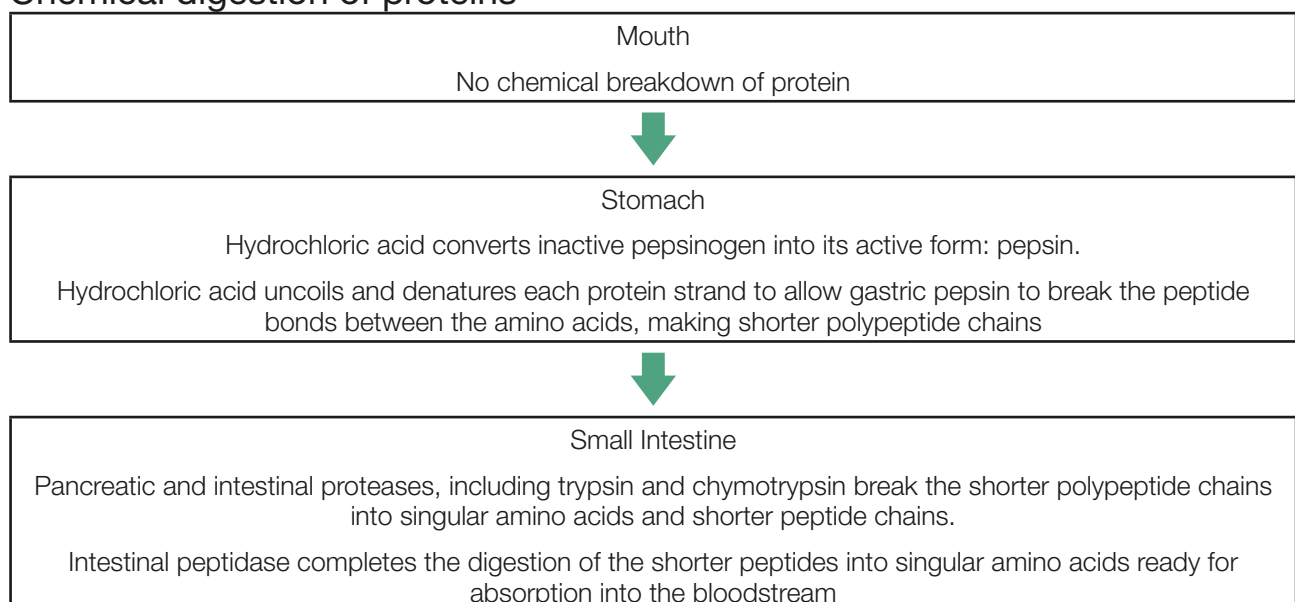
Chemical digestion of carbohydrates



Chemical digestion of lipids



Chemical digestion of proteins



The Microbiome

A healthy gastrointestinal tract is home to a community of 100 trillion microbes, including bacteria, viruses, fungi, protozoa, and other microorganisms. This is collectively known as the human **microbiome**, which can be found within our gastrointestinal tract, skin, reproductive tract, liver, eyes, mouth, nose and even our belly button. However, the microbiome in the large intestine will be the focus as this is where most microorganisms live (as shown in figure 1.8.14).



Figure 1.8.14: The microbiome in the large intestines is home to the most microorganisms in our body.

The balance and diversity of the human microbiome has been proven to reflect the health of an individual and can reduce the susceptibility of diseases, including cancer, inflammatory bowel disease, obesity, and asthma. This is because we have a symbiotic relationship with most of the microorganisms that live on or within us. This includes a mutualistic relationship where we provide these microorganisms with a home, and they benefit us by extracting energy and vitamins from our food for us to absorb.

The role of Prebiotics and Probiotics

Our diet can influence the balance and diversity of our microbiome, with the addition of prebiotics and probiotics. **Prebiotics** are known as 'gut fertiliser' as they provide a source for gut bacteria to feed on, which promotes their growth and enhances the diversity of the microbiome. Examples of prebiotics include non-living, indigestible carbohydrates such as soluble fibre, resistant starch, and oligosaccharides. These cannot be digested by the human body and therefore provide a major source of energy for these microbes as they break them down via fermentation. The process of fermentation produces short chain fatty acids, which are then used as energy for the cells of the colon and assist in protecting against inflammation and disease. Inulin is a common prebiotic, and it is naturally found in garlic, asparagus, onions, leeks, and artichokes. However, prebiotics are also now added to many foods including breakfast cereals, bread, table spreads, drinks, and yoghurt (other food sources are provided in figure 1.8.16). **Probiotics** are foods which contain living good bacteria that can make their way to the gastrointestinal tract. Probiotics assist in maintaining a healthy and diverse gut by restoring the balance of good bacteria versus bad bacteria, boosting the immune system, alleviating diarrhoea, and constipation, protecting against colon cancer, and reducing the symptoms of lactose intolerance and irritable bowel syndrome. Probiotics are generally found in yoghurts and certain fermented foods, such as kombucha, sauerkraut and kimchi (other food sources are included in figure 1.8.16). Therefore, prebiotics act as a food source for probiotics, which are beneficial bacteria for the human microbiome (as shown in figure 1.8.15).

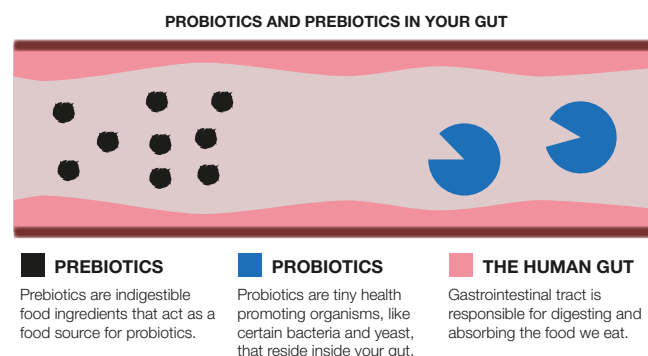


Figure 1.8.15: The role of prebiotics and probiotics in the human gut.

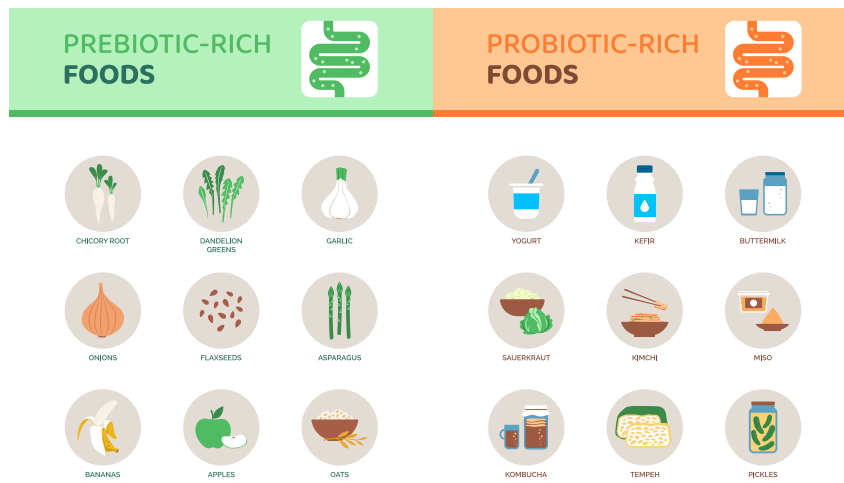


Figure 1.8.16: Sources of Prebiotics (left) and Probiotics (right)

The importance of a diverse microbiome

It is essential that foods high in prebiotics and probiotics are consumed as a way of keeping the microbiome in good shape and maintaining its **diversity**. The more diverse an individual's microbiome is, the more resilient it is and the less likely an individual is to develop adverse health outcomes. When the microbiome becomes unbalanced, indicated by a loss of microbial diversity, it is known as **dysbiosis**. However, a more resilient and diverse microbiome can recover more easily from disturbances that cause dysbiosis, such as infections including food poisoning and antibiotics. Food poisoning can alter the balance of bacteria in the large intestine's microbiome by reducing the number of beneficial bacteria and allowing harmful bacteria to grow. A healthy microbiome elicits an effective immune response against viruses that not only infect the gastrointestinal tract, but other parts of the body. The beneficial microorganisms do this by ordering specialized immune cells to produce potent antiviral proteins that ultimately eliminate viral **infections**. Therefore, a body of a person lacking a diverse microbiome won't have as strong an immune response to invading viruses due to not being able to distinguish the difference between some harmful pathogens and harmless bacteria. As a result, infections might go unchecked, taking a toll on an individual's health. Although **antibiotics** fight infections caused by bacteria, they have been found to reduce the diversity of the microbiome significantly as they don't distinguish between good and bad microbes. Some species of microbiome bacteria may even disappear, either for a short or long period of time. However, the decline in richness and diversity is dependent on the type of antibiotic and the gut microbiome itself. Some of us are more resilient to antibiotics than others, where some people may lose 10 species while others lose up to 24 after a 5-day course of antibiotics. However, the decline in diversity is not permanent for most people, with bacterial species returning to baseline after one to two months. This is why it is recommended to take a probiotic or consume probiotic rich food sources during and after antibiotic use to maintain the diversity of the microbiome or reduce the impact.

The synthesis of vitamin K and short chain fatty acids

The bacteria in the microbiome produce **short chain fatty acids (SCFAs)** as a product of the fermentation of indigestible carbohydrates, including soluble fibre and resistant starch. These SCFAs serve as the main source of energy for the cells lining the large intestine and protect against inflammation of the gut. This protects us against diseases caused by inflammation, such as inflammatory bowel diseases, colorectal cancer, and cognitive decline.

Bacteria in the gastrointestinal tract also release vitamins from our food by increasing their bioavailability. Some vitamins produced include vitamin B₁, vitamin B₂, Folate, vitamin B₆, vitamin B₁₂, vitamin H and vitamin K₂. However, the amount synthesised in this site of the body is insufficient to meet the body's needs, which is why it is essential that these vitamins are provided by the diet also. However, dietary sources of vitamin K₂, which is also known as menaquinone, are scarce, and those that contain this vitamin offer very little. Therefore, a significant proportion of vitamin K₂ intake is produced by the bacteria in our gut microbiome. This form of vitamin K has been found to support healthy bone formation, proper brain function and lower the risk of cardiovascular damage.

Factors that Interfere with the Absorption of Nutrients

An individual with a **malabsorption syndrome** has difficulty digesting and absorbing specific nutrients due to an autoimmune disease, intolerances, or allergies. This can impair an individual's intake of nutrients, therefore requiring them to modify their diet and lifestyle. Two common malabsorption syndromes include coeliac disease and lactose intolerance.

Coeliac Disease

Coeliac disease affects 1 per cent of the world's population, and 1 in 70 Australians. However, 80 per cent of these Australians remain undiagnosed, and are therefore unaware they have this disease. Coeliac disease is an autoimmune disease characterised by the inflammation of the small intestinal walls. It occurs in response to consumption of foods containing **gluten**.

Gluten is made of two proteins: **gliadin** and glutenin. Gliadin is a protein that is toxic to those suffering from coeliac disease. Gluten can be found in products that contain wheat, rye, oats, or barley. In people with coeliac disease, gluten triggers an immune response in the small intestines, which causes inflammation of the walls. This causes the villi to become damaged and flat, reducing the surface area available for nutrient absorption (Figure 1.8.17). This can lead to several nutrient deficiencies, such as protein, vitamins, and minerals. Nutrient deficiencies including anaemia or osteoporosis are common consequences of this malabsorption syndrome.



Figure 1.8.17: The villi of a healthy intestinal wall (image on the left) in comparison to the damaged villi (image on the right) of the intestinal wall of an individual suffering from coeliac disease.

Symptoms

The symptoms of coeliac disease can range from severe to minor and may go undetected. The most common symptoms can include bloating, flatulence, diarrhoea, nausea, fatigue, abdominal cramps, and weakness. These symptoms are due to gluten being unable to be broken down and remaining in the intestines. Symptoms can be like that of irritable bowel syndrome, so a biopsy of the intestinal walls is the only way to confirm the diagnosis of this syndrome.

Dietary management

People with coeliac disease remain sensitive to gluten throughout their entire lives, therefore dietary management is essential, as there is no current cure. A strict gluten-free diet is currently the only recognised treatment for coeliac disease, which removes the stimulus for villi destruction and allows the intestinal wall time to heal and resolve any related symptoms.

The list of foods that should be avoided is extensive; however, all fresh fruit and vegetables, nuts and seeds, meats, poultry, seafood, dairy and some grains and starches (e.g., quinoa, soy) can be consumed. Individuals should look for products labelled as 'gluten free' or displaying the Coeliac Australia endorsement logo (Figure 1.8.18). This endorsement logo allows consumers to shop with confidence, as all products are tested to ensure that no gluten is detected. An individual can also read the ingredients panel on a food label as a food product derived from wheat, rye, oats, and barley must be declared. Products with cross-contamination labels, e.g., 'may contain traces of gluten', should also be avoided.



Figure 1.8.18: Coeliac Australia endorsement logo

Lactose Intolerance

Lactose intolerance results in the inability to digest the disaccharide lactose, which is commonly found in dairy products. This is because the intestinal cells do not produce enough of the enzyme **lactase**, which finishes the digestion of this disaccharide into its two monosaccharides (glucose and galactose) in preparation for absorption in the small intestines (as shown in figure 1.8.19).

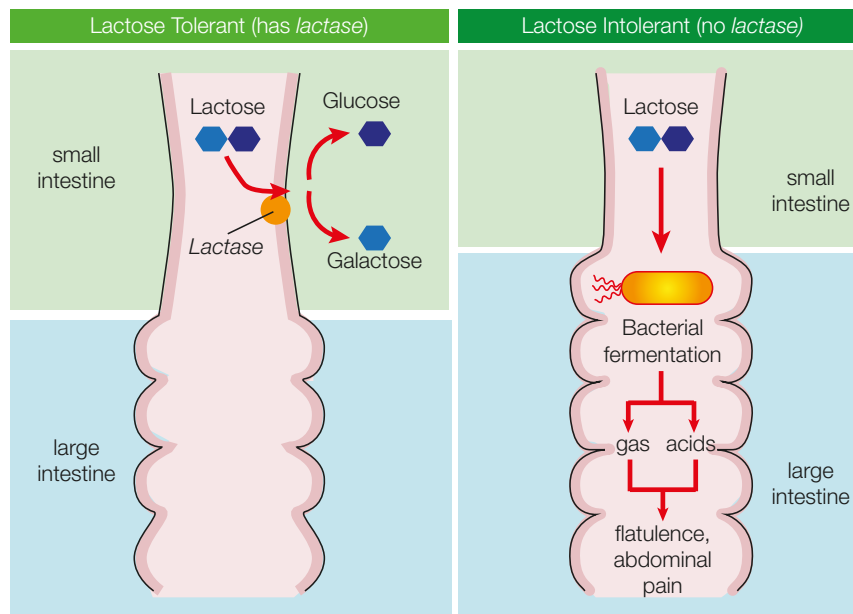


Figure 1.8.19: The digestion of lactose in normal digestion (left) and in an individual with lactose intolerance (right)

Lactase production commonly decreases with age, with the most dramatic decline occurring during childhood and adolescence. Lactase production is the highest immediately after birth, as an infant's only food source is breast milk or formula for the first few months of its life. Humans are the only animal species that continues consuming milk products into adulthood.

Lactase deficiency may also develop when the intestinal villi are damaged due to disease, medication, prolonged diarrhoea, or malnutrition.

Symptoms

When a greater amount of lactose is consumed than the available lactase can handle, lactose molecules are unable to be absorbed across the villi and they travel through to the large intestine. Once the undigested lactose reaches the large intestines, it is fermented by bacteria producing gas and acids that irritate the gut lining (as shown in figure 1.8.19). Lactose also attracts water, causing bloating, further abdominal discomfort, and diarrhoea.

Dietary management

An individual with lactose intolerance is required to make some dietary changes but does not need to eliminate all dairy products from their diet. Excluding all dairy products from their diet can put an individual at risk of being deficient in nutrients, including calcium and phosphorus, as they are predominantly found in these food sources. This can have an implication on the health of bones and teeth.

In many cases, individuals with lactose intolerance can still consume products containing up to 6 grams of lactose without experiencing any of the related symptoms. Milk products that have been fermented (e.g., yoghurt and cheese) can also be tolerated, as the bacteria present in these products have consumed the lactose for their own benefit. This further reduces the lactose present in these products.

Alternatively, individuals may consume enzyme tablets with meals containing lactose. This breaks down a significant amount of the lactose present into glucose and galactose and allows for these monosaccharides to be absorbed without any ill effects.

A lactose-free diet can be restrictive and difficult to maintain; an individual needs to read the food labels and avoid products that contain milk, milk solids, whey (milk liquid) and casein (milk protein). An individual must also read the labels of most pharmaceuticals, as lactose is a common ingredient in medicines.

Key terms

Antibiotics	Gluten	Pancreatic lipase
Bile	Hydrochloric Acid	Peptidase
Chemical digestion	Infections	Peristalsis
Coeliac Disease	Lactose	Prebiotics
Chyme	Lactose Intolerance	Probiotics
Diversity	Lingual lipase	Salivary amylase
Duodenum, jejunum, ileum	Lower oesophageal sphincter	Salivary gland
Dysbiosis	Malabsorption syndrome	Segmentation
Emulsification	Maltase, sucrase and lactase	Short chain fatty acids (SCFAs)
Gastric juices	Mastication	Trypsin and chymotrypsin
Gastric pepsin	Mechanical digestion	Upper oesophageal sphincter
Gastrointestinal (GI) tract	Microbiome	Villi, microvilli
Gliadin	Mixing and churning	Vitamin K2
	Pancreatic amylase	

Review questions: 1.8 Digestion, the Microbiome & Malabsorption

1. Complete the following table, which summarises the secretions of the following organs and glands and the specific actions of their secretions.

Organ or gland	Secretion	Site of release	Action
Salivary gland	Salivary amylase		
		Mouth	Begins the chemical breakdown of lipids into shorter fatty acid chains.
Gastric glands			Gastric juice (hydrochloric acid) is mixed with the bolus, which uncoils proteins and activates gastric pepsin to begin the chemical breakdown of proteins into shorter polypeptide strands.
Pancreas	Pancreatic amylase		
	Pancreatic trypsin and chymotrypsin		
	Pancreatic lipase		
Gallbladder	Concentrated bile	Small intestine	

(7 marks) (KA1)

2. Explain the difference between mechanical and chemical digestion.

(2 marks) (KA2)

3. Explain why fatigue is a symptom that individuals experience with both coeliac disease and lactose intolerance.

(4 marks) (KA2)

4. The ingredients of banana bread are listed below:

• Self-raising flour	• Bananas
• Brown sugar	• Eggs
• Plain flour	• Skim milk
• Rolled oats	• Butter

- (a) Several of the ingredients listed above are a concern for a person with coeliac disease. Identify one of these ingredients and explain why it is a concern.

(2 marks) (KA2)

- (b) State one alternative to the ingredient you identified in part (a) that would make the banana bread suitable for a person who has coeliac disease.

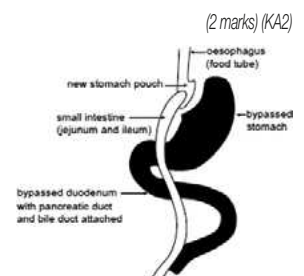
(1 mark) (KA1)

- (c) Explain why a person who has coeliac disease is at risk of developing nutrient deficiencies.

(3 marks) (KA2)

- (d) State one nutrient deficiency and the subsequent diet related disorder that could develop in a person who has coeliac disease.

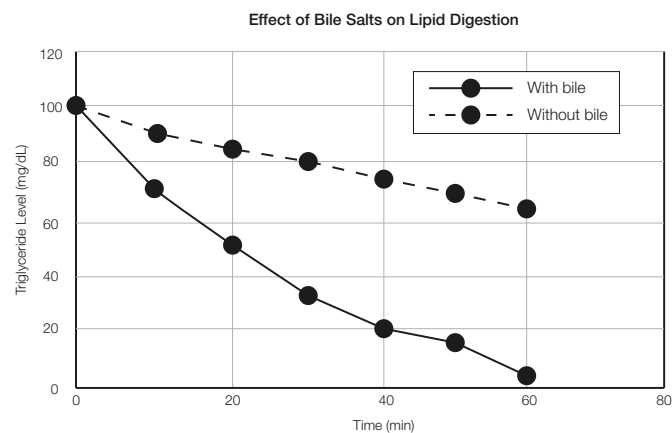
5. Gastric bypass is a common procedure that individuals consider as a weight loss option. Gastric bypass involves creating a smaller stomach pouch which only holds 25mls of food, in comparison to 400mls currently. This is then attached to the second part of the small intestines, the jejunum. The bypassed stomach and the first part of the small intestines (the duodenum) would no longer be functional after the procedure. Explain the implications of the digestion and absorption of nutrients to an individual considering this procedure.



(4 marks) (KA2)

6. Refer to the following graph, which demonstrates the effect of Bile on Lipid (Triglyceride) Digestion.

- (a) Identify the organ in the human body which produces bile.



(1 mark) (KA1)

- (b) Using data from the graph above, describe the effect on triglyceride levels in the body with and without bile after 60 minutes. Provide nutrition justification to support this trend.

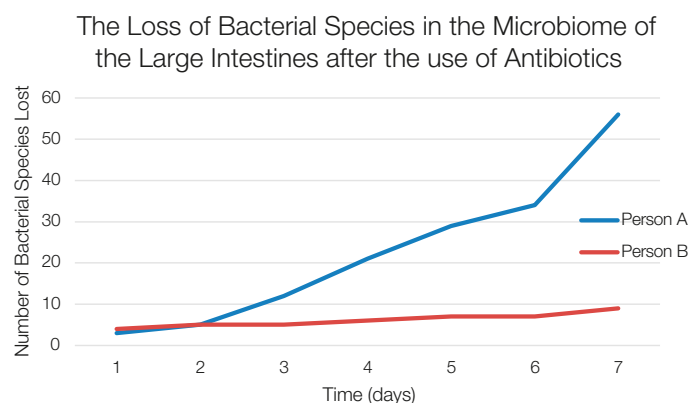
(4 marks) (IAE3, KA2)

7. The gut microbiome in the large intestines is host to most microorganisms in the body.

- (a) Define the gut microbiome.

(1 mark) (KA1)

- (b) The graph below shows the effect of antibiotics taken for 7 days by 2 individuals on the loss of bacterial species in the microbiome of the large intestines.



- (i) Using data from the graph above, describe the effect the use of antibiotics had on the diversity of both Person A and Person B's microbiome of the large intestines.

(2 marks) (IAE3)

- (ii) Probiotics can be taken to enhance the diversity of the microbiome. Explain their role in maintaining the diversity of the microbiome and the effect of antibiotics.

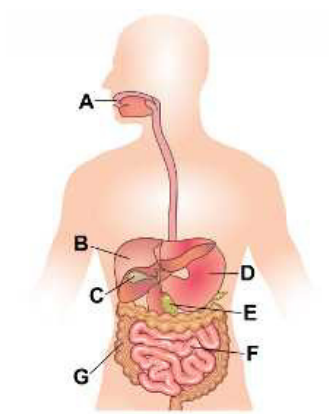
(4 marks) (KA2)

- (iii) Identify two food sources of probiotics.

(2 marks) (KA1)

8. According to health professionals, optimal health depends on the healthy functioning of the gastrointestinal tract. However, gastrointestinal changes occur throughout life, including changes to hydrochloric acid secretion.

- (a) Identify the letter representing the organ where hydrochloric acid is secreted.

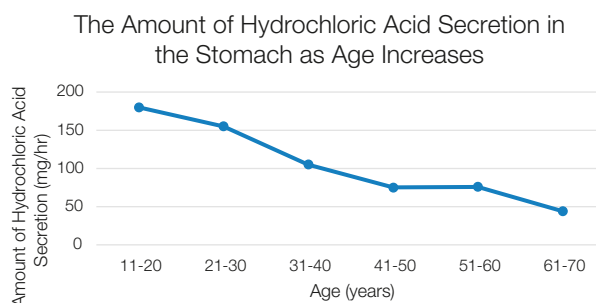


(1 mark) (KA1)

- (b) State two functions of hydrochloric acid in digestion.

(2 marks) (KA1)

- (c) The following graph demonstrates the relationship between age (years) and the amount of hydrochloric acid secreted in the stomach.



- (i) Using data from the graph above, describe the relationship between hydrochloric acid secretion and age.

(2 marks) (IAE3)

- (ii) Explain why people aged 61-70 years have a decreased ability to absorb amino acids from their food compared to those aged 11-20 years.

(3 marks) (KA2)

9. To enhance the health of her intestine microbiome, Angie was recommended by a health professional to increase her consumption of the types of foods and beverages shown in the image below.



- (a) With reference to the image above, identify one food or beverage source that contains prebiotics and one food or beverage source that contains probiotics.

Source containing prebiotics:

(1 mark) (IAE3, KA2)

Source containing probiotics:

(1 mark) (IAE3, KA2)

- (b) Explain how prebiotics and probiotics can increase the diversity of the intestinal microbiome.

(4 marks) (KA2)

10. Explain what occurs to soluble and insoluble fibre in the large intestines and the role it plays at this site of the gastrointestinal tract.

(4 marks) (KA2)

11. The pancreatic duct joins the common bile duct, where both flow into the duodenum releasing their secretions. Explain why a gallstone blocking the common bile duct would reduce the digestion of lipids in the small intestines.

(3 marks) (KA2)

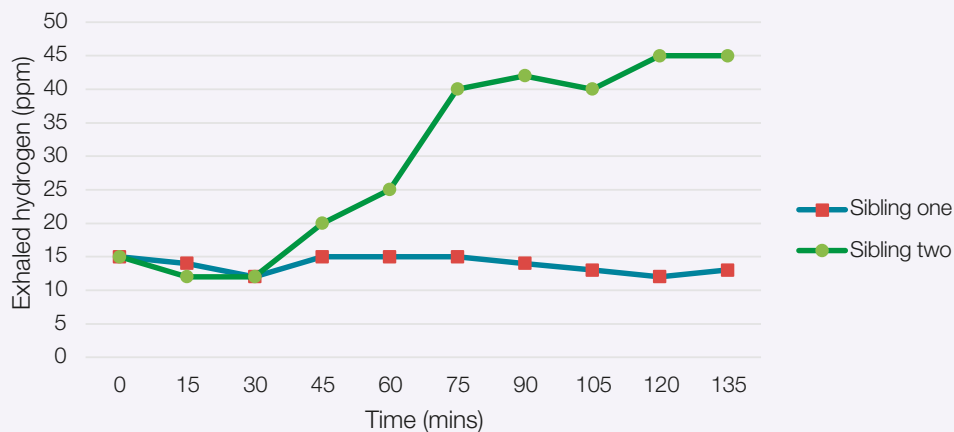
Total: / 60 marks

Case Study

Diagnostic Testing of Lactose Intolerance

Hydrogen gas is a product of the breakdown of lactose by bacteria along the gastrointestinal tract, and being a gas, this allows it to be absorbed into the bloodstream and then excreted by the lungs. Therefore, the hydrogen breath test (HBT), which measures the hydrogen gas excreted by the lungs, is a common method used in the diagnosis of lactose intolerance. After a solution containing lactose is ingested, hydrogen levels are monitored from the gas collected into a breathalyzer machine at intervals of 10-30mins over a period of a few hours. Generally, a rise of hydrogen over 20 ppm for 2 or more consecutive readings is an indication of lactose intolerance. The Women and Children's Hospital have returned the HBT test results of two siblings to their doctor as seen in the graph below.

The Results of the Lactose Hydrogen Breath Test (HBT)
over Time for 2 Siblings



With reference to the information and the graph above:

- Explain the results of the HBT to the 2 siblings, indicating if they have lactose intolerance.
- Discuss possible symptoms that the siblings may have been experiencing to warrant their referral to the hospital for HBTs and provide reasoning for symptom development.
- Describe possible dietary recommendations the doctor may provide to either sibling to reduce the risk of experiencing any lactose intolerant related symptoms.

(10 marks) (KA2)



Science as a human endeavour

Gut bacteria transplants could one day be used as a defence against Alzheimer's Disease.

Source: <https://inews.co.uk/news/science/gut-bacteria-transplants-defence-cognitive-decline-alzheimers-disease-675759>

Gut bacteria transplants could one day be used to protect against Alzheimer's disease after experiments in mice found they had a strong effect on the brain's cognitive abilities.

Researchers found that transplanting faeces between younger and older mice significantly altered the recipient's gut microbiome. This, in turn, affected their spatial learning and memory. The researchers hope that transplanting gut bacteria from younger patients to elderly ones could eventually be used to combat cognitive decline.

"Research has shown that the aging process may be linked with age-related changes in our gut microbiota," said David Vauzour, of the University of East Anglia.

"The existence of two-way communication between the gut and the brain – known as the 'gut-brain axis' has emerged as an important player in shaping aspects of behaviour and cognitive function."

"The procedure had an impact on the expression of proteins involved in key functions of the hippocampus - an important part of the brain that has a vital role in a variety of functions including memory, learning but also in spatial navigation and emotional behaviour and mood.

Prof Claudio Nicoletti, from the University of Florence, Italy, said: "While it remains to be seen whether transplantation from very young donors can restore cognitive function in aged recipients, the findings demonstrate that age-related shifts in the gut microbiome can alter components of the central nervous system."

"This work highlights the importance of the gut-brain axis in ageing and provides a strong rationale to devise therapies aiming to restore a young-like microbiota to improve cognitive functions and quality of life in the elderly," he added.

"Manipulating the microbiome is increasingly being seen as a way of improving or maintaining human health, and these results are an exciting indication of its potential for helping us age healthily" said Prof Arjan Narbad from the Quadram Institute.

1. Discuss how this example above, demonstrates the key concept of **Communication and collaboration**. Provide two clear examples from the example above.

(4 marks) (KA3)

? Science Inquiry Skills

Digestive Enzymes in Action

Introduction:

Amylase is a digestive enzyme found in saliva that begins the breakdown of starches into disaccharides in the mouth. It is present again in the small intestine to continue this function. Pepsin and trypsin are the enzymes required for proteins to be broken down into amino acids, working in the stomach and small intestine, respectively. For lipids to be effectively broken down, first bile works mechanically to disperse fat clumps into smaller fat droplets so that lipase can then work chemically to break apart the bonds of triglycerides into glycerol and fatty acids in the small intestine. An indicator such as hydrogen carbonate can be used to observe the breakdown of triglycerides into fatty acids, which causes a decline in the pH of the solution. Sodium carbonate, an alkaline solution, is added to hydrogen carbonate to raise its pH at first, causing a red purple colour. Hydrogen carbonate will then change colour from red purple to yellow as the pH lowers, as the production of fatty acids increases.

Materials:

- Savoury crackers, such as Jatz or Sao
- Cooked egg white
- 4x 10ml measuring cylinders
- 8x Test tubes
- 2x Test tube racks
- 1x 250ml beaker filled with warm water
- Marking pens and labels
- 1% pepsin solution
- 0.1M hydrochloric acid solution
- Lipase solution 2.5% (2.5g of Lipase powder to 100mL of distilled water)
- Olive oil
- Bile salts solution 5% (5g of bile salts powder to 100mL of distilled water) (or detergent)
- Hydrogen Carbonate Indicator (10mL of the concentrate to 90mL of distilled water; or no dilution needed if already-diluted solution used)
- 0.01M Sodium Carbonate solution
- Transfer Pipettes
- Distilled water
- Stop watches

Method:

PART A: carbohydrate digestion in the mouth

1. Put a small piece of a savoury cracker on your tongue.
2. Take observation of what you feel, as within a few seconds you should start to feel the cracker start to dissolve as amylase from your saliva begins to break down the starch of the cracker.

PART B: protein digestion in the stomach

1. Label four test tubes: W (water conditions), P (pepsin solution), A (acid solution), PA (pepsin and acid solutions)
2. Pour approximately 5mL of water into the test tube labelled 'W'.
3. Pour approximately 5mL of 1% pepsin solution into the test tube labelled 'P'.
4. Pour 5mL of 0.1M hydrochloric acid solution into the test tube labelled 'A'. **It is advised that gloves should be worn when handling acids.**
5. Pour equal amounts (2.5mLs) of 0.1M hydrochloric acid and 1% pepsin solution to a total volume of 5mL into the test tube labelled 'PA'.
6. Carefully place a small piece of egg white into each test tube.
7. Place all test tubes into a 250ml beaker filled halfway with warm water.
8. For 30 minutes, shake each test tube every 10 minutes gently to observe if any egg white specs can be seen. Record your observations at each 10-minute interval in the Part B data table on the next page.

? Science Inquiry Skills

PART C – lipid digestion in the small intestine

1. Label four test tubes: W (water conditions), B (bile solution), L (lipase solution), BL (lipase and bile solution).
2. Place approximately 2mL of olive oil into each of the 4 test tubes.
3. Add 1ml of 5% bile salts solution to each of the test tubes.
4. Add approximately 1.5mL of hydrogen carbonate indicator to each test tube.
5. Give each test tube a shake to mix the contents as much as possible. The oil will separate once it settles, so may need to be shaken again.
6. Starting with test tube 'W', add sodium carbonate drop by drop until the solution changes to a red purple colour. The colour does not need to be exact, just ensure it is no longer yellow. If it turns bright purple, you have added too much and will need to start this sample again. It is likely only a few drops will be needed. Gently shake to mix as best as possible.
7. Repeat step 6 for the remaining test tubes.
8. Add 2ml of distilled water to the test tube labelled 'W'. Gently shake as much as possible to mix well.
9. Add 2ml of Lipase solution to the remaining test tubes (labelled 'B', 'L' and 'BL'). Gently shake as much as possible to mix well.
10. Start the timer and keep observing the test tubes. You may need to periodically shake your test tubes to keep the oil mixed with the other solutions.
11. Take note of the colour change in each test tube over the length of the experiment (1, 2, 5, 10, 30mins) and record your results in the Part C data table.

Raw Data:

Table 1: Part B observations

Test tube	Observations		
	10 mins	20 mins	30 mins
W (water)			
P (pepsin)			
A (hydrochloric acid)			
PA (pepsin and acid)			

Table 2: Part C observations

Test tube	Observations				
	1 min	2 mins	5 mins	10mins	30mins
W (water)					
B (bile salts)					
L (lipase)					
BL (bile salts & lipase)					

? Science Inquiry Skills

Analysis and discussion:

1. Identify the test tube that showed the greatest protein digestion (egg white breakdown) and provide reasoning to explain your result.

2. Identify the test tube that showed the greatest triglyceride breakdown and provide reasoning to explain your result.

3. State the purpose of the 'W' test tube in the experimental procedures.

Extension Activities

1. Find out the length of your gastrointestinal tract by making the following measurement with a piece of string.

Digestive Organ	Instructions on how to Measure	Length (cm)
Mouth	Measure from the corner of your mouth to the midpoint of your ear	
Oesophagus	Measure from the bottom of your chin to the top of your folded arms	
Stomach	Spread the fingers of your hand and measuring the span from the thumb to the little finger	
Small Intestines	Measure your height and then multiply this by 4	
Large Intestines	Measure your height	
Rectum	Spread the fingers of your hand and measuring the span from the thumb to the little finger	
Total Length		

2. Research and explain what the following disorders are and how they can interfere with the absorption of nutrients.
 - (a) Irritable Bowel Syndrome (IBS)
 - (b) Crohn's Disease

3. Research and explain the term heartburn, and its cause.

4. Diffusion, facilitated diffusion and active transport are methods of transportation that may be used to assist with the movement of nutrients across the villi into the bloodstream or lymphatic system. Research and explain what the following transportation methods are and how they can assist with the movement of nutrients:
 - (a) Diffusion
 - (b) Facilitated diffusion
 - (c) Active transport

1.9 Imbalance of Nutrient Intake – Over Nutrition Disorders

Science understanding

Imbalance of nutrient intake is likely to cause diet related disorders, including obesity, type 2 diabetes, cardiovascular disease, and hypertension.

- Describe the signs/symptoms of diet related disorders.
- Explain why specific groups are at increased risk of a diet related disorder.
- Explain how a diet related health disorder could increase the risk of developing a second diet related health disorder e.g., obesity and cardiovascular disease.
- The role of diet and lifestyle in the prevention, control, and/or reversal of such disorders.
- Explain how the following dietary and lifestyle factors, including saturated fatty acids, unsaturated fatty acids, trans fatty acids, exercise, and fibre, can affect cholesterol levels and the risk of cardiovascular disease.

SACE Subject Outline, 2024.

Obesity

Obesity and being **overweight** are defined as abnormal or excessive fat accumulation that presents risk to an individual's health. An individual can be categorised as being overweight if they have a **Body Mass Index (BMI)** equal to or greater than 25. An individual with a BMI greater than 30 is considered obese, and a BMI greater than 35 is considered morbidly obese. The proportion of adults aged 18 years and over in Australia living with overweight and obesity has increased over time (as shown in figure 1.9.1).

Definition

Body Mass Index (BMI) is a diagnostic tool used to assess an individual's weight category, which is calculated by dividing their weight in kilograms by the square of their height in metres.

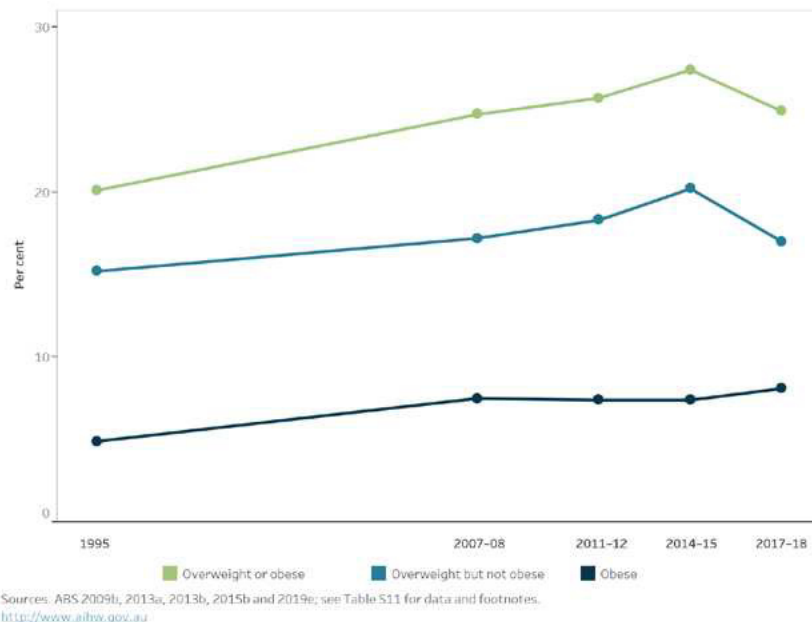


Figure 1.9.1: The increase in the proportion of overweight and obesity in Australians aged 18 and over from 1995 to 2017-2018 (ABS, 2018).

Fast fact

2 in 3 (67%) adults aged 18 and over are overweight or obese. This is equivalent to approximately 12.5 million adults. Of this number of Australians, 36% are living with overweight but not obesity, 31% are living with obesity and 12% are living with morbid obesity.

Signs & Symptoms

The more obese an individual is, the more likely they are to experience symptoms related to obesity. The most prevalent symptom experienced by individuals is visible fat accumulation. Fat can be stored in different areas around the body. In an **android** body shape, the individual will store the fat around his or her abdominal region. This type of body shape will have greater amounts of **visceral fat**, which is located between the organs, contributing to 'belly' fat. These individuals are labelled as having an apple-shaped body shape (as shown in Figure 1.9.2). In a **gynoid** body shape, excess fat is deposited around the hip and thigh regions of the body and is stored under the skin as **subcutaneous fat**. This body shape is labelled as being pear shaped and is more common in women (as shown in Figure 1.9.2). Other symptoms that an individual who is classified as being obese may experience include fatigue, joint pain, and shortness of breath.

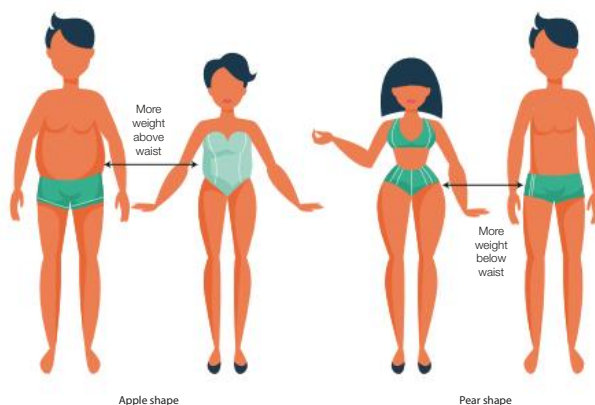


Figure 1.9.2: The different body shapes, which can result from excessive fat accumulation.

Nutrition Related Risk Factors

Energy intake exceeds energy expenditure

The most significant cause of obesity is if an individual has a **positive energy balance**, where the amount of food consumed supplies more kilojoules than the body is burning. When more energy is consumed than expended over a long period of time, the excess energy is stored in the fat cells of adipose tissue as triglycerides. The fat cells accumulate triglycerides and expand in size. When the cells enlarge, they stimulate cell reproduction, so their numbers increase also. Therefore, obesity is a result of increases in the size of fat cells in adipose tissue, as well as increases in the number of fat cells when energy-yielding nutrients are consumed in excess (as shown in Figure 1.9.3). Diets that contribute to this often consist of **energy dense** processed foods that are high in kilojoules and fat, increasing an individual's energy intake and high in simple sugars, which do not provide satiety leading to overeating.

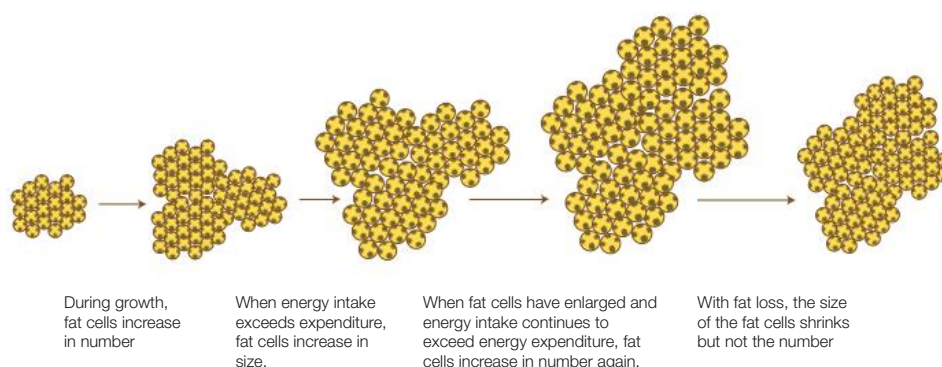


Figure 1.9.3: The development of fat cells when energy intake exceeds energy expenditure.

Fast fact

When energy expenditure exceeds energy intake, the size of the fat cells decreases, but not their number. Therefore, people with an average number of fat cells are more successful in losing weight.

Portion Sizes

One cultural practice that is commonly observed is the expectation that people will “clean their plates”, that is, eat everything served in a meal. The quantity of food on an individual's plate has become an indication of the amount needing to be consumed, rather than a person's hunger and satiety levels. Portion distortion or portion creep, refers to how we perceive the sizes of our food portions, compared to what they were like in the past. What is thought of as ‘normal’ today may very well have been thought of as a large serving in the past, which could be contributing to our growing waistlines. A contributing factor to this portion effect is the growing diameter of the average dinner plate (as shown in figure 1.9.4). As well as this, oversized portions occur when individuals eat out. We are commonly offered the same product in a range of sizes, causing us to think we are getting better value for money with a larger size or an upgrade. This is causing Australians to overeat and consume unwanted kilojoules, ultimately leading to weight gain.



Figure 1.9.4: The increase in the diameter of the average home dinner plate from 24.5cm in the late 1970s to 30.5cm today.

The Role of Diet in Prevention, Control &/or Reversal

The aim of weight loss is to ensure that the diet provides a negative energy balance where less energy is consumed than the body needs to maintain current body weight. It is essential that an individual's energy intake provides nutritional adequacy without excess. It is suggested that an individual reduces their energy intake by 2000–4000 kilojoules per day, producing a weight loss of up to 0.4–0.8 kilograms per week. However, an adequate diet is difficult to achieve on less than 5000 kilojoules a day.

A successful and well-balanced diet encourages an individual to meet the requirements of the Australian Guide to Healthy Eating (AGHE) which promotes the consumption of fruits, vegetables, wholegrains, lean meats, and low-fat milk products. An individual's diet should include nutrient dense foods, which are high in nutrients including vitamins, minerals, dietary fibre, and protein and low in kilojoules.

A plan that provides adequate nutrition supports healthier and more successful weight loss compared to restrictive fad diets, which are trendy weight loss plans that promise dramatic results. These diets are generally kilojoule restrictive and can discourage the consumption of an entire food group. Although, these diets will result in weight loss, both fat and muscle mass are lost. This is because the body is not supplied with sufficient energy, leading to the breakdown of muscle which provides the body with glucose to fuel its daily activities. However, the loss of muscle leads to a reduced basal metabolic rate (BMR). Therefore, if an individual returns to their old eating habits, excess weight will be gained due to their reduced BMR and energy requirements due to the loss of muscle tissue. This is why these types of diets are not recommended, as they are not sustainable, can create feelings of starvation and deprivation, and can lead to more weight gain in the long term.

Lifestyle & Physiological Related Risk Factors

Socioeconomic status

The highest rates of obesity are seen among groups with the lowest levels of education and income. Low socioeconomic areas experience rates of obesity and overweight burden that are 2.3 times greater than high socioeconomic areas (as shown in Figure 1.9.5). There are several factors that contribute to this difference, however families with a lower socioeconomic status generally have less access to foods that are nutrient dense such as fruits and vegetables, as they are more expensive per serving than energy dense processed foods. As well as this, groups with a low level of education and income have limited time, knowledge, and resources to engage in healthy eating and exercise.

Definition

Socioeconomic status refers to the social and economic position of an individual or group of individuals within society. For example, low socioeconomic status (SES) households have limited financial resources, lower levels of education and may be employed in low-paying or unstable jobs.

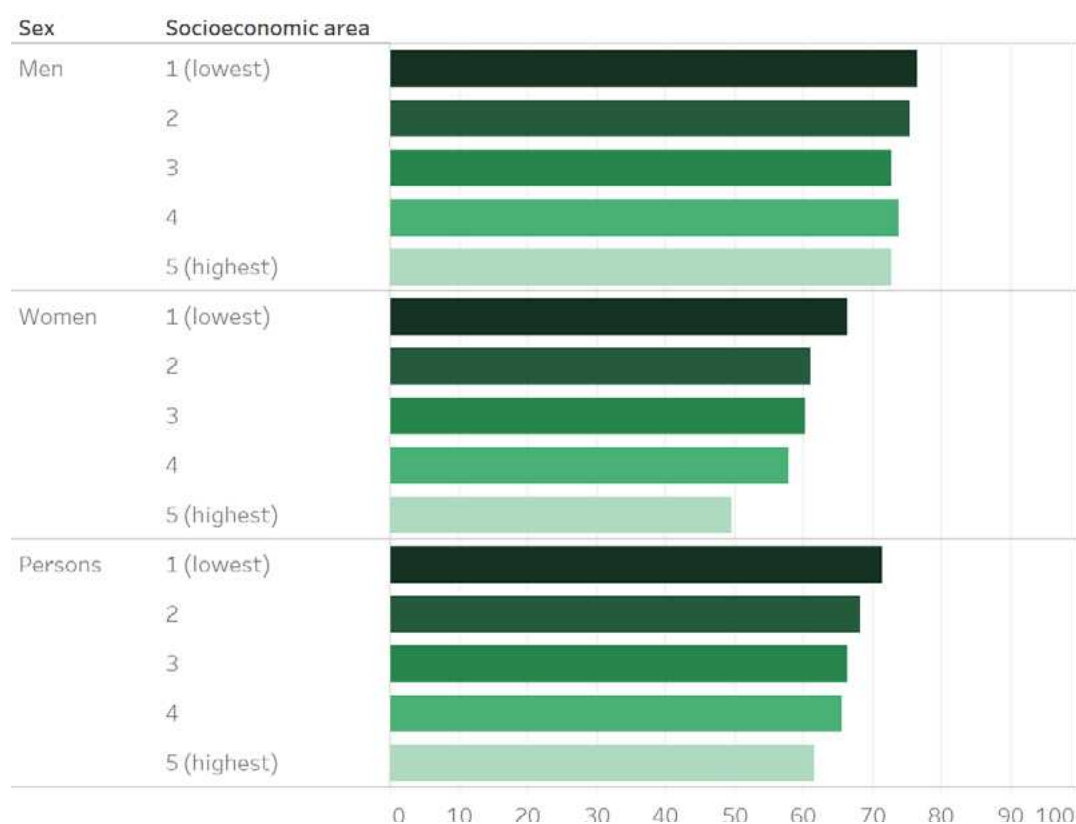


Figure 1.9.5: The proportion of Australian adults overweight or living with obesity by socioeconomic area, where 1 indicates a low socioeconomic status and 5 indicates a socioeconomic status in 2017-2018 (ABS, 2018).

Genetics

Most obesity cases are not caused by an individual's genes; in some cases, though, genetic influences can play a role in the development of obesity. Children whose parents are both obese have a higher risk of being obese when compared to children with non-obese parents. It is difficult to conclude if this correlation results from genetics or from diet and lifestyle habits that parents pass on to their children. However, an individual's genetic makeup can determine how their weight responds to certain diet and lifestyle factors and the rate at which they expend kilojoules (BMR); these genetic factors therefore influence a person's susceptibility to obesity. Some people are more likely to gain or lose weight when overeating or undereating, which contributes to differences in body weight within a population.

Definition

A gene is a segment of DNA inherited from a parent. It determines specific characteristics.

Sedentary lifestyle

Sedentary behaviour is being inactive, either sitting or lying down for long periods (except when sleeping). Sedentary behaviour can be due to factors such as physical limitations like injury or poor health, but is frequently linked to the overuse of technology, including television, video games, computers, and phones. These sedentary habits contribute to weight gain, as they require little energy above an individual's basal metabolic rate, which leads to a positive energy balance. Sedentary habits also replace time spent in more vigorous exercise and can promote the consumption of energy-dense foods (which are advertised on technologies used). **Physical inactivity** means not meeting the daily physical activity guidelines. The proportion of adults who meet the physical activity guidelines declines with age (as shown in figure 1.9.6). Therefore, sedentary behaviour and being physically inactive can result in weight gain and the development of obesity due to a reduced energy expenditure.

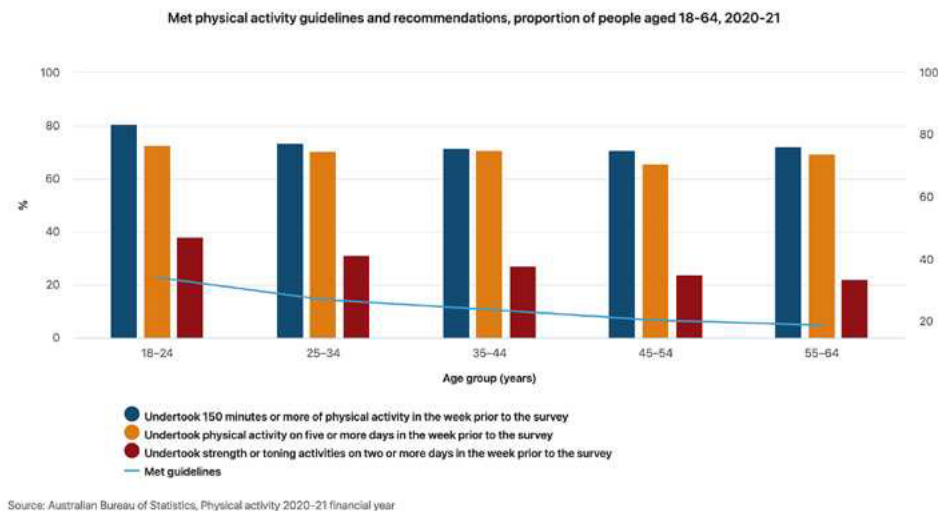


Figure 1.9.6: The proportion of adults aged 18-64 years who met the physical activity guidelines and recommendations in 2020-2021 (ABS, 2021).

The Role of Lifestyle in Prevention, Control &/or Reversal

People who combine dietary and lifestyle management strategies are more successful in losing fat, retaining, and gaining more muscle mass, and reducing the risk of regaining the lost weight.

Physical activity

The best approach to weight management or weight loss includes **physical activity**. Physical activity can take many different forms and can occur in the home, workplaces, or other environments. You can be physically active at different intensities including light, moderate and vigorous. Light activity involves actions you might not even think about, including strolling around the garden, getting dressed or stretching. Moderate activity may involve some effort, but is not strenuous, such as bike riding or going for a brisk walk. Vigorous activity can cause you to be out of breath and lead to sweating, such as jogging, star jumping or doing sit ups.

It is recommended that young people aged 15-17 years complete at least 60 minutes of moderate to vigorous intensity physical activity every day. It is also recommended that young people include strength or toning activities on at least three days per week. People aged 18-64 years should be active on most days of the week (at least five). It is recommended that this age group undertakes either 150-300 minutes of moderate intensity physical activity, or 75-150 minutes of vigorous intensity physical activity, or an equivalent combination of both. It is also recommended that people aged 18-64 years include strength or toning on at least two days per week. For adults aged 65 years and over, it is recommended that at least 30 minutes of physical activity is completed on most, preferably all days.

Exercise expends energy, therefore increasing an individual's energy expenditure can contribute to a negative or equal energy balance. As well as increasing an individual's energy expenditure, physical activity increases their basal metabolic rate too. Over the long term, a person who engages in daily vigorous activity will develop more lean muscle tissue. This causes an individual's basal metabolic rate to increase, as muscle tissue is a faster metabolising tissue than adipose (fatty) tissue. This is why physical activity is a necessary component of nutritional health, as it increases the amount of energy expended, which is vital for energy balance and weight management.

Diabetes Mellitus – Type 2 Diabetes

Diabetes mellitus describes a group of disorders, that are characterised by high blood glucose levels due to disordered insulin production. This may include insufficient insulin, ineffective insulin, or a combination of the two.

Insulin is a hormone produced by **beta (β) cells** in the **pancreas**; it tells the body's cells, namely muscle and liver cells, to receive glucose from the blood. After carbohydrates, except fibre, are consumed and digested, blood glucose levels rise, stimulating the pancreas to produce and release insulin into the bloodstream. Insulin then attaches to insulin receptors on the surface of body cells, triggering the cell to absorb glucose from the blood for energy production (or storage when energy needs have been met). This is illustrated in Figure 1.9.7. Therefore, insulin is often described as a 'key': as it unlocks muscle and liver cells to allow glucose to enter from the blood. In an individual with diabetes, this process is impaired, which causes blood glucose levels to remain high. The two main forms of diabetes mellitus are: type 1 and type 2, which develop differently but produce similar symptoms and complications.

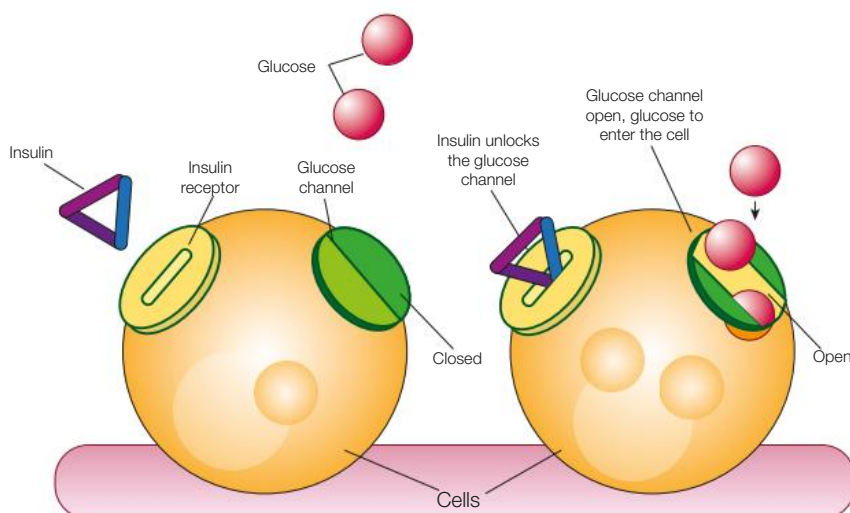


Figure 1.9.7: The role of insulin in managing blood glucose levels, by allowing glucose to enter the body's cells for energy production or storage.

Type 1 Diabetes

Type 1 diabetes is an autoimmune disorder in which the immune system mistakenly attacks and destroys the beta cells in the pancreas. The pancreas loses its ability to produce and release insulin, to sufficiently control blood glucose levels. Therefore, the blood's glucose levels elevate after consuming carbohydrates and remain high as the body's cells are not signaled to uptake glucose from the blood (as shown in Figure 1.9.8). In most cases, type 1 diabetes is inherited and commonly occurs in childhood and adolescence but can be diagnosed at any age. Type 1 diabetes is not caused by poor nutrition and lifestyle related factors and cannot be prevented.

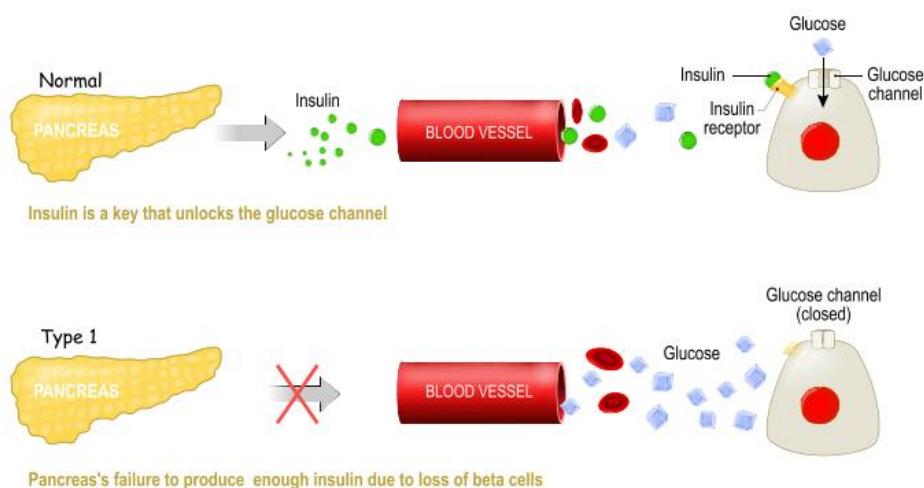


Figure 1.9.8: The effect of type 1 diabetes on blood glucose levels, due to insufficient insulin.

Type 2 Diabetes

Type 2 diabetes is a progressive condition in which the body's cells do not respond to insulin effectively (as shown in figure 1.9.9). This is also known as **insulin resistance**. To compensate, the pancreas secretes larger amounts of insulin to assist in managing blood glucose levels. However, over time the pancreas loses its capacity to compensate for the cell's insulin resistance, exhausting the beta cells of the pancreas and leading to a reduction in insulin production. Therefore, the high blood glucose levels associated with type 2 diabetes are generally caused by a combination of insulin resistance and insufficient insulin.

Although the cause of Type 2 diabetes is unknown, the risk of developing this disorder is increased by specific diet and lifestyle factors (which is why Type 2 diabetes will be the focus of this section). In most cases, Type 2 diabetes is diagnosed in adults over the age of 45 years but is increasingly occurring in younger age groups including children, adolescents, and young adults.

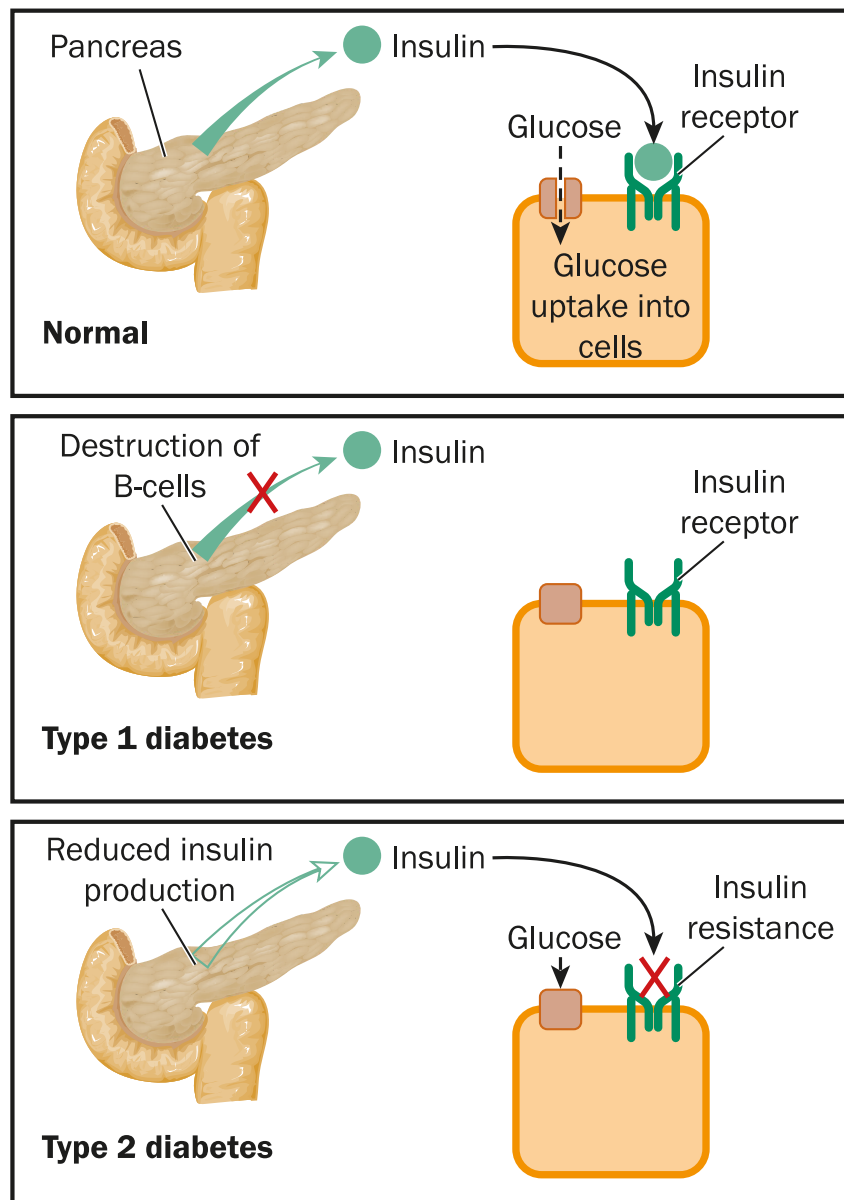


Figure 1.9.9: The management of blood glucose levels in a healthy (normal) individual, type 1 diabetic and type 2 diabetic.

Helpful online resources

Understanding Type 2 Diabetes

<https://www.youtube.com/watch?v=JAJZv41iUJU>



Signs & Symptoms

In type 2 diabetes, glucose slowly enters and/or fails to enter the body's cells and consequently accumulates in the blood. This causes blood glucose levels to remain elevated, which is known as **hyperglycaemia**. When glucose fails to enter the body's cells, this deprives them of energy, as glucose is a vital component in **cell respiration**. This leaves the body feeling fatigued, causing an increase in a diabetic's hunger levels. This hunger can then lead to excessive eating and weight gain.

Definition

Cell respiration is a metabolic process which converts oxygen and glucose into ATP (energy) and waste products.

As blood glucose levels continue to rise, the excess glucose must go somewhere. The kidneys filter our blood and produce urine. Glucose is normally reabsorbed into the blood at this point. However, a type 2 diabetic's unusually high blood glucose levels mean not all glucose can be reabsorbed. The excess ends up in urine. This process results in unusually large volumes of urine, which require more water, resulting in more frequent urination. This frequent urination can lead to dehydration and excessive thirst (as shown in Figure 1.9.10).

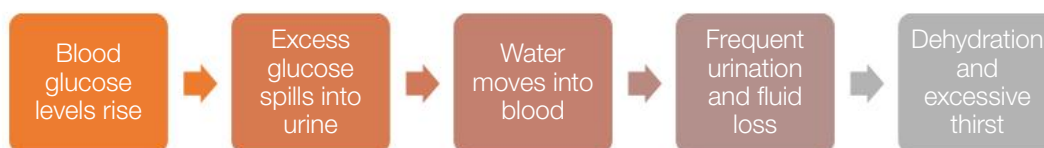


Figure 1.9.10: The development of frequent urination, dehydration, and excessive thirst in a type 2 diabetic.

Type 2 diabetes, that is not managed appropriately can also cause damage to the eyes. When blood glucose levels are high over a long period of time, fluid is drawn into the eye causing it to swell. This can cause blurred vision and can take up to six weeks for the swelling to reduce once blood glucose levels are managed. High blood glucose levels can also cause damage to the blood vessels behind the retina at the back of the eye. The walls of the blood vessels can become very thin and weak, causing blood, proteins, and fluids to leak into the eye, leading to further swelling and damage (as shown in Figure 1.9.11). This damage is known as retinopathy and can lead to permanent vision impairment, including blindness.

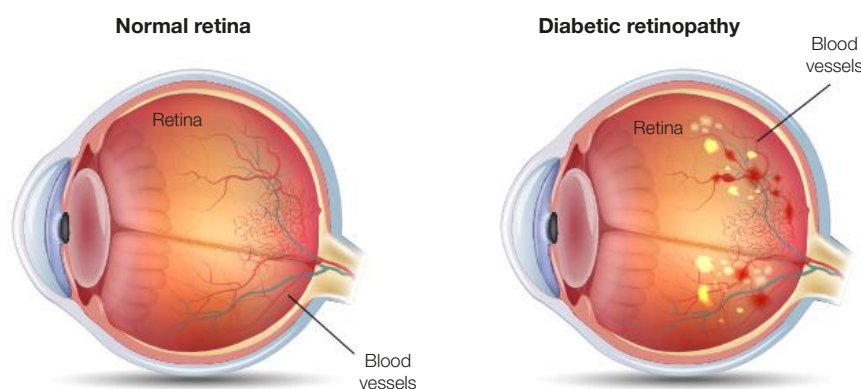


Figure 1.9.11: The effects of type 2 diabetes on the retina, causing the blood vessel walls behind the eye to become thin and weak allowing fluid, proteins, and blood to leak in.

The structures of blood vessels and nerves can also become damaged due to high blood glucose levels and the pressure placed against the nerves and blood vessel walls. This can lead to the loss of circulation and nerve function, which can be expressed as a painful prickling sensation followed by a loss of feeling in the hands and feet. Therefore, a type 2 diabetic is more prone to infection due to poor circulation and glucose-rich blood which provides suitable conditions for bacteria and fungi. Consequently, a diabetic must be cautious of hygiene, as undetected infections can lead to **gangrene**, which can require the amputation of the limbs (most commonly legs and feet).

Definition

Gangrene is the death of tissue due to insufficient blood supply.

Nutrition Related Risk Factors

Carbohydrates – simple sugars

Simple sugars have been found to have direct and indirect links to the development of type 2 diabetes. Simple sugars require little to no breakdown after they have been consumed; therefore, they move into the blood stream very rapidly. This causes a rapid rise in blood glucose levels and a consequential rapid energy release. Carbohydrates that produce this response are known to have a **high glycaemic index (GI)** (Figure 1.9.12). If a large portion of simple sugars are consumed at one time, this can elevate blood glucose levels significantly, stressing the beta cells of the pancreas. As well as this stress, an excessive consumption of simple sugars can contribute to the development of obesity, which is also a risk factor for this disorder.

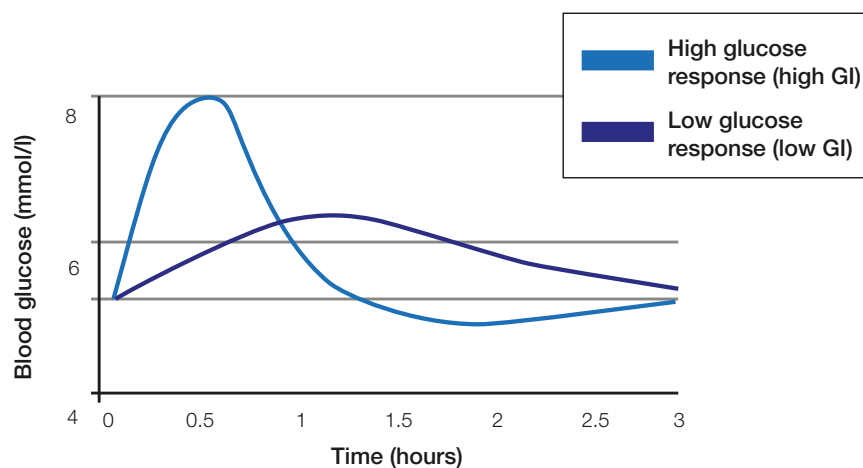


Figure 1.9.12: The effect of the glycaemic index (GI) of carbohydrate- containing foods on blood glucose levels over time.

Dietary Fat

A high consumption of dietary fat has been found to have a role in the development of type 2 diabetes. Foods that have a high fat content are energy dense (have a high kilojoule content). This increases the risk of fat accumulation in adipose tissue and can contribute to the development of an android body shape. This can put pressure on the pancreas, further compromising its ability to produce insulin. However, a high fat content in the bloodstream can also build up inside cells and can block the process whereby insulin signals for a cell's glucose channels to open and allow glucose to enter the cell. This increases insulin resistance and causes blood glucose levels to continue to rise.

The Role of Diet in Prevention, Control &/or Reversal

Carbohydrates

Carbohydrates have the biggest impact on blood glucose levels. The effect of carbohydrates depends on the amount and type of carbohydrate consumed. It is recommended that a type 2 diabetic spreads their intake of carbohydrates throughout the day to avoid causing large rises in blood glucose levels.

The **glycaemic index (GI)** is a scale from 0 to 100 (as shown in figure 1.9.13), which ranks foods based on their effect on blood glucose levels. Foods with a low GI are recommended for type 2 diabetics to consume at every meal, as they take longer to breakdown in the body releasing glucose slowly into the blood. This prevents pressure being placed on the pancreas to produce high amounts of insulin in the management of blood glucose levels. The glucose is also more likely to be used and less likely to be stored as triglycerides in adipose tissue when released slowly into the blood. Examples of low GI foods include traditional rolled oats, wholegrain breads, lentils, sweet potato, milk, yoghurt, and pasta which may be marked with the Glycaemic Index Foundation Symbol (as shown in figure 1.9.14). It is also recommended that, if high GI carbohydrates are consumed, they are best consumed with low GI carbohydrates and moderate amounts of high fibre, which aid in slowing down the absorption of glucose into the blood. However high GI foods should be consumed sparingly, such as lollies, soft drinks, cakes, muffins, biscuits, chocolates, potato chips, pastries, and ice cream.

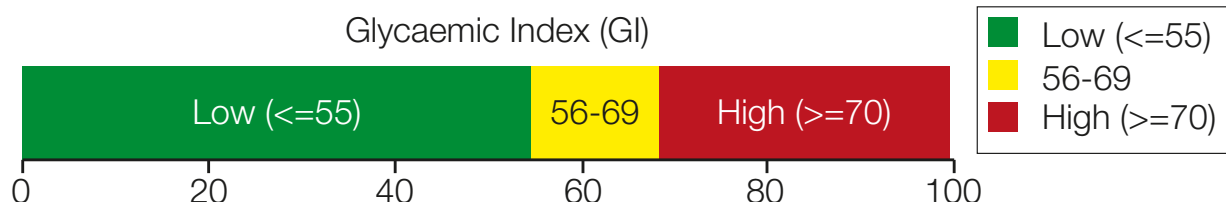


Figure 1.9.13: The Glycaemic Index (GI) rankings



Figure 1.9.14: The Glycaemic Index Foundation Symbol

GI rankings are becoming less relied on; it is the **glycaemic load** (GL) of food that is considered more valuable in predicting a food's effect on blood glucose levels. The GI only provides insight into how rapidly the carbohydrate can be broken down into glucose to affect blood glucose levels (its quality), but not how much of that carbohydrate is in a food serving (its quantity). Whereas the GL of a food represents the amount of carbohydrate in the food as well as its glycaemic index. For example, watermelon has a high GI, but it does not consist of a large amount of carbohydrates and therefore has a low GL. Therefore, the GL gives a more accurate account of the overall effect the carbohydrate food has on blood glucose levels as it considers both quality and quantity. The GL is a scale from 0 to 60 (as shown in figure 1.9.15) and will give similar blood glucose responses to the GI index: low GL will initiate low and sustained blood glucose levels, and high GL rankings will mirror the rapid and high blood glucose response. The GL can be calculated using the following formula:

$$\text{GL} = \frac{\text{Amount of Carbohydrates per serve (g)} \times \text{GI of Carbohydrate}}{100}$$

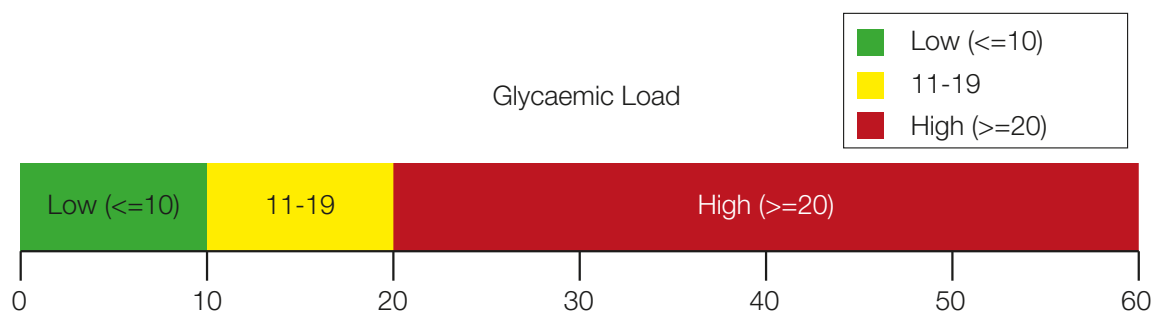


Figure 1.9.15: The Glycaemic Load (GL) rankings

Example

If a potato weighting 100g held 16g of carbohydrate, with a known GI rating of 90, its GL would be:

$$\text{GL} = \frac{16 \times 90}{100} = 14.4 \text{ (Medium GL)}$$

Dietary Fat

Fats provide the greatest energy (kilojoules), which is why it is important to limit fat consumption, as they can increase a person's risk of gaining weight increasing the risk of insulin resistance. Dietary fat intake can be reduced by:

- Choose reduced or low-fat milk, yoghurt, cheese, ice-cream, and custard.
- Choose lean meat and trim any fat off before cooking.
- Remove the skin from chicken, duck, and other poultry (where possible, before cooking).
- Avoid using butter, lard, dripping, cream, sour cream, copha, coconut milk, coconut cream and hard cooking margarines.
- Limit pastries, cakes, puddings, chocolate, and cream biscuits to special occasions.
- Limit pre-packaged biscuits, savoury packet snacks, cakes, frozen and convenience meals.
- Limit the use of processed deli meats (such as fritz, luncheon meat, chicken loaf, salami) and sausages.
- Avoid fried takeaway foods such as chips, fried chicken, and battered fish.
- Choose BBQ chicken (without the skin) and grilled fish instead.
- Avoid pies, sausage rolls and pastries.
- Rather than creamy sauces or dressings, choose those that are based on tomato, soy, or other low-fat ingredients.
- Limit creamy style soups.
- Eat small amounts of polyunsaturated and monounsaturated fats to help ensure you obtain the essential fatty acids and vitamins the body needs. These include sunflower, safflower, soybean, corn, cottonseed, grapeseed, olive, canola and sesame oils, oily fish such as herring, mackerel, sardine, salmon and tuna, and avocado.

Lifestyle & Physiological Related Risk Factors and Prevention, Control &/or Reversal

Physical inactivity

A sedentary lifestyle can result in a positive energy balance, which can lead to excess kilojoules turning into weight gain. As already mentioned, this can put pressure on the already compromised pancreas. A lack of exercise can also cause the body's cells to lose their sensitivity to insulin, increasing insulin resistance in the body. Physical activity also encourages the muscle cells to absorb and use glucose from the blood for cell respiration, reducing blood glucose levels. Therefore, physical activity can assist in the management of blood glucose levels (prevent them from spiking) and the risks associated with type 2 diabetes in several ways.

Alcohol

A lifestyle involving excessive alcohol consumption can cause inflammation of the pancreas leading to the destruction of the beta cells. This can cause the inability to produce enough insulin. As well as this, alcohol can reduce the body's sensitivity to insulin, resulting in insulin resistance. Finally, alcoholic beverages are energy dense and excessive consumption can contribute to weight gain, leading to being categorised as overweight or obese, which is associated with a higher risk of developing type 2 diabetes.

Genetics

Type 2 diabetes does not have a clear pattern of inheritance, unlike type 1 diabetes. However, those that are diagnosed with type 2 diabetes will often have at least one close family member, such as a parent, or sibling, who shares the same diagnosis. The risk of developing type 2 diabetes increases with the number of close family members affected. This increased risk is most likely due to shared genetic factors, which are linked to the body's ability to produce and respond to insulin. However, these genetic factors are also influenced by diet and lifestyle factors, which can be shared by family members, too.

Atherosclerosis & Cardiovascular Disease

The leading cause of **death and disease burden** around the world today are diseases of the heart and blood vessels, collectively known as cardiovascular disease (CVD). The different forms of CVD are usually caused by Atherosclerosis, which is characterised by the accumulation of lipids and other materials along the inner walls of the arteries.

1

Fast fact

According to the Australian Institute of Health and Welfare National Mortality Database, CVD was the underlying cause of 41,800 deaths in 2018 (26% of all deaths), where CVD kills one Australian every 12 minutes and affects one in six Australians.

Atherosclerosis

Atherosclerosis is the build-up of fatty deposits, forming plaques, which can lead to the narrowing and hardening of the arteries. The formation of plaque usually occurs against an injury or imperfection in an artery wall anywhere around the body, especially at a point where an artery branches, or divides. Arteries are the blood vessels that carry oxygenated blood from the heart to the body and to the heart itself from the lungs. Normally they are lined by a thin inner layer of cells called the **endothelium** (see Figure 1.9.16). The endothelium keeps the inside or lumen of arteries smooth, allowing for the easy passage of blood.

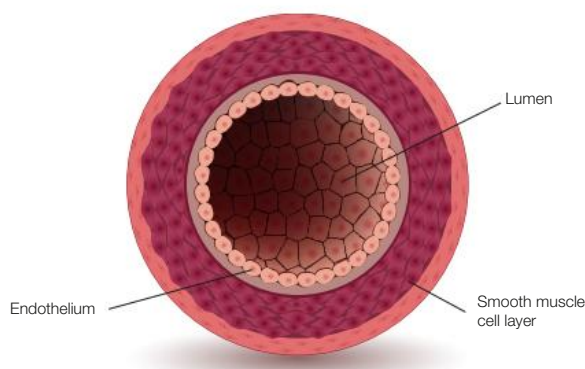


Figure 1.9.16: Endothelial lining of artery.

The exact cause of atherosclerosis is not yet completely understood. It is thought to begin when the endothelium lining is damaged by certain dietary and/or lifestyle risk factors, including high LDL cholesterol, hypertension, or toxins from cigarette smoking. Once damaged, the initial stage of atherosclerosis development is **low-density lipoprotein (LDL)** depositing into the artery walls and becoming entrapped. LDL entrapment in the artery walls may then trigger an inflammatory response, which activates the immune system. The immune system sends a type of white blood cell called a monocyte to 'clean up' the LDL cholesterol. The monocyte will convert into a white blood cell called a macrophage once it enters the endothelial cells. The macrophage will engulf the trapped LDL and become what is termed as a foam cell (see figure 1.9.17). These swell with large quantities of LDL cholesterol becoming trapped, and eventually become the cells of **plaque** (see Figure 1.9.18). Foam cells congregating together is what gives this early stage of atherosclerosis its appearance (under a microscope) as 'fatty streaks' (see Figure 1.9.17).

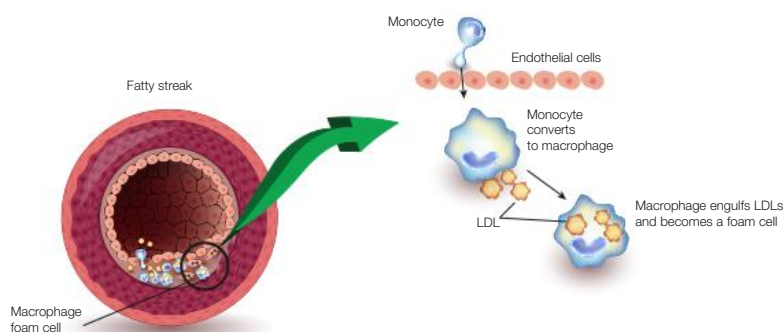


Figure 1.9.17: Fatty streak (foam cells) under artery endothelium lining (left) and foam cell formation (right).

Over many years, LDL cholesterol continues to embed in artery walls, causing foam cells to accumulate into larger deposits known as plaque or atheroma. The smooth muscle cells of the artery walls (as shown in figure 1.9.18) will move and stretch to allow for the growth of the plaque within the layers of the artery wall. This ensures the plaque does not impose on the inside (lumen) of the artery, allowing blood to remain flowing freely through the blood vessels. The muscle cells will also move and stretch to provide a protective thick layer called a fibrous capsule, which forms between the LDL cholesterol deposits and the artery lumen lining (as shown in figure 1.9.18). The fibrous capsule may remain thick and protect the lumen opening of the artery, becoming what is known as a stabilised plaque. This, however, is not always the case, and further plaque build-up may continue.

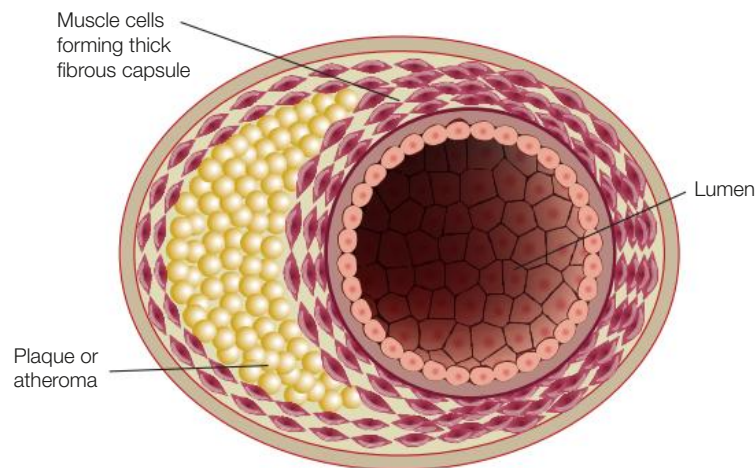


Figure 1.9.18: The formation of a stabilised plaque in the muscle cells of the artery.



Fast fact

No one is free of the fatty streaks, which may become the plaques of atherosclerosis. For most adults, the question is not whether you have plaques, but how advanced they are and what you can do to slow or reverse their progression. Most people have well developed plaques by the age of 30.

Plaque deposits can continue to build, again over many years, until the smooth muscle layer of the artery walls is distended to such an extent it begins to stiffen, unable to stretch further. Plaque growth will then begin to bulge into the lumen instead, imposing on the passage where blood flows through, and thereby narrowing the artery (as shown in figure 1.9.19). The narrowing of the arteries reduces the amount of blood that can flow through and deliver oxygen, glucose, and other nutrients to the cells. The narrowing of the arteries also increases blood pressure because there is less space in the lumen for blood to flow through.

Calcium flowing through the bloodstream may also be deposited in the plaque and calcify or harden, further causing the arteries to stiffen and harden, or lose flexibility and stretching ability. The growth of plaque into the inner artery also thins the protective fibrous capsule (Figure 1.9.19), leaving the atheroma or plaque vulnerable to rupture.

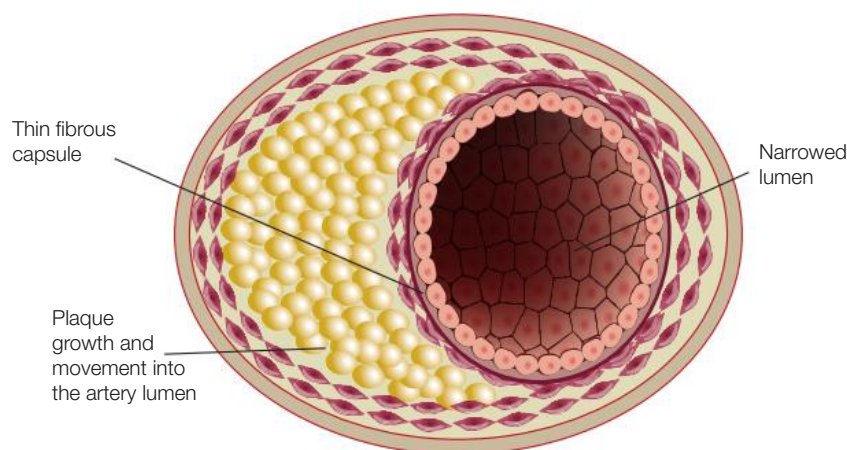


Figure 1.9.19 The development of a vulnerable plaque, at risk of rupturing.

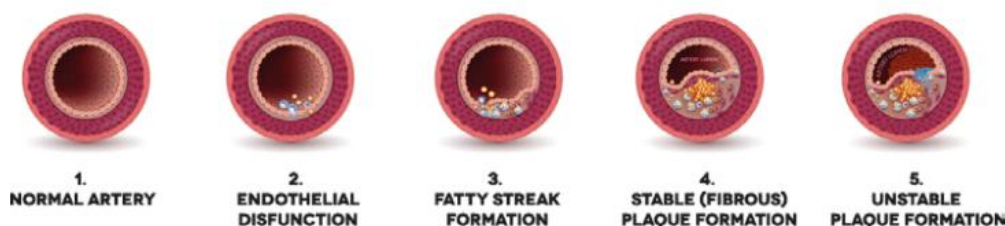


Figure 1.9.20: A summary of the development of Atherosclerosis.

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Helpful online resources

Development of atherosclerosis

<https://youtu.be/Kbz70treoSI?si=5llzDKQqYAW7LzAc>

How lipid plaques form in the walls arteries

<https://youtube.com/watch?v=N33JsBeziEY>



Cardiovascular Disease (CVD)

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. CVD occurs when a vulnerable plaque (as shown in figure 1.9.19 and step 5 of 1.9.20), found in the later stages of atherosclerosis, ruptures. When a plaque ruptures, a blood clot (or thrombus) will form over the ruptured area. This can result in a blockage of blood flow (see Figure 1.9.21). Atherosclerosis can also result in an aneurysm by weakening and damaging the blood vessels. An aneurysm is a bulge in a blood vessel that can burst and lead to internal bleeding (see Figure 1.9.22). As the blood supplies nutrients, oxygen and, therefore, energy, and removes waste products away from the tissues, a blockage or ruptured aneurysm can result in malfunctioning and death of the region of the body the artery was supplying blood to.

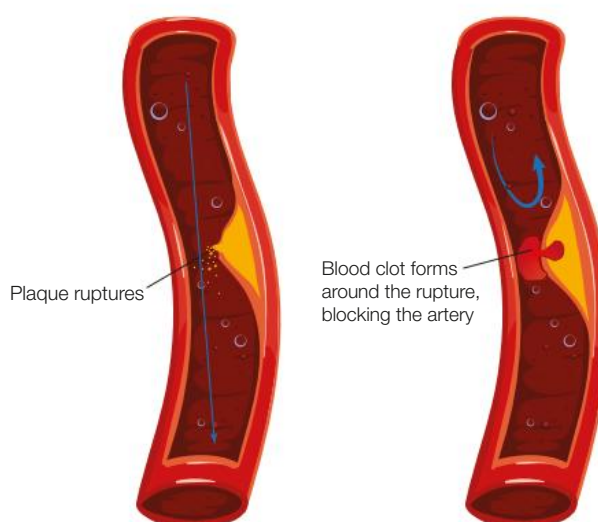


Figure 1.9.21: Vulnerable plaque rupturing (left) and clot formation (right).



Figure 1.9.22: Weakened, bulging artery wall (aneurysm) from atherosclerosis.

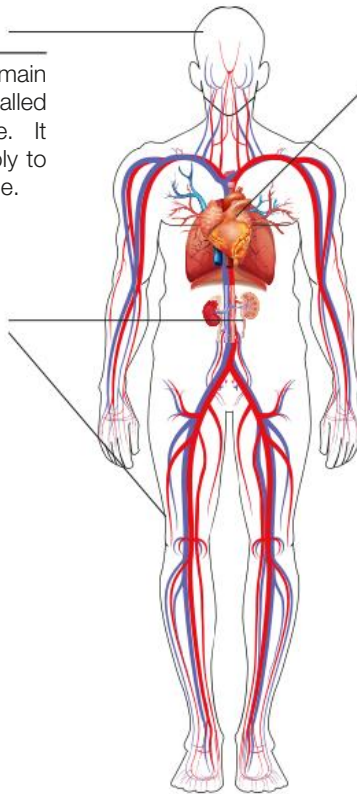
Atherosclerosis can develop in any artery around the body, thereby a rupture and blockage or aneurysm can result in several different diseases that are categorised dependent on the region of the body affected. These diseases are all classified as types of CVD (including those displayed in Figure 1.9.22).

Stroke

There are many types of strokes; the main type connected to atherosclerosis is called a thrombotic (or ischaemic) stroke. It involves a blockage of the blood supply to the brain, often leading to brain damage.

Peripheral vascular disease (PVD)

PVD involves the arteries other than those supplying the brain and heart. It mainly affects blood vessels to the legs (causing gangrene) and kidneys (resulting in chronic kidney disease, CKD).



Coronary heart disease (CHD)

CHD involves the blood vessels supplying blood to the heart: the coronary arteries. The two major forms of CHD are heart attack and angina. A heart attack is caused when blood supply to the heart along a branch of the coronary artery is blocked, causing damage to part of the heart muscle and its ability to function. Angina is caused by a temporary shortage of blood supply to the heart.

Figure 1.9.23: Types of CVD that arise from atherosclerosis (plaque rupture).



Helpful online resources

What happens during a heart attack?

https://youtu.be/3_PYnWVoUzM?si=zfxPY6NkHjVD36A6



What happens during a stroke?

<https://youtu.be/-NJm4TJ2it0?si=u7Ojm4w9K1a9lxwf>



Signs & Symptoms

Atherosclerosis does not have symptoms for many years because the arteries will stretch where plaque deposits occur, ensuring there is no effect on blood flow. It is only when severe narrowing or blockage impedes blood flow that symptoms are felt. At this stage, the narrowing or blockage is typically because a cardiovascular disorder has occurred.

Most of the symptoms associated with each type of CVD indicate that a cardiovascular event is happening. These warning signs should be taken seriously and in many instances an ambulance should be called.

Stroke

When part of the brain dies due to a stroke, it can lead to a sudden impairment in one or more capabilities such as speaking or movement. The symptoms that emerge when a stroke is happening may involve:

- drooping or numbing of the face, particularly on one side
- poor mobility or weakness of arms, uncoordinated movement, or even paralysis of limbs
- slurred speech
- loss of vision or blurred vision
- sudden severe headache.

Coronary heart disease (CHD)

Angina will appear as temporary chest pain during periods of exertion that require additional blood to be pumped to the heart, such as during exercise. The symptoms of a heart attack typically occurs when the coronary artery becomes blocked due to atherosclerosis (as shown in figure 1.9.24), which include:

- chest pain and further upper body pain, e.g., the shoulders and neck
- feeling faint and short of breath
- feeling nauseous
- having cold sweats.

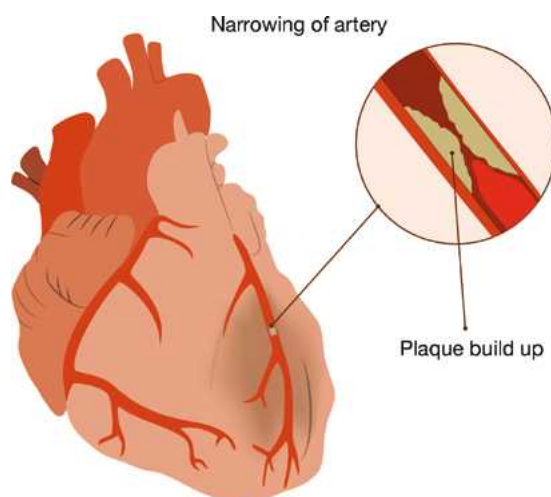


Figure 1.9.24: The plaque build-up caused by atherosclerosis, causing a heart attack, and reducing the supply of oxygen and glucose to the area shaded in grey.

Peripheral vascular disease (PVD)

The symptoms of PVD are dependent on the region of the body affected. When the renal arteries that supply the kidney suffer a blockage, chronic kidney disease (CKD) can be the result. Like most other types of CVD, kidney disease will have few to no symptoms until the kidneys lose most of their functioning ability. The symptoms that may be experienced include:

- changes in urination frequency or pain/blood with urination
- swollen ankles (due to salt/water retention with impaired kidney function)
- back pain (around the kidney area).

If an artery supplying blood to the extremities (typically the legs) is blocked, gangrene can result (see figure 1.9.25). Before gangrene (tissue death) sets in as a sign of PVD, symptoms that can emerge are:

- pins and needles and/or numbness
- intermittent cramp-like pain or heaviness in limbs known as claudication
- poor wound healing of the affected region.



Figure 1.9.25: Gangrene is seen when there is death of the tissues of the extremities.

Nutrition Related Risk Factors

The risk factors that may damage the artery endothelial lining, thereby permitting LDL to deposit and atherosclerosis to develop, can be categorised as either nutrition or lifestyle related risk factors. There are several nutrition related causes of atherosclerosis, which are the same for CVD due to it being a precursor to this diet related disorder.

Cholesterol

Cholesterol from the diet is transported by lipoproteins due to being very slightly soluble in water and blood. Any LDL cholesterol that remains in the blood after the body's cells take up the amount they need, becomes vulnerable to depositing in the artery walls at damaged sites. Therefore, **high LDL and low HDL** correlate directly with atherosclerosis, whereas low LDL and high HDL reduce the risk of the development of this disease. However, cholesterol in food has only a small effect on LDL levels in the blood. Saturated fat and trans-fat pose much greater risks to elevated blood cholesterol (LDL) levels.



Fast fact

Total blood cholesterol levels should not exceed 5.5mmol/L for the general population, and 4mmol/L for individuals at high risk. The proportion of LDL cholesterol should be less than 1.8mmol/L and HDL should be greater than 1mmol/L. These levels can be determined with a blood test.

Saturated Fat

Consumption of foods that are high in saturated fat significantly increases the liver's production of very low-density lipoprotein (VLDL), the precursor to LDL. This increase in VLDL will therefore end up raising LDL cholesterol in the blood, a risk for atherosclerosis.

Trans-fat

By a similar means to saturated fat, a diet high in trans fats will markedly elevate LDL blood cholesterol levels, increasing the chance of LDL becoming plaque deposits. Furthermore, trans fats can lower high-density lipoprotein (HDL). Therefore, trans fat can reduce the amount of LDL cholesterol cleared by HDL.

Unsaturated Fat

Fat consumption should be limited to no more than 30 per cent of an individual's energy intake. Of this percentage, most should come from mono- and poly-unsaturated fats. When a higher proportion of overall fat is unsaturated fat, saturated fats' effect on the liver's 'bad' cholesterol production is limited, thereby LDL levels drop. A higher proportion of unsaturated fats (particularly a good balance of omega 3 and 6), has also been found by some studies to help raise HDL. Therefore, a diet low in monounsaturated and polyunsaturated fat is a dietary risk of atherosclerosis.

Triglycerides

Fat consumption beyond the recommended 30 per cent, results in high blood triglycerides, which is called hypertriglyceridemia. Recent studies are finding that lipoproteins carrying triglycerides can also be found in plaque deposits, therefore hypertriglyceridemia is, like LDL, a direct cause of atherosclerosis. Hypertriglyceridemia has also been found to promote foam cell formation and therefore plaque development.

Simple Sugars

Consuming foods with a high glycaemic index (GI) and glycaemic load (GL), especially foods high in **refined sugar**, have been found to increase LDL by promoting the liver's production of VLDL. Fructose, a monosaccharide composed of refined sugar and a constituent of many foods with a high GI and GL, has been linked strongly with this finding, as it requires metabolism in the liver, the organ that produces VLDL. Foods with a high GI and GL have also been found to decrease HDL.



Definition

When foods have added table sugar (sucrose), for example, cake, the sugar is referred to as refined sugar.

The Role of Diet in Prevention, Control &/or Reversal

Plaque development can be regressed at any stage, even when plaque has become calcified in its later stages. Dietary management is therefore of importance in managing atherosclerosis and preventing CVD.

Cholesterol

Although cholesterol in food only has a small effect on LDL cholesterol levels, it is important to choose foods which reduce blood cholesterol levels to prevent excess from depositing in the artery walls. This can be managed through the following dietary choices:

- Include garlic in the diet, which has been shown to lower blood cholesterol by reducing its synthesis and absorption.
- Use margarines that contain plant sterols that are like cholesterol but are made in plants. Plant sterols disallow cholesterol to be absorbed into the bloodstream,
- Consume foods high in soluble fibre, including fruits, vegetables, oats, legumes, and wholegrains. Soluble fibre binds to cholesterol in the intestines, preventing it from being absorbed into the bloodstream.

Dietary Fat

A diet high in saturated fat and trans-fat, and low in monounsaturated and polyunsaturated fats increases LDL cholesterol levels in the blood. Therefore, to reduce LDL cholesterol levels in the blood and increase HDL cholesterol levels, it is important to swap saturated and trans-fats with unsaturated fats, which can be done through the following dietary management:

- Replace red meat with oily fish high in omega 3, e.g., salmon, herring, sardines, tuna, trout, and mackerel.
- Trim off visible fat off meat before cooking.
- Remove the skin from chicken or turkey before cooking.
- Choose lean cuts of meat, including loin pork and beef.
- Cook with vegetable oils, e.g., olive, and sunflower oils instead of butter.
- Replace some energy-dense snacks like hot chips, ice-cream, and cheese with nuts and seeds.
- Replace full-cream milk with low fat alternatives such as skim, almond, and soy milk.
- Replace butter with margarine.
- Replace highly processed meats used in sandwiches with avocado, tahini spread or vegan cheese (soy).
- Avoid deep fried foods.
- Instead of frying, bake, roast, steam, or boil foods.

Carbohydrates

Carbohydrates with a high GI and GL can increase LDL cholesterol levels in the blood and decrease HDL. Therefore, it is recommended that individuals increase their consumption of carbohydrates with a low GI and GL to avoid this from occurring.

As well as this, carbohydrates with a low GI and GL, are generally a source of soluble fibre also which further reduces LDL cholesterol levels in the blood. Soluble fibre can bind to cholesterol (from food consumed or from bile) and dispose of it through defecation. This can contribute to less cholesterol entering the bloodstream, lowering LDL. Soluble fibre is also associated with slowing initial digestion via the stomach emptying into the duodenum, allowing for a slower absorption of monosaccharides (including glucose) into the bloodstream. Soluble can therefore lower the GI and the blood glucose effect of foods high in simple sugars.



Reminder

Bile is made in the liver from cholesterol taken from either LDL or HDL.

Cholesterol from the diet or unused bile will become the cholesterol in LDL.

The following dietary strategies will increase an individual's consumption of low GI and GL carbohydrates:

- Replace processed snacks, e.g., potato chips, with more fruit and vegetables.
- Replace heavily processed cereals, e.g., Froot Loops, with wholegrain cereals, oats.
- Add legumes to the diet.
- Replace energy-dense snacks like confectionery and biscuits, and heavily processed foods like cereals and cereal bars (that aren't made with wholegrain) with high fibre sources.
- Look for foods marketed as low GI.

Lifestyle & Physiological Related Risk Factors and Prevention, Control &/or Reversal

With atherosclerosis being the precursor to CVD, the lifestyle and physiological risk factors, and management is the same. Many of these risk factors can be modified, making atherosclerosis a disease precursor that should not be as predominant as it is.

Overweight / Obesity

The excessive storage of visceral fat is linked to high blood triglyceride levels (hypertriglyceridemia), high LDL levels and insulin resistance. Obese people also tend to have lower levels of HDL and are at further risk of type 2 diabetes.

Sedentary Lifestyle

A sedentary lifestyle can contribute to the development of atherosclerosis in several ways. A lack of exercise can result in a positive energy balance, with excess kilojoules being stored and leading to weight gain, therefore, increasing the risk of obesity. A lack of exercise can also result in higher blood triglyceride levels (hypertriglyceridemia), as well as lower levels of HDL and higher levels of LDL. Individuals who live a sedentary lifestyle may also have poor blood glucose control and insulin resistance, increasing risk of type 2 diabetes and high blood pressure.

Hypertension

High blood pressure injures the artery endothelium via the sheer force of blood pushing through the arteries. This accelerates plaque formation, thus initiating or worsening the progression of atherosclerosis. The formation of plaque and the narrowing of arteries causing reduced blood flow can further elevate blood pressure.

Smoking

Cigarette **smoking** is a significant risk factor that increases the more a person smokes and is the same for men and women. Drugs in cigarettes can damage the endothelial lining of arteries and cause plaque deposits to grow larger and faster. Cigarettes contain nicotine, which increases blood pressure causing the heart to work harder. As well as this, cigarettes contain carbon monoxide, which is a gas that replaces the oxygen needed by the heart and body for aerobic respiration. When people quit smoking, their risk of atherosclerosis and CVD declines within a few months.



Fast fact

Smoking increases the risk of heart attack by two times, stroke by three times, and PVD (leading to gangrene) by more than five times! Source: <https://www.betterhealth.vic.gov.au/health/HealthyLiving/smoking-and-heart-disease>

Type 2 Diabetes

Ineffective movement of blood glucose into cells, due to insulin resistance or poor insulin production, leaves glucose and insulin levels high in the blood. Both high blood glucose and insulin levels can elevate blood pressure, causing damage to the artery endothelial layer thereby promoting LDL deposition. The longer an individual has had diabetes, especially if uncontrolled, the greater the risk of damage to the blood vessels.

Age

Atherosclerosis steadily progresses with age, as ageing leads to the loss of elasticity or flexibility of the arteries, subsequently resulting in a greater risk of damage to the endothelial layer. This enhances the risk of LDL deposition and the formation of plaque, which leads to the expansion into the artery lumen rather than the growth within the artery wall.

Gender

Men have a greater risk of CVD, commonly developing symptoms at the age of 45, whereas CVD occurs in females approximately 10-15 years later than in men. This difference can be explained by elevated LDL levels and blood pressure in men and lower levels of HDL, as well as the tendency for males to store excess weight around the abdomen (android shape), giving this gender a greater risk of atherosclerosis.

Gender LDL and HDL differences are mainly due to men having low concentrations of the hormone oestrogen in the blood. Therefore, they have lower protection from damage to the functioning of the endothelial cells offered by this hormone. As naturally occurring oestrogen levels gradually taper off during menopause in females, their risk of atherosclerosis increases.

Genetic predisposition

Family history of early heart disease (before the age of 55 if male and 65 if female) increases the risk of atherosclerosis. The more family members affected and the earlier the age of onset, the greater the risk. Genetics and ethnicity can also play a part in blood LDL and HDL levels.

Hypertension

Blood pressure is the pressure the blood exerts against the arterial walls during and between heart beats. During heart beats, when the heart muscle is contracting and pushing blood through the arteries to the body, the blood pressure reading is called **systolic blood pressure**. Between heart beats, when the heart muscle is relaxing and filling with blood, the blood pressure reading taken is called **diastolic blood pressure** (see Figure 1.9.26). This pressure is typically measured in Millimetre of mercury (mmHg).

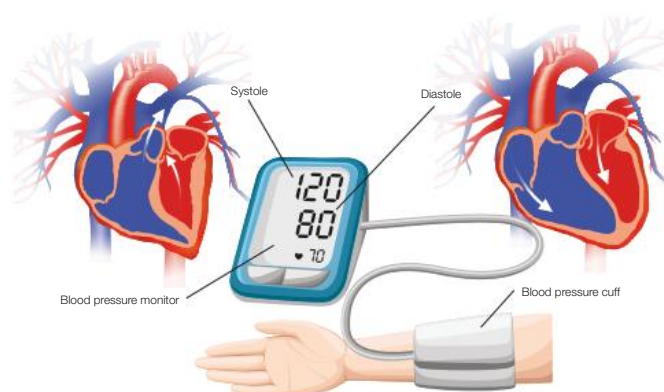


Figure 1.9.26: Blood pressure reading being taken at systole (when the heart is contracting and pushing blood around the body, see heart on the left) and diastole (when the heart is relaxing and filling with blood, see heart on the right).

Normal blood pressure is around 120mmHg for the systolic pressure and 80mmHg for the diastolic pressure (written 120mmHg/80mmHg). When investigating if blood pressure is normal, blood pressure readings are obtained when the body is relaxed. Blood pressure is dependent on the amount of blood being pumped away from the heart, and how easily the blood can flow through the arteries. When the volume of blood being pumped by the heart and the resistance blood encounters in the arteries increases, blood pressure rises. However, systolic changes that are temporary (e.g., during exercise or a stressful situation) are not necessarily concerning. It is when systolic pressure tends to remain at 140mmHg or higher, and diastolic pressure measures at or above 90mmHg, that high blood pressure or **hypertension** is diagnosed (see Figure 1.9.27). Raised blood pressure indicates that blood is not flowing easily through the arteries, which can stiffen and damage the arterial walls promoting plaque formation and the narrowing of arteries. This can increase blood pressure further as narrow arteries increase the resistance to blood flow.

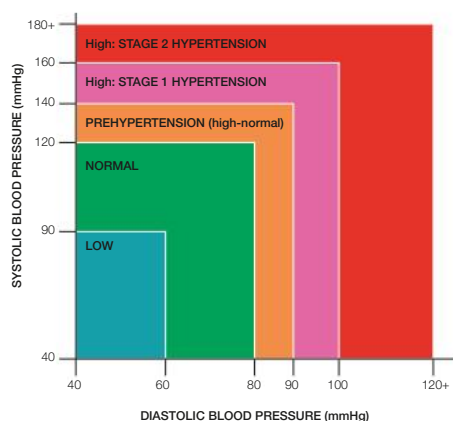


Figure 1.9.27: Blood pressure chart.

Signs & Symptoms

Most people with high blood pressure have no symptoms. A few people with very high blood pressure may experience symptoms such as headaches, dizziness, facial flushing, nosebleeds, blood in urine, chest pain or blurred vision. For most people, it is only when the effects of hypertension lead to a cardiovascular event, such as a heart attack, that symptoms are felt (see Atherosclerosis and CVD symptoms section).

Nutrition Related Risk Factors and Prevention, Control &/or Reversal

The dietary risk factors for hypertension involve the imbalance of nutrients associated with atherosclerosis as well as excess sodium or salt. The main reason for blood not flowing easily through the arteries, leading to heightened blood pressure, is atherosclerosis. Therefore, all nutrition related risk factors and management of atherosclerosis previously mentioned are also behind the development of hypertension occurring and its prevention.

Sodium

Blood pressure is dependent on the amount of blood being pumped through the arteries. When **blood volume** increases, blood pressure increases. Therefore, dietary factors that increase blood volume, namely eating too much salt, pose additional risks for high blood pressure. **Excess salt** in the diet raises the amount of sodium in the bloodstream. Elevated sodium in the bloodstream can then increase blood volume due to retaining water to dilute the sodium in the blood. This causes an increase in blood volume, resulting in higher blood pressure. Should salt be continually high in the diet, the artery walls will become stronger and thicker to cope with the extra strain of pushing a higher blood volume through the arteries. A consequence of the artery walls becoming thicker is that the opening (lumen) of the artery will narrow over time. The narrower the artery, the greater the blood pressure will be. Another consequence is hypertension, which can lead to atherosclerosis due to the damage this higher blood pressure can cause to the endothelium of the artery walls.



Fast fact

Most Australian adults have a daily salt intake of around 10 grams – twice the suggested target of 5 grams! Advice from The National Health and Medical Research Council (NHMRC).

Table salt is composed of sodium chloride and added to flavour and preserve foods. Therefore, many processed foods contain salt, including bread, cereals, ham, salami, pasta sauces, canned soups, pretzels, sauces, and chips. Therefore, a diet low in processed foods will reduce an individual's sodium intake. Other daily strategies to reduce our daily sodium intake can include:

- Avoid adding salt while cooking.
- Use garlic, herbs, spices, lemon juice or vinegars to flavour food instead.
- Avoid placing the saltshaker at the dinner table to stop adding salt to food.
- Avoid naturally salty foods including salted nuts, canned foods, cured meats etc.
- Check the food label and choose foods labelled with low salt, salt reduced or no added salt.
- Cook your own food, rather than purchasing takeaway or prepackaged meals.

Lifestyle Related Risk Factors and Prevention, Control &/or Reversal

With atherosclerosis being a cause of hypertension, the lifestyle risk factors, and management covered earlier are valid for high blood pressure as well.

Smoking

Smoking is a major risk factor, as nicotine found in cigarettes constricts blood vessels (including those in the skin and coronary blood vessels) causing them to narrow. Therefore, smoking is a vasoconstrictor, which narrows the blood vessels increasing the pressure the blood exerts against the arterial walls; thus, increasing blood pressure.

Physical Activity

Regular physical activity can reduce blood pressure by making the heart stronger, which allows it to pump blood through the arteries easier. This reduces the risk of high blood pressure.

Stress

Chronic stress can increase blood pressure due to the release of stress hormones. These hormones activate pathways that increase heart rate and blood pressure as a way of helping your body cope with the situation.

Key terms

Android Body Shape	Glycaemic index	Overweight
Atherosclerosis	Glycaemic load	Pancreas
Beta cells	Gynoid Body Shape	Peripheral vascular disease
Blood volume	High density lipoprotein (HDL)	Physical activity
Body Mass Index	Hyperglycemia	Plaque
Cardiovascular disease	Hypertension	Portion distortion
Cell respiration	Insulin	Positive energy balance
Coronary heart disease	Insulin resistance	Sedentary
Diabetes mellitus	Low density lipoprotein (LDL)	Stroke
Diastolic blood pressure	Negative energy balance	Subcutaneous fat
Endothelium	Nutrient dense	Systolic blood pressure
Energy dense	Obesity	Type 2 diabetes
Fad diets		Visceral Fat

Review questions: 1.9 Imbalance of Nutrient Intake – Over Nutrition Disorders

1. Identify the body type of the following individual, and the type of fat that predominately makes up this body shape.

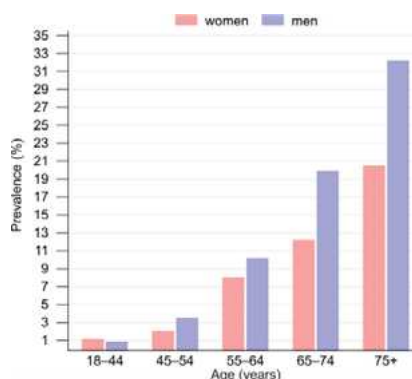


(2 marks) (KA1)

2. Explain the term 'insulin resistance'.

(2 marks) (KA1)

3. An investigation into the prevalence of self-report cardiovascular disease (CVD) in adults was undertaken in Australia. The results of the investigation are shown in the graph, which demonstrates the prevalence of self-reported heart, stroke and vascular disease by age group and gender between 2017-2018.



- (a) State one similarity and one difference in the data for men and women.

Similarity:

Difference:

(2 marks) (IAE3)

(b) State the dependent variable in this investigation.

(1 mark) (IAE1)

(c) Explain why it is important to ensure that investigations such as this one include a large sample size.

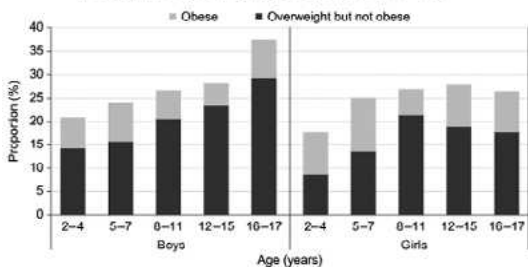
(2 marks) (IAE3)

(d) Identify one factor and explain how it could contribute to the difference in the prevalence of self-reported cardiovascular disease cases between men and women.

(3 marks) (KA2)

4. The proportion of children and young people who were overweight or obese, and those not meeting the recommended amount of daily physical activity were recorded between 2014-2015 and shown in the graph and table below.

Proportion of overweight and obese children and young people, by gender, 2014–15



Proportion of children and young people not meeting the recommended amount of daily physical activity, 2014-15

Age (years)	Proportion %
2-5	39%
5-12	74%
13-17	92%

(a) State one trend in the proportion of children and young people who are overweight and obese that is visible in the graph above.

(1 mark) (IAE3)

(b) State one trend in the proportion of children and young people who are not meeting the recommended amount of daily physical activity that is visible in the table above.

(1 mark) (IAE3)

(c) Explain how children and young people not meeting the recommended amount of daily physical activity may be contributing to them being overweight and obese.

(3 marks) (KA2)

- (d) One of the Australian Dietary Guidelines recommends ‘to achieve and maintain a healthy weight, be physically active and choose amounts of nutritious food and drinks to meet your energy needs’. Discuss how eating nutritious food and drink to meet your energy needs can reduce the proportion of children and young people who are overweight and obese.

(3 marks) (KA2)

5. Processed foods, such as muesli bars can be an energy dense snack.

- (a) Determine which muesli bar is more energy dense by calculating the number of kilojoules per gram that a serving (one bar) will provide. *Show all your working out.*

Chewy Chocolate Chip Muesli Bar		Almond, Cashew & Cranberry Muesli Bar	
Serving size (g)	31.3	Serving size (g)	35
Energy per serving (kJ)	510	Energy per serving (kJ)	692

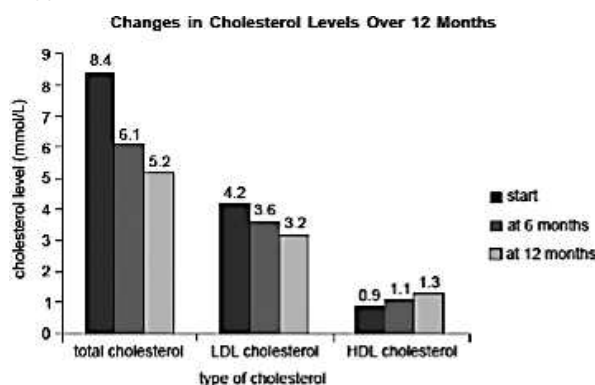
(4 marks) (KA4)

- (b) Explain the difference between energy dense and nutrient dense food.

(2 marks) (KA2)

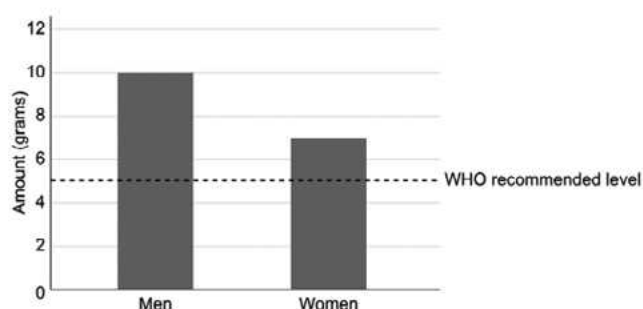
6. A person's cholesterol levels were monitored over a one-year period as shown in the graph below:

With reference to the graph above, describe the trend in LDL and HDL levels and provide reasons for the relationship between these types of cholesterol.



(3 marks) (IAE3, KA2)

7. It is suggested that individuals with hypertension should avoid salty foods. The graph below shows the average daily salt intake of Australian men and women per day.



- (a) Using data from the graph above, compare the amount of salt that Australian men and women are consuming with the amount that the World Health Organisation (WHO) recommends.

(2 marks) (IAE3)

- (b) Describe how excessive salt consumption can lead to the development of hypertension.

(4 marks) (KA2)

- (c) Suggest two ways that Australian men and women can reduce their intake of daily salt.

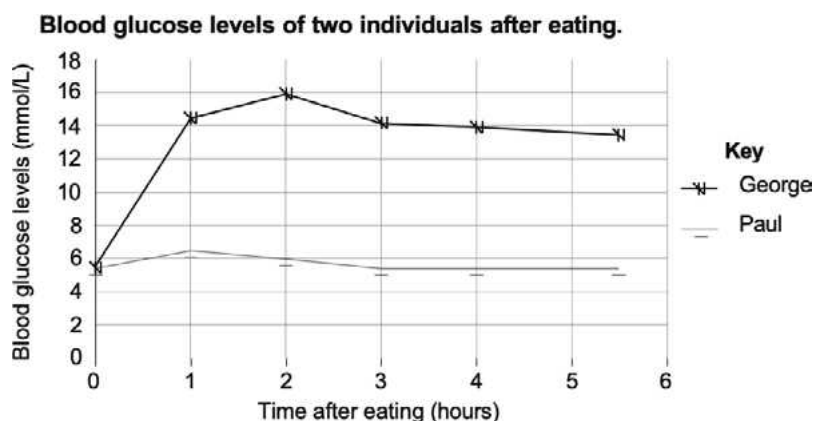
(2 marks) (KA1)

8. Using data from the nutrition information panel displayed below, discuss which meal would be best for reducing the risk of atherosclerosis.

Nutrient	Meal A	Meal B
Energy (kJ)	1089	1549
Total fat (g)	7	4
– Saturated fat (g)	2	3
Total carbohydrates (g)	40	60
– Fibre (g)	10	2
– Sugars (g)	1	10
Protein (g)	9	16
Sodium (mg)	630	561

(3 marks) (IAE3, KA2)

9. 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) (IAE3)

- (b) Identify a symptom that George may be experiencing and describe how it was caused due to his type 2 diabetes.

(2 marks) (KA2)

- (c) George consulted a dietitian to learn how best to manage his type 2 diabetes. Refer to the following consultation notes made by the dietitian:

Date: 29/05/2018 **Age:** 58 years old **Time:** 1.30 pm

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.

Discuss one diet modification that would help George to manage his type 2 diabetes.

(2 marks) (IAE3, KA2)

10. Refer to the following recipe for lasagna served with potato wedges.

Lasagne	
Ingredients 2 tablespoons olive oil 300 g button mushrooms 350 g pork and veal mince 500 g Homemade Napoletana Sauce (see below) 4 lasagne sheets 530 g Béchamel sauce (see below) 2/3 cup grated pizza cheese	Method • Prepare according to recipe instructions. • Bake at 200°C in a greased baking dish 17x28 centimetres and 5 centimetres deep for 45 minutes until golden brown.
Homemade Napoletana Sauce	
Ingredients 2 tablespoons olive oil 1 onion 3 cloves of garlic 1.5 kg tomatoes 1 tablespoon tomato paste 1 teaspoon sugar 2 bay leaves	Method • Prepare according to recipe instructions.
Béchamel Sauce	
Ingredients 60 g butter 1/3 cup plain flour 4½ cups full-cream milk 75 g Parmesan cheese ¼ teaspoon salt pinch of ground nutmeg	Method • Prepare according to recipe instructions.
Potato Wedges	
Ingredients 2 medium potatoes vegetable oil for deep-frying 2 teaspoons salt 1 teaspoon cracked pepper	Method • Peel potatoes and cut into thick wedges. • Deep-fry in hot oil until crisp and golden. • Sprinkle with salt and pepper.

- (a) Recommend two substitutions to the ingredients that would improve the lasagna recipe for a person with cardiovascular disease (CVD).

(2 marks) (IAE3, KA2)

- (b) Describe one modification to the method that would make the recipe for potato wedges more suitable for a person with CVD.

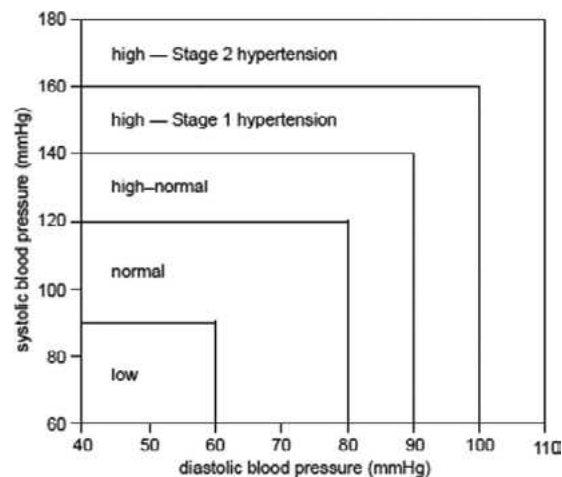
(2 marks) (KA2)

11. Angie is a 31-year-old female who smokes as a method to manage a stressful work environment. She recently had her blood pressure measured, which recorded 145/95mmHg.

(a) Explain what both values represent in her blood pressure reading to Angie.

(4 marks) (KA2)

(b) With reference to the diagram below, determine Angie's blood pressure classification.



(1 mark) (AE3)

(c) Explain how one lifestyle factor may be contributing to Angie's blood pressure reading.

(3 marks) (KA2)

(d) Angie conducted a blood test also, which found her LDL cholesterol levels in the blood were high. Explain how this can contribute to her blood pressure reading.

(2 marks) (KA2)

Total: / 60 marks

Case Study

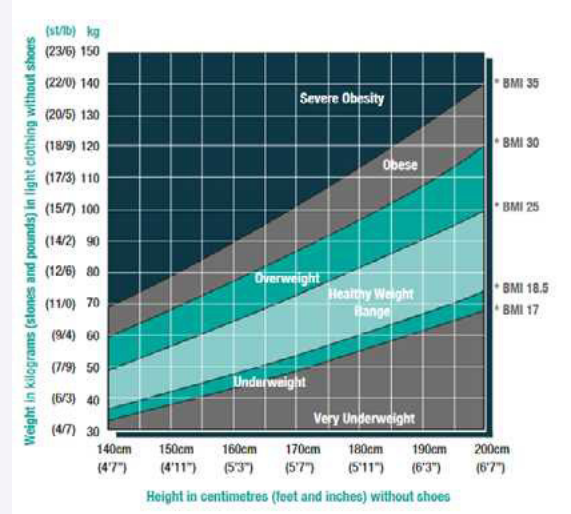
Diagnosis of Diet Related Diseases

Determine one diet related disorder that this patient may be suffering from and make specific diet or lifestyle related recommendations to resolve the patient's condition and/or manage his symptoms. Justify your diagnosis and recommendations using evidence from the sources.

Sex: Male
Age: 59 years
Weight: 120kg
Height: 184cm
Activity Levels: Sedentary
Work: Business
 (works 70+ hours a week)
Smoker: No (but recently quit)

Symptoms:

- Short of breath
- Some chest pain and discomfort
- Irregular heart rate
- Frequent headaches
- Dizziness



Dietitians' notes

After discussion with the patient, his typical diet is outlined below.

Breakfast:

- » 3 x eggs with bacon
- » 2 x slices of white bread
- » 1 x Coffee with cow's milk

Lunch:

- » 1 x meat pie with tomato sauce
- » 1 x can of coke

Dinner:

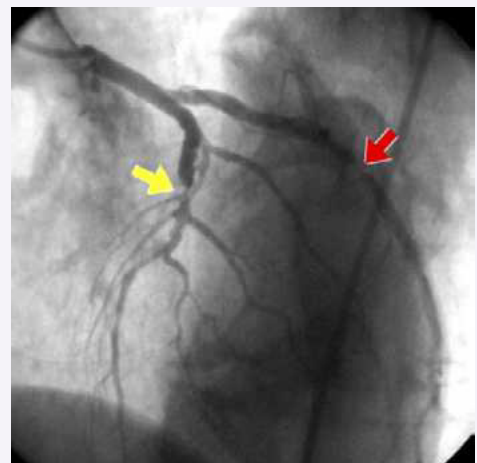
- » 1 x chicken breast with skin
- » Potato fries
- » Steamed broccoli
- » Baked Sweet Potato
- » 1 x beer

Snacks:

- » 1 x chocolate donut
- » 1 packet of original potato chips (crisps)
- » 1 x coffee with cow's milk



After the patient complained of some chest pain and discomfort, along with the monitoring of an irregular heart rate, an angiogram was performed on the main arteries going to the heart (as shown below).



Case Study**1***(10 marks) (IAE3, KA2)*



Science as a human endeavour

Israeli firm develops bio-artificial pancreas that can cure diabetes

Source: <https://www.itwire.com/health/israeli-firm-develops-bio-artificial-pancreas-that-can-cure-diabetes.html>

An Israeli company named Betalin Therapeutics has developed a bio-artificial pancreas that it says can replace the functions of the human pancreas and cure patients who have type 1 and type 2 diabetes and are insulin-dependent.

The artificial organ is made of pig's lung tissue and insulin secreting cells. The bio-artificial pancreas will be implanted under the skin during an outpatient procedure using local anaesthesia. It can be implanted in the human body and can then connect with his or her blood vessels. It would then be able to measure the body's sugar level and secrete an optimal amount of insulin needed to balance blood sugar.

Dr Nikolai Kunicher, chief executive of the Jerusalem-based company, said in a statement that human trials were expected to begin by January 2021.

Betalin, which has been in business for five years, has raised US\$3.5 million (A\$4.89 million) and is looking to raise another US\$5 million before human trials begin. It is expected that the biological pancreas will cost around US\$50,000 per patient.

"This is a new way to treat diabetes," he said. "Today, you only have ways to manage the disease. This is a cure. The diabetic pancreas has lost the function of secreting insulin, and we give it back. The patient should never have to inject insulin into his body again."

There are about 500 million diabetics around the world and of them, Dr Kunicher said, about 160 million were insulin dependent.

Professor Aryeh Warshel, also a Nobel Prize winner (2013 in Chemistry), is a member of the company's scientific advisory board.

1. Discuss how this example above demonstrates the key concept of **development, influence, and communication & collaboration**. Provide one clear example from the article above to demonstrate each of the key concepts.

(6 marks) (KA3)



Science as a human endeavour

Plaques Causing Heart Attacks – Can Nanoparticles Help?

Source: <https://www.azonano.com/article.aspx?ArticleID=5451>

In January 2020, a team of scientists from Michigan State University and Stanford University announced the creation of a nanoparticle that can destroy heart-attack-causing plaques efficiently – from the inside out.

Dubbed the ‘Trojan Horse’ nanoparticle, it has proven itself effective at reducing and stabilizing plaque, as well as clearing debris. Scientists believe the particle will be vital in developing future treatments for one of the leading causes of death in the US: atherosclerosis.

Approximately half of all deaths in the Western world are caused by atherosclerosis, a chronic inflammatory disease where plaque accumulates in the arteries, preventing the transportation of oxygen-rich blood from the heart to the body’s tissues and organs. It is the primary cause of atherosclerotic cardiovascular disease (ASCVD), which leads to heart attacks, peripheral arterial disease, and stroke.

Approximately 25% of deaths in the US are a result of heart disease, amounting to 610,000 people each year, and approximately 735,000 Americans suffer from heart attacks annually. Targeting the root cause, atherosclerosis, is a key focus on research into establishing new methods of treatment and prevention.

In a paper published last month in Nature Nanotechnology, the Michigan State and Stanford team explains that the Trojan Horse nanoparticle is effective at targeting atherosclerotic plaque because of its high selectivity to monocytes and macrophages, two types of human immune cell.

It works by entering the macrophages of plaques to deliver a drug that initiates processes that result in the engulfing and consumption of cellular debris. In essence, the nanoparticles stimulate the reinvigoration of the macrophages, which work to reduce and stabilize the plaque while also clearing the dead cells in the plaque core.

Previously, studies focused on exploring systems that target the cell’s surface, although success was limited. This new method of working intracellularly has shown promise in its ability to stimulate the macrophages.

Clinical trials are planned to investigate the nanoparticle’s effectiveness in reducing the risk of heart attacks. Trials will also ensure the nanoparticle does not have unwanted side effects.

At present, the findings are positive. Data shows the nanoparticle is effective in its ability to stimulate the body’s macrophages to selectively attack and clear dying cells, which are the first stage of developing atherosclerosis. Scientists believe the new method is an improvement on the techniques that are currently used.

Scientists working on the project believe that the nanoparticle will have applications outside of atherosclerosis. However, more research is needed.

1. Discuss how this example above demonstrates the key concept of **influence** and **communication & collaboration**. Provide one clear example from the article above to demonstrate each of the key concepts.

(4 marks) (KA3)

1

Extension Activities

1. Symptoms of obesity can lead to physical, economic and/or social/psychological consequences. Identify two physical, economic, and social consequences that an obese individual may experience.

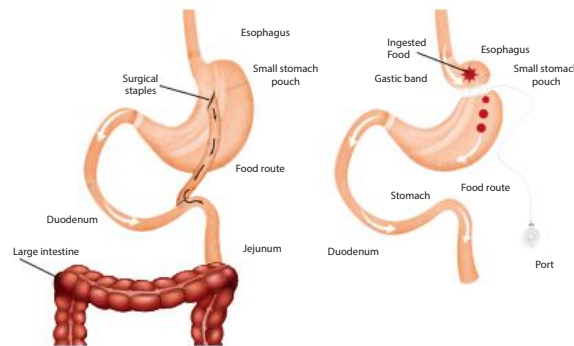
Physical	Economic	Social & Psychological

2. Describe the storage pathways of an excessive intake of each macronutrient: carbohydrates, lipids and protein and explain how they can contribute to the development of obesity.

3. Research an example of a fad diet, and state what it claims to achieve and which nutrients it promotes for consumption.

4. Explain why insulin cannot be given orally as a medical treatment to manage type 1 and type 2 diabetic's blood glucose levels and identify how it is given to treat this diet related disorder.

5. Research and explain how medical surgeries, including gastric bypass and gastric banding procedures, shown below, can be used as an approach to weight loss for an individual who is morbidly obese, after they have tried diet and exercise programs with no success. In your response, also explain why individuals who opt for these procedures may develop micronutrient deficiencies.



6. Another form of diabetes is gestational diabetes, which occurs in pregnant females and Type 1.5 diabetes which is diagnosed during adulthood. Research and describe both forms of diabetes and how they differ to type 2 diabetes.
- Gestational Diabetes
 - Type 1.5 Diabetes
7. Immediate medication is started if CVD is suspected, in many cases, even before diagnosis is confirmed. After diagnosis, non-surgical procedures are used to restore blood supply, with surgical methods being required next, should the non-surgical methods be unsuccessful. Research and explain how aspirin, a catheter, bypass surgery or ACE inhibitors can be administered for the treatment of all types of CVD.

9. Recipe Modifications can be successful in the management of diet related disorders, where recipes can be adapted to decrease the amount of sugar, salt, and saturated fat. Recipes can be adapted by substituting specific ingredients for another ingredient, to enhance the overall nutrient density of the meal.

[illegible]

1.10 Imbalance of Nutrient Intake – Under Nutrition Disorders

Science understanding

Imbalance of nutrient intake is likely to cause diet related disorders, including constipation/diverticular disease, iron deficient anaemia and osteoporosis.

- Explain how a deficiency in iron and calcium can result in health issues and why specific population groups could be at higher risk of a deficiency.
- Describe the signs/symptoms of diet related disorders.
- Explain why specific groups are at increased risk of a diet related disorder.
- The role of diet and lifestyle in the prevention, control, and/or reversal of such disorders.

SACE Subject Outline, 2024.

Constipation & Diverticular Disease

Everyone's digestive tract has its own cycle of waste elimination, which depends on the person's health, the type of food eaten, when it was eaten and when the person takes time to **defecate**. The normal number of times to defecate is different for every individual; however, what is considered normal is between a range from several times daily to three times a week. Therefore, **constipation** is defined as having difficulty passing stools as often or easily as they are used to and fewer times than three times a week due to being dry and hard. Constipation is considered a precursor to diverticular disease.

Definition

To defecate is the excretion of faeces/stools from the body.

Diverticular disease includes both diverticulosis and diverticulitis. **Diverticulosis** is a condition where small pockets or pouches develop along the inner lining of the colon, most commonly the **sigmoid colon** - the segment of the colon before the rectum (refer to figure 1.10.1).

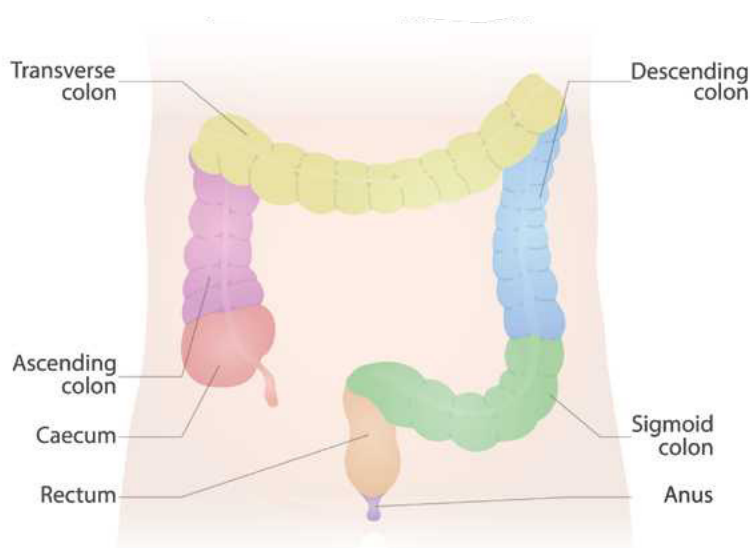


Figure 1.10.1: The labelled parts of the Large Intestine, outlining the sigmoid colon where diverticular disease most commonly occurs.

Fast fact

Diverticular disease is very common. While it is rare before the age of 35, the incidence increases with age. One third of Australians over 45 years of age, and two thirds over 85 years have some diverticular disease. Many are unaware they have it.

The pouches (**diverticula**) push outwards through areas where muscles of the intestinal wall are weakened. It is thought that these pouches form due to increased pressure in the intestines and increased straining during defecation, especially when constipated. **Diverticulitis** is a condition where the diverticula become infected or inflamed when faeces become trapped, encouraging bacterial growth within a pouch (Figure 1.10.2).

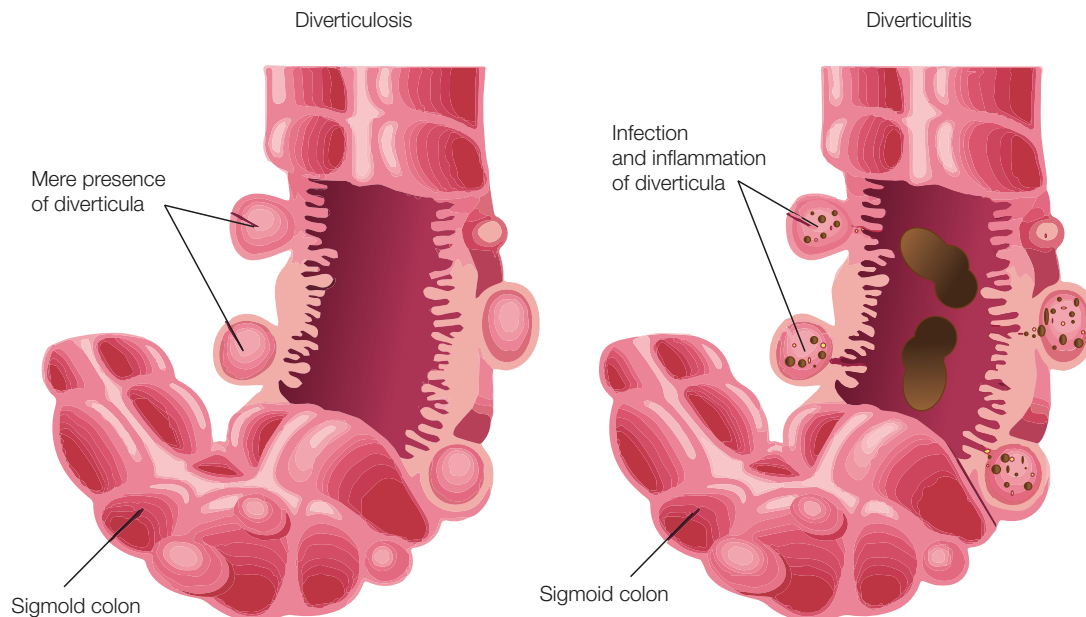


Figure 1.10.2: The development of Diverticulosis (left) and Diverticulitis (right) in the Sigmoid Colon.

Signs & Symptoms

A sudden change in an individual's bowel movements and the number of times they defecate can be a reason for concern. The consistency, colour and density of faeces can be a sign of the health of your large intestines. Lumpy stools (as shown as type 1 and type 2 below in figure 1.10.3) could be an indication of diverticular disease, where pockets may have developed in the large intestines.

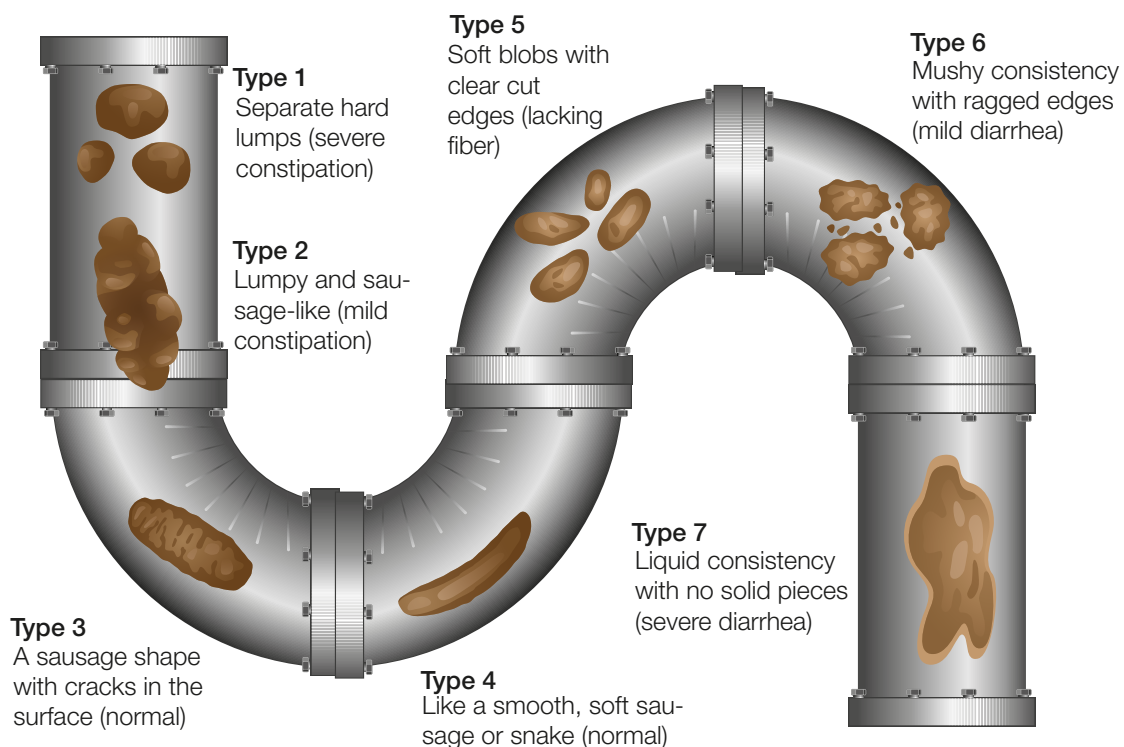


Figure 1.10.3: The consistency and colour of your stools, which can indicate the health of your large intestines.

Diverticulosis usually has no symptoms unless numerous diverticula (pouches) are present. When there are many diverticula present, the normal functioning of the intestines can be affected and lead to symptoms such as:

- abdominal pain and bloating
- excessive flatulence
- bowel movements alternating between constipation and diarrhoea
- blood in the faeces (usually minor, only heavy if a diverticulum pushes through the intestinal wall near a blood vessel).

For those who develop diverticulosis, there is a chance it may progress to diverticulitis at some stage. It is uncommon for a person to suffer from diverticulitis more than once in their lifetime, however symptoms of diverticulitis tend to be more distressing, including:

- sharp abdominal pain (most commonly from the lower left side of the abdomen)
- distention (bloating) of the abdomen
- Infection may cause nausea, fever, and vomiting.
- blood in the faeces (occasional and rare symptom).

Nutrition Related Risk Factors

The exact cause of diverticulosis, or pouches forming, is unclear. However, a diet low in **dietary fibre** and water increases the chances of developing diverticular disease via becoming constipated over a long period of time. Constipation and subsequent straining to pass hard and dry faeces (or stools), can increase pressure in the intestines or colon. A higher pressure needs to be generated to push hard and dry stools through the gastrointestinal tract. This high pressure can force the lining of the intestines to pocket outwards, through the muscle layer where weaknesses occur, leading to the formation of pouches and diverticulosis. Diverticulitis may then be caused by small fragments of faeces becoming trapped in these pouches, encouraging bacterial growth, and causing infection and inflammation.

The Role of Diet in Prevention, Control &/or Reversal

To reduce the chance of diverticular disease, a gradual increase in the consumption of dietary fibre and fluids is needed in the diet. It is important to introduce it gradually as a sudden significant increase in dietary fibre can cause bloating and cramping. However, eventually a daily intake of 30 grams of fibre is recommended as it helps to make stools softer, which speeds its movement through the digestive tract, reducing pressure on intestinal walls and the likeliness of constipation occurring. A high fibre diet may also prevent further diverticula forming.

Adequate water intake can also help prevent dehydration and dry stools. Individuals who are dehydrated are at an increased risk of experiencing constipation as less water is available to soften stools. A high consumption of diuretics, such as caffeine and alcohol can also reduce the volume of water available as they trigger an increased loss of water from the body via urine. Therefore, drinking plenty of water and reducing the consumption of diuretics assists in keeping stools soft and allowing them to pass easier through the intestines.

Lifestyle & Physiological Risk Factors and Prevention, Control &/or Reversal

Diverticulosis is quite common in the elderly, for both genders. Its progression takes considerable time which explains why age is a risk factor. However, regular exercise is a lifestyle management that is key in protecting against diverticular disease. Exercise can improve gut motility. Gut motility is the speed at which the intestinal muscles contract to move food/faeces through the digestive tract. Exercise directs more blood flow to the digestive muscles, allowing them to contract quicker and more efficiently. This speeds up the movement of faeces through the colon, thereby reducing the pressure in the intestines and the risk of constipation.



Helpful online resources

Diverticular Disease | Diverticulitis | Gastrointestinal Society

<https://youtu.be/j57TBHSaL-w?si=RKIOE1pZnzfDqCoF>



Iron Deficient Anaemia

Anaemia is a condition with lower-than-normal concentrations of haemoglobin or a lower number of quality red blood cells. There are different types of anaemia, but **iron deficiency anaemia** is the most common and widespread nutrient deficiency in the world.

Red blood cells are the most abundant cell type in the blood. Their primary function is to transport oxygen to the body's muscles and tissues and deliver carbon dioxide to the lungs. A healthy red blood cell has a concave shape on both sides (biconcave), where its surface curves inwards (as shown in Figure 1.10.4). Its flexible disc shape increases its surface area to volume ratio, allowing for oxygen and carbon dioxide to be exchanged more readily. Its shape is also essential for its ability to move through tiny blood vessels to reach all tissues in the body.



Figure 1.10.4: The biconcave shape of red blood cells in an artery allows for efficient gas exchange and movement throughout the body's blood vessels.

Red blood cells contain enormous amounts of a protein known as **haemoglobin**, which binds to oxygen (as shown in Figure 1.10.5) when the blood passes through the lungs. Haemoglobin also provides the characteristic red colour of blood when it has an attached oxygen molecule.

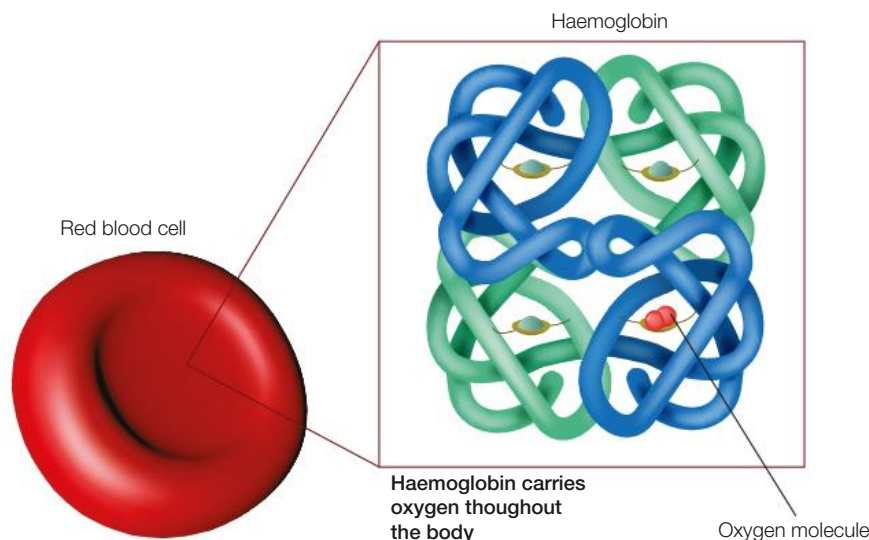


Figure 1.10.5: A haemoglobin molecule of red blood cells showing where oxygen is bound.

Helpful online resources

The role of red blood cells in anaemia

https://youtu.be/_ZV5140OykE?si=vU_ZfbgepQnuL6Kg



Signs & Symptoms

The red blood cells of people with iron deficiency anaemia have a reduced amount of haemoglobin, which reduces the amount of oxygen supplied to tissues. A lack of oxygen over a long period of time can cause the following signs and symptoms:

- fatigue
- pale/yellowish skin (as shown in figure 1.10.6)
- fast heartbeat
- shortness of breath
- chest pain
- headaches and dizziness
- difficulty with concentration and memory
- cravings for unusual objects, e.g., dirt.

In mild cases of iron deficiency anaemia, a person is unlikely to experience more than the symptoms listed above. However, if anaemia is left unmanaged, additional complications can occur. Possible complications may include:

- slow growth and development delays in infants and children.
- heart failure due to how it compensates for a lack of oxygen.
- pregnancy complications, including low birth weight or premature birth.

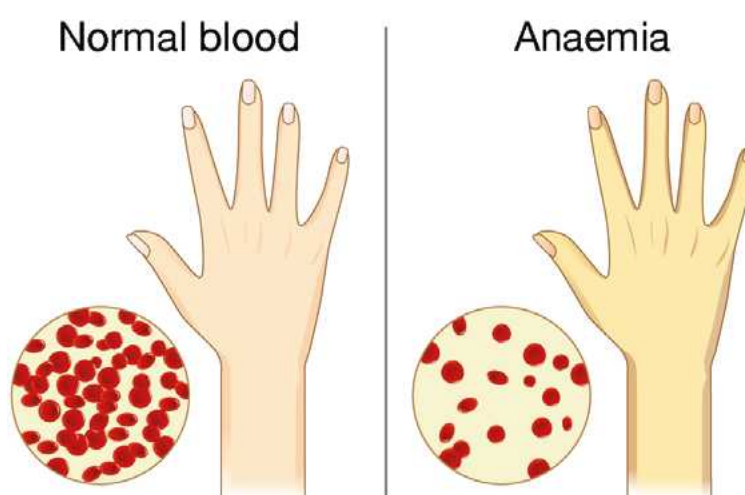


Figure 1.10.6: Individuals with anaemia have a lower number of quality red blood cells with oxygen-carrying capacity, which can result in a paler or more yellow complexion of the skin.

Nutrition Related Risk Factors

Considering **haem iron** is the more readily absorbed form of iron, having low amounts of it in the diet is a common nutrition related risk factor. However, a diet low in either iron type (**non-haem**, haem, or a combination of iron types) and Vitamin C, an iron absorption enhancer, can contribute to the development of iron deficiency anaemia.

A high intake of **iron absorption inhibitors** (as shown in Table 1.10.1), excessive consumption of diuretics like caffeine, sodium, and alcohol, plus conditions that can impair iron absorption, can also contribute to the development of iron deficiency anaemia.

Table 1.10.1: Iron absorption inhibitor food sources and their responsible components.

Food sources	Component
Eggs	Phosvitin
Dairy	Calcium
Tea, spinach, kale, nuts, chocolate, strawberries, herbs	Oxalates
Cocoa, coffee, apples, herbal teas, blackberries, raspberries, blueberries	Polyphenols
Walnuts, lentils, wholegrains, cereals, dried beans, almonds, rice	Phytates

The Role of Diet in Prevention, Control &/or Reversal

The management of iron deficiency anaemia is through dietary changes when an individual increases their intake of iron, particularly haem iron if possible, and decreases their intake of iron absorption inhibitors (as shown in table 1.10.1). Foods that are high in vitamin C, including citrus fruits like oranges, other fruits including kiwifruit and strawberries, and green leafy vegetables like kale, spinach and broccoli, act as an **iron absorption enhancer** and should therefore be increased. Vitamin C will protect iron, especially non-haem iron from oxidation, allowing it to remain in a form that the body can absorb. This will enhance the absorption of iron, especially non-haem, from digested food into the bloodstream if eaten with foods high in vitamin C in the same meal.

Lifestyle & Physiological Risk Factors

Different groups in Australia are at greater risk of developing iron deficiency anaemia due to several lifestyle and physiological risk factors.

Periods of Rapid Growth

Life stages, including puberty and pregnancy, can result in a rapid increase in **blood volume**. This increases a person's recommended daily intake of iron to provide an adequate amount of haemoglobin for the increase in red blood cell production. This compensates for the increase in blood volume and, in the case of pregnant women, supports the needs of a developing foetus.

High energy demands

Endurance athletes are at risk of iron deficiency anaemia due to increased demands for iron. Iron is essential for athletic performance due to its role in haemoglobin production, which is responsible for the transportation of oxygen to the muscle cells in preparation for energy production via aerobic respiration. Iron is also needed for its role in myoglobin production, which stores oxygen and makes it available to the muscle tissue when the body's demand for oxygen is greater than the supply. Endurance athletes also require more iron to replace any blood lost through internal or external bleeding caused by **injury**. Iron is water soluble and therefore the volume lost through heavy sweating experienced during training and games also needs to be replaced.

Fast fact

Endurance athletes can damage the red blood cells in their feet because of the way the foot lands while running on hard surfaces. This can further cause a loss of blood.

Vegetarian and Vegan Lifestyle

Individuals who are **vegetarian** or **vegan** can be at greater risk of iron deficiency anaemia if proper care is not taken when selecting foods. Foods derived from animal sources provide both haem and non-haem iron, whereas plant sources only provide non-haem iron (as shown in Figure 1.10.7). Therefore, if an individual does not consume the flesh of animal products, only non-haem iron is consumed, which is not absorbed as readily as haem iron is.

Fast fact

The recommended intake of iron for vegetarians and vegans is usually 1.8 times greater than for people who consume animal products.

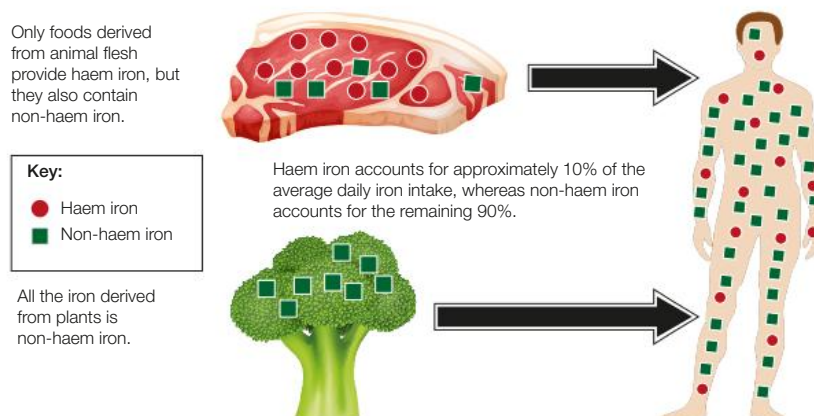


Figure 1.10.7: The composition of animal and plant iron sources.

Significant blood loss

Blood carries iron stored in red blood cells, therefore people who lose blood from the body will lose their iron stores. Menstruating females are therefore particularly at risk with monthly blood loss, especially those with heavy menstrual bleeding. A significant amount of blood loss can occur from injury, surgery, conditions that cause internal bleeding or the overuse of pain medications (which causes digestive bleeding).

Bone marrow disorders

Bone marrow is a soft, spongy tissue found in the centre of bones. Bone marrow produces stem cells, which then develop into red blood cells, white blood cells and platelets. However, several diseases can affect the function of bone marrow, including some cancers. This disrupts the production of red blood cells, decreasing the number of healthy blood cells circulating in the blood stream.

Autoimmune disorders and infections

Autoimmune disorders (such as haemolytic anaemia) and infections (including malaria and septicaemia) can reduce the life span of a red blood cell. These conditions can cause premature rupturing of healthy red blood cells, decrease red blood cell production, or cause the body's immune system to attack red blood cells as if they were substances foreign to the body. This increases the demand for red blood cells from the bone marrow.

Osteoporosis

Osteoporosis is one of the most prevalent diseases within the ageing population, affecting more than 1.9 million Australians. Osteoporosis is a disorder characterised by low bone density and the **structural deterioration of bone tissue**, which becomes more **porous** and fragile (as shown in Figure 1.10.8). This leads to weakened bones, which are compressible like a sponge, thus increasing the risk of fractures in the bones.

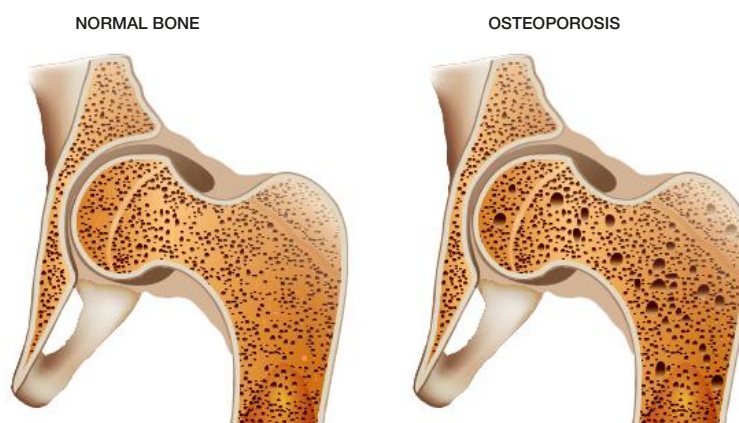


Figure 1.10.8: A comparison between healthy bone (left) and osteoporotic bone (right).



Fast fact

When viewed under a microscope, healthy bones appear like honeycomb, where the spaces are small and densely packed. When osteoporosis occurs, the holes and spaces in the honeycomb are much larger.

There are 206 connected bones in the adult body. Bones provide a frame to support the body, protect vital organs and enable movement. They are attachment points for muscles, tendons, and ligaments. Bone tissue is a dense connective tissue, which is composed of a protein, collagen, and a mineral, **calcium phosphate**. The combination of collagen and calcium phosphate make bones strong and flexible enough to withstand stress.

Bone is a living tissue that is constantly growing, rebuilding, repairing, and replacing. Throughout an individual's lifetime, a process of **bone remodelling** is constantly taking place: where mature bone is removed, known as **bone resorption** by osteoclasts and replaced with new bone, known as bone ossification or **bone formation** by **osteoblasts** (as shown in Figure 1.10.9). It is a process that continues throughout life and is important for healing fractures and changing bone density in response to mechanical stress.

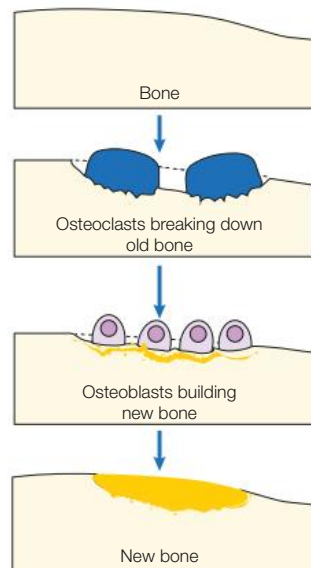


Figure 1.10.9: The continuous process of bone remodelling throughout life, where bone resorption – performed by osteoclasts – removes mature bone and bone formation – performed by osteoblasts – replaces it with new bone.

During childhood and adolescence, the process of bone formation is greater than bone resorption, resulting in larger, heavier, and denser bones. Bone formation continues to exceed the rate of bone resorption until an individual reaches their early to mid-twenties, which is when they reach their **peak bone mass**. An individual's peak bone mass is the greatest amount of bone they will attain in their lifetime and is therefore when bones are at their strongest. After peak bone mass is achieved, the rate of bone resorption is equal to the rate of bone formation until an individual reaches the age of approximately 40. After this age, the rate of bone resorption becomes greater than the rate of bone formation leading to bone loss. Therefore, osteoporosis is an imbalance in the turnover of bone, where bone resorption significantly exceeds bone formation (as shown in Figure 1.10.10).

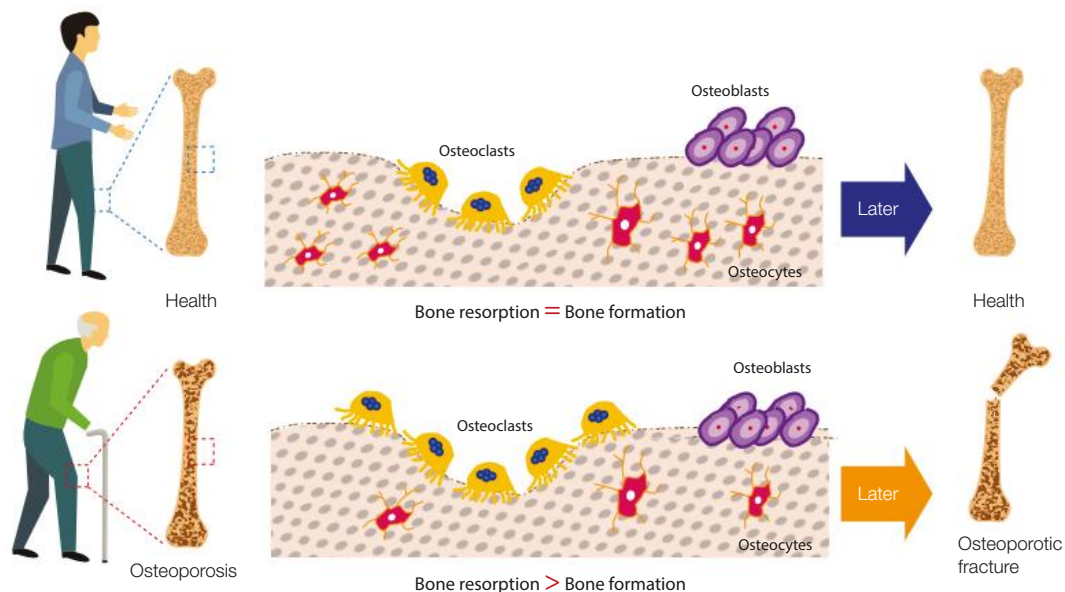


Figure 1.10.10: The process of bone remodeling throughout different life stages.

Signs & Symptoms

Osteoporosis generally has no symptoms until a complete or partial break in a bone, called a fracture, occurs, which is why it is known as a silent and progressive condition. As bones become more brittle and fragile, even a minor bump, fall, cough, or sneeze can cause a **fracture** (as shown in Figure 1.10.11). The symptom associated with an osteoporotic fracture is usually chronic pain.



Figure 1.10.11: The complete fracture of the hip bones is highlighted in red.

Any bone can be affected by osteoporosis, but the most common sites include the hip, spine, and wrist. A small fracture in the spine can result in height loss or a stooped posture, due to the collapse of the vertebrae. This collapse gives individuals a hunched appearance of the upper back, often called a 'dowager hump' (as seen in figure 1.10.12). Changes to an individual's posture can also increase the risk of a fall or difficulties breathing or digesting. A hip fracture is generally a result of trivial slip and fall accidents. A fracture that occurs during normal activity (e.g., while walking or stepping onto a curb) is known as a stress fracture. A fractured bone can be serious and lead to long term disability, including reduced mobility. Osteoporotic fractures are responsible for significant pain, decreased quality of life, lost workdays, and disability. Elderly patients can develop possible consequences, including pneumonia and blood clots in the legs that can travel to the lungs, due to prolonged bed rest after a hip fracture. In addition, once an individual has experienced a fracture due to osteoporosis, he or she is very likely to suffer from another fracture in the future.



Fast fact

In Australia, of all osteoporotic fractures 46% are spine, 16% are hip, and 16% are wrist.

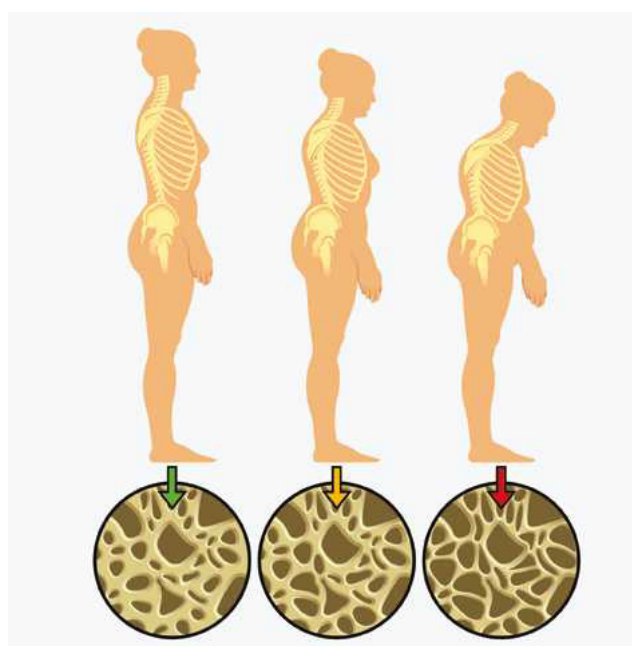


Figure 1.10.12: The development of the 'dowager hump' due to osteoporotic fractures in the spine.

Nutrition Related Risk Factors

Osteoporosis can be caused by poor nutrition, where the diet is insufficient in calcium, phosphorus and nutrients that can assist in their absorption.

The main role of calcium and phosphorus is in the development of the bone's structure. These two minerals combine to make the bone matrix denser, which provides strength and rigidity to the bones. Most of the body's calcium is stored in the bones, which acts as a calcium bank. Therefore, if the diet is low in calcium, consequently there is not enough calcium available in the blood to perform its other functions in the body. The body will then absorb calcium from the bones, making them more porous and fragile over time. Therefore, the body requires a calcium balance where the amount of calcium absorbed in the intestines is equal to the amount of calcium lost to prevent calcium being taken out of the bones. As phosphorus is found in most foods, a deficiency of phosphorus is not common.

Some dietary foods and beverages can inhibit the absorption of calcium by binding to the mineral when consumed at the same time, forming insoluble salts. Table 1.10.2 shows dietary sources of components that inhibit (block or reduce) calcium absorption. Excessive sodium, alcohol and caffeine intakes can reduce calcium **bioavailability** by promoting greater calcium urinary excretion. Therefore, consuming a high intake of **calcium absorption inhibitors** and having conditions that can impair calcium absorption can contribute to the development of osteoporosis.

Definition

Bioavailability is the degree to which a nutrient is absorbed and utilised by the body.

Table 1.10.2: Calcium absorption inhibitor food sources (when consumed in excess) and their responsible components.

Food sources	Component
Processed foods, cured meats, salted nuts, cold cuts, sauces, canned products	Sodium
Soft drinks	Phosphoric Acid
Tea, spinach, kale, nuts, chocolate, strawberries, herbs	Oxalates
Cocoa, coffee, apples, herbal teas, blackberries, raspberries, blueberries	Polyphenols
Walnuts, lentils, wholegrains, cereals, dried beans, almonds, rice	Phytates

The Role of Diet in Prevention & Control

To reach optimal peak bone mass and maintain ideal bone remodeling, several dietary modifications can be implemented, including an increase in food sources high in calcium, phosphorus and vitamin D. Foods such as fortified margarine and oily fish that are high in Vitamin D, a **calcium absorption enhancer**, increases the blood concentrations of calcium and phosphorus by enhancing their absorption from the small intestines and by reducing the amount lost via urine. Enhanced absorption of the minerals that strengthen bones will reduce the risk of an individual developing osteoporosis later in life or slow the condition from progressing. As well as this, reducing the intake of calcium absorption inhibitors will also reduce calcium from being reabsorbed from bones, making them weaker and porous.

Lifestyle & Physiological Risk Factors and Prevention & Control

There are groups of people who are at greater risk of developing osteoporosis due to the presence of several lifestyle and physiological risk factors. Some of these lifestyle risk factors can be reversed to reduce the risk to these groups of people.

Smoking

There is a direct relationship between tobacco use and decreased bone density. Studies have found that smoking can possibly decrease bone density in multiple ways:

- Reduces blood supply to bones. This is associated with bone loss due to the inhibition of osteoblast function and increasing bone resorption.
- Slows down the production of osteoblasts, reducing the rate of bone formation. This can be caused by nicotine.
- Decreases intestinal calcium absorption.
- Affects the balance of hormones in the body, which assists in managing bone formation.

Therefore, smokers have a greater risk of developing osteoporosis at an earlier age and experiencing fractures. Fractures can take longer to heal due to the harmful effects of nicotine on the production of osteoblasts.

Lack of weight-bearing and resistance exercise

Certain types of exercises have been shown to minimise the loss of, and even show an increase in, bone mineral density, which is beneficial for the prevention and management of osteoporosis. The most effective types of physical activity include **weight-bearing exercises** that are done on your feet, such as walking, running, hiking, dancing, low impact aerobics, stair climbing, gardening and resistance training, such as weightlifting. These types of exercises activate large groups of muscles in the body, which tug and pull on the bones as this is their attachment point (as shown in Figure 1.10.13). The mechanical load applied during these activities' places stress on the bones, encouraging osteoblasts to migrate to these stressed areas to begin laying down new bone. This increases bone strength in these areas, as a greater amount of calcium phosphate is deposited. Exercising can also help to maintain muscle strength, coordination, and balance, which in turn helps to prevent falls and related fractures. This is especially important for elderly people and individuals who have been diagnosed with osteoporosis.

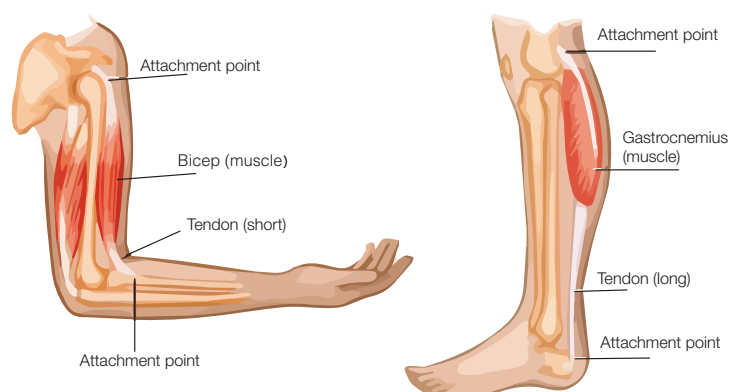


Figure 1.10.13: The attachment of muscles to bones by a tendon on each end

Limited exposure to sunlight

The body can produce a precursor of vitamin D from cholesterol. However, exposure to sunlight is essential to convert this form of vitamin D into an active form which can be used by the body. The amount of sunlight required for adequate vitamin D levels depends on a range of factors including the **UV level**, length of exposure and an individual's skin type. During summer in Australia, all states experience periods during the day when UV levels reach 3 or above (as shown in table 1.10.3). Therefore, most adults will maintain adequate vitamin D levels during typical day to day activities which is why sun protection is recommended. However, in winter in the southern parts of Australia, where UV radiation levels are below 3, sun protection is not recommended. At this time of the year, people are encouraged to be outdoors for a few minutes with their skin uncovered to ensure sufficient vitamin D is maintained. The exception to this is outdoor workers who are unlikely to be deficient in vitamin D. Individuals with darker skin may need more sun exposure than those with fair to olive skin, as the melanin in dark skin affects UV penetration and can reduce the synthesis of vitamin D.

Table 1.10.3: Australian capital city average daily maximum UV levels by month (values have been rounded to the nearest whole number). Highlighted months have an average daily maximum UV index less than 3, even when rounding has made it appear otherwise).

Location	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Darwin	12	13	12	11	9	8	9	10	12	13	12	12
Brisbane	12	11	9	7	5	4	4	5	7	9	11	11
Perth	12	11	9	6	4	3	3	4	6	8	10	11
Sydney	11	10	8	5	3	2	3	4	5	7	9	10
Canberra	11	8	7	5	3	2	2	3	5	7	9	11
Adelaide	11	10	8	5	3	2	2	3	5	7	9	11
Melbourne	10	9	7	4	2	2	2	3	4	6	8	10
Hobart	8	7	4	3	1	1	1	2	3	4	6	7

Gender

Females have a greater prevalence and earlier onset of osteoporosis than males because they experience **menopause** at approximately 50 years of age (as shown in figure 1.10.14). For approximately the first 10 years following menopause, there is a significant decline in the amount of the hormone oestrogen in a woman's body. In menopause, oestrogen deficiency decreases the efficiency of calcium absorption in the intestines and increases the rate of bone resorption decreasing bone density and strength. During this time, women may lose 2 to 4 per cent of their bone density each year.

Definition

Menopause is a change that a female goes through, either just before or just after she stops menstruating, marking the end of her reproductive period.

Males generally have a greater bone density than females. However, males who have low levels of the primary male sex hormone testosterone are at greater risk of developing osteoporosis earlier in life. Testosterone plays an essential role in building and maintaining bone density. Some males may have low testosterone levels, but factors including excess weight, a sedentary lifestyle, and some medicines can reduce testosterone levels in the body. Testosterone levels also reduce with age but at a slower rate than what oestrogen levels reduce in a female's body.

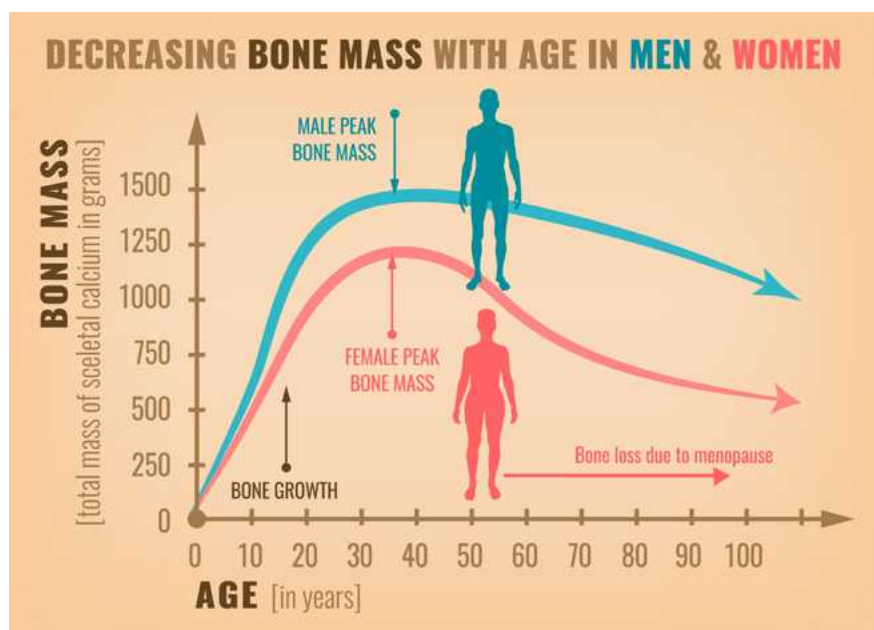


Figure 1.10.14: The bone mass in males and females as age increases

Being underweight

Being underweight can be characterised by having a low BMI and is a result of an individual's energy expenditure exceeding their intake over a considerable amount of time. A low BMI is often associated with poor nutrition, which can affect bone health, especially if the diet is insufficient calcium. Therefore, this generally results in low levels of calcium in the blood, promoting the reabsorption of calcium from bones. This can contribute to a reduced peak bone mass, diminished bone density and increased risk of fractures.

Excessive alcohol consumption

Excess alcohol consumption can interfere with calcium balance in the body by disrupting the production of vitamin D in the liver, which is essential for calcium absorption. Chronic alcohol consumption can also kill the cells that make bone and cause hormonal imbalances which increases the breakdown of bone.

Helpful online resources

Osteoporosis

https://youtu.be/XHRRCaY_H9E?si=DA3OB-1IA2151L54



Key terms

Blood volume	Diverticular	Non-haem iron
Bone Formation	Disease	Osteoblasts
Bone Remodeling	Diverticulitis	Osteoclasts
Bone Resorption	Diverticulosis	Osteoporosis
Calcium Absorption Enhancer	Fracture	Peak bone mass
Calcium Absorption Inhibitor	Gut motility	Porous
Calcium Phosphate	Haem iron	Red blood cell
Constipation	Haemoglobin	Sigmoid Colon
Dietary Fibre	Iron Absorption Enhancer	UV level
Diverticula	Iron Absorption inhibitors	Weight-bearing Exercise
	Iron Deficient Anaemia	

Review questions: 1.10 Imbalance of Nutrient Intake – Under Nutrition Disorders

- Fred is a retired 78-year-old man who does little exercise. Living alone, he lacks motivation to cook for himself and eats mostly processed energy-dense foods.
 - List a dietary risk factor that may lead to Fred developing diverticular disease and discuss how this risk factor may cause this condition.

(3 marks) (KA2)

- List and describe a lifestyle management strategy Fred should adopt to reduce his chance of developing diverticular disease.

(2 marks) (KA2)

- Name the digestive organ where diverticula pouches typically develop.

(1 mark) (KA1)

- Describe the cause of one symptom Fred could suffer from if he develops diverticular disease.

(2 marks) (KA2)

2. According to recent statistics, iron deficiency affects the health of 25 per cent of Australian women and 10 per cent of men in Australia.

(a) There are two forms of iron. State the two forms of iron.

(2 marks) (KA1)

(b) The following table provides the iron content of different foods:

Food	Iron content (mg per 100 g)
Broccoli	1.0
Canned steak and vegetables	0.8
Dried rice cereal	34.0
Lamb chop	1.7
Salami	2.4

- (i) With reference to the table above, state the food source which might contribute to the development of iron deficient anaemia.

(1 mark) (AE3)

- (ii) State a micronutrient and provide a specific food source that could be consumed with broccoli to increase the absorption of iron.

Micronutrient:

Food source:

(2 marks) (KA1)

(c) Describe one function of iron that can affect the quality of red blood cells.

(2 marks) (KA2)

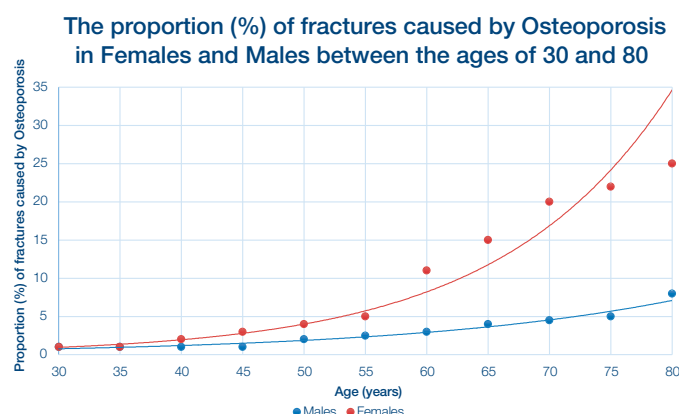
- (d) Explain the importance of the shape of a healthy red blood cell and how this changes in an individual with iron deficiency anaemia.

(3 marks) (KA2)

(e) Identify two groups of individuals who are at greater risk of developing anaemia.

(2 marks) (KA1)

3. A study was conducted, which measured the proportion (%) of fractures in females and males between the ages of 30 and 80 that were caused by osteoporosis. The results of this study are shown in the graph below.



- (a) It was hypothesized: *As the age of a female and male increases, the proportion of fractures caused by osteoporosis will increase.* Using data from the graph above, justify if the hypothesis was supported or not supported.

(2 marks) (IAE3)

- (b) Explain why this study began its investigation of females and males beginning at the age of 30.

(2 marks) (KA2)

- (c) Explain *one* reason why females had a greater proportion of fractures caused by osteoporosis than males.

(2 marks) (KA2)

- (d) The average daily diet of a middle-aged woman was evaluated and is shown below:

Breakfast	1 slice of toast with peanut butter 1 long black coffee
Lunch	Chicken salad with spinach, lentils, tomato, cucumber, red onion, avocado 1 slice of banana bread 1 can of coke
Dinner	Spaghetti Bolognese with beef mince 1 slice of garlic bread 1 can of lemonade
Snacks	Handful of salted nuts English breakfast tea

- (i) Identify *one* food or beverage source from her diet above that may increase her risk of experiencing fractures caused by osteoporosis. Explain how this source can contribute to her osteoporosis.

(2 marks) (IAE3, KA2)

- (ii) Identify *one* nutrient which this female should increase her consumption of to assist in managing her osteoporosis and in preventing further fractures.

Nutrient:

(1 mark) (KA1)

Suggest *two* specific food or beverage sources of the nutrient identified above, ensuring one is suitable for a vegan.

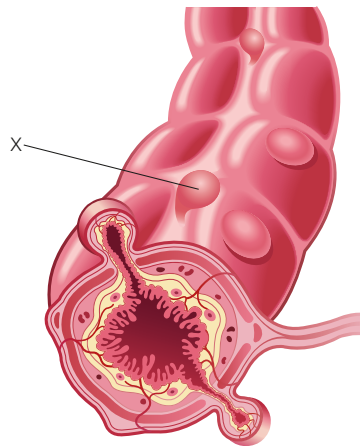
Food sources:

1)

2)

(2 marks) (KA1)

4. Refer to the image below:



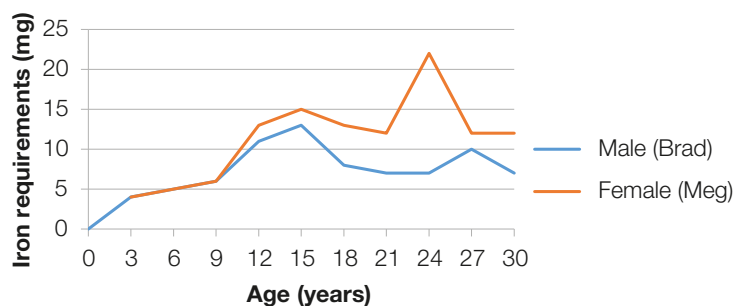
- (a) Name the structure labelled X in the image above.

(1 mark) (KA1)

- (b) Name the specific type of diverticular disease shown in this image above, which shows empty sacs.

(1 mark) (KA1)

5. The following graph shows changes in iron requirements for two people of different genders over part of their life spans. Refer to the following graph, which demonstrates the iron requirements for Brad and Meg over part of their lifespan to answer the following questions.



- (a) State at what age Brad has his greatest iron requirement.

(1 mark) (IAE3)

- (b) Using data from the graph, explain the trend in the iron requirements for Brad from ages 3 to 15 years.

(2 marks) (IAE3)

- (c) Suggest a possible reason for the significant increase in Meg's iron requirements at the age of 24 years.

(1 mark) (KA2)

- (d) State a food or beverage source that could reduce Brad's iron absorption at the age of 27 years, putting him at risk of developing iron deficient anaemia.

(1 mark) (KA2)

- (e) If Brad fails to meet his iron requirements, he is at risk of developing anaemia. Identify one symptom he may develop because of this deficiency and explain why it might develop.

(3 marks) (KA2)

6. There are two different types of dietary fibre: soluble and insoluble fibre. Both types are important for health, digestion, and the prevention of constipation.

- (a) Describe how and where soluble fibre is broken down in the body.

(2 marks) (KA2)

- (b) Explain one specific function of both soluble and insoluble fibre and how this prevents constipation and identify one specific food example for each type of fibre in the table below.

	Soluble Fibre	Insoluble Fibre
Function that prevents constipation		
Specific Food Source		

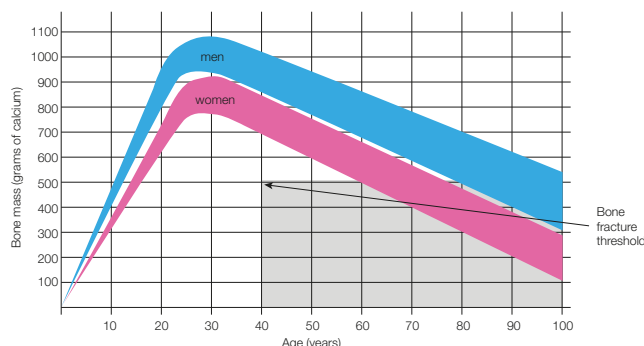
(6 marks) (KA1, KA2)

7. State one reason why the following groups of people would be at greater risk of developing iron deficient anaemia.

Individual at risk of iron deficient anaemia	Reason
Pregnant Female	
Female Marathon Athlete	
Chronic coffee consumer	
Vegan	
Individual with a serious injury to the skin	
Adolescent female	

(6 marks) (KA2)

8. Nutritionists are often concerned that people do not consume adequate amounts of calcium during their lifespan, putting them at risk of calcium deficiency disorders.
- (a) Name one vitamin that is necessary to prevent the onset of some disorders caused by calcium deficiency.
- (1 mark) (KA1)
- (b) Refer to the following graph, which shows the relationship between bone mass, age, and the bone fracture threshold, in men and women.



Explain one reason why the bone fracture threshold is at a much younger age for women than for men.

(2 marks) (KA2)

- (c) Explain how one lifestyle strategy could delay the onset of osteoporosis in women.

(2 marks) (KA2)

Total: / 60 marks

Case Study

Diagnosis of Diet-related Disorder

With reference to the materials below, determine the diet related disorder that this patient is suffering from and make recommendations to resolve the patient's condition and/or manage her symptoms. Justify your diagnosis and recommendations using evidence from the materials.

Symptoms:

- Abdominal pain, lower lefthand side (x-ray was taken of the large intestines due to this pain, as shown on the right)
- Occasional blood in stools
- Constipation
- Small, hard stools

Sex: Female
Age: 65 years
Weight: 55kg
Height: 160cm
Activity Levels: Sedentary



Dietitians' notes

After discussion with the patient, her typical diet is outlined below.

Breakfast:

- >> 3x eggs with bacon
- >> Black coffee

Lunch:

- >> White bread sandwich with ham and cheese

Dinner:

- >> Steamed fish and hot chips

Snacks:

- >> Packet of plain salted chips (crisps)
- >> Black coffee

Case Study**1***(10 marks) (IAE3, KA2)*



Science as a human endeavour

Science as a Human Endeavour: How a NASA inspired belt could treat low bone density using vibration to prevent osteoporosis.

Source: <https://www.nsmedicaldevices.com/analysis/using-vibration-to-prevent-osteoporosis>

Osteoporosis is increasingly becoming an epidemic, with the International Osteoporosis Foundation reporting one in three women and one in five men will experience an osteoporotic fracture in their lifetimes.

Currently, the American Journal of Managed Care identifies that there are 54 million people with low bone density in the US, and half of all women will have a fracture in their lifetime. They also expect there to be over three million osteoporotic fractures a year by 2025, with related expenditures of \$25bn per year.

Laura Yecies describes “when I was growing up, I’m sure my grandmother had osteoporosis. She shrank a lot and became hunched over. In college I worked in a nursing home where my dad was medical director, and patients were there either because of Alzheimer’s or hip fractures.

The current treatments of osteoporosis are cost effective and include oral medications and injections that reduce the rate of resorption, or breakdown, in bones, as well as strengthening the bone that’s already there. Although these treatments work, they have a lot of side effects, which is why they are only used once a person is diagnosed with osteoporosis, rather than as a prevention method.

But one company, OsteoBoost, wants to prevent osteoporosis before it occurs by providing patients with an easily-accessible, low-effort way to create the impact needed to stimulate bone to rebuild stronger – simply wearing a vibration belt.

The research story starts with NASA (National Aeronautics and Space Administration), which funded several projects in the early 2000s looking at whether standing on a vibrating plate could counteract the rapid bone loss experienced by astronauts in the weightless state they enter in space due to low levels of gravity. However, these vibrating plates have little scientific credibility and can run into thousands of dollars to purchase.

However, a belt is great because you can wear it while walking the dog, or doing the laundry, and it applies a vibration to the most vulnerable areas of the body – the hips and the lumbar spine. It is expected the product will cost probably around \$800, but the decision on price won’t be finalised until the company can take OsteoBoost to market.

Bone Health Technologies is still conducting the pivotal trial that will spell success or failure for the product, but research conducted on animals and humans already shows a positive link between use of the device and improved bone density levels.

The company took 17 postmenopausal women and measured their NTX levels – a peptide found in urine known to be a reliable indicator of the rate of bone resorption. They found that one 30-minute treatment reduced NTX levels by 14%, which Yecies says is equal to the effect of exercise and medication.

The device itself features an accelerometer and a pressure sensor, allowing it to measure the amount of vibration reaching the bones, which will be dependent on how much adipose tissue or clothing there is to navigate, and automatically adjust it to ensure it’s effective to prevent osteoporosis. Once this data is acquired, the plan is to integrate it with a companion app that will help users track their usage and encourage them to pick up the belt more often if they’re behind on the schedule.

According to developers, OsteoBoost mimics weight-bearing exercises with gentle mechanical stimulations to the hips and spine based on whole-body vibration technology.

1. Explain how the OsteoBoost belt can delay the onset and severity of osteoporosis.

(3 marks) (KA2)



Science as a human endeavour

2. Choose at least **one** of the key concepts of Science as a Human Endeavour and explain how the article on the previous page highlights the interaction between science and society.

(4 marks) (KA3)

3. Explain the **impact** the OsteoBoost belt will have on society, if used as the predominant prevention method for Osteoporosis in the future.

(2 marks) (KA3)

Extension Activities

1. Research and explain what the colour and density of your stools may tell you about the health of an individual.

Colour:

Density:

- 212

1.11 Nutrition through the Life Cycle

Science understanding

- Explain why nutrition needs and energy requirements change for the different stages of the life cycle, including:
 - Infancy
 - Childhood
 - Adolescence
 - Adulthood
 - Elderly
 - Pregnancy and Lactation
- Explain the factors that determine an individual's physiological need for nutrients (age, gender, body size, activity level).

SACE Subject Outline, 2024.

Nutritional Needs and Energy Requirements

The nutritional requirements of the human body change as our physiological features develop through different life stages. Nutrient Reference Values (NRVs) specify the nutritional needs at various stages of life. Physiological factors also influence metabolic rate and the number of kilojoules needed. During the lifecycle, major physiological changes allow humans to be grouped as infants, children, adolescents, adults, and the elderly. Life stages of pregnancy and lactation also bring large changes in physiological factors and therefore nutritional and energy needs.

Infancy

Infancy is the first stage of the human lifecycle (as shown in Figure 1.11.1). This 12-month life stage includes the newborn period from 0-3 months.



Figure 1.11.1: The first stage of the human lifecycle: infancy.

Physiological characteristics

- Aged between 0 and 12 months.
- Rapid growth rate, where infant's length increases approximately 25 centimetres from birth to one year (as shown in Figure 1.11.2) and triple their weight by one year, typically reaching 9.5 to 10 kilograms (as shown in Figure 1.11.3)
- Not very active – by five months many babies can roll, by 8-9 months most can crawl and pull up to stand, and by 12 months some infants will be walking.

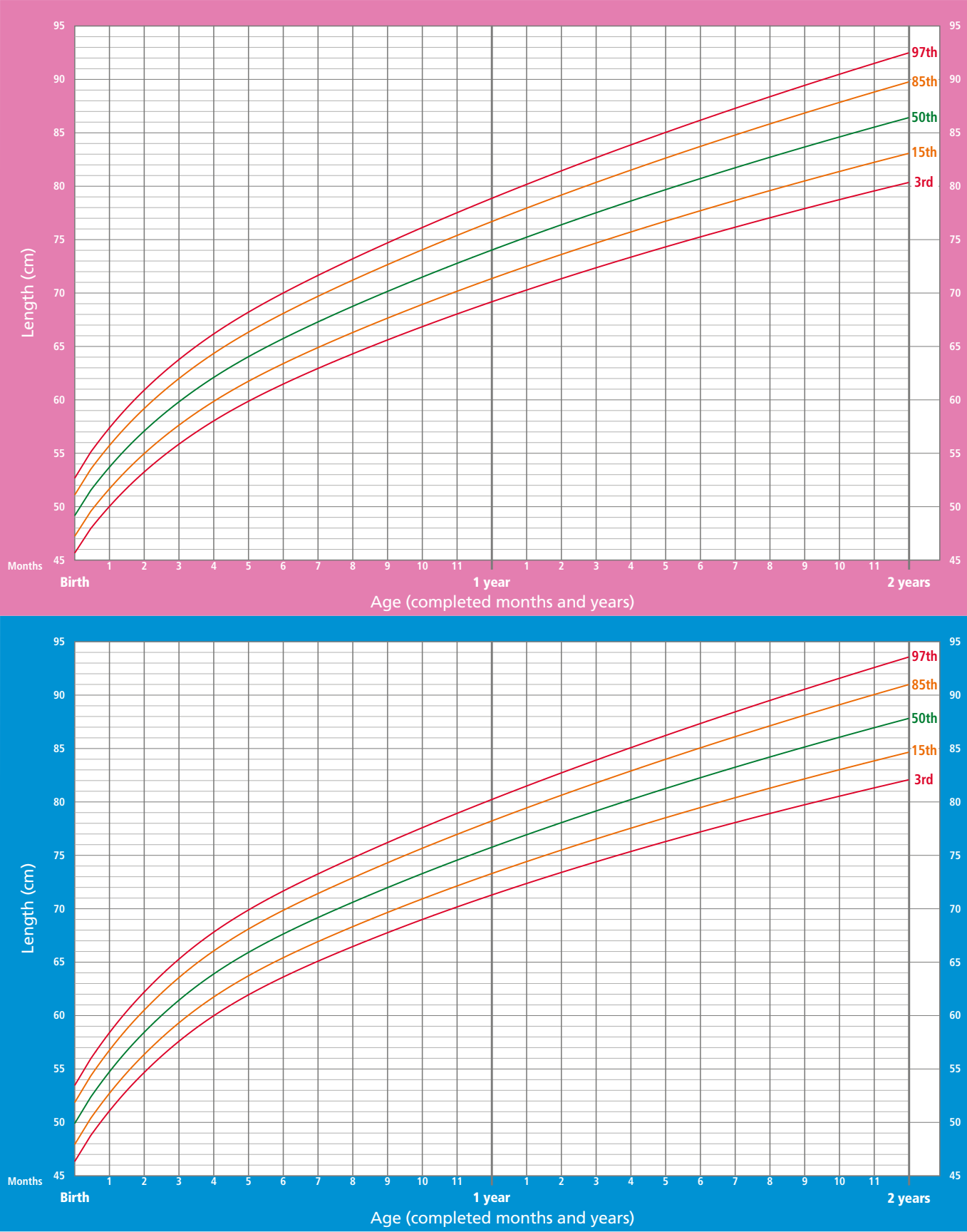


Figure 1.11.2: The growth chart for Girls (top) and Boys (bottom) between 0-2 years for length Source: The Royal Children’s Hospital Melbourne

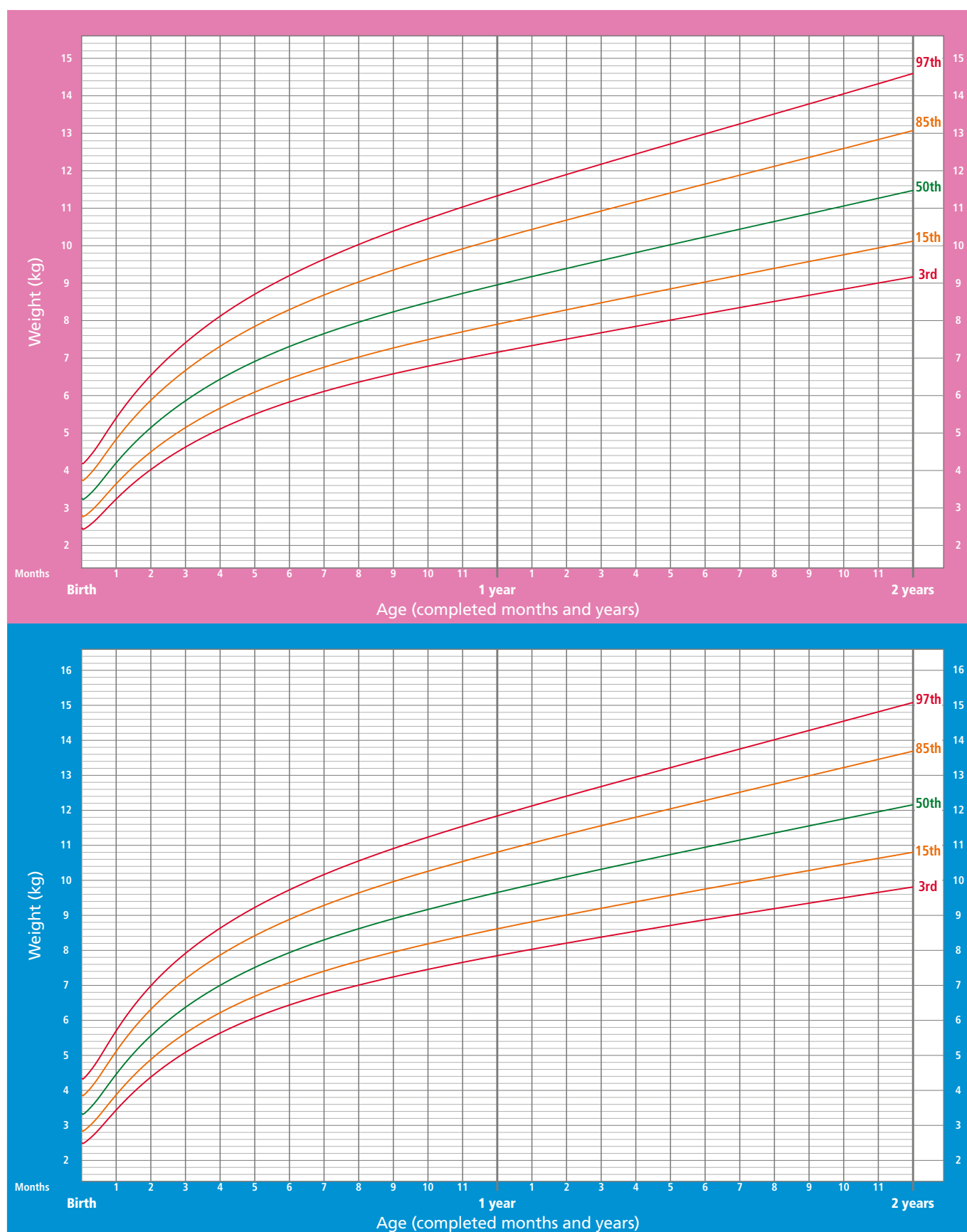


Figure 1.11.3: The growth chart for Girls (top) and Boys (bottom) between 0-2 years for weight Source: The Royal Children's Hospital Melbourne

Nutritional Needs

Although NRVs may show smaller quantities of each nutrient during this life stage, the intake of most is higher relative to the body size compared to adults (as shown in Figure 1.11.4).

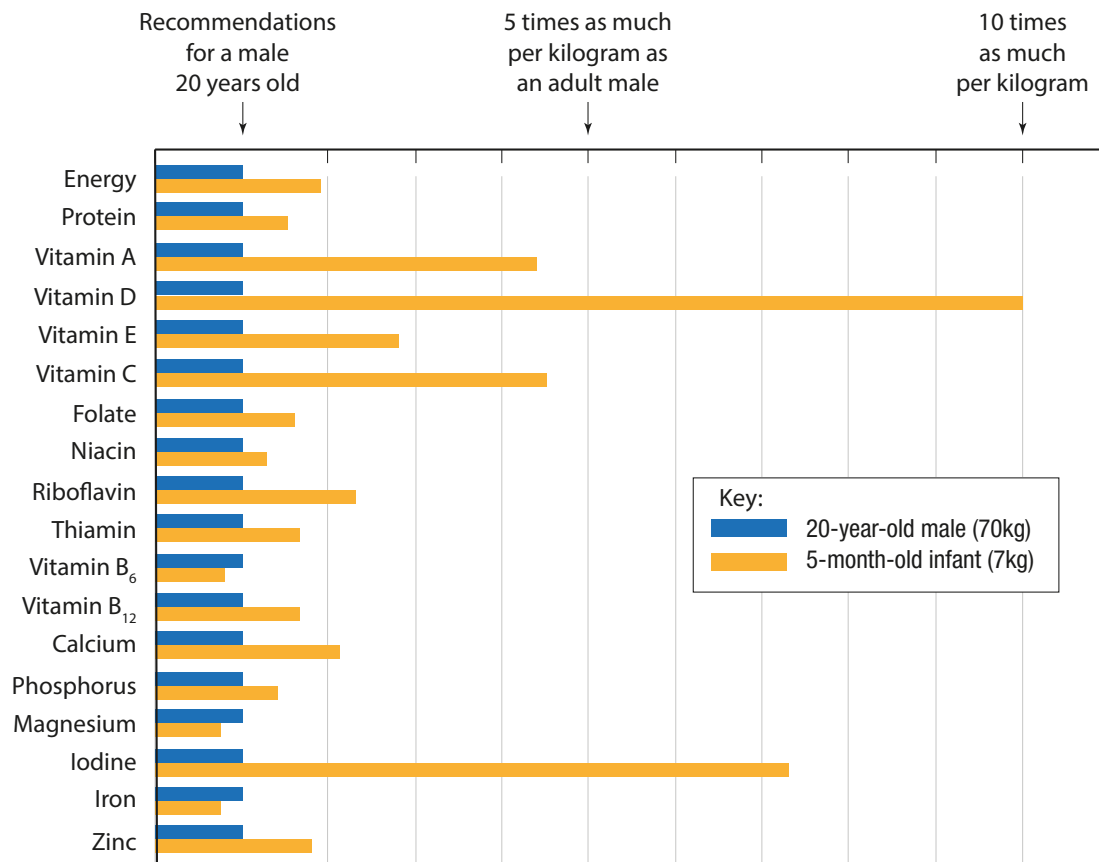


Figure 1.11.4: The recommended intakes of an infant and an adult, relative to body size.

The two dietary practices that have the most significant effect on an infant's nutrition are the type of milk the infant receives and the age at which solid foods are introduced. **Breast** milk is recommended for healthy full-term infants where possible until at least six months of age. Breast milk excels as a source of nutrients for an infant, where it supplies the required amounts of energy, macronutrients, micronutrients, and water. It also provides protective **immunological factors** that promote optimal development of the baby's immune system. If breastfeeding isn't possible, then an appropriate infant formula that imitates the nutrient composition of breast milk is an acceptable alternative.

Definition

Immunological factors are substances that play a role in the functioning of the immune system, for example, antibodies and white blood cells which are present in high amounts in colostrum, which is the first milk that comes out of the breasts after birth. There are antibodies in breastmilk the entire time a mother continues to nurse also.

From six months, solid foods should be introduced and given to the infant in conjunction with breast milk until 12 months. The purpose of introducing solid foods is to provide the needed nutrients that are no longer supplied adequately by breast milk or formula. The addition of solid foods should consider the infant's nutritional needs, the infant's physical readiness to chew and swallow different foods and the need to detect allergic reactions. If there is a family history of allergic reactions, it is recommended that foods should be introduced individually and in small portions over a few days to identify any food allergies. It is also strongly recommended that infants should not be given foods high in sugar or salt, due to the sensitivity of their taste buds, which can potentially set them up for negative habits and promote obesity later in life. Full fat products should also be given, rather than low or reduced fat products also, as fat provides the energy and essential nutrients for growth and physical activity.

Energy Requirements

An infant's energy requirements are remarkably high – approximately twice that of an adult, based on body weight. A newborn baby requires 1800-2000 kilojoules per day, which calculates to 420-450 kilojoules per kilogram of body weight per day. However, after six months, the infant's energy needs decline as growth rate slows. Some of the energy saved by slower growth is spent on increased activity.



Fast fact

Most adults require 8500 kilojoules per day, calculating to fewer than 170 kilojoules per kilogram of body weight. If an infant's energy needs were applied to an adult, a 70kg adult would require over 30,000 kilojoules a day.

Carbohydrates, fat, and protein are energy yielding and therefore are recommended based on the average intakes of healthy full-term infants fed breast milk in the first six months. During the second six months of life, recommendations are based on the typical intake from solid foods, as well as breast milk. Carbohydrates provide energy to all the cells of the body, especially those in the brain which predominantly rely on glucose as its fuel. An infant's brain is larger, relative to its body's size and therefore uses 60% of the total daily energy intake. Fat is energy dense and provides most of the energy in breast milk and standard infant formula, which supports the rapid growth of early infancy. Protein acts as a secondary energy source and should not be relied on due to its essential role acting as a basic building block of the body's tissues which are growing rapidly.

Childhood

After infancy is childhood (as shown in Figure 1.11.5), which includes toddlers, preschoolers, and primary school-aged children.



Figure 1.11.5: The second stage of the human lifecycle: childhood.

Physiological characteristics

- Aged between 1 and 12
- Steady, consistent growth (with intermittent mini growth spurts) until rapid growth with puberty, which starts around 10 years for females and 11 for boys.
- Bones and muscles increase in mass and density.
- Activity levels increase due to learning how to walk, run, talk, concentrate, jump, and climb.
- Hormone levels start to increase due to the onset of puberty, which varies for everyone. Puberty for girls usually begins between 10 and 11 years old and usually begins around 11 or 13 for boys.

Nutritional Needs

During this stage of life, toddlers adjust from a diet of breastmilk or infant formula to a diet of adult foods. The nutrient needs of children increase with age, where a balanced diet is required to meet the needs of these nutrients. Growth and higher activity levels require extra energy, protein, low GI carbohydrates, fat (low-fat products are inappropriate for children under two years of age), calcium, vitamin D and iron. Ideally, children should be accumulating their stores of these nutrients and body fat in preparation for puberty by eating a wide range of foods. It is also essential as in infancy, that fruit juices, sugar-sweetened fluids, sugar, salt, and saturated fat are limited to prevent the development of childhood obesity. In addition, some children become fussy about the foods they eat, which can interfere with critical brain growth and development during this time. It is essential that parents promote nutritious choices and healthful habits by providing access to nutrient dense and delicious foods. This ensures that good habits are established at a young age to prevent the development of bad habits and potentially diet related disorders later in life.

Energy Requirements

Children's appetite begins to decline after the age of one, which is consistent with their slowing growth. A child's energy intake varies, depending on their growth and physical activity. Therefore, their required energy intake does increase slightly with age but declines gradually per kilogram of body weight.

Adolescence

Adolescence (as shown in Figure 1.11.6) is the life stage between childhood and adulthood.



Figure 1.11.6: The adolescent stage of the human lifecycle.

Physiological characteristics

- Aged between 13 and 18 years.
- The steady growth of weight and height in childhood speeds up abruptly and dramatically, which lasts for approximately two and a half years. On average, males grow 20cms taller and females grown 15cms taller. Males gain approximately 20kgs and females gain approximately 16kgs.
- During the adolescent growth spurt, differences between males and females become apparent in the skeletal system, lean body mass and fat stores, where fat accounts for a larger percentage of the total body weight in females and lean body mass (muscle and bones) increases much more in males than females.
- Hormone levels continue to increase due to puberty (which generally starts at the end of childhood). This determines the growth spurt of an adolescent, affecting the shape of their body and every organ in their body (including the brain).
- Blood volume increases due to rapid growth spurt in height.
- Muscles can increase in strength and size with puberty (dependent on physical activity)

Nutritional Needs

Adolescents make many choices for themselves when it comes to choosing the foods they consume, however, these can be influenced by peers and the media. The **recommended daily intake** for most nutrients increases during this life stage due to the onset of puberty and the steady growth in weight and height they experience. In general, nutrient needs rise throughout childhood, peak in adolescence and then level off as individuals enter the next life stage: adulthood. The need for Iron increases during adolescence for both females and males; however, for different reasons. Both females and males require higher levels of iron to compensate for the increase in blood volume they experience with their steady growth in height and weight. However, female's iron needs also increase as they start to menstruate, and male's needs also increase as their lean body mass develops requiring myoglobin. The requirement for calcium also reaches its peak during these years, as it is a crucial time for bone development. A low calcium intake and physical inactivity can compromise the development of their peak bone mass, putting them at greater risk of developing osteoporosis earlier in life.



Fast fact

One in five adolescents skip breakfast, however those who eat breakfast are more likely to meet their nutrient intake recommendations, than those who skip this meal.

Energy Requirements

Energy needs are greater during adolescence than at any other time of life (except during pregnancy and lactation). An adolescent's energy needs are dependent on their current rate of growth, gender, body composition and physical activity. Generally, males have higher energy requirements due to a greater growth rate and developing a greater proportion of lean body mass. However, a female's energy requirements during this life stage peak sooner than a male due to experiencing their growth spurt earlier. In general, the adolescent growth spurt begins at the age of 10 or 11 for females and at 12 or 13 for males. Therefore, an active 15-year-old male may require 14000kJ or more a day to maintain his weight, whereas a 15-year-old female may only require 8200kJ a day.

Adulthood

Adulthood (as shown in Figure 1.11.7) follows adolescence and is the longest of the life stages.



Figure 1.11.7: The longest stage of the human lifecycle: adulthood.

Physiological characteristics

- Ages 18 to 65 years.
- Growth ceases (most females have already stopped growing by adulthood, and most males stop around age 20).
- Activity levels decrease.
- Lean muscle mass and bone density slowly decrease after approximately 30 years of age, while body fat steadily increases.

Nutritional Needs

The slowing down of physiological changes in this life stage results in lower nutritional requirements per kilogram. However, during this stage an increased prevalence of overnutrition and undernutrition diseases occurs, therefore foods rich in fibre, iron and calcium should be included while alcohol, saturated fats, sugar, and salt should be reduced. It is recommended by the Australian Guide to Healthy Eating that a wide variety of nutritious foods from the five food groups should be consumed daily.

Energy Requirements

The average adult requires 8700kJ daily to maintain a healthy weight and to ensure the intake of all recommended nutrients are consumed. However, this is dependent on body composition, physical activity, and gender.

Elderly

Following adulthood is being elderly (as shown in Figure 1.11.8), the final stage of the human lifecycle.



Figure 1.11.8: The final stage of the human lifecycle: being elderly.

Physiological characteristics

- **Ages 65 years and above.**
- Activity levels continue to decrease, leading to a decline in lean muscle mass and bone density, while body fat continues to increase. This can lead to joint pain, arthritis, muscle weakness, limited mobility and increased chance of falls and fractures.
- Bone resorption is greater than bone formation, further leading to a decline in bone density.
- Functioning of the immune system declines with age and can become compromised further with nutrient deficiencies; therefore, increasing the risk of illness and chronic disease.
- GI tract loses strength and elasticity with age, slowing its motility and making constipation more common.
- Appetite diminishes due to hormonal changes, which can lead to a decreased energy intake and weight loss.
- Tooth loss and gum disease are common in old age, making chewing hard foods (e.g., red meat) difficult and painful. Dentures may be fit; however, these are still less effective than natural teeth.
- Sensory losses, such as failing eyesight and diminishing taste buds.
- Psychological changes, including dementia, depression, loss of motivation.



Fast fact

The population of Australia is growing older, and the ratio of elderly people to younger people is increasing. In 2014, approximately 14.7% of Australians were elderly, however projections for 2050 indicate that one in four Australians will be over the age of 65. Since 1950, the population of those over 65 has almost tripled.

Nutritional Needs

Nutritional needs of elderly are difficult to determine due to individual differences, such as genetics, chronic diseases, and the administration of various medicines. However, nutrients of greatest concern include water, protein, carbohydrates, fibre, fat, vitamin D, calcium, and iron.

Dehydration is a risk for older people, as they do not seem to feel thirsty or notice a dry mouth and their total body water decreases with age. Therefore, to prevent dehydration, older people need to drink at least six glasses of fluid a day. Protein is essential to obtain from high quality sources, including lean meats, poultry, fish and eggs, legumes, and low-fat dairy products. This macronutrient is important to support a healthy immune system, prevent muscle wasting and optimise bone mass. However, high quality protein sources can be difficult to chew due to poor dental health leading to a reduced intake of these foods causing a deficiency. Carbohydrates are

needed to protect protein from being used as a secondary source of energy. Sources of complex carbohydrates include legumes, vegetables, whole grains, and fruits, which are also good sources of fibre. The consumption of fibre and water is essential to alleviate constipation.

Fat intake needs to be moderate, enough to provide for its important roles in the body and prevent significant weight loss, but not so much to increase the risk of obesity and atherosclerosis. Vitamin D deficiency can be a problem in elderly people as they are often less exposed to sunlight and the ability to produce vitamin D and convert it into its active form is reduced with age. As well as this, calcium intakes of older people are below the recommendations as dairy products can be avoided because they are disliked or cause stomach discomfort. However, an increase in the intake of vitamin D and calcium are essential to improve bone strength and reduce the severity of osteoporosis. Iron deficient anaemia is less common in elderly than in younger people, especially females as menstruation ceases. However, iron deficiency may develop in older people if their energy intake is low, they experience chronic blood loss from diseases or suffer from poor iron absorption. Therefore, it is important for older people to take iron supplements, consume haem iron sources and include vitamin c rich foods in their diet.

Energy Requirements

The energy requirements decline an estimated 5% per decade beyond the age of 50. The main reason for this is because people usually reduce their physical activity as they age. Another reason is that their basal metabolic rate declines 1 to 2 percent per decade, due to lean body mass diminishing. Therefore, with limited energy allowances, it is essential that older individuals consume mostly nutrient dense foods rather than foods with added sugars and high in saturated fat.

Pregnancy & Lactation

Pregnancy can be broken into three trimesters: trimester one is the first three months (or weeks one to 12), trimester two is from three to six months, (weeks 13 to 27) and trimester three, the last trimester, is from six to nine months (weeks 27 to 40, the average duration of pregnancy). A female can become pregnant during her menstruating years (as shown in Figure 1.11.9). Lactation, also known as breastfeeding, is the life stage that follows the birth of a child. It describes the period where a mother secretes milk from the mammary glands in her breasts to feed her infant. The mammary glands develop during puberty but remain inactive until pregnancy.

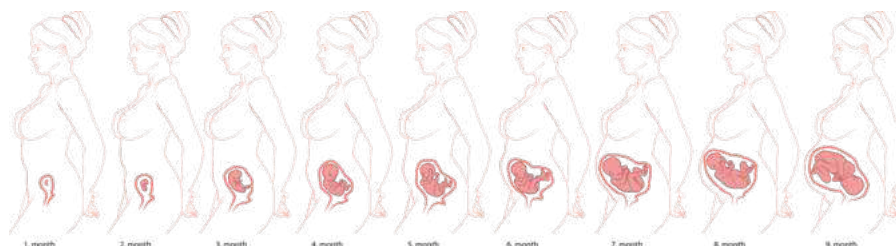


Figure 1.11.9: The stages of pregnancy and changes that occur in a female's body.

Physiological characteristics

- Weight gain of around 10 to 13 kg during pregnancy (dependent on pre-pregnancy weight).



Fast fact

When a baby is born, it typically weighs between 2.5 and 4 kg. The remainder of pregnancy weight gain is from uterus, blood volume and breast-size increases, plus the placenta, amniotic fluid surrounding the fetus in the womb, body fluid, and body fat.

- Morning sickness (nausea and vomiting), especially during the first trimester.
- Activity levels tend to decrease, particularly in trimesters two and three, although recommendations are to continue pre-pregnancy exercise, or begin regular exercise if sedentary, taking precautions as to exercise type and intensity.
- Times of intense development and rapid cell division are common in the first 12 weeks (as shown in Figure 1.11.10).
- Postpartum (period after childbirth) physiological changes, e.g., uterus reducing in size, return the mother to pre-pregnancy characteristics.
- Generally, a reduction in the body fat gained during pregnancy is experienced during lactation.

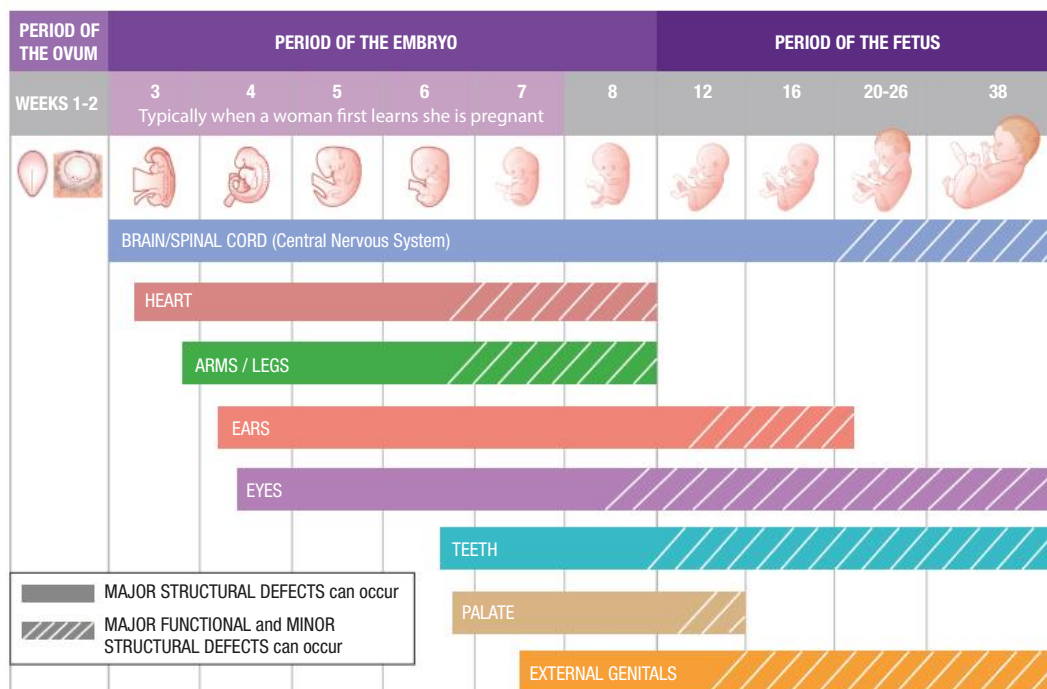


Figure 1.11.10: The critical periods of development, where deficiencies can cause major structural defects that are irreversible and in the later stages of development nutrient deficiencies can be less critical and relatively minor or reversible.

Nutritional Needs

From conception to birth, all parts of the infant's bones, muscles, organs, blood cells, skin and other tissues are made from the nutrients in the food that the mother consumes. For most women, nutrient needs during pregnancy and lactation are the highest than at any other time. It is crucial for a woman to make careful food choices to ensure she meets these higher nutrient requirements (as shown in Figure 1.11.11); however, her body will also assist in maximising nutrient absorption and minimising losses.

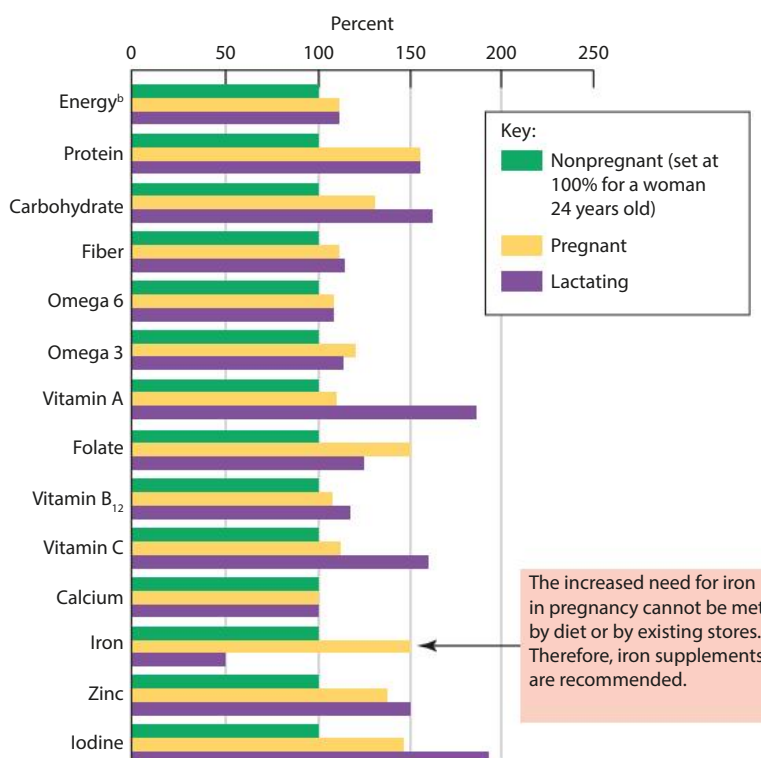


Figure 1.11.11: Comparison of nutrient recommendations for non-pregnant, pregnant, and lactating females.

Pregnant women need to increase their consumption of carbohydrates to ensure adequate fuel is provided for the growth and development of the foetus. Essential fatty acids are important for the growth, function, and structure of the foetus' brain as it is largely made of lipid material. Folate, Vitamin B₁₂, Iron and Zinc play a key role in the synthesis of DNA and new cells and to support a female's enlarged blood volume. Iodine regulates the thyroid gland which maintains metabolic processes, including growth and energy use. An insufficient intake of vitamin D, calcium, phosphorus, magnesium, and fluoride may produce abnormal foetal teeth and bones. Pregnant women who make wise food choices can meet most of their nutrient needs, with the possible exception of iron, calcium, and folate to which supplementation is recommended.

Lactating females require additional intake of most nutrients also; however, if she fails to get enough in her diet, the quantity of her breast milk may reduce but not the quality. The quality of breast milk is maintained at the expense of the mother's nutrient stores. Therefore, women can still produce high quality breast milk with an inadequate intake of protein, carbohydrates, fat, most minerals, and folate. However, the female may experience symptoms of these nutrient deficiencies. The nutrients in breast milk that are most likely to decline in response to long term inadequate intake includes vitamins A, D and B₁₂ especially. However, most women can obtain all nutrients they need from a well-balanced diet and some supplementation to refill their depleted stores. As well as this, lactating mothers need to consume an additional 500ml of water each day to compensate the water lost through her breast milk.

Energy Requirements

The enhanced work of pregnancy and lactation increases the female's basal metabolic rate and requires additional energy. An additional 1400kJ per day is required during the second trimester and an additional 1900kJ per day is required in the third trimester. A woman should choose to consume more nutrient dense foods to supply these extra kilojoules, rather than consuming energy dense foods. This not only ensures that energy requirements are met, but also nutrient requirements. Foods such as wholegrain breads and cereals, legumes, dark green leafy vegetable, citrus fruits, low-fat milk and milk products, lean meats, fish, poultry, and eggs should be chosen.

A nursing mother produces approximately 750ml of milk per day, which can vary from woman to woman and in the same woman from time to time. To produce an adequate supply of milk, a woman requires an additional 2000kJ a day above her regular needs. Women lactating require the same intake of protein and fat than they did during pregnancy; however, additional carbohydrates are recommended. An increase in carbohydrate intake is needed to replace the glucose used to make the lactose in breast milk.

Key terms

Adolescence	Childhood	Lactation
Adulthood	Elderly	Pregnancy
Breast milk	Infancy	

Review questions: 1.11 Nutrition through the Life Cycle

1. Match the applicable life stage to its physiological characteristic (note that the life stages can be used more than once).

Life stage	Physiological characteristic
	Growth ceases
	Aged between 1 and 12 years
	Activity levels can decrease due to joint/muscle pain
	Very fast growth rate (can double in height in one year)
	Puberty begins
	Very rapid growth rate, but exercise may cease for some
	Lean muscle mass and bone density begin to decline
	Immune system function declines

(8 marks) (KA1)

2. Infancy is the first year of the human lifecycle, which is characterised by rapid growth.

- (a) With reference to Figure 1.11.2, determine the percentile the following infants would be categorised in at the following age and length:

- (i) 7-month-old girl who is 67 cm long.

(1 mark) (IAE3)

- (ii) 11-month-old boy who is 78cm long.

(1 mark) (IAE3)

- (b) With reference to Figure 1.11.3, determine the percentile the following infants would be categorised in at the following age and weight:

- (i) 12-month-old girl who weighs 9kg.

(1 mark) (IAE3)

- (ii) Newborn (0 months) boy weighing 4.2kg.

(1 mark) (IAE3)

- (c) With reference to figure 1.11.4:

- (i) Identify two nutrients where a five-month-old infant requires between 5-10 times more per kilogram than an adult male.

(2 marks) (IAE3)

- (ii) Identify two nutrients where a 20-year-old male requires more per kilogram than a five-month-old infant.

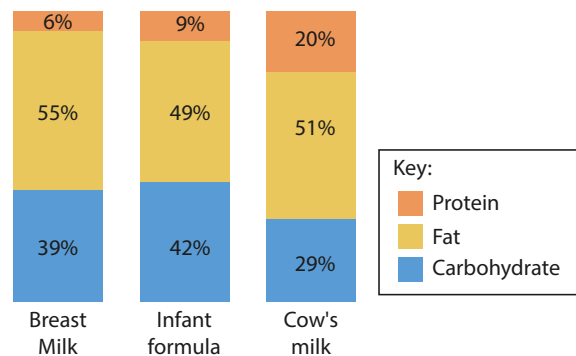
(2 marks) (IAE3)

3. For each row, circle which of the following situations, 1 or 2, that would require greater energy requirements in an adolescent.

Row	Situation 1	Situation 2
1	Increase in physical Activity	Living a sedentary lifestyle
2	Being a 10-year-old female	Being a 10-year-old male
3	Developing greater adipose tissue	Developing greater lean body tissue
4	Being a 16-year-old female	Being a 16-year-old male
5	The onset of puberty	The completion of puberty

(5 marks) (KA2)

4. The average proportions of energy yielding nutrients in human breast milk, formula and cow's milk differ, as shown in the graph below.



- (a) With reference to the graph above, describe the difference in the proportions of all three energy yielding nutrients between human breast milk, infant formula, and cow's milk.

(3 marks) (IAE3)

- (b) With reference to the graph, outline the implications of introducing cow's milk to an infant within the first 12 months in replacement of human breast milk.

(2 marks) (KA2)

5. Explain why a lactating female is at greater risk of developing a diet related deficiency, than a female who feeds their baby formula. Use a nutrient as an example in your response.

(3 marks) (KA2)

6. Elenor is a 75-year-old, recently widowed woman who has a limited income. She lives alone and does not have any family nearby. Elenor is slightly underweight and has severe osteoporosis, which limits her mobility.

Identify three barriers to Elenor meeting her nutritional needs and describe a strategy that will assist her to overcome each of these barriers.

Barrier:

Strategy:

(3 marks) (KA2)

Barrier:

Strategy:

(3 marks) (KA2)

Barrier:

Strategy:

(3 marks) (KA2)

7. Snacks for a four-year-old child have been listed below. Not all these snacks, however, are appropriate for the child's younger brother who is six months old. Make two modifications to the following snacks for the six-month-old and discuss why you would make these changes.

Child's snacks: apple, nuts, juice, yoghurt

Modification one:

Modification two:

(4 marks) (KA2)

8. A breastfed baby presents as being underdeveloped at its 3-month checkup due to vomiting up the breastmilk that coincides with after the mother consumes cow's milk. Explain what changes would need to be made to aid the baby's development and how this could impact the mother's health.

(4 marks) (KA2)

9. Explain why older people are at greater risk of the following diet related disorders, in relation to their age and physiological characteristics.

(a) Constipation

(2 marks) (KA2)

(b) Iron deficient anaemia

(2 marks) (KA2)

(c) Osteoporosis

(2 marks) (KA2)

10. Some of the physical changes that occur in adolescence are listed below. Identify the key nutrient required by the body to support that change and explain how it does so.

(a) Growth in length and width of the skeleton

(2 marks) (KA2)

(b) The development of secondary sexual characteristics e.g., puberty

(2 marks) (KA2)

(c) Increase in muscle mass and body weight.

(2 marks) (KA2)

(d) Increase in volume of blood.

(2 marks) (KA2)

Total: / 60 marks

Case Study

Amy is 17 years old and is currently in her final year of High School. She used to love eating meat but became a vegan when she was 15 because many of her friends did not eat meat. Lately she is not doing well in school. Her teachers have noticed that she is not concentrating in class. At home, her mother finds her falling asleep at her desk instead of doing her homework. She is irritable to her family, and she complains that she is too tired. She does not participate in school sports. However, she aspires to become a professional dancer and attends ballet and other dance classes every evening except on Sundays.

At a health check-up the following information was obtained:

- Amy is 163 cm tall (without shoes) and weighs 45 kg in light indoor clothing.
- Blood test results were haemoglobin = 10 g/dL, and her blood ferritin (protein that carries iron around in the blood) level was 18 µg/L.
- Amy started her period at age 12; her monthly period lasts about one week, with heavy flow the first three days.

Her food intake from the last 24 hours is as follows:

Breakfast	1 coffee with a dash of almond milk
Morning snack	1 banana
Lunch	1 cup of mixed salad (lettuce, 1 tomato, ½ avocado, 1 cucumber, ½ green capsicum, ¼ red onion) 1 apple
Dinner	1 medium plate of curry lentils ½ cup of brown rice ½ cup of steamed vegetables (broccoli, carrots, and peas)
Snacks	1 small handful of unsalted mixed nuts 6 x mini original rice crackers 1 can of diet coke

Her diet was entered into MyFitness Pal to determine her current energy and nutrient intake and compared with the recommended intakes based on her age and gender. The significant nutrient imbalances are shown in the table below:

	Energy (kJ)	Protein (g)	Iron (mg)	Calcium (mg)
Actual Intake	3455	23.3	3.6	312
Recommended Intake	8996	45	15	1300

Her information was then compared to the ranges for an individual of her age, as shown below:

Age	Healthy Haemoglobin Levels (g/dL)	Age	Healthy Ferritin Levels in the Blood (µg/L)
Newborn	14-24	Newborn	25-200
2 — 6 months	10-17	1 month	200-600
6 months — 6 years	9.5-14	2 — 5 months	50 - 200
6 — 18 years	10-15.5	6 months — 15 years	7-140
Adult Women	12-16	Adult Women (16+ years)	24-307
Adult Men	14-18	Adult Men (16+ years)	24-336

Case Study

With reference to the information and materials on the previous page, answer the following questions:

- Using data to justify, identify an undernutrition disease and discuss how it could be behind Amy's symptoms.
- Discuss the implications of Amy's nutrient imbalances in relation to the physiological changes expected for her age and gender.
- Create a meal plan that caters for her dietary needs and provide reasoning for the dietary changes recommended.

Breakfast	
Morning snack	
Lunch	
Dinner	
Snacks	

(10 marks) (AE3, KA2)



Science as a human endeavour

Lab-made ‘human’ breast milk may soon be an option for parents who can’t breastfeed but don’t want to use formula.

Source: <https://www.businessinsider.com.au/lab-grown-human-breast-milk-may-soon-be-option-biomilq-2020-2>

When Leila Strickland was pregnant with her first child, she worried about the impending labour and delivery. But thoughts about what would happen after that – like breastfeeding – did not take up much emotional real estate. What was there to think about except the fact that she would do it because “breast is best?” Her own mum had breastfed her until she was two.

“I had the expectation that that this is something of course my body would be able to do,” Strickland, a cell biologist in North Carolina, told Insider. In reality, her son was born early, he had trouble latching, and she struggled to stimulate enough milk. She ended up “pumping constantly” and felt beat down by messaging that if breastfeeding didn’t come easily, she just had to try harder. “Being unable to do this really critical thing that I hadn’t anticipated struggling with and that I knew was super important really affected how I felt about myself as a woman and as a mother,” Strickland said.

Now, about 10 years later, Strickland and food scientist Michelle Egger are aiming to help new mums with breastfeeding challenges by giving them what they say is an option that is superior to formula: Lab-grown breast milk. While the product is still in development, they believe the components they have created so far are enough to get them there soon.

Securing the funding was challenging, but necessary, Egger said, because babies need to eat, global crisis or not. “No matter what else changes,” she said, “infant nutrition is still going to be fundamentally important for generations to come.”

Strickland and Egger say they have created the two main components in breast milk. Though Strickland has been growing mammary cells in a lab since 2013, she didn’t partner with Egger and launch Biomilq until last year.

In February, they announced they had reached a pivotal step in achieving their goal of creating a cultured breast milk that’s “nutritionally equivalent” to the real thing. They had proven, they wrote on Medium, that their lab-grown mammary cells made the two key components of breast milk: lactose and casein.

“We are the first company to produce vital components of milk together within the same system using a process that is sterile from start to finish and free of all contamination,” they wrote. “Most importantly, this innovation allows us to create the full constellation of complex components in perfect proportion.”

The American Academy of Paediatrics and the World Health Organisation recommend babies exclusively breastfeed for the first six months of life. The guidance is based on extensive research showing that breastfeeding is linked to a host of physical and mental health benefits for both the birthing parent and baby.

Breast milk’s changing makeup, for example, helps protect babies from issues like childhood leukemia and obesity, and is associated with a lower risk of type 2 diabetes and certain cancers in the birthing parent. The process of breastfeeding, too, has its own benefits, including helping a new parent heal from childbirth and encouraging bonding between the parent and infant.

Formula – while “a safe, relatively affordable, thoughtfully designed, rigorously tested, and continually improving” alternative, according to paediatrician Dr. Kelly Fradin – cannot replicate all those benefits since it’s not made from human-made. Instead, it comes from cows, plants, or both. Plus, formula can be harder for the baby to digest and doesn’t adapt to the infant’s changing needs like breastmilk, according to the US Department of Health and Human Service’s Office on Women’s Health.

The founders don’t claim their future product will be identical to breast milk in every way – it won’t morph to a specific baby’s needs or offer the same protections for a baby’s immune system – but they do expect it to produce all 2,500-some components of human breast milk since a single cell, the human mammary epithelial cell, produces them all.

It could especially come in handy for dads, non-biological parents, or parents whose babies have food allergies and can’t tolerate breast milk after their birthing parent has eaten that allergen. She wouldn’t choose it over human breastmilk, though, due to its inability to transmit antibodies and build up the baby’s immune system.



Science as a human endeavour

Heather Guith, a Washington, DC, mum to a 1-and-a-half-year-old for whom nursing “mostly worked out,” told Insider she’s skeptical it will be even that. She said she would only choose it if it were priced similarly to formula – which Egger says it will be, at least eventually – or if her baby had a condition that didn’t allow them to digest formulas.

“Otherwise, I think it’s marketing itself as something it’s not and making great parents feel bad about using formula because there might be a ‘better’ option.” Instead, they want to introduce another option into a decision that has thus far been mostly binary: breastfeeding or using infant formula. A third option, using donor milk, is expensive and limited when accessed via a doctor’s prescription, and unregulated when accessed via a black market.

“We have had the same two solutions for like a hundred years now... and breastfeeding is wonderful, but it’s not always the best option for everyone. And mums deserve better mums and families deserve better,” Egger said.

“I think pretty much everyone is in agreement that the most important thing is to get fundamental nutrition right for an infant,” she said. “And if we have a new tool in our toolbelt that’s able to get us there faster or better than the existing options that are sold in the market today, then everyone should be wholeheartedly excited about it.”

1. Discuss how this example above demonstrates the key concept of **Development** and **Influence**. Provide two clear examples from the article above to demonstrate each key concept.

(8 marks) (KA3)

Extension Activities

1. Research and suggest at least five benefits of breastfeeding infants over bottle-feeding, and then five benefits of bottle-feeding infants over breastfeeding.

Benefits of Breastfeeding	Benefits of Bottle Feeding

2. Research and explain why it is recommended that infants should not be given cow's milk or honey in the first 12 months.

3. Physical activity demands carbohydrates and fat for fuel, protein to build and repair lean body tissues, vitamins, and minerals to support both energy metabolism and tissue building, and finally, water to assist with the distribution of fuels and to disperse the resulting heat and wastes.

Research and suggest what nutrients are crucial for an athlete involved in endurance sports and high intensity training should consume, before, during and after their physical activity. Provide reasons for the suggested nutrients and recommend a meal that caters for your suggestions also.

High intensity athlete e.g., a sprinter

	NUTRIENT/S	REASONS	POSSIBLE MEAL
BEFORE			
DURING			
AFTER			

Endurance athlete e.g., a marathon runner

	NUTRIENT/S	REASONS	POSSIBLE MEAL
BEFORE			
DURING			
AFTER			

Topic One Summary Test

1. Refer to the following Nutritional Information Panel (NIP) of a popular breakfast cereal.

	Quantity per serving	Quantity per 100g	Daily Recommended Energy Distribution (%)
Protein (g)	8.5	21.2	15-25
Fat – Total (g)	0.2	0.6	20-30
Fat – Saturated (g)	0.1	0.3	<10
Carbohydrates (g)	26.6	66.4	45-65
Sugars (g)	18.6	46.5	10
Dietary Fibre (g)	2.0	5.1	

Ingredients: Cereals (46%), Wheat Flour, Oatmeal, Maize Flour, Sugar, Oat Fibre, Salt, Minerals (Calcium, Potassium), Barley Malt Extract, Raising Agent, Flavour, Natural Colour, Vitamins (Vitamin B₁₂, Vitamin D).

- (a) Calculate the total energy supplied by a *serving* of this breakfast cereal. *Show all your working out.*

Total Energy provided by one serving:

kJ

(4 marks) (KA4)

- (b) The World Health Organisation recommends that our added sugar consumption should only make up 10% of our total daily energy intake.
- (i) Calculate the proportion (%) of energy that is provided by sugar only in a *serving* of this breakfast cereal. *Show your working out.*

Proportion of Energy provided by sugar: _____ %

(2 marks) (KA4)

- (ii) The overconsumption of sugar is a nutrition related risk factor for Type II Diabetes. Explain how the overconsumption of sugar frequently can contribute to the development of Type II Diabetes.

(4 marks) (KA2)

- (c) Coeliac disease affects 1% of the world’s population, and 1 in 70 Australians. However, many remain undiagnosed and are therefore unaware they have this malabsorption syndrome.
- (i) Identify *two* ingredients in the breakfast cereal in which an individual diagnosed with Coeliac Disease would not be able to consume.

(1 mark) (IAE3, KA1)

- (ii) Explain why an individual with Coeliac Disease is at greater risk of nutrient deficiencies if the ingredients identified in part (c)(i) were to be consumed on a regular basis.

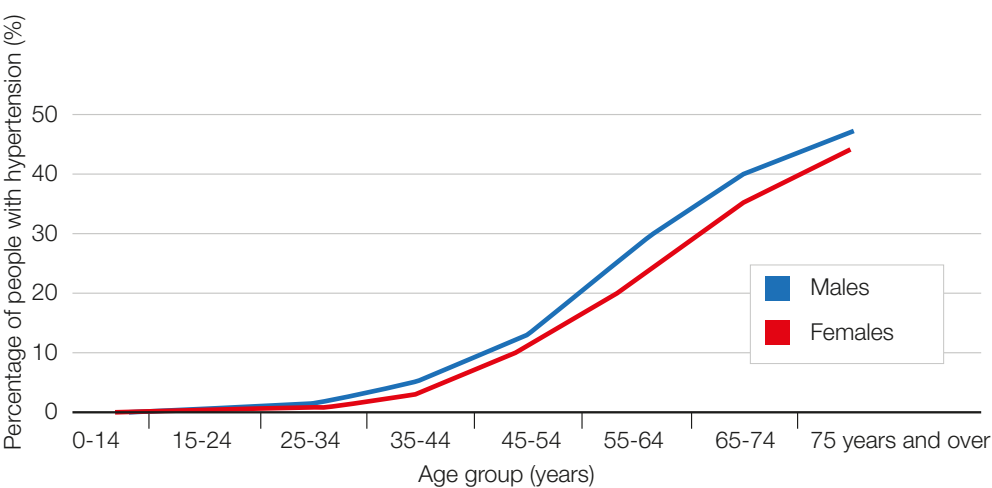
(2 marks) (KA2)

- (d) Select *one* of the Vitamins this breakfast cereal has been fortified with (as shown in the ingredients list) and identify *one* function, *one* specific food source and the name of its deficiency.

Vitamin	One Function	One Food Source	Name of Deficiency

(3 marks) (KA1)

2. Refer to the following graph that shows the prevalence of people with hypertension in Australia between 2014-1015 according to the National Health Survey.



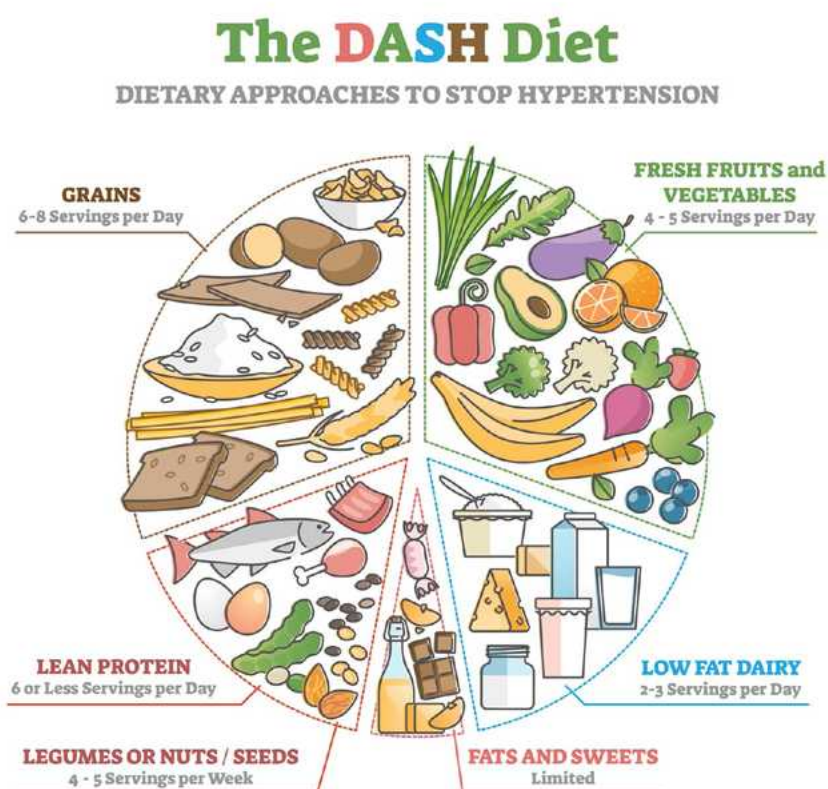
- (a) Using data from the graph above, describe the trends in the percentage of males and females with hypertension as age increases.

(2 marks) (IAE3)

- (b) Both Atherosclerosis and Hypertension can be precursors to each other.
- (i) Explain how hypertension can lead to atherosclerosis.
 - (ii) Explain how atherosclerosis can lead to hypertension.

(4 marks) (KA2)

- (c) The DASH diet (as shown below) was developed to reduce high blood pressure. Explain one way that this diet could assist in managing and reducing an individual's blood pressure, who suffers from hypertension.



(3 marks) (KA2)

3. Tim is a 58-year-old male who consults you as his nutritionist. Refer to his consultation notes and the Body Mass Index (BMI) chart below to answer the following questions.

Date: 29/05/2021

Time: 1.30 pm

Age: 58 Years old

Weight: 115kg **Height:** 161cm

Symptoms: fatigue, excessive thirst, and numbness in feet

Blood glucose level: 16.0 mmol/L (high) 2 hours after eating

Exercise: 1-3 hours of light exercise per week

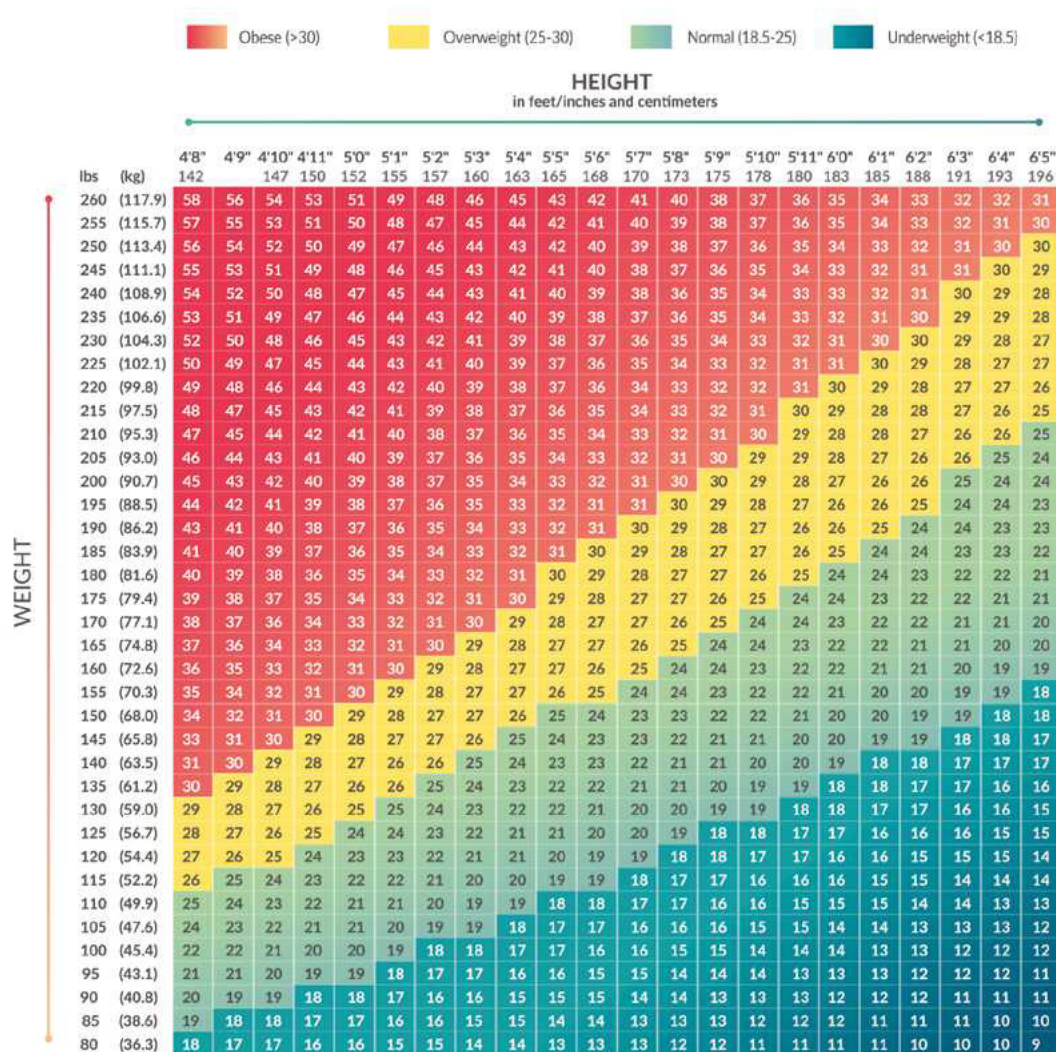
Smoker status: Non-smoker

Alcohol intake: 3-5 glasses a week:

Current diet habits: Regularly consumes pre-packaged and convenience foods or eats at work. Does not like the taste of most vegetables.

Body Mass Index (BMI) Chart

Body Mass Index (BMI) Table for Adults



Note: BMI values rounded to the nearest whole number. BMI categories based on CDC (Centers for Disease Control and Prevention) criteria.
 $BMI = \text{Weight}[\text{kg}] / (\text{Height}[\text{m}] \times \text{Height}[\text{m}]) = 703 \times \text{Weight}[\text{lb}] / (\text{Height}[\text{in}] \times \text{Height}[\text{in}])$

- (a) Using information from Tim's consultation notes and the BMI chart, state the diet related disease you believe he is suffering from.

(1 mark) (KA2)

- (b) Justify your diagnosis by using evidence from the consultation notes and the BMI chart.

(6 marks) (AE3, KA2)

- (c) Identify one other symptom that Tim may be experiencing and explain how it may have developed.

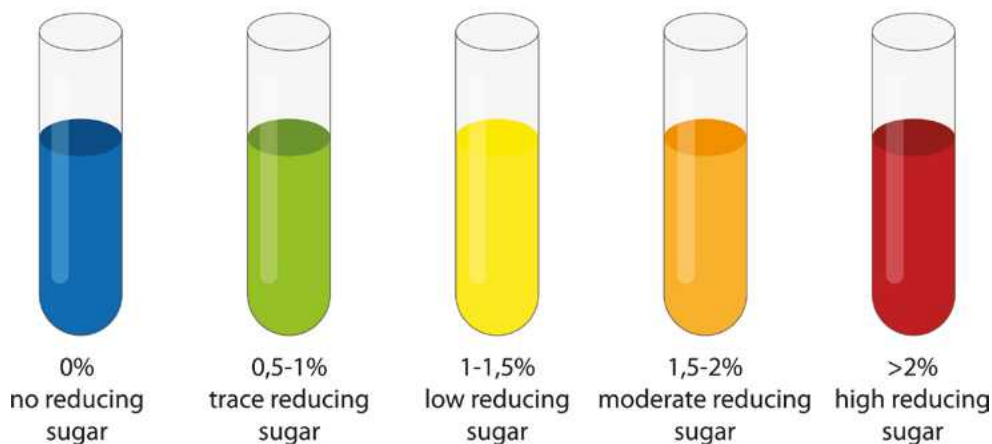
(2 marks) (KA2)

- (d) With reference to the consultation notes, identify and explain how one lifestyle modification would help Tim in managing or preventing the development of the disease you have identified.

(2 marks) (KA2)

4. Benedict's solution was used to test several sports drinks to determine the presence of simple sugars, such as glucose. Benedict's solution is blue, but if simple sugars are present, it will change colour – green/yellow if their presence is low and red if high (as shown in the image below).

Benedict's Test for Reducing Sugars



The results of the investigation are shown in the data table below, where five samples of three different sports drinks were tested using Benedict's solution to determine the presence of simple sugars.

Sports Drink	Presence of Simple Sugars using Bendict's Solution				
	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Accelerade	Red	Red	Orange	Red	Red
Replensihier	Yellow	Green	Green	Red	Green
PREPD	Orange	Orange	Orange	Orange	Orange

- (a) With reference to the results in the data table, identify which sports drink is composed of the smallest quantity of simple sugars.
- (1 mark) (IAE3)
- (b) With reference to the results in the table above, identify an outlier and propose a reason for this outlier in the data set.

(2 marks) (IAE1)

- (c) Identify one variable that must remain constant during the experiment and explain why this must be kept controlled.

(2 marks) (IAE1)

- (d) The glycaemic index (GI) ranks carbohydrates in food according to how the consumption of the food affects a person's blood glucose levels. Another system that ranks carbohydrates in food is glycaemic load (GL). Foods can be classified as having a low, medium, or high GL, as shown in the table below.

GL Classification	GL Range
Low	10 or less
Medium	11-19
High	20 or more

Accelerade has a GI of 78 and a carbohydrate content of 44g.

Calculate the GL of one serving of Accelerade using the following equation and classify its GL using your answer.

$$\text{GL} = \frac{\text{GI} \times \text{Carbohydrate Content per serving (g)}}{100}$$

(2 marks) (KA4)

- (e) Using your answer to part (d), explain how drinking one serve of Accelerade would affect a person's energy levels for the first few hours after consumption.

(2 marks) (KA2)

- (f) Explain the difference and advantage of using GL rather than GI to rank carbohydrates in food.

(2 marks) (KA2)

5. A study has found that middle-aged women (aged 40-60 years) have a high risk of developing osteoporosis.

- (a) Identify one vitamin that can reduce the risk of developing osteoporosis.

(1 mark) (KA1)

- (b) Explain the role of one lifestyle modification in delaying the onset of osteoporosis in middle-aged women.

(2 marks) (KA2)

- (c) Calcium is an important mineral in delaying the onset of osteoporosis in middle-aged women. The estimated average requirements (EAR) and recommended daily intake (RDI) for females throughout their life cycle is shown in the table below.

Age (years)	EAR (mg)	RDI (mg)
1-3	360	500
4-8	520	700
9-11	800	1000
12-18	1050	1300
19-50	840	1000
50+	1100	1300

- (i) Explain why the EAR is always smaller than the RDI.

(2 marks) (KA2)

- (ii) With reference to the table above, explain why the RDI of calcium is greatest when females are aged between 12-18 and again over the age of 50 years old.

(4 marks) (KA2)

- (iii) Identify and explain how one factor can interfere with the absorption of calcium in the body.

(2 marks) (KA2)

6. Grass-fed beef has increased in popularity in recent years, and many consumers believe it to be more nutritious than grain-fed beef because it has higher omega-3 fatty acid content.

- (a) Omega-3 fatty acids are a type of polyunsaturated fat. State one feature of the chemical structure of polyunsaturated fat that is different from that of a saturated fat.

(1 mark) (KA1)

- (b) State two functions of omega-3 fatty acids in the human body.

(2 marks) (KA1)

- (c) Describe why polyunsaturated fats are referred to as essential fatty acids.

(2 marks) (KA2)

- (d) Refer to the following table, which shows the omega-3 fatty acid and omega-6 fatty acid content of grass-fed and grain-fed beef.

Feeding system	(mg/100g of lean meat)	
	Omega-3 fatty acids	Omega-6 fatty acids
Grass-fed beef	155	334
Grain-fed beef	97	354

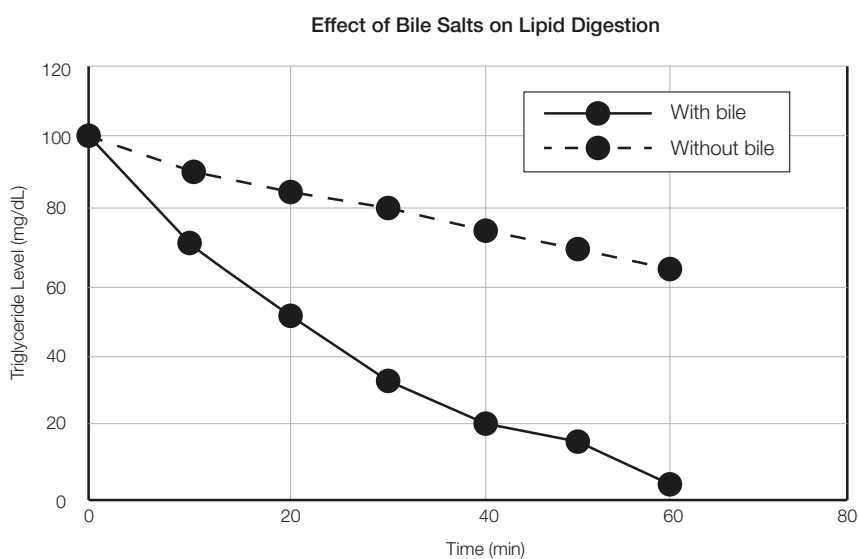
The recommended daily intake (RDI) of omega-3 fatty acids for a 15-year-old male is 610mg. Calculate the percentage of the RDI of omega-3 fatty acids that a 15-year-old male would consume if he ate 100g of grass-fed beef. *Show your working out.*

(2 marks) (KA4)

- (e) Polyunsaturated fats are labelled as 'good fats', while saturated fats are labelled as 'bad'. Provide reasons why these fats are labelled this way in relation to their role in the development of atherosclerosis.

(4 marks) (KA2)

- (f) Refer to the following graph that shows the effect of bile salts on triglyceride digestion.



- (i) Identify the organ in the human body which produces bile.

(1 mark) (KA1)

- (ii) Using data from the graph from the previous page, explain why there is a difference in the triglyceride level after 60 minutes with reference to bile's role in the mechanical and chemical digestion of triglycerides.

(4 marks) (IAE3, KA2)

7. Energy balance is an issue for many when attempting to manage their weight, use the supplied data of a male to make the calculations required to answer the following questions.

Male 94kg

Avg. daily food intake 13504kJ

Thermic Effect of Food 1350.4kJ

Avg. daily energy expenditure on exercise 430kJ

- (a) Basal metabolic rate (BMR) can be defined as the rate at which the body expends energy for basal metabolic activities, which supports all basic processes of life.

Calculate the BMR of this male in kilojoules, using the formula below. *Show your working out.*

$$\text{BMR} = \text{weight (kg)} \times 1.0 \times 24 \times 4.2$$

(1 mark) (KA4)

- (b) Identify *one* factor that may influence his BMR and explain what effect it would have and why.

(3 marks) (KA2)

- (c) Calculate his total daily energy expenditure. *Show all your working out.*

(1 mark) (KA4)

- (d) Determine his energy balance and explain how this would contribute to the development of Obesity. *Show all your working out.*

(3 marks) (KA2, KA4)

8. There are many factors that can affect the development of the gut microbiome and it starts before we are even born, where it forms when the foetus is in the uterus.

- (a) Explain the role of prebiotics and probiotics in the development of the gut microbiome.

(4 marks) (KA2)

- (b) Refer to the following extract on genetically engineered probiotics to answer the next two questions.

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 normally 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 mice with ulcerative colitis. This treatment prevented the symptoms associated with colitis, such as bloody diarrhea 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.

- (i) Explain one **limitation** of genetically engineered probiotics.

(2 marks) (KA3)

- (ii) Explain a possible **application** of genetically engineered probiotics.

(2 marks) (KA3)

Total: / 90 marks

Topic 2: Health promotion and emerging trends

2.1 Diagnostic tools

Science understanding

Diagnostic tools assist individuals and health professionals in evaluating health and diet:

- Body mass index (BMI)
- The limitations, advantages and disadvantages of using the BMI compared to one of the following: waist circumference, waist-to-hip ratio, weight for height tables, blood analysis, Nutrient Reference Values (NRV's).

SACE Subject Outline, 2024.

Anthropometry Diagnostic Tools

A **diagnostic tool** or test is a measure to help determine whether someone is at risk of a particular health condition. **Anthropometry** refers to measurements of the human body. Anthropometric measurements are used to assess size (e.g., height), shape and body composition (e.g., percentage of body fat). They can also be used on children to assess growth. Anthropometry can be used for diagnosing malnutrition, overweight or obesity and when there is an increased risk of over-nutrition diseases associated with obesity. Common measurements include body mass index (BMI), waist circumference and waist-to-hip ratio (WHR).

Body Mass Index (BMI)

BMI offers a way to assess whether an adult's weight is in a healthy range for their height. It is calculated by dividing body weight (in kilograms) by height (in metres) squared and is expressed in units of kg/m² (refer to equation below).

$$\text{Body Mass Index} = \frac{\text{Weight (kg)}}{\text{Height}^2 \text{ (m}^2\text{)}}$$

The result of the calculation is used to indicate whether someone is in the underweight, healthy weight, overweight or obese weight category (see Figure 2.1.1). This classification can then be used to assess the risk of obesity-related diseases such as CVD and Type 2 Diabetes (normally in conjunction with further assessments).

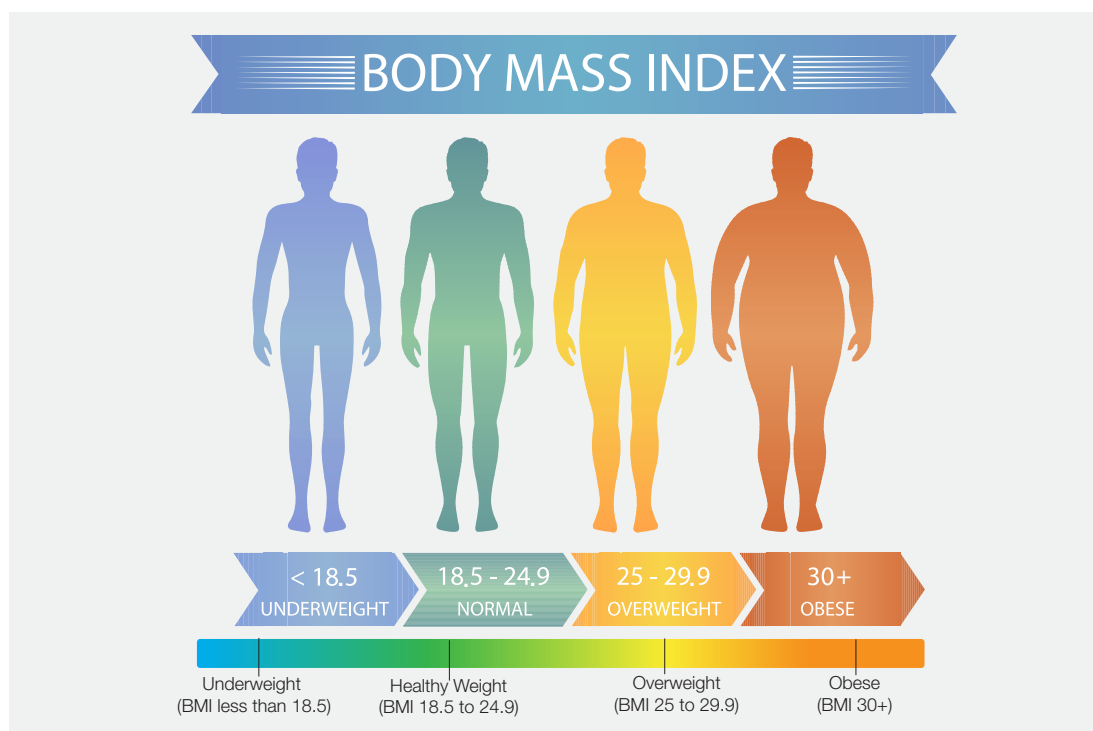


Figure 2.1.1: BMI classifications.

Although BMI is widely used in Australia with several advantages, it also has several disadvantages and limitations (see Table 2.1.1).

Definition

A limitation is defined as a restriction, and in the case of diagnostic tools, they are the groups of people who are restricted from being able to use the BMI accurately. Limitations can also be considered disadvantages, with disadvantages focusing on factors that reduce the chances of success when using diagnostic tools.

Table 2.1.1: Advantages, disadvantages and limitations of BMI as a diagnostic tool

Advantages	Disadvantages	Limitations
- inexpensive - non-invasive - equipment is easy and straight forward to use - not very time consuming	- BMI is only an estimate (it doesn't consider age, ethnicity, gender and body composition) - requires a calculation - recording of height and weight can be inaccurate and misleading if the equipment is poor or if improper techniques are used, for example weighing someone on an uneven surface	- pregnant women - the elderly - people with a physical disability - people under 18 years - BMI does not distinguish between fat or muscle when looking at body weight. It is therefore less accurate in certain groups who may genetically have a different body shape/ muscle fat balance, including: - Torres Strait Islander people, Maoris, Aboriginals, and Asian populations - body builders - some high-performance athletes

Weight-for-height tables/charts

BMI classifications of underweight through to obesity can also be determined using **weight-for-height tables or charts**. Weight-for-height charts use contour lines or colours to show the different BMI categories (see Figure 2.1.2). Their advantages, disadvantages and limitations are very similar to those of BMI (see Table 2.1.1).

Weight-for-height charts also exist for children and infants and BMI classifications for the obese category are available for children. However, it is not always easy to tell if a child is a healthy weight for their age and height due to growth rates differing for individuals.

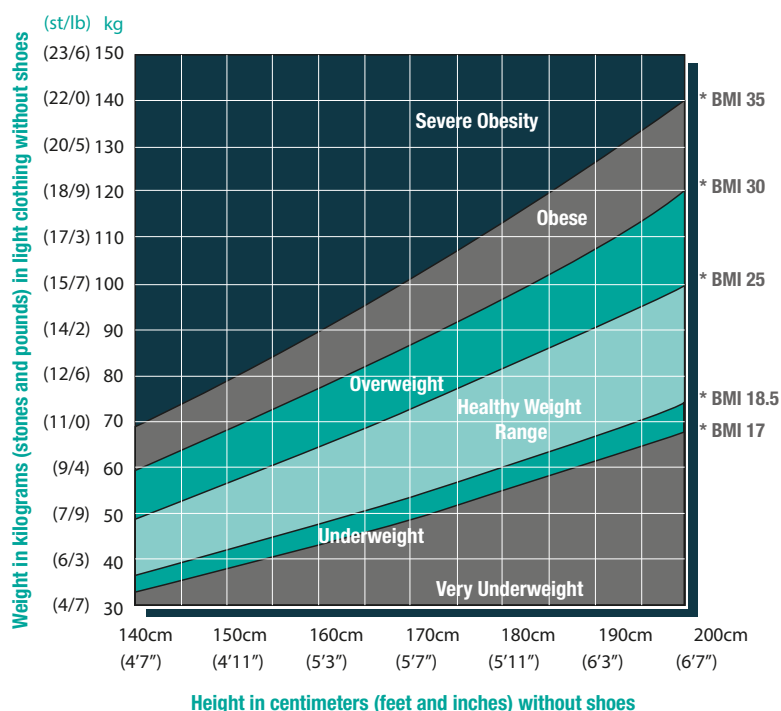


Figure 2.1.2: BMI chart for adults.

Waist circumference

Measuring **waist circumference** is used to check if someone is carrying excess body fat stored around the abdomen, called visceral fat. It is found by measuring around the waist, halfway between the lower rib and top of the hipbone (or roughly in line with the belly button), after breathing out normally.

For most adults, measuring 94cm and above for males and 80cm and above for females, is an indication that the level of visceral body fat deposits coating the heart, kidneys, liver, digestive organs, and pancreas is too high and there is an increased risk of weight-related diseases like CVD and Type 2 Diabetes. Above 102cm and 88cm for men and women respectively, indicates an even higher increased risk (see Figure 2.1.3).

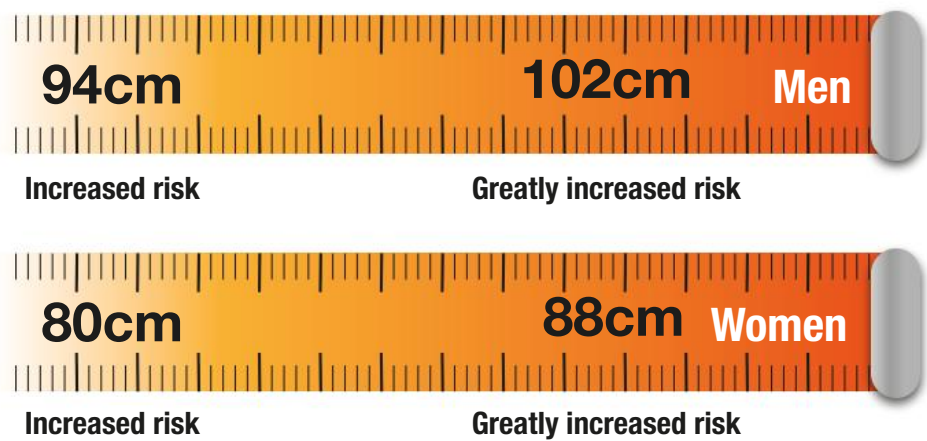


Figure 2.1.3: Waist circumference risk classifications.

Waist circumference is another diagnostic tool that is useful in determining whether someone is at risk of an obesity-related overnutrition disease. However, it also comes with advantages, disadvantages and limitations (see Table 2.1.2).

Table 2.1.2: Advantages, disadvantages and limitations of waist circumference as a diagnostic tool.

Advantages	Disadvantages	Limitations
• inexpensive • non-invasive • minimal equipment • simple to perform	• measuring waist circumference can be inaccurate and misleading if improper techniques are used (a high level of training is required to achieve accurate measurements)	• pregnant women • people under 18years • certain groups of people who may genetically have a different body shape, such as Aboriginal and Torres Strait islanders and Japanese adults

Waist-to-hip ratio (WHR)

Using **WHR** is another diagnostic tool to check if someone is carrying excess body fat around the abdomen and is therefore at risk of overnutrition diseases. The WHR assesses whether the waist is wider than the hips (apple/ android body shape), or smaller than the hips (pear/ gynoid body shape). Waist circumference is measured in cm and then divided by hip circumference in cm (refer to equation below). Waist circumference is again found by measuring around the waist, halfway between the lower rib and top of the hipbone after breathing out normally, whilst hip circumference is found by measuring around the point where the buttocks are the widest.

$$\text{Waist to Hip Ratio} = \frac{\text{Waist circumference (cm)}}{\text{Hip circumference (cm)}}$$

Excess visceral fat and an increased risk for weight-related diseases is indicated by a WHR greater than:

- 0.9 for males
- 0.8 for females

Considering WHR incorporates measuring around the waist in its calculation, it therefore has similar advantages, disadvantages and limitations to the waist circumference diagnostic tool (see Table 2.1.2).

Nutrient Reference Values (NRVs)

The NRVs (see Topic 1.1 for details of each of the NRVs) can be used by dietitians, nutritionists and other health professionals to assess the dietary needs of individuals and groups, for example, residents of a nursing home. Although the values of NRVs are expressed daily, patients are typically assessed over 3 or more days, collecting information about what they eat, and physical activity performed. Most health professionals in Australia utilise nutritional analysis computer software such as FoodWorks to analyse the information collected by patients in food dairies. Such software can generate the actual intake of nutrients compared to the NRVs, with values lower than **EAR** useful in diagnosing deficiency diseases and higher than **UL** useful in diagnosing over-nutrition health concerns. **RDI**s tend to be the most used value to correct nutritional intake of patients, giving a value to aim for.



Reminder

EAR = Estimated Average Requirement; RDI = Recommended Daily Intake; UL = Upper Limit

Unlike the anthropometry diagnostic tools, there are no limitations for collecting food diaries and analysing nutrient intake to diagnose potential deficiencies and excesses as NRV analysis can be utilised by people of all ages, genders and life stages. There are, however, several advantages and disadvantages (see Table 2.1.3).

Table 2.1.3: Advantages, disadvantages and limitations of NRVs as a diagnostic tool.

Advantages	Disadvantages
- Can test for a range of both nutrient deficiencies and excesses - Non-invasive	- Nutrient analysis software may not be updated timely enough to match NRV changes and new foods entering the market - Time consuming and costs may be involved (dietician/nutritionist) - NRVs for each age, gender and life stage are based on an average body weight - Quality of results is dependent on participant's accuracy in recording food intake and physical activity

Nutrient blood analysis

A blood test for nutrient analysis typically involves a small amount of blood being taken from a vein in the arm using a hypodermic needle, or a finger prick may be used in patients where it can be more difficult to draw blood; for example, infants. The blood is analysed in a laboratory with a purpose to uncover a nutrient deficiency or excess and then diagnose any associated health risks (using patient history and symptoms to assist the diagnosis).

Like the use of NRVs, a wide range of nutrient imbalances can be uncovered and there are no limitations to who can undertake blood analysis. There are, however, several advantages and disadvantages of nutrient blood testing (see Table 2.1.4).

Table 2.1.4: Advantages, disadvantages and limitations of blood testing as a diagnostic tool.

Advantages	Disadvantages
- Can test for a range of both nutrient deficiencies and excesses - Generally accurate, although 'false positive' results suggest something is abnormal when it is not and 'false negative' results return normal findings despite them actually being too high or too low	- Time consuming and costs may be involved (Doctor and Pathology laboratories) - Discomfort: some blood tests require fasting; pain, bleeding and bruising can occur at the site where blood is taken; some people can feel anxious, dizziness, fainting prior to, during or after a blood test

Summary

Utilising information about each diagnostic tool, it is possible to compare the limitations, advantages and disadvantages of using BMI in comparison to each alternate diagnostic tool (see Table 2.1.5).

Table 2.1.5: Advantages, disadvantages and limitations of using BMI compared to alternate diagnostic tools.

Diagnostic tool	Advantages compared to BMI	Disadvantages compared to BMI	Limitations compared to BMI
Height-for-weight charts	Calculation not required	–	–
Waist circumference	- Calculation not required - Fewer measurements needed (one vs two) - More accurate diagnostic tool for overnutrition disease risk for those with a higher muscle mass e.g. athletes, or the elderly with a reduced muscle mass with age (see limitations) - Less equipment required (no weight scales)	Higher likelihood of measuring waist circumference inaccurately compared to familiar height or weight measures (at home)	Limitation of lean muscle mass not being distinguished is removed due to this measure focusing on body fat distribution, not weight
Waist-to-hip ratio	- More accurate diagnostic tool for overnutrition disease risk for those with a higher muscle mass e.g. athletes, or the elderly with a reduced muscle mass with age (see limitations) - Less equipment required (no weight scales)	Higher likelihood of measuring waist and hip circumference inaccurately compared to familiar height or weight measures (at home)	Limitation of lean muscle mass not being distinguished is reduced due to this measure focusing on body fat distribution, not weight
NRVs	- More accurate - Range of nutrient levels could be looked at to confirm specific overnutrition diseases vs the general 'at risk' diagnosis from using BMI e.g. kJ balance, fat intake for obesity or types of each triglyceride and sodium for hypertension - Able to diagnose nutrient deficiencies and associated health concerns as well	- Time consuming - More complex to obtain a diagnosis (recorded food intake for a few days vs some simple measurements/calculation) - Costly (if run via Dietician)	Unlike BMI, no limitations (food diaries can be completed at any age, gender, etc)
Nutrient blood analysis	- More accurate - Range of nutrient levels could be looked at to confirm specific overnutrition diseases vs the general 'at risk' diagnosis from using BMI e.g. total LDL & HDL cholesterol levels for CVD risk - Able to diagnose nutrient deficiencies and associated health concerns as well	- Time consuming - Can be more complex to obtain a diagnosis, particularly if it requires fasting for 12 hours prior and a 2hr blood test period vs. some simple measurements and calculation - Costly (if not bulk billed) - May involve discomfort regarding a needle being used	Unlike BMI, no limitations

Key terms

Anthropometry	Nutrient Reference Values (NRVs)
Body Mass Index (BMI)	Weight-for-height charts
Diagnostic tool	Waist circumference
Nutrient blood analysis	Waist -to-hip ratio (WHR)

Review questions: 2.1 Diagnostic tools

1. Body Mass Index (BMI) is a commonly used diagnostic tool. Classifications for BMI are shown in the figure below.

Weight Categories	BMI (kg/m ²)
Underweight	< 18.5
Healthy Weight	18.5-24.9
Overweight	25-29.9
Obese	30-34.9
Severely Obese	35-39.9
Morbidly Obese	>40

- (a) Define body mass index (BMI) and its purpose.

(2 marks) (KA1)

- (b) List two advantages, disadvantages and limitations of using the BMI as a diagnostic tool:

Advantages:

- 1)
- 2)

Disadvantages:

- 1)
- 2)

Limitations:

- 1)
- 2)

(6 marks) (KA1)

- (c) An experiment is performed on twenty 50-year-old men to find out the average BMI. To calculate BMI, scales should be used on a hard level surface, with a subject wearing light clothing and standing on the centre of the scales. The tape measure for height should be vertically taped to a hard wall with the subject standing straight with feet together and back to the wall. A ruler should be used parallel on top of the head to find the height.

- (i) Identify a possible source of systematic error in this experiment and discuss how it may affect the results:

(2 marks) (IAE4)

- (ii) Identify a possible source of random error and an improvement to reduce the impact of this error:

(2 marks) (IAE4)

- (d) A 32-year-old male weighs 88kg and is 154cm tall.

- (i) Show the formula used to calculate BMI:

Formula =

(1 mark) (KA1)

- (ii) Calculate the male's BMI (round to the nearest whole number):

BMI = kg/m²

(1 mark) (KA4)

- (iii) Identify his BMI/weight classification using the table shown earlier:

(1 mark) (AE3)

- (e) The man's father weighs 90kg and is slightly shorter at 1.51m.

- (i) Calculate his BMI and round to the nearest whole number:

BMI = kg/m²

(1 mark) (KA4)

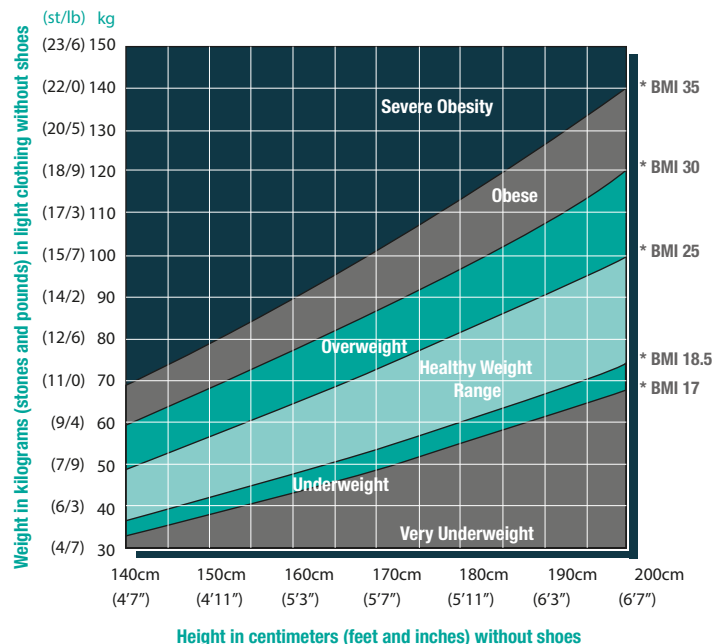
- (ii) Identify his BMI/weight classification using the table shown earlier:

(1 mark) (AE3)

- (f) Should BMI measurement result in an obese classification, state a typical body shape observed in a male.

(1 mark) (KA1)

2. An extension of BMI classification table is a weight-for-height chart as shown below.



- (a) A 20-year-old male is 1.75m and 60kg. Identify his BMI classification using the given weight-for-height chart.

(1 mark) (AE3)

- (b) A 20-year-old female is 195cm tall. Using the given weight-for-height chart, state the weight range for her to be classified as healthy.

(1 mark) (AE3)

- (c) List an advantage of using a height-for-weight chart instead of using BMI as a diagnostic tool.

(1 mark) (KA1)

3. George has a waist circumference of 104cm which puts him at risk of developing over-nutrition diseases.
- (a) Explain how a large waist circumference puts George at risk of developing either cardiovascular disease or Type 2 Diabetes
- (2 marks) (KA2)
- (b) A medical student found George's waist circumference 10 times before averaging measurements to give his result of 104cm.
- (i) State two possible sources of random error when taking the measurements and discuss how the error could impact upon the measurement.
- Error one:
- (2 marks) (IAE4)
- Error two:
- (2 marks) (IAE4)
- (ii) Discuss the benefit of taking 10 measurements, rather than 1.
- (2 marks) (IAE4)
- (c) BMI can misclassify some groups of people as obese. Name a group of such people who may find the accuracy of using waist circumference better in comparison to using the BMI:
- (1 mark) (KA2)
- (d) List a further advantage of using the waist circumference, compared to BMI, as a diagnostic tool.
- (1 mark) (KA1)
4. A doctor ordered lipoprotein blood tests for a 72-year-old man presenting with chest pain upon getting up in the morning or when out walking the dog. Pathology results returned a total cholesterol level of 212 mg/dL, HDL 39mg/dL and LDL of 187mg/dL. The doctor compared the man's pathology results to the tables below.

Total Cholesterol Level	Category
Less than 200 mg/dL	Desirable
200 – 239 mg/dL	Borderline high
240 mg/dL and above	high

LDL (Bad) Cholesterol Level	LDL Cholesterol Category
Less than 100 mg/dL	Optimal
100 – 129 mg/dL	Near optimal / above optimal
130 – 159 mg/dL and above	Borderline high
160 – 189 mg/dL	High
190 mg/dL and above	Very high

HDL (Good) Cholesterol Level	HDL Cholesterol Category
Less than 40 mg/dL	A major risk factor for heart disease
40 – 59 mg/dL	The higher, the better
60 mg/dL and higher	Considered protective against heart disease

- (a) Identify the cholesterol categories of the patient using the table above:
- (i) Total cholesterol category: (1 mark) (IAE3)
- (ii) HDL cholesterol category: (1 mark) (IAE3)
- (iii) LDL cholesterol category: (1 mark) (IAE3)

- (b) Discuss the suitability of the patient's total cholesterol levels using data from the tables above:

(2 marks) (IAE3)

- (c) Name a disease that the doctor would diagnose based on the blood test results and symptoms presented by the 72 year-old man:

(1 mark) (KA2)

- (d) Match further blood analysis results of the 72-year-old to their associated health risk below:

Health concern	Blood analysis result
Osteomalacia	Low Vitamin D
Type 2 Diabetes	Low folate
Megaloblastic anaemia	Sustained elevated blood glucose after consumption of sugary beverage

(3 marks) (KA1)

- (e) Instead of the blood tests, the patient could have done a BMI test at home to diagnose his risk of overnutrition diseases.

- (i) List an advantage for the patient if using the BMI as a diagnostic tool instead of getting blood tests.

(1 mark) (KA2)

- (ii) List an advantage of going to the doctors to have blood tests instead of calculating one's BMI at home:

(1 mark) (KA2)

- (iii) Identify a disadvantage and limitation for the patient if using BMI at home rather than blood test analysis to diagnose an overnutrition disease.

(2 marks) (KA2)

5. State one limitation, advantage and disadvantage of using BMI compared to Nutrient Reference Values (NRVs) in diagnosing nutritional concerns.

(3 marks) (KA1)

6. Jasper visits his doctor (G.P.) and dietician for a health check-up. The following information is recorded about him.

Case study notes

Sex: Male

Age: 62

Weight: 88kg

Height: 170cm

Activity level: Moderately active (jogs 30mins every second night and weights session x 60 mins once a week)

Weight Categories	BMI (kg/m ²)
Underweight	< 18.5
Healthy Weight	18.5-24.9
Overweight	25-29.9
Obese	30-34.9
Severely Obese	35-39.9
Morbidly Obese	>40

- (a) Using the information from the sources above, calculate Jasper's BMI and identify his weight category.

(2 marks) (IAE3, KA4)

- (b) Should the doctor not have a set of weighing scales to find out Jasper's weight and calculate BMI, identify an alternate diagnostic tool the doctor could utilise to monitor Jasper's health regarding his risk of weight-related conditions.

(1 mark) (KA1)

- (c) Describe an advantage of the diagnostic tool identified in part (b) in comparison to using BMI.

(2 marks) (KA2)

- (d) Jasper's dietician enters his food intake over 3 days into a program that gives his nutrient intake compared to the NRVs. Identify three NRVs his dietician should compare his nutrient intakes to and discuss how they can be used to identify Jasper's risk of developing any diet related disorders.

(6 marks) (KA2)

- (e) State two reasons why Jasper may prefer to opt for a health check that only involved his GP and the BMI in future.

(2 marks) (KA2)

Total: / 60 marks

Case Study

Evaluating Health and Diet with Diagnostic Tools

The following consultation notes are recorded about Jessie when she visited a dietitian for a check-up.

Name: Jessie

Age: 48

Weight: 52kg

Height: 177cm

Waist measurement: 55cm

Hip measurement: 73cm

Activity level: Moderately active (jogs 30mins every second night and weights session x 60 mins once a week)

Average intake of nutrients from a one-day food diary: 700mg calcium, 1300 calories, 1.85g Vitamin B₁₂

Blood test results: Haemoglobin (Hb) 105g/L

- Using three diagnostic tools of your choice, analyse Jessie's clinical findings presented in the consultation notes to identify her risk of developing any diet-related health concerns based on her physiological needs.
- Selecting two of your chosen diagnostic tools, discuss why Jessie's dietitian uses them as an indicator only, and will not diagnose a health concern without further testing.



Helpful online resources

The following websites can be used to identify typical nutrient, energy and health requirements for someone of Jessie's age, gender and activity level:

<https://www.nrv.gov.au/nutrients-energy-calc>

<https://www.eatforhealth.gov.au/webform/daily-energy-requirements-calculator>

Anaemia | Lifeblood

<https://www.lifeblood.com.au/patients/reasons-for-a-transfusion/anaemia>



(10 marks) (IAE3, KA2, KA4)



Science as a human endeavour

BMI to be replaced!

Article adapted from: <https://www.sciencealert.com/new-accurate-rfm-body-fat-measure-could-end-bmi-body-mass-index> and <https://www.nature.com/articles/s41598-018-29362-1>

BMI is a widely used diagnostic tool for determining weight classification; but its disadvantages and limitations have led scientists to develop new technology: specifically, a new calculation called the relative fat mass index (RFM). RFM considers the waist circumference in relation to height, rather than weight. It is calculated using the formulas:

MEN: $64 - (20 \times \text{height/waist circumference})$

WOMEN: $76 - (20 \times \text{height/waist circumference})$

The team of researchers behind RFM say it's more accurate than BMI and gives a better idea of whether someone's body fat is at a healthy level or not. "The results in a large number of subjects confirmed the value of the new formula is a better measure of body mass than many indices used in current medicine and science, including the BMI" says lead researcher Orison Woolcott, from the Cedars-Sinai Medical Center in California. Based on data from 3,456 adult patients in the US, the RFM measurements closely matched those taken by a high-tech DXA body scan, widely considered the gold standard for measuring body tissue, bone, muscle and fat. In other words, RFM was almost as good a gauge of body fat as a specialist bit of medical equipment – and all it needs is a tape measure!

Compared to BMI, RFM was not only more accurate in estimating whole-body fat percentage, but it gave fewer false negative cases, or misclassification of body fat-defined obesity among all women or men regardless of whether they are Caucasian, Mexican, European, or African ethnicity.

It's hoped that the new calculations will help anyone struggling with weight issues and associated health problems (like diabetes and high blood pressure) to better track their body fat levels. For now, though, more research across a greater number and a greater variety of people is required to make sure RFM is as accurate as its creators think it is. If that proves to be the case, it might be time to say goodbye to BMI.

1. Discuss why the **development** of RFM should replace BMI.

(4 marks) (KA3)

2

? Science Inquiry Skills

Using NRVs as a Diagnostic Tool

Introduction:

Dieticians utilise nutritional analysis computer software to analyse the information collected by patients in food diaries. Such software can generate actual intake of nutrients compared to the NRVs, with values lower than EAR useful in diagnosing deficiency diseases and higher than UL useful in diagnosing overnutrition health concerns. RDIs tend to be the most used value to correct nutritional intake of patients, giving a value to aim for.

Method:

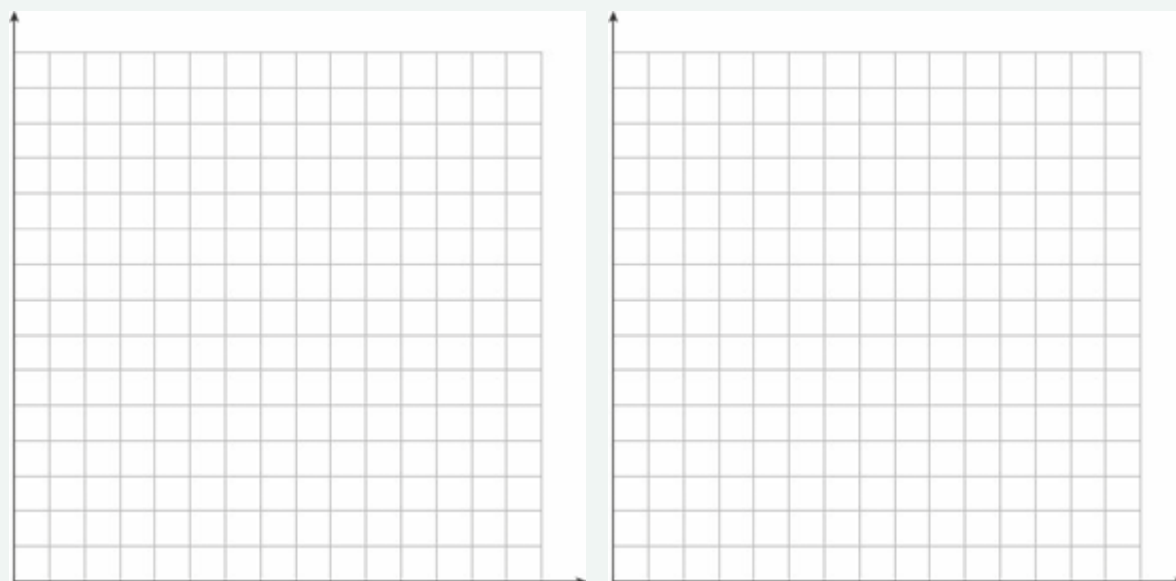
Using a website or app such as MyFitnessPal, Cron-o-meter, Easy Diet Diary and Lose it, enter the food diary below for a 30-year-old female undertaking light to moderate exercise.

3-day food diary

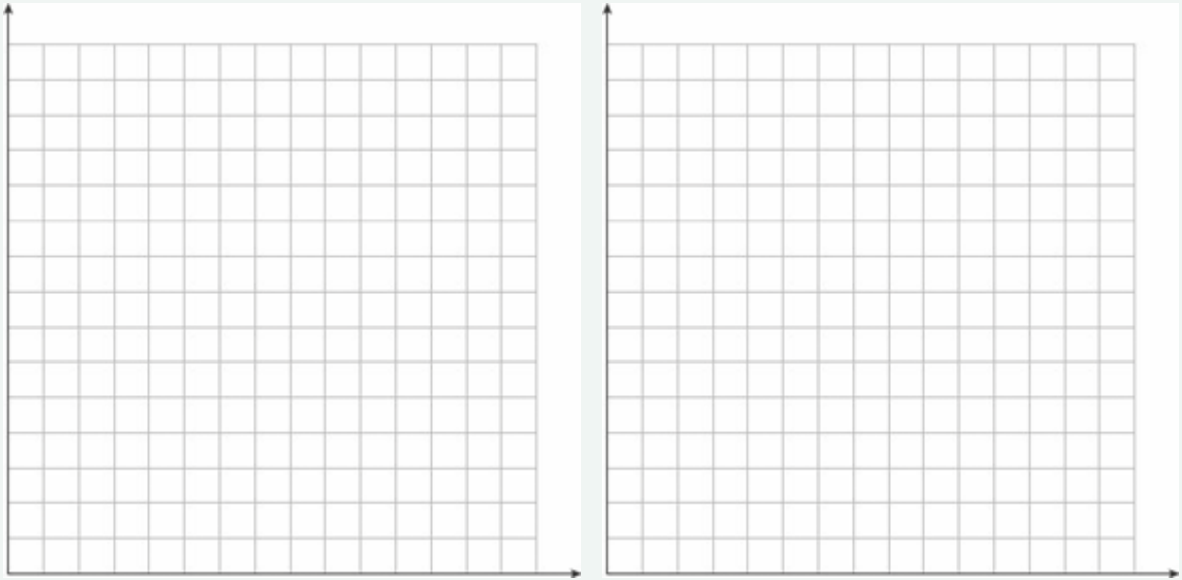
Meal	Day 1	Day 2	Day 3
Breakfast	• Black coffee with 1 tsp sugar • 1 large orange • 1 slice wholemeal toast with tsp butter and 1 tbs peanut butter	• Black coffee with 1 tsp sugar • 1 large egg (cooked any way) • 1 slice wholemeal toast with 1 tsp butter • 1 medium banana	• Black coffee with 1 tsp sugar • 1 medium apple • 1 slice wholemeal toast with 1 tsp butter and 1 tbs peanut butter
Lunch	• ½ cup tuna • 2 slices of toast with 2 tsp butter	• 1 cup cottage cheese • 10 jatz crackers • Black coffee with 1 tsp sugar	• 1 large hardboiled egg • 1 slice white toast with 1 tsp butter • 1 large orange
Dinner	• 150g chicken breast • 1 cup beans • 1 cup carrots • Sprinkle salt and pepper	• 2 beef sausages • 1 cup broccoli • 1 cup carrots • Sprinkle salt and pepper	• 1 cup tuna • 1 cup cauliflower • 1 cup beans • Sprinkle salt and pepper
Snacks	• 1 medium apple • 1 cup vanilla ice-cream	• 1 medium banana • ½ cup mixed salted nuts	• 1 cup rockmelon • 1 cup vanilla ice-cream

Results:

1. Create graphs of actual nutrient intake from the food diary, compared to applicable NRVs, for two macronutrients, one mineral and one vitamin of your choice. Graphs can be hand drawn on the axes provided, or computer-generated and pasted on top of the empty graphs (make sure to include appropriate graph features).



? Science Inquiry Skills



Analysis & Discussion:

2. With reference to the graphs above, analyse the individual's nutrient intake in comparison to their NRVs. Ensure you use data in your analysis.

3. Use your analysis in question 1 to diagnose this individual with the one diet-related disorder they are at greatest risk of developing in future, providing justification to support your diagnosis.

2.2 Educational aids for food selection

Science understanding

Educational aids are available to help improve individuals' dietary patterns and health.

- Importance of government dietary guidelines such as the Australian Dietary Guidelines and the Australian Guide to Healthy eating.
- Social marketing campaigns and programs about adopting healthy nutrition behaviour.
- Food models (e.g., Canadian model compared to the Australian Guide to Healthy Eating or the Aboriginal and Torres Strait Islander Guide to Healthy Eating).

SACE Subject Outline, 2024.

Australian Dietary Guidelines

The Australian Dietary Guidelines (ADGs) are aimed to provide dietary patterns that will enable people to get enough of the essential nutrients for good health. They are also aimed to help reduce the risk of over-nutrition diseases such as obesity, CVD and Type 2 Diabetes. There are currently 5 guidelines, which are equally as important as each other regardless of their number. These guidelines help adults choose wisely from the wide variety of foods and drinks available in Australia. These guidelines and their importance are presented below.



Helpful online resources

The ADGs described below have been extracted from the following document:

https://www.eatforhealth.gov.au/sites/default/files/2022-09/n55_australian_dietary_guidelines.pdf



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.

The rates of overweight and obese Australian adults and children are increasing, which increases the risk of high blood pressure, muscle, bone and respiratory disorders and chronic disease including type 2 diabetes, heart disease, stroke, and some cancers, and reduces life expectancy. Being underweight carries health risks also.

Being overweight or obese, especially in childhood and adolescence can also cause social discrimination, low self-esteem, poor body image and depression.

Most weight related illnesses are preventable or reversible by adopting a nutritious eating pattern and being physically active, whereby the total energy needs for the day are slightly less than you need.

Adults need at least 30 minutes of moderate intensity physical activity on most, preferably all days of the week. Children and adolescents over 5 years of age should be physically active every day for at least 60 minutes of moderate to vigorous activity.

Guideline 2: Enjoy a wide variety of nutritious foods from these five food groups every day:

- Plenty of vegetables of 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.

The five food groups make up the central plate of the Australian Guide to Healthy Eating (see Figure 2.2.1) and are grouped by their type and their contribution of nutrients to individuals.

Consuming a variety of nutritious foods from all five food groups over a week can increase the likelihood of obtaining sufficient intake of all nutrients. This can protect our bodies from chronic disease and increase the quality of life and longevity.

Guideline 3: Limit intake of foods containing saturated fat, added salt, added sugars and alcohol.

- Limit intake of foods high in saturated fats such as many cakes, pastries, pies, processed meats, commercial burgers, pizza, fried foods and potato chips, crisps and other savoury snacks.
 - Replace foods with ingredients high in saturated fat such as butter, cream, cooking margarine, coconut and palm oil with foods containing ingredients of predominantly polyunsaturated and/or monounsaturated fats such as oils, spreads, nut spreads and avocado.
 - Low fat diets are not suitable for children under the age of 2 years.
- Limit intake of foods and drinks containing added salt
 - Read labels to choose lower sodium options amongst similar foods.
 - Do not add salt to foods in cooking or at the table.
- Limit intake of foods and drinks containing added sugars such as confectionary, sugar sweetened soft drinks and cordials, fruit drinks, vitamin waters, energy, and sports drinks.
- If you choose to drink alcohol, limit your intake. For women who are pregnant, planning a pregnancy, or breastfeeding, not drinking alcohol is the safest option.

Most foods and drinks containing significant amounts of saturated fat, added salt, added sugars and alcohol are not a necessary part of our diet and are classified as discretionary choices. These foods should only be consumed sometimes and in small amounts.

These foods are associated with an increased risk of obesity and chronic diseases, including heart disease, stroke, type 2 diabetes, and some cancers.

Guideline 4: Encourage, support, and promote breastfeeding

Breastmilk is the ideal start for infant growth and development, as it provides a unique mix of nutrients, fluid and other substances that can reduce the risk of infection and may also help reduce the risk of asthma, eczema and other allergies, and sudden infant death syndrome. Being breastfed can also reduce the risk of high blood pressure in childhood and may reduce the risk of becoming obese in childhood, adolescence, and adulthood, which in turn reduces the risk of related chronic diseases.

For the mother, breastfeeding can help recovery from birth, and help mothers return to their pre-pregnancy weight and reduce the risk of some cancers.

Breast milk is also a natural, convenient, hygienic, and inexpensive food for babies, however sometimes this is not possible. A mother's choice should be supported, and babies who are not breastfed require an infant formula.

Guideline 5: Care for your food; prepare and store it safely.

All foods, and particularly fresh foods, need to be transported, stored, and prepared properly to avoid contamination and the risk of food poisoning if these foods are consumed.

Food contamination can occur when foods aren't kept at the right temperature, when raw foods aren't separated from cooked foods or poor hygiene.

Most healthy individuals recover quickly from food poisoning, but those with weakened immune systems, pregnant women, infants, and elderly are at greater risk.

Australian Guide to Healthy Eating (AGHE)

The AGHE is an extension of the ADGs. It summaries the guidelines visually (see Figure 2.2.1), particularly guideline 2 which splits foods into the five predominant food groups. These food groups are split based on their type and contribution of nutrients to the Australian diet, and represented as a plate, in the proportions recommended for consumption each day. The food groups included in the plate are:

- Grain (cereal) foods, mostly wholegrain and/or high cereal fibre varieties
- Vegetables and legumes/beans
- Fruits
- Lean meats and poultry, fish, eggs, tofu, nuts and seeds, and legumes/beans.
- Milk, yoghurt, cheese and/or alternatives (mostly reduced fat)

Food and drinks which are not part of the five food groups are shown outside the central plate (or main circle). Alcohol and highly processed foods (high in kJ, sugar, fat and sodium), or **discretionary foods**, appear at the bottom right of the AGHE. They are only to be consumed sometimes and in small amounts. Outside of the plate there is also advice to drink plenty of water and a recommendation to use spreads/oils in small amounts.



Australian Government
National Health and Medical Research Council
Department of Health and Ageing

www.eatforhealth.gov.au

Australian Guide to Healthy Eating

Enjoy a wide variety of nutritious foods from these five food groups every day.

Drink plenty of water.

Grain (cereal) foods, mostly wholegrain and/or high cereal fibre varieties



Vegetables and legumes/beans



2

Lean meats and poultry, fish, eggs, tofu, nuts and seeds and legumes/beans



Milk, yoghurt, cheese and/or alternatives, mostly reduced fat



Fruit



Use small amounts



Only sometimes and in small amounts



Figure 2.2.1: The Australian Guide to Healthy Eating.

To assist further in selecting nutrient-dense foods in appropriate amounts from each of the five food groups, suggested dietary patterns for all ages and genders are suggested (see Figure 2.2.2 and Figure 2.2.3).

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, such as breads, cereals, rice, pasta, noodles, polenta, couscous, oats, quinoa and barley	Lean meat and poultry, fish, eggs, 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 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, 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, and 2 serves [14-20g] per day for adolescents 14-18 years of age and for pregnant and lactating girls).

Figure 2.2.2: Suggested daily serves of the food groups across Years 2-18 all life stages.

Recommended average daily number of serves from each of the five food groups*							Additional serves for taller or more active men and women
	Age	Vegetables and legumes/beans	Fruit	Grain (cereal) foods, mostly wholegrain, such as breads, cereals, rice, pasta, noodles, polenta, couscous, oats, quinoa and barley	Lean meat and poultry, fish, eggs, 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 discretionary choices
Men	19-50	6	2	6	3	2½	0-3
	51-70	5½	2	6	2½	2½	0-2½
	70+	5	2	4½	2½	3½	0-2½
Women	19-50	5	2	6	2½	2½	0-2½
	51-70	5	2	4	2	4	0-2½
	70+	5	2	3	2	4	0-2
Pregnant	(19-50)	5	2	8½	3½	2½	0-2½
Breastfeeding	(19-50)	7½	2	9	2½	2½	0-2½

* Includes an allowance for unsaturated spreads or oils, nuts or seeds (4 serves [28-40g] per day for men less than 70 years of age; 2 serves [14-20g] per day for women and older men).

Figure 2.2.3: Suggested daily serves of the food groups across Years 19-50

Grain (cereal) foods, mostly wholegrain and/or high cereal fibre varieties

Grain (cereal) foods are made from grains such as wheat, oats, rice, rye, barley, millet, quinoa, and corn (refer to Figure 2.2.4 which shows some examples of serving sizes of grains). The different grains can be cooked and eaten whole, or ground into flour to make a variety of cereal foods. The grain (cereal) food group includes breads, breakfast cereals, rice, pasta, noodles, polenta, couscous, bulgur, oats, quinoa and barley. Wholemeal or wholegrain varieties are preferable because they provide complex carbohydrates and more dietary fibre, as well as vitamins such as niacin, riboflavin, thiamine, folate and minerals such as iron.

What is a serve of grain* (cereal) food?

A standard serve is (500kJ) or:

1 slice (40g)	bread
½ medium (40g)	roll or flat bread
½ cup (75-120g)	cooked rice, pasta, noodles, barley, buckwheat, semolina, polenta, bulgur or quinoa
½ cup (120g)	cooked porridge
⅔ cup (30g)	wheat cereal flakes
¼ cup (30g)	muesli
3 (35g)	crispbreads
1 (60g)	crumpet
1 small (35g)	English muffin or scone



*Grain (cereal) foods, mostly wholegrain and/or high cereal fibre varieties

Figure 2.2.4: Examples of serves of grains (cereals) foods.

Vegetables and legumes/beans

Vegetables and legumes/beans are nutrient dense and supply high levels of dietary fibre, vitamins, minerals, and **phytonutrients** that are needed by the body for different functions (refer to Figure 2.2.5 for examples of serving sizes). Vitamins and mineral content differ across the vegetable, legume/bean types, hence the food group includes a variety of coloured vegetables: green (such as broccoli and spinach), orange/yellow (for example pumpkin and carrot) and red (such as capsicum and tomato). It also displays different types of vegetables, for example from the leaves and roots of plants, as well as legumes such as beans, lentils and chickpeas. Canned and frozen vegetables are also included in this food group, if they have no added salt.



Definition

Phytonutrients are natural plant-based compounds, which can provide the food's colour or smell. These compounds can have a beneficial effect on the body including acting as an antioxidant, enhancing immunity, reducing inflammation, preventing some cancers, protecting the brain from disease, and reducing the effects of aging.

What is a serve of vegetables?

A standard serve is about 75g (100–350kJ) or:

- ½ cup cooked green or orange vegetables (for example, broccoli, spinach, carrots or pumpkin)
- ½ cup cooked dried or canned beans, peas or lentils (preferably with no added salt)
- 1 cup green leafy or raw salad vegetables
- ½ cup sweet corn
- ½ medium potato or other starchy vegetables (sweet potato, taro or cassava)
- 1 medium tomato



Figure 2.2.5: Examples of what a serve of vegetables and legumes/beans visually looks like.

Fruit

A wide variety of fruit is grown and available in Australia. Like vegetables, choosing different coloured and types of fruits increases an individual's intake of dietary fibre, water, vitamins, minerals, and phytonutrients consumed. Fruit also has a greater content of natural sugars than vegetables, which is why the recommended serve of fruit is less than vegetables (refer to Figure 2.2.6 for examples of a serve). Canned or frozen fruit is also a suitable option, if found in natural juice (without added sugars), not syrup.

What is a serve of fruit?

A standard serve is about 150g (350kJ) or:

- 1 medium apple, banana, orange or pear
- 2 small apricots, kiwi fruits or plums
- 1 cup diced or canned fruit (no added sugar)

Or only occasionally:

- 125ml (½ cup) fruit juice (no added sugar)
- 30g dried fruit (for example, 4 dried apricot halves, 1½ tablespoons of sultanas)



Figure 2.2.6: Examples of what a serve of fruit visually looks like.

Lean meat and poultry, fish, eggs, tofu, nuts and seeds and legumes/beans

Red meats tend to be consumed too often in the Australian diet (mostly by adult males), forming the main part of dinner meals. Variety is therefore key within this food group and frozen/canned options are suitable if low in salt and saturated fat (refer to Figure 2.2.7 for examples of a serve). All foods within this food group are rich in protein as well as providing a wide range of nutrients such as essential fatty acids, iron and vitamin B12. Legumes/beans provide some similar nutrients to those in lean meat, poultry, fish (and other seafood), which is why they are included in an additional food group.

How much is a serve of lean meat and poultry, fish, eggs, nuts and seeds, and legumes/beans?

A standard serve is (500–600kJ):

65g	cooked lean red meats such as beef, lamb, veal, pork, goat or kangaroo (about 90-100g raw)
80g	cooked lean poultry such as chicken or turkey (100g raw)
100g	cooked fish fillet (about 115g raw) or one small can of fish
2 large (120g)	eggs
1 cup (150g)	cooked or canned legumes/beans such as lentils, chick peas or split peas (preferably with no added salt)
170g	tofu
30g	nuts, seeds, peanut or almond butter or tahini or other nut or seed paste (no added salt)*



*Only to be used occasionally as a substitute for other foods in the group

Figure 2.2.7: Examples of what a serve of lean meat, poultry, fish, eggs, nuts and seeds and legumes/beans visually looks like.

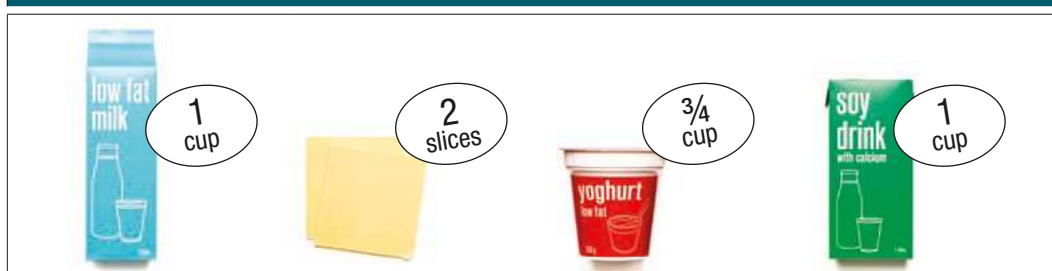
Milk, yoghurt, cheese and / or their alternatives (mostly reduced fat)

Milk, cheese, and yoghurt are important in the diet because they provide nutrients including calcium, potassium, vitamin A, vitamin D and vitamin B12 (refer to Figure 2.2.8 for examples of a serve). Low or reduced fat milk, yoghurt and cheese choices are recommended for most people two years and over who wish to reduce their saturated fat intake. A wide range of milk and milk products are available with varying amounts of fat. For example, milk can be fresh, evaporated or UHT (long life) and is able to be purchased as full fat, low fat, fat free and more! Individuals may be lactose intolerant, which is a simple sugar commonly found in milk and milk products; therefore, alternatives need to be consumed to ensure they meet their calcium requirements.

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 2.2.8: Examples of what a serve of milk, yoghurt, cheese and alternatives visually looks like.

Discretionary Choices

Discretionary choices are known as this as they are not an essential or necessary part of healthy dietary patterns and appear in the bottom right-hand corner of the Australian Guide to Healthy Eating. Discretionary choices are energy dense, making them high in kilojoules as well as saturated fat, added salt and added sugars. Australians should only consume discretionary choices sometimes and in small amounts, however, foods and drinks from this group are commonly consumed instead of choosing foods from the five food groups (refer to Figure 2.2.9 for examples of a serving size of a discretionary choice). The overconsumption of these foods and drinks can lead to obesity and chronic disorders, including type 2 diabetes, heart disease, some cancers and can reduce the quality and longevity of life.

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 2.2.9: Examples of what a serve of a discretionary choice visually looks like.

Food models

Aside from the AGHE, there are several other food selection models that exist. Each **food model** aims to represent the proportions of recommended foods, typically arranged into food groups, to assist in selecting a daily diet. Some examples of food selection models are the Aboriginal and Torres Strait Islander Guide to Healthy Eating (which is adapted from the AGHE) and the Healthy Eating pyramid, which was created to reflect Australia's NRVs (as was the AGHE) (see Figures 2.2.10 and 2.2.11 below).

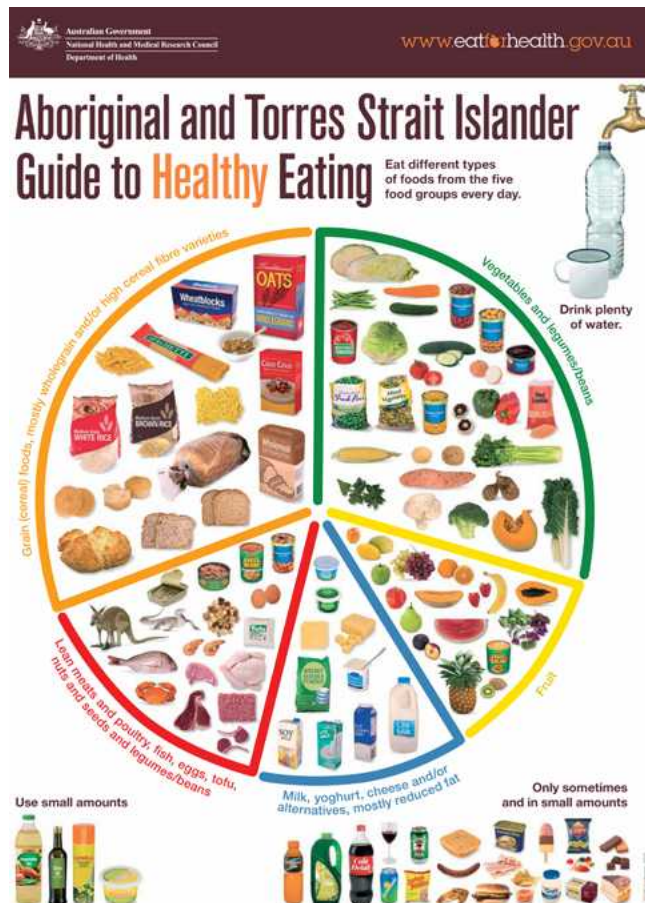


Figure 2.2.10: AGHE adapted for aboriginal and Torres Strait Islanders. Figure 2.2.11: Healthy Eating Pyramid.

Social marketing campaigns

Social marketing campaigns are advertisements that do not aim to sell a product, but instead aim to educate individuals and communities about healthy lifestyles. Although there is no current national social marketing campaign screening, previous marketing campaigns funded by the Australian Government include: 'Go for 2 & 5', 'Measure Up', and 'Stop it, don't swap it'.

Go for 2 & 5

The Go for 2 & 5 was a series of commercials that were active between 2005–2008. The commercials revolved around human figures comprised of fruit and vegetables (see figure 2.2.12), to encourage viewers to consume 2 and 5 serves of fruit and vegetables respectively.



Helpful online resources

'Go for 2 & 5 TV commercial'

<https://youtu.be/FtFKtZLVT68>



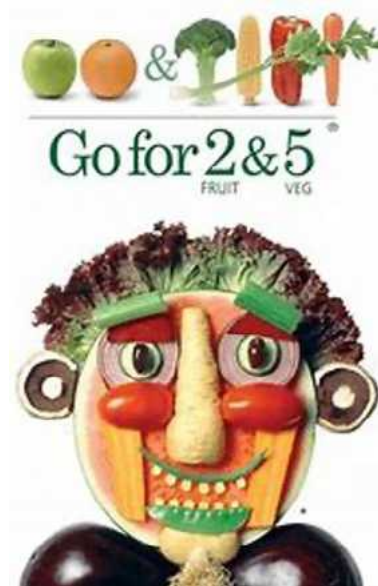


Figure 2.2.12: Go for 2&5 Social Marketing Campaign

Measure Up

The measure up campaign ran between 2008–2010. The commercials of the campaign followed a father's weight gain, followed by weight loss journey, with his family watching on, to promote the importance of waist circumference and its correlation to chronic disorders and quality of life (see figure 2.2.13).

Helpful online resources

'Measure Up TV Commercial'

<https://youtu.be/9dL4IN6GKi4>



Figure 2.2.13: Measure Up Campaign

Swap it, Don't Stop it

Swap it, Don't Stop it, was a series of commercials active between 2011–2013. The commercials revolved around animated family members, urging people to swap current habits for healthier alternatives (see Figure 2.2.14).

Helpful online resources

'Swap it don't swap it TV commercial'

https://youtu.be/98P_Jk5IZJw





Figure 2.2.14: Swap it, Don't Stop it Campaign.

Target Audiences

Each social marketing campaign centred around a male adult in the 45–60 age group, but also featured family members, including children. Male adults 45–60 were a target audience because this age group is where many people are likely to have been diagnosed with a chronic disease or are experiencing the consequences of an unhealthy lifestyle. Parents/carers around 25–50, who were the primary targets of the campaigns, were featured due to their behaviours being likely to influence their children's lifestyle behaviour, including their exercise patterns and food choices. It was also noted that parents/carers are grocery buyers and meal preparers, and tend to be interested in their own health as they want to see their children grow up. Children and adolescents were an additional secondary targeted audience of each campaign, in an aim to influence their current habits and to encourage healthier long-term habits.

Aim of the Campaigns

The general aim of all the social campaigns was to prevent risky health behaviour such as being sedentary, and promote better lifestyle alternatives, such as exercising and eating more vegetables. Specific objectives of the Go for 2&5 campaign were to raise awareness of the combination of healthy eating and physical activity being necessary and that eating two serves of fruit and five serves of vegetables each day is an important part of eating healthy. The Measure Up campaign aimed to increase the awareness of the link between chronic disease like obesity, CVD, and type 2 diabetes with dietary or lifestyle risk factors such as poor nutrition, physical inactivity and unhealthy weight. It hoped to generate positive attitudes and confidence in achieving recommended diet and exercise changes in one's lifestyle as well as appreciation of the significant benefits of a healthier lifestyle (better quality of life). In the long term, the Measure Up campaign had objectives of encouraging Australians to make and sustain increased levels of physical activity and healthier eating (2 serves fruit and 5 serves of vegetables) and therefore, reduce **morbidity and mortality** due to lifestyle chronic disease. The 'Swap it, don't stop it' campaign built on the awareness created by the Measure Up campaign. In fact, it was an extension of the Measure Up campaign (Phase 2 of Measure Up). It focused on encouraging overweight Australians to take steps to reduce their waistline. It promoted simple everyday changes that people could make to see improvements in their health and waistline. Key advice included: swap big for small (portion size control); swap often for sometimes (reducing discretionary foods); swap sitting for moving (promoting physical activity and use of kilojoules); and swap watching for playing (promoting physical activity).



Definition

Morbidity refers to having a disease (or suffering from the symptoms of a disease) while mortality refers to the number of people who die due to the disease.

To deliver their determined aims more effectively, the TV advertisements were often supported by several additional resources such as: radio segments, facebook community pages, and websites containing recipes, healthy eating tips, 'swapping' tips, nutritional information, planners for meals and activities, waist measurement tools, and more!

Impact of the Campaigns

The impact of the Go for 2&5 social marketing campaign saw an increase of 0.8 serves of fruit and vegetables per day for the entire population. The greatest increase of fruit and vegetable consumption was amongst males who had a low consumption rate before the campaign ran. The Measure Up campaign had a significant impact on its intended target audiences. The commercials promoted six health changing behaviours including: increase exercise (around 30 mins daily); increase vegetable intake (5 serves/day); increase fruit intake (2 serves/day) and reduce waist circumference. Around half of the target audience claimed to have engaged in at least one of the health promoting behaviours because of seeing the campaign. Unfortunately, the 'Swap it, don't stop it' marketing campaign achieved modest population awareness and demonstrated limited effects in motivating behavioural changes to reduce waistlines and tackle Australia's obesity problem (and its associated chronic diseases).

Programs Encouraging Healthy Nutrition Behaviour

Although there is currently no active national social marketing campaign screening on our TVs, the federal government is making a concerted effort to battle our obesity epidemic and prevalence of diet-related diseases associated with obesity via a variety of methods including the implementation of a policy called the "Healthy food partnership" and the "Health star rating system" for food labelling (see Figure 2.2.15).



Figure 2.2.15: Health Star Rating (left) and Health Star Rating with individual nutrient contributing to rating (right).

Within the schooling setting, the main Government endorsed program implemented across Australia to encourage healthy nutrition behaviour stems from the **National Healthy School Canteens (NHSC) project**. The NHSC project offers resources such as canteen posters, canteen staff training manuals and of most importance: a set of guidelines, based on the AGHE and ADGs (for children and adolescents). The guidelines document is aimed to assist those running school canteens to select food and drinks to sell that encourage and promote a healthy eating pattern. The NHSC guidelines centre around a healthy eating message that is conveyed by use of a traffic lights food categorization system (see Figure 2.2.16)

Each traffic light zone: green, amber, and red, is expanded upon in the NHSC guideline document, listing many foods that belong to each category. Examples of some of those food categories are displayed in Table 2.2.1.

Table 2.2.1: A sample of foods and drinks categorised as green, amber and red.

Food	Green	Amber	Red
Drinks	- Low or reduced-fat milk and soy drinks, plain and flavoured - Water	- Full fat milk and soy drinks (e.g., soy milk), plain and flavoured - Fruit/vegetable juice with at least 99% fruit/vegetable juice, including sparkling varieties, no added sugar (max 250mL serve size)	- Soft drinks, iced tea, cordial, sports waters, sports drinks, flavoured mineral water, energy drinks, sweetened waters. - Fruit/vegetable juice with less than 99% juice and/or added sugar and/or greater than 250mL serve size.
Fruit	Fresh, in-season is the best choice. Frozen, pureed or canned in natural juice (does not include dried fruit).	Dried fruit or fruit leathers (leathers must be 100% fruit) and keep the serve size small.	
Fats and oils		Choose polyunsaturated and monounsaturated oils and spreads and use sparingly (for example: sunflower, safflower, corn, soya bean, olive, canola).	Cream, coconut cream, coconut milk, butter, copha, ghee, lard.



Figure 2.2.16: Traffic light system of the NHSC.

Implementation of the NHSC project has been at the discretion of each state and territory government. Some have implemented the NHSC in full, while others have used components of the guidelines to create their own nutritional policies. Although the NHSC project is no longer running, the main principals of the traffic light system have been implemented as the **Rite Bite policy** in South Australia (see Figure 2.2.17) and the **School Nutrition and Healthy eating policy and guidelines** in the Northern Territory, both of which are still active. These programs are compulsory in all department or public schools, both primary and secondary, with independent and catholic school strongly encouraged to adopt them.



Figure 2.2.17: Rite Bite strategy symbol.

Key terms

Australian Dietary Guidelines (ADG)	Guideline 1	National Healthy School Canteens (NHSC) project
Australian Guide to Healthy Eating (AGHE)	Guideline 2	Rite Bite Policy
Discretionary food group	Guideline 3	School Nutrition and Healthy eating policy and guidelines
Five food groups	Guideline 4	Social marketing campaign
Food models Go for 2&5	Guideline 5	Swap it, Don't Stop it
	Measure Up	

Review questions: 2.2 Educational aids

- The food eaten by an 18-year-old male in a day is as follows:
 Breakfast: **2 eggs, 2 rashers bacon, 2 slices white toast, 2 tbs butter**
 Snack: **Apple**
 Lunch: **White roll with ham and cheese**
 Snack: **Apple**
 Dinner: **Ham and pineapple pizza, 1 glass of milk**
 - Suggest two substitutions for the food eaten so that it follows Australian Dietary Guideline (ADG) #2 more actively and justify the substitution.
 Substitution one: (2 marks) (KA2)

 Substitution two: (2 marks) (KA2)
 - Suggest two substitutions to the foods eaten so that it follows ADG #3 more actively.
 Substitution one: (1 mark) (KA2)
 Substitution two: (1 mark) (KA2)
- The nutritional information panels (NIPs) of two different snack foods are shown in the following table.

	Food A	Food B
Nutrition	Avg Qty Per 100g	Avg Qty Per 100g
Energy	1258kJ	2170kJ
Protein	2.7g	4.6g
Fat, total	20.0g	26.9g
—saturated	15.0g	15.1g
Carbohydrate	27.2g	63.9g
—sugars	24.0g	44.9g
Sodium	47mg	161mg

State which snack (food A or B) meets the ADGs the best, and justify your response using data from the NIPs:

(3 marks) (IAE3)

3. The ADG/AGHE food groups can be considered 'nutrient-dense', while discretionary foods can be considered as 'energy-dense'. Justify the use of these terms with their respective food groups.

(2 marks) (KA2)

4. State ADG number 5

(1 mark) (KA1)

5. Name two foods and/or beverages from different AGHE food groups that are high in water.

(1 mark) (KA2)

(1 mark) (KA2)

6. Name two foods from different food groups of the AGHE poster that are a good source of vitamin D:

(1 mark) (KA2)

(1 mark) (KA2)

7. One of the ADGs encourages the consumption of different colours and types of vegetables. Provide reasoning, using specific examples, to support this ADG.

(4 marks) (KA2)

8. All government social marketing campaigns that have run in the past, have aimed to reduce obesity rates in Australia.

- (a) Name a chronic disease associated with obesity:

(1 mark) (KA1)

- (b) Discuss why adults with children have been a target audience of social marketing campaigns:

(2 marks) (KA2)

- (c) Discuss why adults aged 45-60 were a targeted age group of social marketing campaigns.

(2 marks) (KA2)

9. Identify two differences and two similarities between the AGHE and the Aboriginal and Torres Strait Islander Guide to Healthy eating (see below).



Similarities:

(2 marks) (KA2)

Differences:

(2 marks) (KA2)

10. The Canadian food guide is a food selection model (see below). State two similarities and two differences between the Canadian model and the AGHE:



Similarities:

(2 marks) (KA2)

Differences:

(2 marks) (KA2)

11. The traffic light system of red, amber and green foods is evident in many S.A. school canteens.

(a) Name the traffic light healthy eating program in S.A. school canteens.

(1 mark) (KA1)

(b) Fruit is classified as a 'green' food, but dried fruit in small servings is classified as amber. Provide reasoning for its classification.

(2 marks) (KA2)

(c) A white bread sandwich with salami, cheese and tomato has been classified as 'amber' food. Suggest a modification to the sandwich that could move it into the green category.

(1 mark) (KA2)

12. (a) Identify the triglyceride classification (s) of the spreads and oils that appear in the bottom left-hand corner of the AGHE.

(1 mark) (KA1)

(b) Name a health benefit of consuming small amounts of the spreads/oils, instead of butter:

(1 mark) (KA2)

13. In one day, Matty, a 15-year-old adolescent, eats the following foods:

2 slices bacon with 2 large eggs

2 pancakes with maple syrup

Sandwich with 50g cheese and 65g sliced beef.

30g handful of nuts

Around 160g chicken breast in honey mustard sauce on rice

Apple

Ice cream with chocolate topping

- (a) With reference to Matty's daily diet above, calculate how many serves Matty has in a day from the lean meat and poultry, fish, eggs, nuts and seeds, and legumes/beans food group using the serving size guide below. Show all working out.

A standard serve is (500–600kJ):

65g	cooked lean red meats such as beef, lamb, veal, pork, goat or kangaroo (about 90-100g raw)
80g	cooked lean poultry such as chicken or turkey (100g raw)
100g	cooked fish fillet (about 115g raw) or one small can of fish
2 large	(120g) eggs
1 cup	(150g) cooked or canned legumes/beans such as lentils, chick peas or split peas (preferably with no added salt)
170g	tofu
30g	nuts, seeds, peanut or almond butter or tahini or other nut or seed paste (no added salt)*

(4 marks) (IAE3)

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

- (b) Referring to data in the table above, give a concluding statement about Matty's lean meat and poultry (etc.) serves calculated from 13(a), in comparison to the daily recommended serves for his age.

(2 marks) (IAE3)

- (c) Discuss a health concern that may develop should Matty continue to eat this daily quantity from the lean meat and poultry (etc.) food group:

(2 marks) (KA2)

14. Refer to some of the swapping tips from the Swap it, don't swap it campaign (see below):



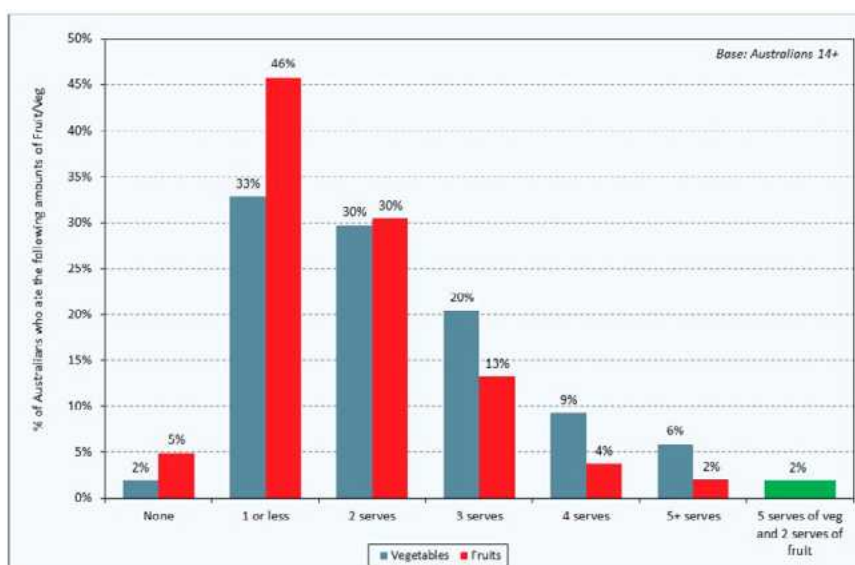
- (a) Explain why swapping fizzy drink for water is recommended:

(2 marks) (KA2)

- (b) Explain why eating less 'sometimes' food is recommended:

(4 marks) (KA2)

15. Refer to the figure below, which demonstrates the serves of fruit and vegetables eaten each day by Australians aged 14 years and over, to answer the following questions:



- (a) State the percentage of Australians (aged 14 +) meeting the 'Go for 2 & 5' campaign goals **of at least** 2 serves of fruit daily.

(1 mark) (IAE3)

- (b) State the percentage of Australians (aged 14 +) meeting the 'Go for 2 & 5' campaign goals **of at least** 5 serves of vegetables daily.

(1 mark) (IAE3)

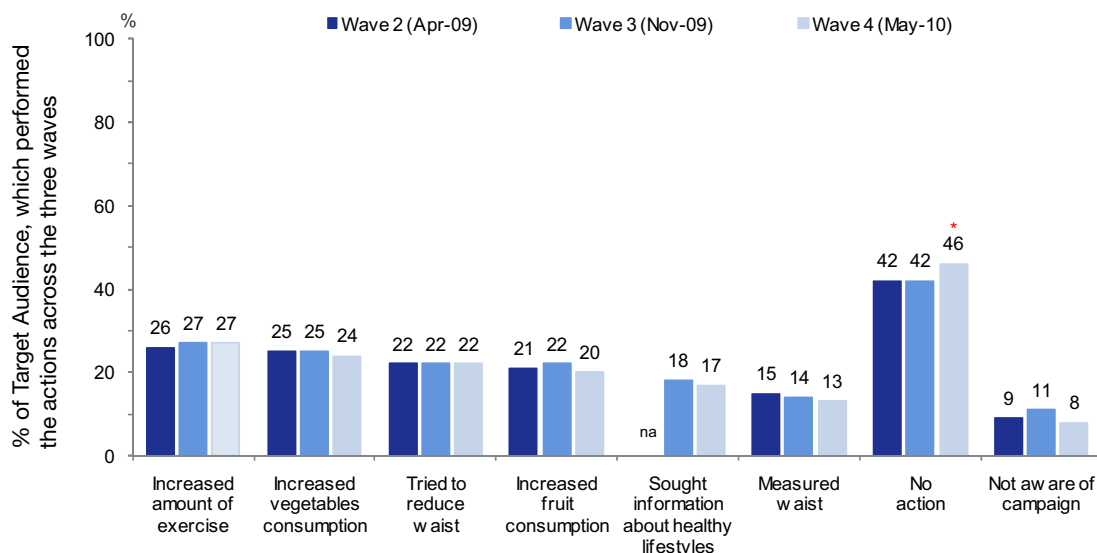
- (c) Identify the proportion of Australians (14+) who are not consuming any vegetables at all:

(1 mark) (IAE3)

- (d) Identify how many Australians (14+) are not getting the recommended serves of 5 vegetables **and** 2 fruits:

(1 mark) (IAE3)

16. Refer to the figure below which demonstrates the action taken by target audiences because of seeing the Measure Up campaign advertisements across three different waves (time periods).



Actions Performed by Target Audience after viewing the Measure Up Campaign

- (a) Waves 2, 3, and 4 represent when surveys were taken to obtain data (see key of graph in the figure above). With reference to data from the figure above, give a concluding statement about the impact or effectiveness of the Measure Up campaign over the three waves.

(2 marks) (IAE3)

- (b) Identify the health changing behaviour people tried to perform the most after being influenced by the Measure Up Campaign:

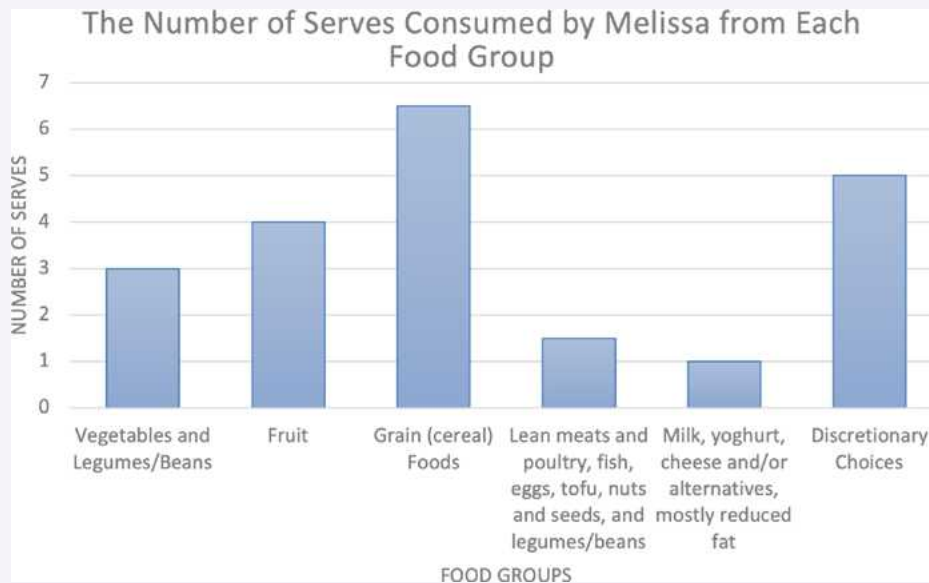
(1 mark) (IAE3)

Total: / 60 marks

Case Study

Evaluation of number of food group servings

Melissa is a 38-year-old accountant, which requires her to work long hours leaving her little time to cook home cooked meals and regularly exercise. Her current diet was evaluated and the number of serves she currently consumes from each food group was determined, as shown in the graph below.



With reference to the data in the graph above and the recommended average daily number of serves from each food group for her age and gender (as shown in Figure 2.2.3):

- Compare her current serves with what is recommended for her to consume.
- Identify one diet related disorder Melissa is at risk of developing due to her under or over consumption of a specific food group and explain how this can contribute to this disorder.

(10 marks) (IAE3, KA2, KA4)



Science as a human endeavour

Could Australia's next social marketing campaign be – 'Rethink sugary drink'!

Article adapted from: <https://static.diabetesaustralia.com.au/s/fileassets/diabetes-australia/545a6e5a-f1ab-4f1b-88ef-455153d506bd.pdf>

Moving forward, it has been proposed that Australia's next social marketing campaign be focused on reducing our sugar consumption.

Key messages

- The consumption of sugar-sweetened beverages is associated with increased energy intake and in turn, weight gain and obesity. It is well established that obesity is a leading risk factor for diabetes, cardiovascular disease and some cancers.
- Young Australians are very high consumers of sugar-sweetened beverages, and sugar-sweetened soft drinks in particular. The highest consumers of sugar-sweetened beverages are young males (12 to 24 years of age) and males are higher consumers than females across all age groups.
- The prevalence of sugar-sweetened beverages' consumption is higher among lower socio-economic groups, compared to higher socio-economic groups.
- A range of factors influence the consumption of sugar-sweetened beverages, including availability, price and marketing.

Recommendations

- Rethink Sugary Drink (Rethink) partner organisations (Heart foundation, Cancer Council Australia, Diabetes Australia, Nutrition Australia, Obesity Policy Coalition, Australian Dental Association Inc., and more!) recommend that adults and children should limit sugar-sweetened beverages and instead drink water or reduced-fat milk. Australian governments should support this call and encourage consumers to limit their sugar-sweetened beverage consumption in line with the new dietary guidelines. Rethink partners recommend comprehensive action by governments, schools, non-government organisations and others to inform the public about the health impacts of sugar-sweetened beverages and to influence the public to limit their consumption. A comprehensive approach should include:
 - A social marketing campaign, supported by Australian governments, to highlight the health impacts of sugar-sweetened beverages consumption and encourage people to reduce their levels of consumption
 - An investigation by the federal Department of Treasury and Finance into tax options to increase the price of sugar-sweetened beverages relative to healthier options to change purchasing habits and achieve healthier diets
 - Comprehensive restrictions by Australian governments to reduce children's exposure to marketing of sugar-sweetened beverages, including through schools and children's sports, events and activities
 - Comprehensive mandatory restrictions by state governments on the sale of sugar-sweetened beverages (combined with an increase in the availability of free water) in all schools, government institutions, children's sports and events and places frequented by children, i.e. activity centres
 - Development of policies by state and local governments to reduce the availability of sugar-sweetened beverages in workplaces, government institutions, health care settings and other public places.

1. Outline the **influences** driving the 'Rethink sugary drink' campaign:

(2 marks) (KA3)

2. Predict the effect of **applying** a tax on beverage manufacturers for the addition of added sugars:

(2 marks) (KA3)

? Science Inquiry Skills

Table 2: Serving size comparison to ADG/AGHE recommended serves

Food Group:	Grain (cereal) foods	Vegetables, legumes/ beans	Fruit	Milk, yoghurt, cheese, etc.	Lean meat, poultry, etc.	Discretionary
Total serves (tally)						
Total serves/day						
Recommended number of serves						

*Take note: different quantities and types of food tend to be eaten daily, therefore a 2-day comparison to recommended servings is not an ideal or realistic comparison. Should you have any concerns, seek professional advice.

Analysis & Discussion:

1. Analyse your findings by comparing your actual daily intake of each food group to the recommended number of serves of each food group based on your age and gender.

2. Evaluate the procedures in collecting your data set and comment on the limitations of possible conclusions and identify the occurrence of potential random and systematic errors.

? Science Inquiry Skills

Effectiveness of Social Marketing Campaigns

Introduction:

Each of Australia's social marketing campaigns including Go for 2 & 5, Measure Up and Swap it, don't stop it was aimed to change its viewers dietary patterns and/or exercise habits. Specifically, to increase physical activity and to consume higher quantities of daily fruit and vegetables. As a group, you are to design an experiment that would test the effectiveness of a selected social marketing campaign upon physical activity levels or fruit or vegetable consumption.



Helpful online resources

Go for 2 & 5 campaign: Go For 2 & 5 More Fruit And More Vegies 2007 Ad - YouTube; 303s Go for 2&5@ Nutrition campaign

<https://youtu.be/BvLKGO3jjzE?si=-bT7pshWLHpzn8Y0>



Swap it, don't swap it: Swap It Don't Stop It "Become A Swapper" (JWT Melbourne) -

https://www.youtube.com/watch?v=98P_Jk5IZJw



Measure Up campaign:

<https://www.youtube.com/watch?v=2gWCITWdCu8>



Note: links to additional adverts for each campaign can be found in helpful online resources in the social marketing campaign section of this chapter.

Method:

1. Record the social marketing campaign your group wishes to test the effectiveness of as your independent variable.

2. Decide on your dependent variable or which factor you will observe to investigate the effectiveness of your campaign (fruit or vegetable intake or physical activity levels).

3. Discuss and document at least three factors you will need to control to create a fair investigation, and discuss how these will be controlled and the effect on the data if not controlled.

Control variable	Effect of variable if not controlled and how you will control it

? Science Inquiry Skills

4. Identify one factor that cannot be controlled and discuss the effect this factor may have on the data.

5. Create an instructional method for a participant in your investigation. Factors to consider in your method include:

- How often, time of day and over what length of time to view the commercials
- Age group of participants in your investigation
- Steps to ensure your control variables are being met
- How you will collect your results; for example, a survey to collect data of eating/exercise patterns of a participant prior to, and after watching the commercials.

? Science Inquiry Skills

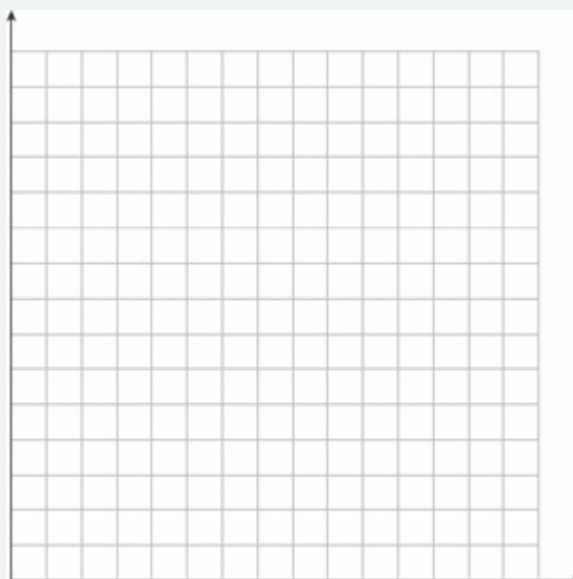
Rite Bite Policy Adherence

Introduction:

The Rite Bite policy employs the traffic light system: with red foods being energy-dense; orange foods still having moderate kJ and/or saturated fat, sugar, sodium, but containing some valuable nutrients; and green foods being nutrient-dense.

Method & Results:

1. Design a table in the space below to tally the total amount of food/beverages from one section of your school canteen (e.g. the drinks fridge or hot food section) into red, amber, or green categories. Use Table 2.2.1 and Figure 2.2.15 to assist.
2. Convert your tally in the table above into a column graph using the space below. Be sure to include axis labels and a title.



Analysis & Discussion:

1. Discuss your school canteen's adherence to the Rite Bite policy and provide any advice/alternatives you see fit to enhance the options available which fit the amber and/or green category (*if applicable*).

Extension Activities:

1. Take the following quiz from the Australian dietary guideline's summary document to create a case study surrounding your dietary intake compared to the AGDs/AGHE (note the survey is intended for adults but is still mostly applicable for an adolescent; however, the alcohol question should be ignored).

Take this quick quiz for adults to find out the answer – be honest! Give yourself one point for each box you tick if you:

- Eat at least 5 serves of vegetables every day. A serve is $\frac{1}{2}$ cup cooked vegetables (hot chips don't count!) or 1 cup of salad.
- Eat at least 2 serves of fruit every day. A serve is 1 medium piece or 2 small pieces of fresh fruit, or one cup of chopped or canned fruit (no added sugar).
- Have at least 2 serves of reduced fat milk, yoghurt, cheese or alternatives every day (for example, 1 slice of reduced fat cheese, a small tub of reduced fat yoghurt (preferably no added sugar), 1 cup of milk or 1 cup of soy milk with added calcium).
- Eat mostly wholegrain cereals (such as high fibre breakfast cereal and wholemeal bread).
- Eat at least a small serve of lean meat or chicken (fat and/or skin cut off) or fish, or eggs or some nuts or legumes (for example, lentils, chickpeas, beans such as kidney beans or baked beans) every day.
- Drink plenty of water every day and limit drinks with added sugars, such as soft drinks, cordial, energy drinks and sports drinks.
- Limit takeaway foods such as pizzas, commercial burgers, hot chips or other deep fried foods to once a week or less.
- Limit store-bought cakes, muffins, pastries, pies and biscuits to once a week or less.
- Limit salty foods like processed meats (for example, salami and bacon), crisps and salty snacks to once a week or less, and avoid adding salt during cooking or at the table.
- Drink no more than 2 standard drinks containing alcohol on any one day.

How did you rate?

8–10 points Congratulations, you're already a pretty healthy eater!

6–8 points Keep going, you're nearly there!

4–6 points There's plenty of room for improvement.

Less than 4 It's time for a serious overhaul.

Use the information in this booklet for some great ideas.

Poor eating habits are sometimes hard to break. For adults, it's not too late to make changes if poor eating habits have crept up, but it's important to keep changes realistic using the practical information in this booklet should help.

For more information go to:

www.eatforhealth.gov.au



2. The grain (cereal) food group includes cereal foods and grains that you may not be familiar with, namely: millet, rye, quinoa, polenta, couscous, bulgur, and barley. Google images of each to find out what each grain looks like, then find out if and how each can be eaten whole, as well as some recipes or foods they are commonly used in/with.

Foods part of the grain (cereal) food group	Suitable Recipe or Food they are Commonly used in/with
Millet	
Rye	
Quinoa	
Polenta	
Couscous	
Bulgur	
Barley	

3. Programs for encouraging healthy nutritional behaviour implemented by our federal government are the 'Healthy food partnership' and the 'Health star rating' system.
- Describe what the 'Healthy food partnership' policy is, some of the food manufacturers involved, and what demographic might benefit from this partnership.
 - Define what the 'Health star rating (HSR)' system is, describe how the HSR is calculated for a food, and discuss how the HSR can help Australians make healthier choices.

4. The National Healthy School Canteen project is the predominant program for encouraging healthy nutritional behaviour in schools. However, there are many other programs run on a smaller scale both in and out of schools. In class groups, present information about each of the programs in the table below, such as: age of cliental aimed at and key principals of the program. It is important to note that some programs that have been included in the table below are no longer active, but their principals have become embedded in schools or communities and therefore in essence they are still active!

Program	Details
Stephanie Alexander Kitchen Garden Foundation	
OPAL (Obesity Prevention and Lifestyle program for children)	
Get Healthy program: Information and Coaching services	
Crunch & Sip	
Eat Well Be Active Primary School or Community program	
Eat a rainbow	

5. In groups, brainstorm some initiatives the federal government could apply across all states to help Australians (both adults and children) reduce their waistlines and the obesity prevalence, and therefore prevalence of diet-related diseases by either: increase fruit and vegetable intake; increase exercise levels; and/or decrease amount of discretionary foods eaten.
6. Research and explore food models around the world. Find an image of the food model and share similarities and differences of the selected food model in comparison to the AGHE with the class.

2.3 Food sociology

Science understanding

Food sociology deals with understanding the factors that affect food selection by individuals. Factors selecting food selection include:

- Sensory reactions to food
- Psychological influences
- Social and environmental factors
 - Social influences effect food selection
 - Food regulation, marketing and advertising including social media and celebrity endorsements
 - Food affordability and food availability

SACE Subject Outline, 2024.

Sensory Factors affecting Food Choices

The basic biology underlying food intake is that it is closely linked to pleasure. Our senses are stimulated by sensory factors including the appearance, flavour, smell, texture and sound of food. These sensory factors, can increase (or decrease) our appetite or desire to consume the product, making them predominately internal factors influencing food choices. One of the most important goals of the food industry is to determine how food products affect a consumer's senses. Sensory factors can also be a primary concern for nutritionists and dietitians when modifying recipes to make them healthier. As our senses act as a determinant of food consumption, consumer reaction is considered a vital measure of food development. As no apparatus or equipment can substitute the five senses of a human response to food, individuals are used as test subjects in sensory evaluations. These types of tests are becoming more prevalent, despite their limitations and the potential biases of humans.

Sensory characteristics

The characteristics and quality of food are perceived by the five senses: sight, taste, smell, touch and sound, which can be used to judge a food product's appearance, flavour, smell, texture and sound (common descriptive words used to describe these characteristics are shown in Table 2.3.1). These senses are used to determine a human's response to a food product.

Table 2.3.1: A tasting test word bank, which can be used to describe specific characteristics of food products.

Appearance	Flavour	Smell	Texture	Sound
Appetising	Acidic/Sour	Aromatic	Airy	Bubbling
Attractive	Bitter	Burnt	Brittle, Crumbly or Flaky	Crackly
Brittle/Dry	Bland	Coffee	Chewy or Sticky	Crunchy
Burnt	Burnt	Fermented	Coarse	Grating
Clear	Buttery	Floral	Cold or Hot	Fizzy
Cloudy	Creamy	Fresh	Crisp or Crunchy	Percolating
Colourful	Fatty	Fruity	Crystalline	Sizzling
Colourless	Herby	Musty	Dry	Snapping
Dark	Pleasant	Pungent	Effervescent or Fizzy	
Foamy	Salty	Rancid	Fibrous	
Fresh	Sharp	Roasted	Fine	
Grained	Smokey	Smokey	Flat	
Greasy	Spicy	Sour	Foamy	
Healthy	Stale	Spicy	Grainy, Gritty or Lumpy	
Opaque	Sweet	Stale	Greasy	
Pale	Tangy	Strong	Hard or Firm	
Shiny	Tart	Weak	Juicy	
Slimy	Tasty		Moist	
Smooth	Tasteless		Mushy	
Sticky	Undercooked		Powdery Rubbery	
Translucent	Watery		Slimy	
Watery			Smooth	
			Soft	
			Spongy	
			Sticky	
			Soggy	
			Tender	
			Tough	
			Watery	

Appearance

The eyes perceive the initial appearance of the food, which includes colour, size, shape, transparency, dullness, and gloss. The colour of food may accurately indicate ripeness, strength of dilution, or the degree to which the food has been cooked or reheated. The colour is used to evaluate a food's desirability and acceptability. Green bananas, burnt meat or dark brown avocado can send a visual signal which changes a person's food choice. The shape, size, and surface appearance, such as width, length, thickness, distribution of pieces, dullness, shininess, smoothness or roughness, can also influence consumers and provide information about food quality.

Flavour

Flavour is a combined sense of taste, aroma, and **mouthfeel**. Taste is the most influential factor in a person's selection of a particular food. It is perceived by the stimulation of the **tastebuds** on the surface of the tongue (shown in Figure 2.3.1) and in areas of the throat. The tongue can detect five different tastes, including sweet, salty, sour, bitter and umami.



Definition

Mouthfeel is the way an item of food or beverage feels in the mouth as detected by the teeth and nerves of the tongue.



Fast fact

The human tongue has on average between 2000 and 8000 tastebuds, though this number decreases with age. This can be why older people seek more spices, sugar, and salt in their food.

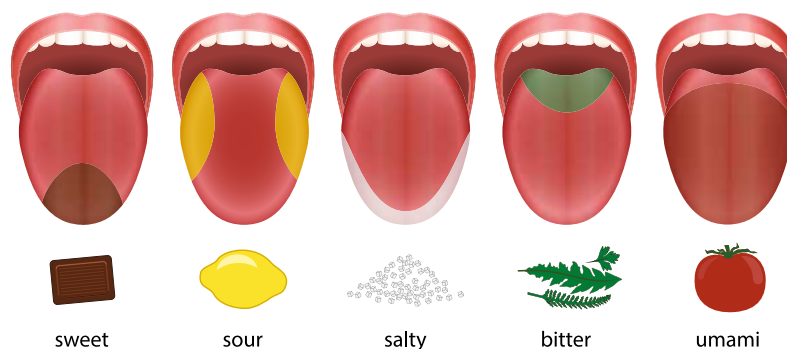


Figure 2.3.1: A common myth is that the tongue has predominant locations where each of the different taste senses are detected. Recent studies have debunked this myth..

Smell

Aroma or odour contributes to approximately 75 per cent of a food product's perceived flavour (which can be tested by pinching your nose the next time you're eating a flavoured food item). It can be detected directly through the nose or by entering the mouth and flowing to the back of the throat and up into the nasal cavity. The strength of an odour is related to temperature, with it being easier to smell hot foods compared to cold ones. For example, the aroma of hot tea is much easier to detect than iced tea. Human subjects have varying sensitivities to odours, depending on hunger, satiety, mood, concentration, presence or absence of respiratory infections, and gender.

Texture

The texture of a food product is complex, as it is determined firstly by an individual's visual perception, then our sense of touch through oral sensations on the skin, or the movement of utensils through the food, before finally being influenced by mouthfeel.

Sound

Sound is another sense used in evaluating food quality. Sounds such as sizzling, crunching, popping, bubbling, squeaking, dripping, exploding, and crackling can communicate much about a food. A majority of these sounds are impacted by the food's water content; therefore the presence of these sounds indicates a product's freshness and ripeness.

Sensory evaluation

A sensory evaluation is defined as a scientific discipline used to invoke, measure, analyse and interpret reactions to specific characteristics of foods, which are perceived by the five senses: sight, smell, taste, touch, and sound. A sensory evaluation uses collected numerical data to determine the relationship between specific characteristics and human perceptions, which is a necessary part of both product development and quality control. Food manufacturers and retailers may use this type of testing during various stages of the food production process, which may include testing raw ingredients, reviewing newly developed dishes, analysing food samples for improvements, gauging responses to dishes to determine if they are acceptable or unacceptable, or testing the products after they have been stored. To ensure that the sensory testing is fair and not biased, it is important that conditions are carefully controlled. This involves:

- swirling and sipping water in between each sample to remove the taste and debris of any previous food.
- using separate testing areas so that testers are not influenced by others.
- not allowing communication between members on the panel.
- conducting testing between 10am and 12 noon, or 3pm and 5pm.
- labelling samples with numbers or letters to keep the products anonymous – this way the testers will not recognise brand names (e.g., could use a random three-digit code).
- having a well-lit room with few distractions, including colours on the walls, noises, and smells.
- using clean cutlery and utensils for each sample.
- using blindfolds (blind testing) so that the tester is not influenced by the appearance of the food.
- making each sample of food the same size and temperature.
- allocating samples randomly to testers.
- completing odour observations prior to tasting.
- making sure scorecards are typed, simple and clear.
- having at least six testers due to people perceiving sensory characteristics differently e.g., varying sensitivities to odours.

Testers must not be:

- suffering from a condition, that could affect their sense of taste (e.g., they should not be a heavy smoker, an individual with a cold, or a person taking strong medication).
- allergic to food or ingredients.

A significant limitation of this type of scientific testing is that data is generated from human responses, which can be highly variable. Therefore, this is a subjective method. For example, one consumer may describe a sample as unpalatable while another consumer may consider the same sample acceptable. These differences are common in a sensory evaluation, and can be explained by an individual's past experiences, values, beliefs, family habits, attitudes, and personal preferences.

Common sensory evaluation tests that can be used to measure an individual's response to a food product can include a star profile, ranking test, rating test or a triangle test.

Star profile

A star profile can be used to test a single food product or a range of food products. This type of sensory evaluation test can be used to evaluate differences in similar products, analyse specific characteristics, compare similarities in a range of products or show new opportunities for product development. A star with between five and eight points is then labelled with words that describe different sensory characteristics of the tested product (see example characteristics in Table 2.3.1). A member on the panel is then asked to place the food sample on a scale from one to five for each characteristic, where the highest number represents the greatest intensity. These results are then plotted onto the star profile (also known as a radar graph, an example of which can be seen in Figure 2.3.2). It is possible to compare similar products (e.g., two types of biscuits) by plotting them on the same star profile.

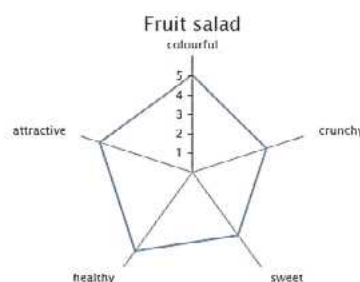


Figure 2.3.2: An example of a star profile analysing the specific characteristics of a fruit salad.

Ranking test

A ranking test is a quick, simple, and useful tool to assess the differences in preference or intensity of sensory attributes of multiple products (usually between 3 to 5 samples). Panelists are given coded products and asked to put them in order of preference, or in order against a specific sensory attribute (e.g., most to least sweet). An example of a ranking test can include four different samples of apple juice with assorted amounts of citric acid added to them. Panelists are then asked to sample them in any order and rank them from most to least sour, to determine which amount of citric acid is most preferred. An example of a scorecard given to testers is shown in Table 2.3.2.

Table 2.3.2: An example of a scorecard given to each tester on a panel of a ranking test where panelists are asked to rank a food product based on its sweetness.

Date:	Name:				
Panelist Number:	Product:				
Sample	Ranking of samples				
	1st	2nd	3rd	4th	Comments

Rating test

A rating test asks testers to rate a product using either a five-, seven- or nine-point scale. A rating test may be useful if a baker has produced, for example, a new low-fat cake in which butter has been replaced with applesauce. The test would try to determine which recipe produces the same moistness as the original, but with a lower fat content. The baker would make four samples with four levels of applesauce substitution (0%, 33%, 66% and 100%); he would select moistness as the most suitable sensory characteristic to measure. Testers would then be asked to evaluate the moistness of the cake using a rating scale from 1 to 9 (as shown in Figure 2.3.3).

Sample code:

- Extremely wet
- Very wet
- Moderately wet
- Slightly wet
- Neither wet or dry
- Slightly dry
- Moderately dry
- Very dry
- Extremely dry

Figure 2.3.3: An example of a rating test scorecard used to assess the moistness of a modified cake.

Triangle test

In a triangle test, testers are presented with three coded samples, but two of them are identical or alike. The members on the panel should be presented with all three samples at once and instructed to taste them from left to right. The combinations given to each tester should be randomised, as shown in Table 2.3.3.

Table 2.3.3: An example of the random allocation of two samples (A and B) to each tester in a triangle test.

Tester	Sample 1	Sample 2	Sample 3
1	A	A	B
2	A	B	A
3	B	A	A
4	B	B	A
5	B	A	B
6	A	B	B

The testers are asked to identify the 'odd one out' by placing an X on the scorecard and any comments describing what is different about the identified sample. An example of a triangle test scorecard is shown in Table 2.3.4. This test is useful for comparing different brands of the same product or for ensuring that all batches from production are identical. A triangle test can also be used to determine if there is a sensory difference between two products. For example, a food manufacturer may want to see if changing one ingredient in a recipe to make a certain food product will alter the final taste. Another example could include a manufacturer wanting to confirm if there is a significant sensory difference between a canned product and a paper carton product, as they are considering changing to cartons due to the desire for more sustainable packaging by consumers. The testers have a 33% chance of simply guessing correctly, however fatigue is a factor, which requires panelists to re-taste the samples several times.

Table 2.3.4: An example of a triangle test scorecard given to each tester on the panel.

Name:	Product:
Panelist Number:	Date:
Instructions: You are presented with three coded samples of . Two of these samples are identical or alike, while the third is different or odd. Taste and smell each sample, and then place an X in the second column next to the sample code that you identify as being odd. Write any comments below describing what is different about the sample. You may test each sample several times if required.	
SAMPLE CODE	ODD SAMPLE
Comments:	

Helpful online resources

Sensory evaluation summary'

<https://www.youtube.com/watch?v=qW5oZI2Mry4>



Food Processing Center: Sensory Lab

<https://www.youtube.com/watch?v=QupZlmliekM>



What It's Like To Be Paid To Taste Food

<https://www.youtube.com/watch?v=IVe25lpVK0c>



Psychological Factors affecting Food Choices

Psychological factors relate to the mind. They refer to thoughts and feelings that can affect attitudes, behaviours, and the way we think. They differ for every individual and depend on things such as lifestyle and upbringing. Some psychological factors such as values, beliefs, and self-image can have a constant influence on foods selected. Other psychological factors such as emotions can vary day to day and have more temporary effects on food choices.

Values

A value is a strong personal feeling about what is important to a person. An individual's values typically reflect those of the family and culture in which they were raised. Cultural and family traditions often result in the development of food habits or dietary patterns, such as eating cereal at breakfast time, sprinkling salt on meals before tasting, and eating cake on birthdays.

Cultural values

Some food choices or meal gatherings valued by the Australian culture include barbeques, 'meat and three veg' for dinner, meat pies at football matches, and popular food items like vegemite! However, Australian culture is quite difficult to define because it is one of cultural diversity. After the Second World War, millions of migrants from many different nations brought their cultures and traditions to Australia. The food, lifestyle and cultural practices of immigrants have been immersed into today's Australian culture, giving Australia its reputation as a multicultural nation. Some of the common cultural groups within Australia adding to our multicultural identity are Chinese, Indian, and Vietnamese, with values and traditions such as: dishes of noodles/rice and main meals often served in large dishes and shared, using spices generously in foods, and rice being a part of almost every meal, respectively. Australian culture also has important heritage from its Indigenous people, and it is commonplace for restaurant and pub meals to offer local produce, such as kangaroo, crocodile, and macadamia nuts.

Despite our diversity, the culture of Australia is primarily a western culture. The impact of such see's food choices such as: fast food outlets creating energy-dense foods in large serving sizes, a high intake of alcohol and over-indulgence in discretionary foods like cake and confectionery.

Ethical values

Apart from family and cultural influences, values may also be instilled from personal life experiences. The value most likely to influence food choices is the maintenance of health. For example, health scares such as a heart attack are known to motivate changes in diet and physical activity regimes. Placing value on health typically sees food choices of the nutrient-dense kind and minimal alcohol being included in the diet.

Further values affecting food choices that are gaining popularity and awareness are the support for environmental sustainability and animal rights. Selecting organic produce is often a reflection of these values, which are those farmed without the use of synthetic chemicals that have known consequences on the environment. Animals are also raised humanely and with respect (e.g., chickens are free range and not kept in cages). Some people regard animals' rights to freedom so highly that they abstain from all animal products, called veganism or from some animal products, which is vegetarianism. The three main types of vegetarianism are:

- **Lacto-ovo vegetarians** – people who do not eat any meat and seafood, but include dairy foods, eggs (typically free-range) and plant foods.
- **Lacto-vegetarians** – people who avoid meat, seafood, and eggs, but include dairy foods and plant foods.
- **Vegans** – people who consume only plant foods.

Human welfare is another value which can drive food choices towards selecting fair-trade produce. Foods with the fair-trade logo (see Figure 2.3.4) ensure producers are paid fairly and more of the profit is returned to small-scale farmers and workers in developing countries, rather than larger, dominant, and often wealthy corporations. In addition, the 'fairtrade' premium provides extra money as a communal fund which can be put towards community needs, for example, better healthcare for children. This can help improve social, economic, and environmental conditions, e.g., help fight poverty.



Figure 2.3.4: Fairtrade logo found on food labelling.

Beliefs

A belief is an acceptance or opinion that something exists or is true, without the need for scientific proof. Beliefs about what is acceptable to eat **vary throughout the world** and are often related to family and cultural traditions and religion.



Fast fact

Uncommon and often unusual beliefs called 'food taboos' exist in some cultures around the world, particularly in remote areas where education levels are poor. They include: meat and eggs not being given to children because parents believe it will make the children steal; coconut milk for children is taboo or prohibited as it is believed that it will render them unintelligent; women are thought to be 'sickly' because of recurring menstruations and are not allowed fresh meat, juicy bananas and all fruits of the forest of a red colour; eggs are avoided because they are believed to destroy human fertility.

The **predominate belief or religion in Australia is Christianity**, with Islam, Hinduism and Buddhism also having large followings. Although Christianity has some customs affecting food choices, Islam, Hinduism, and Buddhism are the religions expanded upon as they impose food restrictions that can impact more substantially on nutritional status.



Fast fact

Australia's most recent census (2021) showed 43.9% are Christians, 3.2% of the population are Muslim, 2.7% follow Hinduism and 2.4% follow Buddhism.

Islam

Followers of the Islam religion are called Muslims. Muslim food choices are influenced by several dietary restrictions. Muslims believe that eating is for good health and that failure to eat correctly minimises spiritual awareness. Some of the dietary restrictions are:

- Prohibited (haram) foods and beverages include pork and pork products, alcohol, and non-halal derived animal ingredients such as gelatine. These products are considered impure, unhealthy, and harmful for human consumption.
- All other meat is to be from certified halal meat (halal certified food label shown in figure 2.3.5).
- Most dairy products are halal and able to be eaten, unless they have added animal enzymes that are not certified as halal. For example, rennet is an animal product from non-halal meat that is used in some cheesemaking, therefore making cheese with rennet forbidden.
- Fasting is required for approximately 30 days during Ramadan, the ninth month of the Islamic calendar, when Muslims must refrain from consuming food, beverages and medication between sunrise and sunset.



Figure 2.3.5: Halal certified food label.

Hinduism

Most Hindus do not eat pork or beef; in fact, beef is avoided because the cow is considered a holy animal, but dairy products are acceptably consumed. Some Hindus eat lamb, chicken, or fish, but the majority are lacto-vegetarian.

Buddhism

The Buddhist religion doesn't specifically restrict any food or food group. However, its beliefs, which centre on the cessation of suffering, or doing no harm, are expressed through practicing a vegetarian diet. Lacto-vegetarianism is the most common type of vegetarianism among Buddhists. Many are also vegans.

Emotions

An emotion is a mental state associated with thoughts, feelings and behavioural responses caused by your circumstances, mood, or the people you are with. Emotions, or strong feelings, are often an influence over the foods we ingest. Being in good spirits can stimulate us to feel relaxed and eat larger quantities of food. However, negative emotions such as boredom, depression, anxiety, and stress are the best-known emotional influencers, resulting in poorer food choices, especially when eating privately. Negative emotions can be linked to a significant reduction in food intake, for example feeling too busy to eat when stressed, or they can be linked to comfort eating. **Comfort eating**, or emotional eating, is associated with satisfying the need to feel good, happy, or calm to reduce the negative emotion that drove the person to eat in the first place. Emotional eating, typically being of energy-dense foods (Figure 2.3.6), can be distinguished as follows:

- It typically involves a craving for a certain food.
- It requires immediate satisfaction and eating may continue past the feeling of [satiety](#).
- Although the immediate feelings are positive, emotional eating can cause guilt and regret afterwards.



Reminder

Satiety is the feeling of fullness.



Figure 2.3.6: Comfort eating of energy-dense foods when depressed.

Self-image

Self-image (or body image) is the way a person views their appearance (and abilities and personality), or it's how someone sees themselves. It is also how you believe others see you. Self-image does not always coincide with reality. The way we view ourselves is often distorted and unrealistic (see Figure 2.3.7). Humans can be very critical of themselves and their abilities. Dissatisfaction with body image tends to increase from around the age of puberty until the mid-20s, especially in females. Many individuals have a desire to lose weight and improve their body image. This can lead to food choices that restrict kilojoules and turning to 'fad diets'.



Figure 2.3.7: Distorted (or negative) self-image.

Fad dieting

A fad diet is a short-term or temporary eating plan that often promises rapid weight loss but is not based on sound science. Fad diets are often highly restrictive, either on kilojoules, foods and/or nutrients, and, in some cases, eliminate entire food groups! Unfortunately, fad diets are frequently undertaken in Australia. Common fad diets include those that recommend cutting out sugar, drinking meal replacement shakes, following a low carbohydrate diet, detox diets, fat-free diets, and more!

Fad diets can provide short-term results of weight loss. Unfortunately, most of the weight lost is water and lean muscle mass, not fat. Loss of muscle mass will reduce a person's [basal metabolic rate \(BMR\)](#). Adding to this, severe restriction of kilojoules for a weight loss fad diet will also cause the body to respond by slowing its metabolism. A slower metabolism and reduced muscle mass (the kJ burners) result in the body using kilojoules less efficiently, therefore, once the fad diet is completed and the dieter returns to their usual diet, weight can be more easily put back on. Not only this, but fad diets can lead to yo-yo dieting and disordered eating conditions like bulimia nervosa and anorexia nervosa.



Reminder

BMR is the minimal energy used to keep the body functioning, e.g., breathing, maintaining muscle tone, maintaining a heart rate.

Past Experiences

Past experiences can influence food choices. Foods eaten habitually with family and friends often remain firm regulars in the diet. A powerful negative experience with a food, however, can result in aversion to or avoidance of that food for a lasting period (sometimes as long as the unpleasant memory of the food endures). The most well-known reason for food aversion is because the food has made the consumer sick and caused food poisoning. Presentation of that same food can bring nauseating sensations and feelings of disgust. It is an innate rejection of food to protect us from potential toxins or poisoning. Food poisoning and toxins are known to elicit vomiting. Therefore, our bodies are protecting us from a food that on one occasion, or past experience, has caused vomiting.

Attitude (Likes and Dislikes)

An attitude is the way in which a person views something and behaves towards it. In relation to food, attitude is our likes and dislikes (see Figure 2.3.8). Whether we evaluate a food positively (like) or negatively (dislike) affects food selection. Food attitude, our likes, and dislikes, are shaped by many factors, including cultural and family traditions, our beliefs, sensory preferences, health and safety perception of the food, past experiences with food and the emotions experienced with consumption of the food, e.g., guilt, comfort, etc. Even perceived status and cost of the food can influence food attitude. For example, lobster and truffles tend to have a higher status (and cost!). This could create a negative attitude towards these foods for those of lower socioeconomic status.



Figure 2.3.8: Food attitude, our like and dislikes.

Social and Environmental Factors affecting Food Choices

Social and environmental influences on food intake refer to the impact that external factors or other people have on the eating behaviours of others. This influence can be direct or indirect, or conscious or subconscious. Examples of social and environmental influences include the media and advertising, an individual's geographic location, socioeconomic status, a person's level of education and peer pressure.

Peer pressure

Food is an important part of socialisation and recreation. Accordingly, food preferences and behaviours are shaped in the context of many social settings, including the home and social networks. Beliefs about what other people think of a particular behaviour can influence food preferences and choices in a social setting. These influences are particularly relevant during childhood and adolescence where long-term food preferences and **eating behaviours are developed**. Family members can exert a strong influence on a child's dietary habits by facilitating or limiting access to certain foods in the house. Parents' attitudes towards food, combined with their level of knowledge, can also shape a child's food preferences. While family members and carers have the strongest influence on a child's food preferences, peer groups can influence eating behaviours, especially as children grow older. For example, adolescents may choose not to consume certain foods as they fear appearing weird or different to their friends.



Fast fact

Evidence suggests that dietary habits established during childhood and adolescence influence people's food choices later in life, where they tend to consume takeaway foods more and have breakfast less often.

Media and advertising

Commercial media promotes advertising campaigns that communicate messages with the aim of influencing potential consumers to purchase products. Various forms of media include television, print (e.g., magazines) and social media, which have all been found to have a significant impact on an individual's food choices and access to food information. Media has rapidly developed alongside changes in technology. Individuals now have easy access to portable internet at the touch of their fingers. The media attempts to persuade consumers (change their views) through the biased portal of information, using **advergaming** (see Figure 2.3.9), interactive programs, cartoons, and celebrity endorsements to promote food products. The media influences consumers' food choices by exposing or not exposing them to specific food information, and by promoting socially idyllic bodies or stereotypes.



Figure 2.3.9: Advergame 'Crazy taxi' with observed KFC advertising.

Studies have revealed that individuals who watched a lot more television and viewed more commercials, developed positive associations and attitudes towards junk food, leading to greater consumption of these foods. Salty snacks and soft drinks are advertised predominantly, whereas fruit and vegetables are advertised the least. Although nutritious foods are advertised, these commercial campaigns do not lead to positive attitudes or increased consumption as successfully as junk food advertisements do. Therefore, prolonged exposure to media, such as television and social media, has been directly linked with an increased consumption of energy-dense foods and an increased body mass index (BMI) of Australians. Whereas the promotion of the "idyllic" body has been associated with fad dieting and disordered eating.

Although the diet should be parental controlled at a young age, media and peer food envy can even influence young children into becoming fussy eaters; using tantrums, food refusal or pestering (called **pester power**) to gain their own food choices. This is why 'junk food' advertisements are restricted during children's TV programs. Parents, however, should persist their control over the diet and provide good role models, reinforcing ideal eating habits at this life stage, especially considering children will often mimic their parent's behaviours.

Food Regulation

The government regulates the food industry so food is safe to eat, and consumers can make informed choices about food. Healthy food choices are advocated through government initiatives such as the ADGs and AGHE, in the hope to affect our food preferences positively (see chapter 2.2).

Food Availability and Geographic Location

Food security can be defined as follows: when all people, at all times, have physical and economical access to sufficient, safe, and nutritious food to meet their dietary needs and food preferences for an active and healthy lifestyle. A person's ability to acquire appropriate and nutritious food on a regular basis is determined by the availability of food and that person's capacity and resources to access that food.

Geographic location affects the price, quality, and availability of foods, and therefore significantly impacts one's ability to access, choose and consume healthy foods. The cost of healthier and nutritious foods is approximately 30 per cent higher in rural and remote areas compared to urban areas. Elevated prices are associated with transport, storage, and handling. In remote areas, these factors are compounded by a lack of demand and competition from other **marketplaces**. Fresh foods – such as fish, lean meats, fruit, and vegetables – are also limited in rural and remote areas of Australia, restricting food choices further. These price and availability differences make it harder for people in rural communities to purchase nutritional foods and achieve a secure food supply. In contrast, people living in urban areas are generally closer to supermarkets and fruit and vegetables stores. This proximity means these individuals have greater food access, choice, and ability to consume healthy foods. Therefore, in summary, the more remote an area is, the higher the cost of food, the more limited the availability, and generally, the lower the quality of fresh produce. This limits people's food choices and food security and increases the risk that those people will develop diet-related disorders.

Definition

A marketplace is a place where consumers purchase food, which may include the corner store, small local supermarket, or an urban shopping centre.

Food affordability

The cost of food is a primary determinant of food choice. Therefore, food access, choice, purchases, and consumption depend on an individual's **socioeconomic status**. Socioeconomic status refers to the social and economic position of an individual or group of individuals within society. Evidence shows that people living under financial constraints tend to preferentially choose high-energy, nutrient-poor food, to maximise their energy intake value for money. For example, foods such as rice, pasta and sweets are high in energy and are relatively cheap. Fresh fruit and vegetables have high nutrient value, but they cost considerably more for the energy they provide. Therefore, low socioeconomic groups tend to consume unbalanced diets, which can lead to the development of both undernutrition and overnutrition disorders. Not surprisingly, households with the highest incomes and resources available have a greater average weekly expenditure on food and beverages than the lowest income households (as shown in Table 2.3.5).

Table 2.3.5: The average weekly expenditure on food and beverage by household income (Biro, 2022).

Household Income	Average Weekly Grocery Bill
Less than \$30,000	\$123
\$30,000 to \$49,999	\$146
\$50,000 to \$79,999	\$147
\$80,000 to \$119,999	\$163
More than \$120,000	\$179

People eat foods that are not only within their financial means but that are accessible, quick, and easy. Today's consumers value convenience and are willing to spend more than half of their food budget on meals that require little, if any, further preparation. They frequently eat out, bring home ready-to-eat meals, or have food delivered. This is because households may be lacking in resources, including cooking equipment, transportation, and time to prepare healthy meals. These economic factors are affected by an individual's occupation, earnings, labour force participation, knowledge and skills, socioeconomic status, and the number of children in the household. For example, having multiple jobs, inflexible hours and night shifts can limit the amount of time available to choose and prepare healthy meals. Elderly people can also have limited access to food, as they may be retired and, on a pension, and therefore under financial constraints. These individuals may skip meals, consume takeaway meals, eat out more often or use premade ingredients when cooking.

Methods for reducing the Food Bill

Socioeconomically disadvantaged groups or lower income households can adopt methods to reduce their food bills (as shown in Figure 2.3.10) to increase the affordability of healthier foods.



Figure 2.3.10: Methods for reducing the food bill for an Australian household.

Level of education

Education is an important determinant of food access, choice and eating behaviours. Education provides the fundamental food and nutrition-related knowledge required to make informed food choices. Therefore, an individual with a high level of education generally has increased opportunities for food access, choice, and consumption of healthier foods. In contrast, a lack of nutritional knowledge – as well as a lack of knowledge and skills required to successfully budget, plan, and cook healthy meals predisposes people with low levels of education to eat poor quality meals that do not meet nutritional requirements. Individuals with higher education levels tend to also have better employment outcomes with higher incomes, which in turn improves health habits.



Helpful online resources

Factors affecting food choices

https://www.youtube.com/watch?v=r6Uezl_Pveg



Key terms

Appearance	Food security	Rating test
Belief	Hinduism	Self-image
Buddhism religion	Islam religion	Sensory evaluation
Comfort eating	Lacto-ovo vegetarian	Social and environmental factors
Cultural values	Lacto-vegetarian	Socioeconomic status
Emotion	Level of education	Sound
Ethical values	Media	Smell
Fad diet	Methods to reduce food bills	Star profile
Five human senses: sight, taste, smell, touch, and sound	Mouthfeel	Texture
Flavour	Peer pressure	Triangle test
Food availability	Ranking test	Values
Food regulation		Vegan

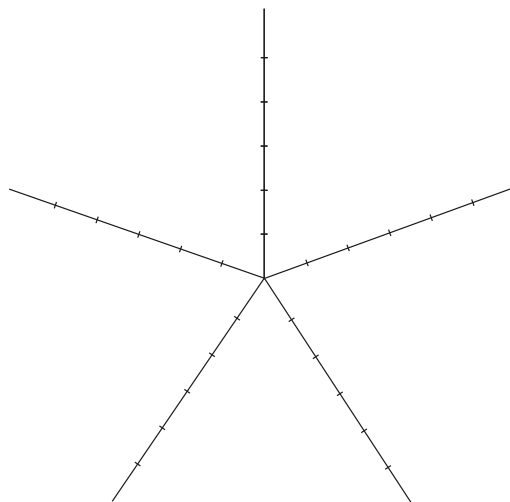
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Review questions: 2.3 Food sociology

1. Refer to the following table, which shows some sensory characteristics of three types of lactose-free milk:

Sensory characteristics	Type of milk		
	X	Y	Z
Packaging (1 – unappealing, 5 – attractive)	4	2	3
Texture (1 – watery, 5 – thick)	4	2	2
Aroma (1 – unpleasant odour, 5 – neutral odour)	2	5	4
Colour (1 – grey, 5 – bright white)	5	3	4
Sweetness (1 – sour, 5 – sweet)	4	2	4

- (a) Graph the sensory characteristics of each milk onto the axes of the star profile below.



(4 marks) (IAE2)

- (b) Identify two factors that need to be held constant during sensory testing to improve the reliability of results.

(2 marks) (IAE1)

- (c) Using the data in the table and/or graph above, determine which milk is likely to be the most popular.

(1 mark) (IAE3)

2. Describe the term 'fad diet' and identify a concern of partaking in a fad diet.

(2 marks) (KA1)

3. Match the following psychological factors that influence food choices to their definitions.

Value	A mental state associated with thoughts, feelings and behavioural responses caused by one's circumstances, mood or the people you are with.
Belief	Strong personal feeling about what is important to you.
Emotions	Thinking that something exists or is true, without the need for scientific proof.
Attitude	The way a person views their appearance (and abilities and personality).
Self-image	Food likes and dislikes

(5 marks) (KA1)

4. Make two modifications to the following meal plan to accommodate for a follower of the Islam religion.

Breakfast	Bacon, cheese, and egg muffin with orange juice
Lunch	Beef and salad sandwich
Dinner	Vegetable stir-fry with wine
Dessert	Jelly and ice-cream

Modification one:

(1 mark) (KA2)

Modification two:

(1 mark) (KA2)

5. Refer to the following average daily diet of an Australian adult named Justine.

Breakfast	Vegemite on toast, coffee
Lunch	Sushi
Dinner	Salt and pepper crocodile with chips
Snacks	Apple, nuts, biscuits, yoghurt

- (a) Identify a food choice that has most likely been influenced by Indigenous culture, one that is distinctly Australian and another that has been influenced by the diversity of cultures in Australia.

Indigenous influence:

(1 mark) (KA1)

Distinctly Australian:

(1 mark) (KA1)

Multicultural influence:

(1 mark) (KA1)

- (b) Justine has a bad day at school, and it leaves her feeling emotionally upset. Describe how this may affect her food choices.

(2 marks) (KA2)

6. Describe one economic factor that might influence the protein intake of elderly people and suggest one-way elderly people can ensure they meet their protein requirements.

(3 marks) (KA2)

7. Discuss the effect of one social or environmental factor on the food choices of children aged between 4–8 years.

(2 marks) (KA2)

8. Fred and Penny live in a small town and have two primary school aged children, Joe 11, and Tina 5. Fred was a chef before he became the manager of a hospitality business, and he enjoys cooking for the family. Penny has recently had her part-time work hours reduced to three and a half days a week. Joe is highly active and is easily influenced by his friends. Tina has just started primary school and has had to adjust to a new routine. The family live near Penny's elderly mother, Eva 82 years old, who is needing more help with preparing food due to health problems affecting her mobility and movement.

Identify three social and environmental and/or psychological factors that could affect this family's food choices and explain how they may influence them.

Factor:

Explanation:

Factor:

Explanation:

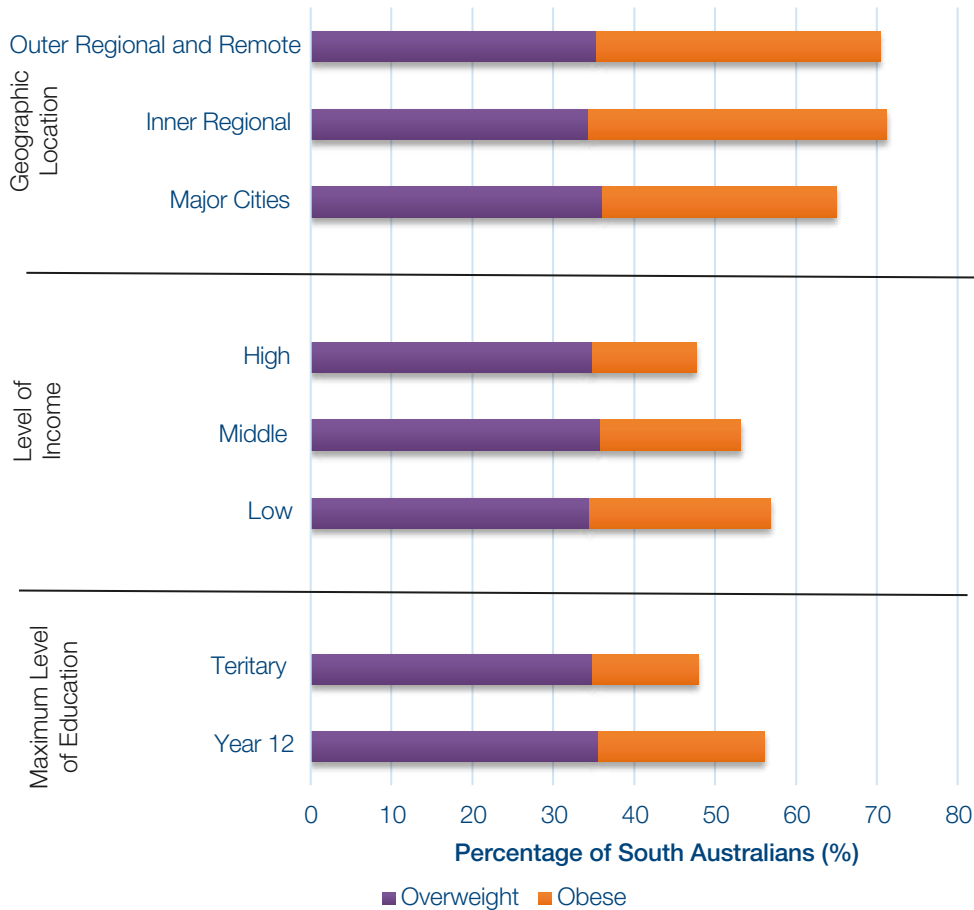
Factor:

Explanation:

(9 marks) (KA2)

9. Social and environmental factors can affect people’s food choices, which can impact their health status. The effect of three factors are shown in the graphs below on the percentage of South Australians and their weight category.

The Effect of Social and Environmental Factors on the Percentage of South Australians who are considered Overweight or Obese



- (a) With reference to the graph above, state one conclusion that you can draw about the relationship between the maximum levels of education and the percentage of the population that is obese.

(2 marks) (IAE3)

- (b) With reference to the graph above, describe the relationship between the levels of income and the percentage of the population that is overweight and obese.

(2 marks) (IAE3)

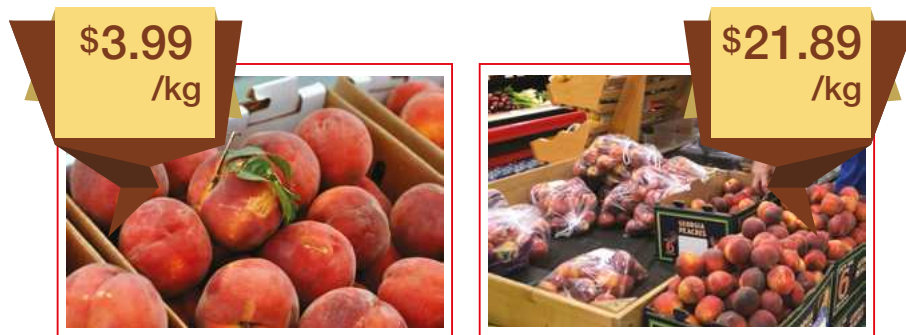
- (c) Suggest two strategies that an individual on a low income could use to reduce food costs and still maintain a nutritionally balanced diet.

1.

2.

(2 marks) (KA2)

- (d) The price of produce can be a contributing factor to the difference in the percentage of South Australians which are overweight or obese based on their geographic location. As shown in the image below, peaches in a major city were priced at \$3.99/kg and peaches in a remote/regional community were priced at \$21.89/kg.



Explain one reason why there is a significant price difference between the peaches.

(2 marks) (KA2)

10. In the creation of a food product, the bliss point is the perfect quantity of salt, sugar, and saturated fat to increase the sensory appeal to consumers. However, with recent health food trends manufactures are attempting to reduce these quantities to cater to a new market of consumers. Below is the nutritional information panels of two products, the original and a new modified product.

	Original	Modified
Energy (kJ)	1158	718
Protein (g)	2.9	1.5
Fat – Total (g)	11.5	10.6
Fat – Saturated (g)	5.6	4.8
Carbohydrates (g)	42.7	23.4
Sugars (g)	24.2	6.9
Sodium (mg)	134	130

A sensory evaluation was completed on both the original and modified recipe to identify any weaknesses in the taste, texture, and appearance of the manufacturer's modified product and to ensure it was appealing to consumers.

- (a) Identify a testable hypothesis that could be used for this investigation, to determine if the modified product has the same sensory appeal to consumers.

(1 mark) (IAE1)

- (b) Identify the dependent variable of this investigation.

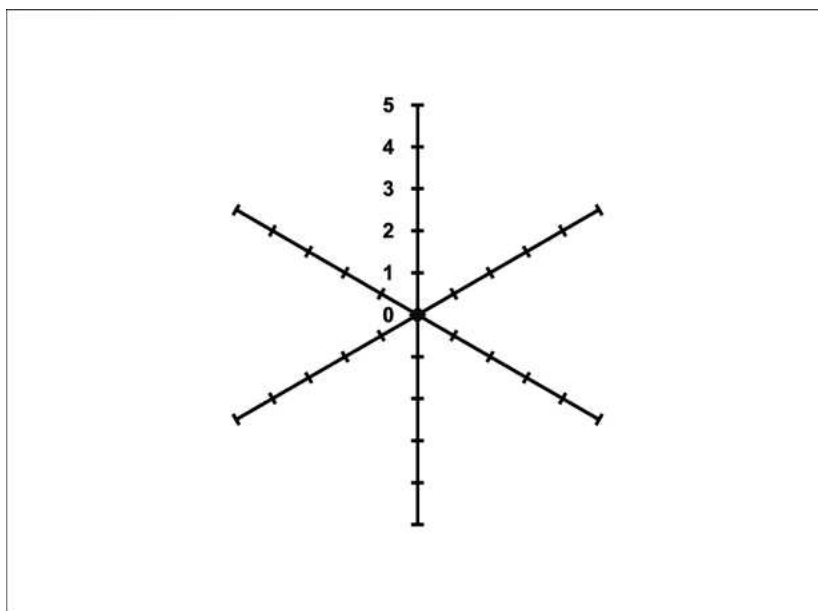
(1 mark) (IAE1)

- (c) Several factors were held constant to ensure the test was reliable. Identify one factor that would have been held constant when this test was conducted and explain its importance.

(2 marks) (IAE1)

- (d) The consumer's evaluations are displayed in the results Table below. Using the blank star diagram provided below, plot the results of the sensory evaluation test.

Product	Sweetness	Crunchiness	Oiliness	Aroma	Golden colour	Flavour
Original	4	3	2	5	3	4
Modified	4	5	1	4	5	4



(4 marks) (IAE2)

- (e) With reference to the results table and the star graph above, explain if the manufacturers were successful in producing a product that is just as appealing to consumers as the original product, if not more. Provide data to support your answer.

(3 marks) (IAE3)

- (f) Identify and explain the impact of one weakness using sensory evaluation tests to collect data.

(2 marks) (IAE4)

11. An adolescent living independently finds that most of their income is being spent on groceries. The most recent receipt of their grocery shop is shown below. With reference to the receipt below, suggest *four* changes that this adolescent can make to reduce their food bill.

Supermarket Adelaide	
05/06/2023 1:53pm	
1 Sanitarium Weet-bix 575g	\$4.20
1 Precut Fruit Salad 250g	\$7.00
1 NSW Farmer's Own Reduced Fat Milk 3L	\$4.50
1 Bill's certified Organic Sourdough Loaf 500g	\$7.50
1 Punnet of Blueberries	\$9.99
1 Jalna Sweet & Creamy Greek Yoghurt 2kg	\$12.50
1 Leatherwood Organic Honey 500g	\$14.00
1 Quilton Toilet Paper Triple Length 3ply 540 sheets 6pkt	\$9.00
Total:	\$68.69
Cash:	\$70.00
Change Due:	\$1.30
<i>Thank you for choosing to shop with us.</i>	

- 1.
- 2.
- 3.
- 4.

(4 marks) (KA2)

Total: / 60 marks

Case Study

Dietary influences

Sana is a 15-year-old Muslim female who is overheard saying: “I think I’m going to try the new ‘Cabbage Soup’ diet”. The cabbage soup diet is a seven-day fad diet that is low in fat and high in fibre (refer to the image). The diet requires followers to consume low kilojoule cabbage soup multiple times a day, along with vegetables and fruit.



Discuss

- How Sana's cultural upbringing may influence her typical food selections daily, and the impact this may have on her health in the long term.
- Possible factors which may have influenced Sana to try a new fad diet, such as the Cabbage Soup Diet and provide health advice which identifies the potential dangers of Sana following this type of diet.

(10 marks) (KA2)



Science as a human endeavour

Can you change your sensory appeal to adapt to nasty tastes?

Article adapted from: <https://www.sciencealert.com/you-can-modify-your-saliva-to-make-things-taste-better-study-shows>

What goes on inside your body to make your mouth and brain enjoy the flavour of a food you once wanted to spit out? Scientists, including food scientist Cordelia Running from Purdue University, think they've now cracked this puzzle, and it could be the key to making healthy foods taste better for everybody (not just kids who hate vegetables).

Proteins released by our salivary glands are thought to bind to flavour compounds in food, and also to taste receptor cells in your mouth. The thing is those proteins aren't static. Previous research with rats demonstrated that when the animals were fed a diet of bitter food, the expression of these flavour proteins in the rodents' saliva was altered. When the proteins changed, so did the rats' feed behaviour. They were able to eat more of the bitter food. What Running wanted to know was whether the same thing happens in humans. It's an important question, and one which might just seal the fate of broccoli and Brussels sprouts forevermore!

"If we can change the expression of these proteins, maybe we can make the 'bad' flavours like bitterness and astringency (slightly acidic and bitter) weaker," Running explains.

To find out, Running and fellow researchers carried out sensory evaluation tests with 64 volunteers, who had to drink a bitter-tasting chocolate almond milk three times daily for a week, rating the flavour as they went. Much like the rodents before them, the experiment showed that the volunteers' scores for bitterness and astringency decreased as time went on, but that's not all that was changing. Changes in the makeup of their saliva were also taking place, with Running observing that the levels of proline-rich proteins – which can bind to the bitter and/or astringent compounds in the milk – was increasing in the participants' saliva.

It's only a hypothesis for now – and the research has not yet been peer-reviewed – but the team suggests these two changes are related. "Saliva modifies flavour, which in turn modifies dietary choices. "One day, these proteins might even be isolated and consumed as a separate food additive, to help eaters stick to healthy choices they still don't like the flavour of, researchers suggest. But even if that doesn't happen, the notion that your saliva can be recruited as an ally to help you eat better is a nice idea, meaning we have more than just our willpower to rely on.

1. Discuss the **application** and possible impact of this study's findings.

(4 marks) (KA3)

2

? Science Inquiry Skills

Testing your Sense of Food!

Introduction:

Your sense of smell is closely linked to your sense of taste, and the visual appearance of a food can also influence taste perceptions. It can be possible to 'trick' some of your senses to better understand how tasting food is a sensory experience. It involves all our senses rather than just that detected from our taste buds.

Materials:

- Small pieces of diced apple (with skin cut off)
- Small pieces of diced pear (with skin cut off)
- Different coloured skittles
- Lemonade (or lemon cordial)
- Lemonade with red food colouring (or lemon cordial with red food colouring)
- Hygienic equipment for experimenters to pass out food samples e.g., tongs, toothpicks, serviettes, hand sanitizer, etc.
- Equipment for food samples e.g., small recyclable or biodegradable plates or glasses
- Blindfolds
- Personal water bottles for each participant

Method:

1. Blindfold the participant.
2. Without identifying the food, randomly select a food (apple or pear) and give to the participant to chew and consume.
3. Record in the 'blindfold only' row and second column of the results table below if the participant was able to correctly identify the food.
4. Repeat steps 1-3 by randomly selecting a food (apple or pear) four times, and then total the number of tallies and place in the last column.
5. Ask participants to rinse their palates with water before moving to the next taste testing.
6. Repeat steps 1-4 by randomly selecting a different coloured skittle and giving it to the participant to determine if they can correctly identify the flavour of the skittle.
7. Ask participants to rinse their palates with water before moving to the next taste testing.
8. Aroma or odour is said to contribute to approximately 75% of a food product's perceived flavour. To test this finding, ask each participant to be blindfolded again and ask them to pinch their nose closed.
9. Without identifying the food, randomly select a food (apple or pear) and give to the participant to chew and consume.
10. Record in the 'blindfold and nose blocked' row and second column of the results table below is the participant was about to correctly identify the food.
11. Repeat steps 8-10 by randomly selecting a food (apple or pear) four times, and then total the number of tallies and place in the last column.
12. Ask participants to rinse their palates with water before moving to the next taste testing.
13. Repeat steps 8-11 by randomly selecting a different coloured skittle and giving it to the participant to determine if they can correctly identify the flavour of the skittle.
14. Ask participants to rinse their palates with water before moving to the next taste testing.
15. Allow students to observe the samples of lemonade vs creaming soda (lemonade with pink/red food colouring).
16. Without identifying the drinks, ask students to sip and consume each sample (rinse palate between each tasting).
17. Tally whether the participant was able to correctly identify the flavour of the soft drink in the visual perception row of the results table.
18. Repeat steps 15-17 nine times, and then total the number of tallies the participant got correct in the place in the last column of the last row.

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Results Table:

Type of Sensory Test	Food guessed correctly (tally)	Total Foods guessed correctly
Blindfold only		
Blindfold and nose blocked		
Visual perception		

Analysis & Discussion:

- Using data from the results table, give a concluding statement about how each sense tends to affect taste perceptions.

- Identify at least three factors that have not been controlled well in the method and explain how these would impact the sensory evaluation results (see sensory evaluation section for assistance).

- Explain why this experiment should be conducted between 10am-12pm OR 3pm-5pm.

? Science Inquiry Skills

Advertising your Food Choices!

Introduction:

Studies have shown that the more we see 'junk food' adverts, the more we normalise this food and associate with it positively. Therefore, it would be ideal to see healthier adverts, yet it is the 'junk food' adverts that bombard us, with a multitude of social media platforms available to food manufacturers that affect our daily food choices.

Method:

- Complete the table below by tallying and totaling the number of food and beverages advertised during the allocated viewing times of TV/social media scrolling over a few nights that are either:
 - nutrient-dense e.g., belong in the AGHE encouraged food choices.
 - energy-dense e.g., surround the AGHE recommended food groups found in the discretionary food group, which include foods to be consumed in small amounts or only sometimes and in small amounts.

Results Table:

Viewing Time	Tally for nutrient-dense foods	Tally for energy-dense foods
3-6pm		
6-9pm		
9pm-12am		
	Total:	Total:

Analysis & Discussion:

- Referring to your collected data above, describe the trend in TV food/beverage commercials across the different viewing times.

- Discuss the affect media advertising may have on Australia's dietary food choices, and how this may impact the populations health status.

? Science Inquiry Skills

The Effect of Recipe Modifications on the Sensory Evaluation of Chewy Chocolate Chip Cookies

Introduction:

Recipes can be modified to reduce the overall sugar, sodium, or fat content to nutritionally suit an individual suffering from a diet related disorder, such as Type 2 Diabetes or CVD. However, when a recipe is modified the sensory appeal of the recipe must be maintained to encourage the individual to consume this food item and continue to make healthy food choices to assist in managing their diet related disorder.

Sensory analysis is a scientific discipline that uses principles of experimental design and statistical analysis for the evaluation of consumer products using human senses. Evaluators use their five human senses to conduct the sensory evaluation to determine the effect of modifying an original recipe on the overall sensory appeal.

Hypothesis:

If the sugar/saturated fat content is reduced in the chocolate chip cookies, then the overall sensory appeal will be reduced.

Materials/Ingredients:

• 63g butter	• Measuring cups
• ½ cup brown sugar	• Measuring spoons
• 1/8 cup caster or white sugar	• Whisk or Fork
• 1 small egg	• Sift
• 1 tsp. vanilla essence	• Wooden Mixing Spoon
• ½ cup self-raising flour	• Baking Tray lined with Baking Paper
• 1/3 cup plain flour	• Chopping board
• 1 tsp. baking powder	• Knife
• ½ cup milk chocolate chips	• Kitchen scales
• Modified Ingredients (refer to table below)	• Oven
• Large Microwave safe Bowl	• Microwave or Stove
• Small Mixing Bowl	

Method:

1. Prepare the Original Recipe of Chocolate Chip Cookies by completing steps 2-9.
2. Preheat the oven to 160°C.
3. Melt butter in a saucepan over medium heat (or in the microwave) and set aside to cool slightly.
4. Pour butter into a large bowl and stir in brown sugar and caster sugar until smooth and sugar is mostly dissolved.
5. Lightly beat the egg with a whisk or fork and stir into the sugar mixture along with the vanilla.
6. Sift both flours and baking powder together into a small bowl and then gradually mix into sugar mixture until combined.
7. Stir through chocolate chips.
8. Drop rounded tablespoons of the cookie mixture onto lined baking trays.
9. Bake for 12 minutes or until golden then remove from oven and allow to cool on trays for 3 minutes before transferring to a wire rack to cool completely.
10. Repeat steps 2-9 to prepare a modified version of the Chocolate Chip Cookies by substituting at least three of the original ingredients. Use the following table to assist you with the substitutions to the original ingredients (see suggestions on the next page).

? Science Inquiry Skills

Original Ingredient	Healthier alternative
63g Butter	63g Greek Yoghurt 63g Banana 63g Apple sauce
½ Cup brown sugar	½ cup/170g honey ½ teaspoon stevia 1/3 cup/ 80g maple syrup
1/8 cup Sugar - white/castor	1/8 cup/ 43g honey 2 teaspoons of monk fruit
½ cup Self-raising flour	½ cup/ 60g Whole wheat flour + 1 tsp baking powder ½ cup/60g Spelt flour + 1 tsp baking powder ½ cup/48g Almond flour + 1 extra egg/applesauce/banana
1/3 cup Plain flour	½ cup/44g Oat flour 1/3 cup/53g Rice flour + ½ tsp baking powder 1/8 cup/14g Coconut flour + 1 extra egg
½ cup Milk chocolate chips	½ cup/60g Cacao nibs ½ cup/85g Carob chips ½ cup/85g Dark Chocolate chips

11. Once both the original and modified chocolate chip cookies have been prepared and cooked, wait for both to cool down to the same temperature.
12. Once at the same cool temperature, measure the size of the cookies to ensure that each taster receives an equal mass and size (cookies may need to be cut and weighed using scales to achieve this).
13. Complete a sensory evaluation of both the original and modified cookies, with at least a sample size of six testers:
 - (a) Provide a table such as the following to each tester for each sample.

SAMPLE:			PARTICIPANT NAME:		
Directions: Circle one rating for each of the characteristics: Aroma/smell, sweetness, chewiness, moistness, and overall tastiness.					
Aroma / Smell rating	1 = Unappetizing Aroma	2 = Aroma is not appealing	3 = Acceptable Aroma	4 = Appealing Aroma	5 = Wonderful Aroma
Sweetness	1 = Bitter	2 = Slightly Bitter	3 = Neither sweet nor bitter	4 = Slightly Sweet	5 = Sweet
Chewiness	1 = Soft & Crumbly	2 = Slightly soft	3 = Soft interior & chewy exterior	4 = Slightly Chewy	5 = Crunchy & Chewy
Moistness	1 = Too dry	2 = Slightly Dry	3 = Acceptable	4 = Slightly Moist	5 = Moist
Tastiness	1 = Flavour did not appeal to me	2 = Bad	3 = Acceptable	4 = Tasted good	5 = Tasted great

? Science Inquiry Skills

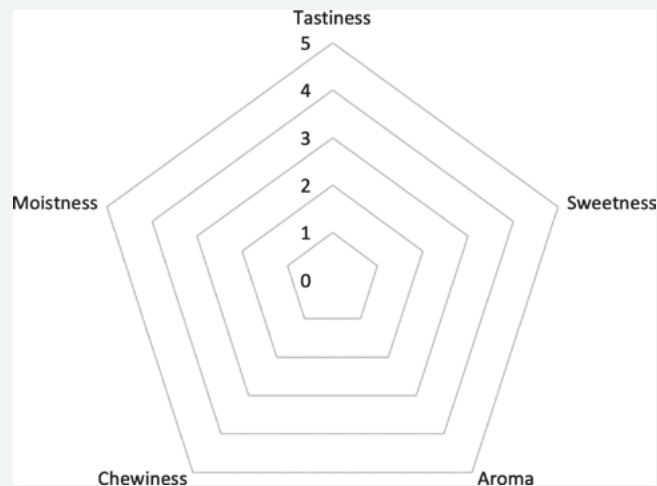
- (b) Blindfold each taster and get them to evaluate the cookies based on the following characteristics: aroma/smell, sweetness, chewiness, moistness, and tastiness on a scale from 1 (lowest intensity) to 5 (highest intensity).
- (c) Randomly allocate each sample to each taster and ensure not to disclose whether it is the original or modified cookie.
- (d) Instruct each taster to rinse their palates with water between each sample and to not communicate with other tasters during the testing.

Results:

Determine the average rating of each characteristic for each sample and place in the results table below.

Characteristic	Original Sample	Modified Sample
Aroma / Smell rating		
Sweetness		
Chewiness		
Moistness		
Tastiness		

Plot the average results of each characteristic for each sample on the blank star graph below:



Analysis and Discussion:

1. With reference to the data in the table or on the graph above, discuss whether modifying the recipe of a chewy chocolate chip cookie for an individual with a diet related disorder was successful in maintaining its sensory appeal in comparison to the original recipe.

? Science Inquiry Skills

2. Identify one potential random and systematic error that could have been present and explain their effect on the data.

Random:

Systematic:

3. Discuss the limitations of the conclusion and how these could be improved.

Extension Activities:

1. Describe what the recently discovered taste, umami is, and what foods it can be found in.
2. Discuss how each of the following factors may affect an individual's taste and how it may modify their ability to detect odours.

Hunger:

Satiety:

Mood:

Concentration:

Respiratory infection:

Gender:

2

3. Other common religions with food restrictions include Judaism, Jainism, Mormonism and Rastafarianism. Research and describe the food restrictions of each religion and share findings with your class.

Religion	Dietary restrictions
Judaism	
Jainism	
Mormonism	
Rastafarianism	

4. Emotions can have an intermittent effect on your food choices, whilst food habits like cereal for breakfast are harder to break, as are further psychological factors affecting food choices such as past experiences.
- (a) Think back to a time where an emotion and a past experience has influenced the foods you chose to eat, and record these below.

Emotion:

Past experience:

- (b) State some of your habits that affect your eating patterns and food selections.

Habits:

- (c) How do attitudes affect your food choices? List a food you like or dislike with psychological reasoning behind the food attitude.

Attitude (food like and dislike):

5. Select a current media campaign/advertisement that can affect our food selection. Identify the message of the campaign/advertisement and identify methods of how it influences the audience.

Media Campaign/ Advertisement	
Message	
Methods Used to Influence the Audience	

6. Suggest two strategies that can be implemented by the government to:
- Close the gap in health outcomes between rural/remote and urban Australians.
 - Increase educational levels of Australians and enhance their food knowledge, skills, and cooking abilities.

7. Research the price of the following supermarket items to demonstrate how an individual can reduce a person's food bill.

ORIGINAL FOOD BILL		REDUCED FOOD BILL	
Item	Price (\$)	Item	Price (\$)
Name-brand product		Home brand product	
Beef steak		Can of lentils	
Individual item		Item in bulk	
Organic peanut butter		Non-organic peanut butter	
Fruit not in season		Fruit in season	
Item not on special		Item on special	
Pre-packaged lettuce		Loose lettuce	
Total		Total	

8. Explore and research different food advertisements by companies and food businesses over the past century and determine if the media has shifted its focus as time has progressed. A timeline of different advertisements through the decades could be created as a class to see how they have changed.

1900s

2000s



2.4 Safe Food: FSANZ and Contamination

Science understanding

In Australia, the sale of food is regulated and the consumers are protected by government legislation and regulation.

- The role of Food Standards Australia New Zealand (FSANZ) in regulation of food production and consumer safety
- Food-borne illnesses (botulism, listeria, *E. coli*, and salmonella) from food contamination and how these are prevented

SACE Subject Outline, 2024.

FSANZ food standards code

FSANZ, a government authority, developed a 'food standards code' that covers many legislations, or standards, in the areas of primary production (or agriculture/farming), composition of food, food processing, food labelling, food safety and food handling (for a full list of all legislations of the food standards code, see the helpful resource link below). Those with relevance to Nutrition studies include:

- Food additives used by manufacturers must be rigorously assessed for safety, approved by FSANZ, used in the lowest quantity possible to perform their function and appear in the ingredients list.
- All packaged foods sold in Australia must comply with the mandatory (or compulsory) labelling requirements prescribed by FSANZ; country of origin labelling, however, is overseen by Australian consumer laws.
- Packaging regulations set by FSANZ maintain that packaging is 'safe'; for example, food businesses can only use materials that will likely not contaminate the food.
- Food manufacturers must follow stringent requirements for making 'gluten free' or 'low gluten' claims about their food.
- The food standards code regulates the use of added vitamins and minerals to food, called food fortification.
- Nutritional and health claims made on food labels are regulated by FSANZ; the food standards code specifies many definitions for claims food manufacturers can use such as:
 - 'Reduced fat or salt' claim – products should have at least 25% less fat/salt compared to the original product
 - 'Fat free' claim – food products must be less than 0.15% fat
 - 'Good source of...' – the food must contain no less than 25% of the RDI for that micronutrient



Helpful online resources

Food standards code

<http://www.foodstandards.gov.au/code/Pages/default.aspx>



The standards of the code place responsibilities on **food businesses** to produce food that is safe and suitable to eat, all to lower the incidence of foodborne illness. The food standards code enforcement is the responsibility of state and local governments. It is an offence to sell food not compliant with the FSANZ food standards code.



Definition

A **food business** could be a food manufacturer or any business like a restaurant that involves the handling of food for sale. It does not include temporary or home-based businesses.

Beyond the food standards code, FSANZ also has many other roles in Australia including coordinating food surveillance (monitoring food for safety and ensuring it complies with standards such as those for microbiological contaminants, pesticide residue and chemical contamination), offering food recall systems (recall webpage displaying foods and alert feeds possible with subscription) and providing a Nutrition panel calculator to help food manufacturers prepare a Nutrition Information Panel (NIP) for their products.



Helpful online resources

FSANZ: Who we are and what we do

<https://www.youtube.com/watch?v=XeMHXehEBHw&t=45s>



Food contamination

Humans with poor hygiene standards or **sanitisation** practices, particularly those who produce, process, or serve food, pose the strongest threat to food safety, through the risk of food contamination and its consequences. If the microbes that contaminate food are given favourable conditions in which to multiply, the consequences of contamination can result in food spoilage (which leads to food wastage) or food poisoning.

Types of food contamination

At each stage of food processing, it is possible for food to be **contaminated**. **Food contamination** occurs when foods have been tainted because they contain substances such as microorganisms or toxins that make them unfit for consumption. Contaminants can be classified as biological, chemical, or physical.

Fast fact

Intentional contamination of food via the deliberate addition of a harmful or poisonous substance to a food product is a criminal act known as **food fraud**. Note that intentional contamination is just one kind of many types of food fraud.

Physical contaminants

Physical contamination refers to any foreign object found in food such as pieces of plastic, glass, hair, fingernails and band-aids (see Figure 2.4.1 for further sources of physical contamination). This could happen at any stage of the food production process. The added risk of physical contamination is that the foreign object could also be a source of biological contamination.



Figure 2.4.1: Physical contaminants.

Biological contaminants

Biological contamination is the most common source of contamination. It includes the **microorganisms**: **bacteria** (plus the toxins they may produce), **viruses** and **fungi** (mould and yeast). Bacteria – particularly *Salmonella*, *Escherichia coli* (*E. coli*) and *listeria* – and viruses – namely *norovirus* – are the most well-known causes of biological contamination. They often enter foods transferred via poor human hygiene, such as unclean hands or unsanitary food-handling equipment (see Figure 2.4.2 for further methods of biological food contamination).



Figure 2.4.2: Typical means of biological contamination (transfer of microbes from humans, waste bins, insects, cross-contamination of raw meat, unwashed fruit and vegetables, and more.)

Chemical contaminants

Chemical food contaminants that can enter the food supply chain include cleaning agents, pesticides, natural food toxins and heavy metals (see Figure 2.4.3 for further chemical contaminants). Pesticides may reside on unwashed fruit/vegetables or be transferred from the soil in which the food was grown. Cleaning agents can enter foods during manufacturing processes. Toxic metals – including lead, cadmium, arsenic and mercury – can pass to food through soil/water or via processing, preparation or cooking.



Figure 2.4.3: Chemical contaminants.

Contaminated food

Definition

Microbe(s) or microbial (relating to microbes) are terms that can be used interchangeably with microorganism(s).

Factors Favouring Microbial Growth

Once contaminants enter food, they can make the food unfit for consumption. Biological contamination generally has minimal repercussions unless the microbes are given favourable conditions in which to multiply to dangerous numbers in the food. These favourable conditions include food/nutrients, optimal pH, optimal temperature, time, oxygen, and moisture/water. These conditions can be remembered using the acronym: FATTOM (as shown in Figure 2.4.4). In comparison, viruses don't require these favourable conditions in food to replicate as they only use food as a medium to transfer to their host e.g., a human. Viruses will then use the host cells to replicate after the food is consumed.



Helpful online resources

Bacterial Growth

https://youtu.be/et_6QwJi5bQ?si=PN-PojlCQNpZYzwq

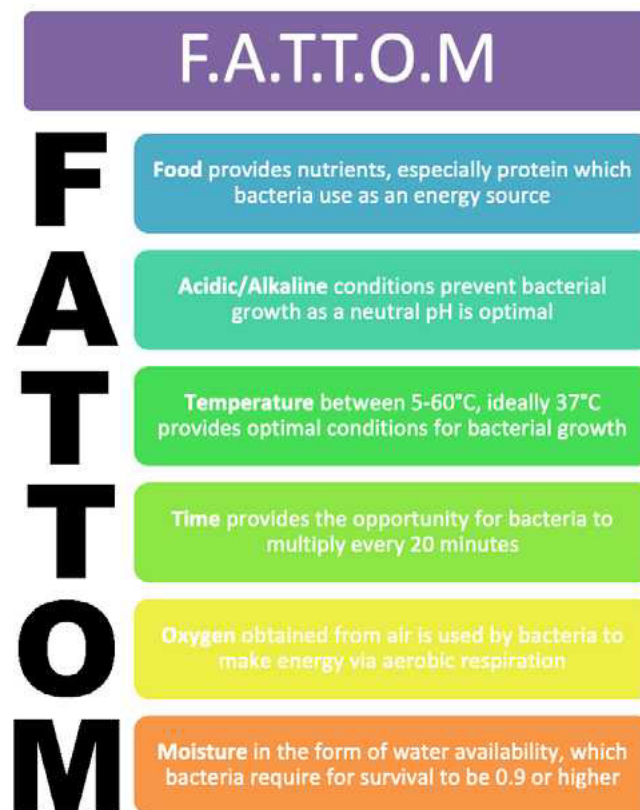


Figure 2.4.4: The Acronym: FATTOM, for favourable conditions for bacteria growth.

Food/Nutrients

Most foods and/or beverages provide a sufficient nutrient source for microbes to flourish. A primary nutrient needed by bacteria is protein, therefore high-protein foods such as meats are particularly vulnerable to bacterial biological contamination. Other energy sources bacteria can use to function, and replicate are sugars, starch, and fats.

Optimal pH

pH is measured on a scale of 0 to 14, with seven being neutral (see Figure 2.4.5). If the pH value of a food or beverage is below 7, it is acidic. If it is above 7, it is considered alkaline. How acidic or alkaline a food or beverage is, is an important factor affecting microbial growth. Bacteria tends to multiply best around a neutral pH of 7 as this is where their enzymes function best. Although a pH of 7 is preferred, bacteria can still reproduce function within a range of around 4.5 to 10.

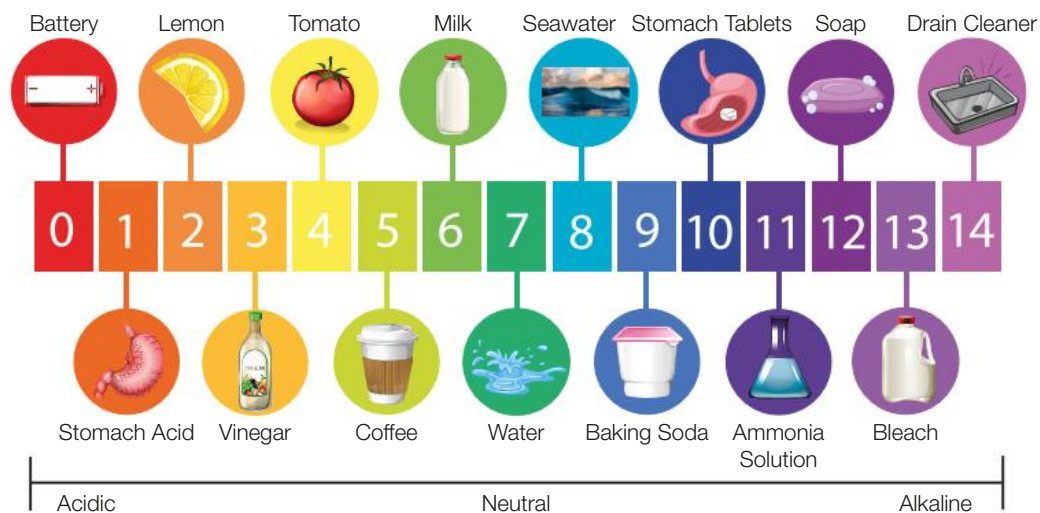


Figure 2.4.5: pH scale and some examples of substances at the various levels of the pH scale.

Optimal temperature

Most bacteria multiply in temperatures ranging between around 5°C and 60°C, which is known as the **danger zone** (as shown in Figure 2.4.6). However, the ideal temperature for bacterial growth is human body temperature, which is approximately 37°C. At this temperature bacteria are at their most active, as their enzymes are catalysing reactions needed for functioning well.

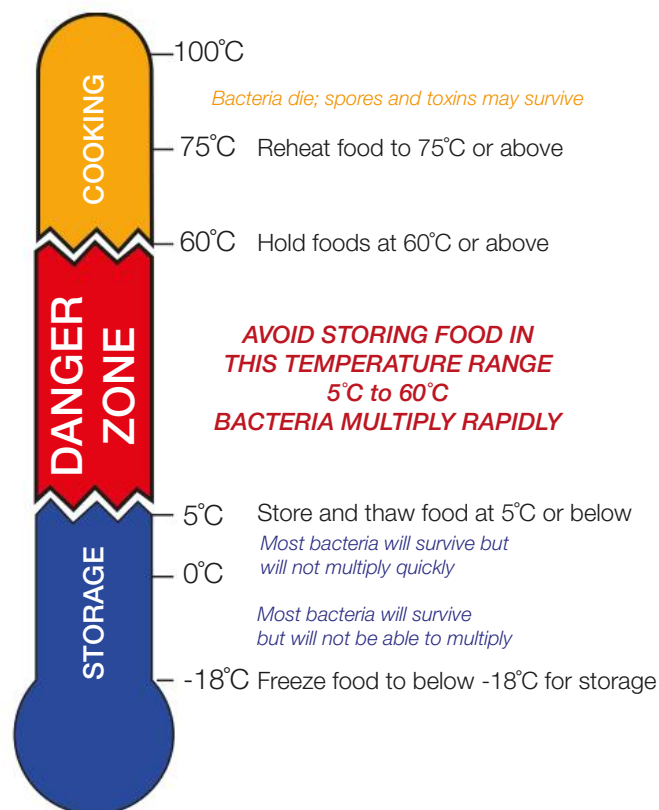


Figure 2.4.6: A summary of the storage, cooking, and danger zone temperatures and their effect on bacterial growth.

Time

In ideal conditions, bacteria grow exponentially, with some bacteria able to double in as little as 20 minutes; this can equate to two million in seven hours! Bacteria reproduce by **binary fission** (see Figure 2.4.7), a process in which their DNA duplicates within a cell, which then divides into two new bacterial cells.

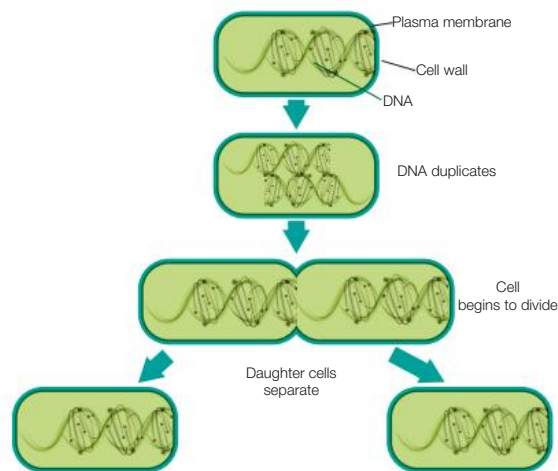


Figure 2.4.7 Stages of binary fission for bacterial reproduction.

2

Oxygen

Most microbes require air, specifically the oxygen in air, to survive, grow and reproduce. Those that utilise oxygen to make energy via aerobic respiration, are called **aerobic microorganisms**. Some microorganisms, however, called **anaerobes**, can create energy without oxygen, and others can even **shift between being aerobic or anaerobic** depending on environmental conditions.

Definition

Microbes that can respire with (aerobic) or without oxygen (anaerobic) are called **facultative anaerobes**.

Moisture/Water Availability

Water is essential to microbes; their cells require it for exchanging substances, running their metabolic processes or microbial reactions, and dissolving the food they use for energy and growth. Generally, the more water in the food/beverage, the better! This water, however, needs to be 'free' water, meaning the water within the food needs to be useable, and not bound to molecules such as **sodium**, which makes the water inaccessible to microbes.

Water activity (a_w) is the measure of the available or useable water in food. The water activity scale runs from 0.0 to 1.0, with pure water being 1.0 (therefore all foods and beverages fall below this value). The lower the a_w , the less water is available in a form that can be used by microbes. Most bacteria require a water activity of around 0.90 or higher to be able to function (as shown in Figure 2.4.8).

Definition

Sodium is defined as an electrolyte, meaning it attracts and binds water.

Product	a_w	Microorganism	a_w
water	1	<i>Clostridium botulinum</i>	0.97
meat	0.97 - 0.99	<i>Escherichia coli</i>	0.95
milk	0.97	<i>Salmonella</i>	0.95
juice	0.97	<i>Listeria monocytogenes</i>	0.92
cheeses	0.93 - 0.96	Most of the moulds (fungi)	0.70
bacon	<0.85	No development	0.60
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		

Figure 2.4.8: Examples of the water activity in some foods, and the minimum water activity required by various microorganisms

Food Poisoning and Spoilage

Contamination of food will typically result in either food poisoning, spoilage, or wastage. Whether the consequence is food wastage, **food poisoning**, or neither, can depend on the type of contaminant (biological, chemical, or physical).



Definition

Food poisoning can also be referred to as **foodborne illness**. Gastroenteritis, the term for a condition with symptoms of diarrhea and vomiting, is typically seen with food poisoning.

The Impact of Contamination on Consumers

Physical contaminants tend to be noticed in food and the food gets discarded, adding to food wastage. If it is ingested, they may cause harm such as lacerations of the digestive organs.

The consumption of food with **chemical** contaminants can result in concerns ranging from mild gastroenteritis to fatal cases of kidney or neurological problems. These results may be immediate, such as with some natural toxins in plants, or may only be apparent after many years of accumulation, such as with some of the heavy metals, like mercury. Because chemical contaminants can cause gastroenteritis (or worse), they are known to cause food poisoning, or foodborne illness.

When **biological** contaminants are exposed to favourable conditions, they can multiply rapidly. Once high numbers of these contaminants are present, they can cause food poisoning (see Figure 2.4.9) or food spoilage. Food poisoning is typically caused by **pathogenic** bacteria (see Table 2.4.1 for further details about some common pathogenic bacteria behind food poisoning) or viruses. Biological contamination leading to **food poisoning is more common** than that of chemical contamination because bacteria and viruses tend to be odourless, flavourless and invisible to the naked eye, and thus get consumed. Some bacteria can produce toxins that can be heat-resistant and persist in food even after heating. These toxins can also cause food poisoning when eaten. When food with pathogenic bacteria or their toxins are consumed, the typical results are gastroenteritis symptoms of vomiting and diarrhoea, particularly for those with weakened immune systems, such as infants, pregnant females, the elderly, and those who are immunocompromised.



Definition

A **pathogenic** bacterium is one that is harmful to health.

1. Bacteria enters the food source; this can occur at any point from production to serving food.
2. The contaminant multiplies quickly under favourable conditions.
3. Contaminated food is consumed; when the microbe passes from the food to a consumer it is referred to as 'foodborne'. If the consumed microbe is pathogenic, it will cause illness or infection. This is referred to as 'foodborne illness' which is an interchangeable term for food poisoning.

Figure 2.4.9: Process leading to biological food poisoning



Fast fact

An estimated 4.1 million Australians are affected by food poisoning each year.

Source: <http://www.foodauthority.nsw.gov.au/fp/food-poisoning>

Table 2.4.1: Information about some common food poisoning bacteria

Bacteria & illness it causes	Sources of contamination and foodborne illness	Symptoms	Prevention & other information
Clostridium botulinum (<i>C. botulinum</i>) causes botulism	• Soil • Raw foods (including seafood) • Honey • Improperly cooked, preserved, or canned foods where growth of the bacterium has produced the toxins.	• Onset of symptoms between 12-36 hours after its consumption • Progressive fatigue • Extreme weakness making it hard to open your eyes, speak and even find the strength to breath. • Adults with botulism can also exhibit diarrhoea, vomiting, dry mouth, and blurred vision. • It is sometimes fatal.	• Botulism is very rare. • Australian honey thus far has never tested positive to having <i>C. botulinum</i>. • Honey is not recommended to consume until 12+ months • Throw away canned food that is past its date marking, damaged or spoiled • Cover open wounds when gardening or in contact with soil.
<i>Listeria monocytogenes</i> (<i>L. monocytogenes</i>) causes listeriosis	• Soil • Water • Animals • Pests • Raw organic manure • High-risk foods commonly associated with listeriosis include: unpasteurised milk, soft cheeses e.g. brie and feta, soft serve ice cream, pre-packaged fruit and vegetable salads, deli ready-to-eat meats e.g. ham and raw or ready-to-eat seafood e.g. smoked fish, sashimi.	• Can take weeks or even months to develop • Healthy individuals may develop 'flu-like' and/or gastroenteritis-like symptoms at most. • Individuals with a weaker immune system, may experience a fever, headache and tiredness that can lead to meningitis (brain infection) and even death. • Can cause miscarriage, stillbirth, premature birth, or a very ill baby when born	• Can grow at temperatures as low as 0 °C which permits exponential multiplication in refrigerated foods. • Easily killed by heat • Listeriosis can be treated with antibiotics, but prevention and avoidance of high-risk foods is key for those more susceptible.
Escherichia Coli* (<i>E. coli</i>) *Pathogenic strain	• Gut of warm-blooded animals • Having close contact with farm animals • Eating undercooked beef, in particular minced beef • Consuming unpasteurised milk • Drinking or swimming in contaminated water • Close contact with a person who has the bacteria in their faeces • Lettuce, spinach, sprouts, salami, and fruit juices	• Takes between 2-8 days for the first symptoms to appear • Symptoms can last five to 10 days • Diarrhoea, stomach pain, nausea, vomiting and fever. • Can lead to a serious illness called haemolytic uraemic syndrome (HUS) in which damages blood cells and can cause the kidneys to fail in immune compromised individuals	• Ensure all raw meat and food is cooked thoroughly as bacteria and its toxins are heat sensitive and destroyed by high temperatures • Avoid unpasteurised milk • Wash hands (and implements) after handling raw meat, going to the toilet, changing a child's nappy, and after having contact with animals.
Salmonella causes salmonellosis	• Present in the intestines of many animals • Contaminated food, water, surfaces, hands (yours or contact with another person's) or from animal faeces • Eating undercooked animal products, such as poultry and eggs, or by eating cooked or ready-to-eat food that has been contaminated from raw food or poor hygiene practices	• Gastroenteritis symptoms of diarrhoea, vomiting, headache, and fever start between 6-72 hours after infection and usually last for 2-7 days • Severity of symptoms is determined by the number of bacteria consumed and immune system strength • Although the illness usually only lasts a few days, you can spread it for as long as you carry the bacteria. It can be present in your faeces for several weeks!	• Animal foods should be thoroughly cooked, • Dirty/cracked eggs should be discarded • Good storage, sanitisation and hygiene practices should be used • Pet food should be handled with similar practices • If travelling to high-risk regions e.g., the Middle East, avoid raw foods such as chopped salads and raw/cold meats. It is also recommended to use bottled water for drinking and brushing one's teeth

* Poor equipment sanitisation, hygiene when handling foods and storage are causes of contamination for all bacterial infections listed in the table above.

Food Spoilage

Food spoilage can be defined as changes in food and/or beverages that render it undesirable for consumption, leading to its disposal and contributing to food wastage. **Food wastage** is when food is not consumed but thrown away as rubbish somewhere along the food supply chain. Signs of food spoilage can be unusual texture, odour, taste, and appearance, and there a variety of factors that can cause it, including those seen in Figure 2.4.10.

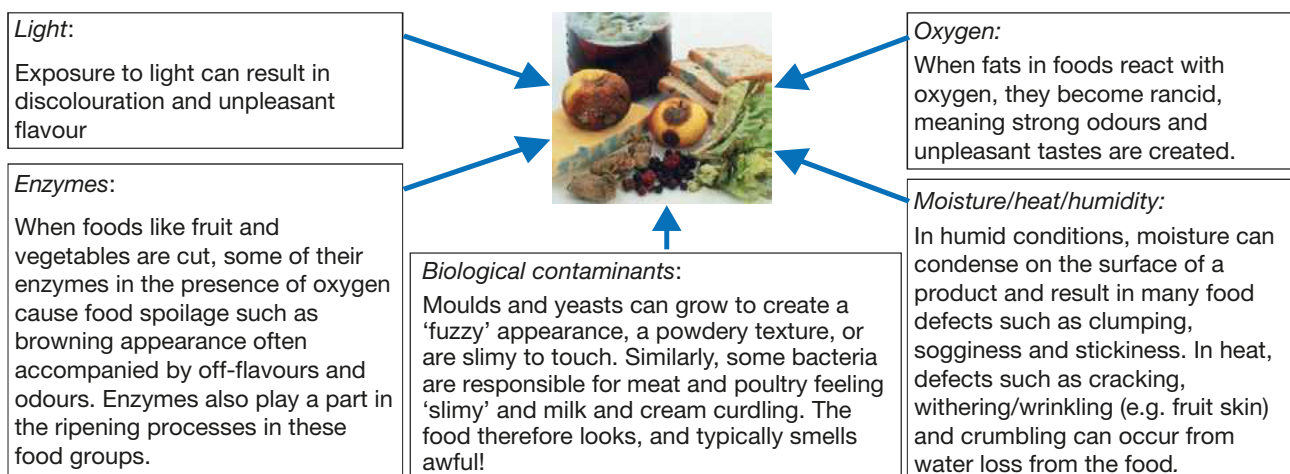


Figure 2.4.10: Factors that contribute to Food Spoilage

Prevention of food contamination and poisoning

Foodborne illness begins by food becoming contaminated by microbes, which is frequently caused by poor human hygiene or by improper handling procedures. Once contaminated, bacteria can then multiply to potential food poisoning numbers when food is incorrectly stored, prepared, or cooked. Prevention measures are therefore required at each potential hazard point of food production. The focus of this section will be on food safety preventative measures in the home.



Helpful online resources

WHO - Five keys to safer food:

<https://www.youtube.com/watch?v=ONkKy68HEIM&t=13s>



Hygiene and food handling

It is essential that all people who handle food do so in a safe and hygienic manner to ensure food poisoning is not the result for people who eat the food that they prepare. **Hygiene** is the practice or principles of cleanliness while poor food handling revolves around cross-contamination. **Cross-contamination** is the accidental transfer of contaminants from one surface, object, or person: to food. It usually refers to biological contamination but can also be physical or chemical. Cross-contamination can happen in a variety of ways.

Some of the more common sources are:

- Dirty hands used in food preparation; for example, not washing hands with soap after going to the toilet.
- Used utensils; for example, the same chopping board and knife are used to prepare raw chicken followed by a roast chicken.
- Dirty clothes or cleaning implements; for example, a T-shirt with pasta sauce on it from lunch worn to prepare dinner or the same tea towel is used to dry hands over the course of a day.
- Pests: for example, flies, mice, and cockroaches can carry pathogenic bacteria or leave their faeces which harbour bacteria.
- Poor personal hygiene: for example, coughing/sneezing over food or even licking fingers and scratching one's head before handling food

Measures to avoid cross-contamination therefore include:

- Storing and preparing raw and cooked foods separately (unless washing preparation utensils thoroughly between each use).
- Washing and drying hands with soap and running water for 20 seconds or longer before handling food, including during preparation if contact is made with possible contaminated body parts.
- Keeping pets out of the kitchen.
- Using disposable paper towels to dry your hands.
- Refraining from food preparation for others when feeling unwell.

Food preparation and cooking

Before food is prepared, there are several precautions that should be followed to ensure the food being prepared is not contaminated or does not host bacteria in dangerous numbers already.

Precautions include:

- Purchase hot and cold food last when grocery shopping to reduce the time this food spends in the danger zone; carry items in insulated shopping bags and store food appropriately quickly.
- Do not purchase or use food past its use-by date.
- Do not purchase or use food that is in swollen or in damaged packaging (Figure 2.4.11)..
- Check that service staff use separate serving utensils for different foods, that gloves are worn when necessary, and do not handle money if serving food.



Figure 2.4.11: Dented (left) and swollen (right) canned foods.

Apart from applying good hygiene and food handling practices, there are several additional tips to reduce the occurrence of food poisoning when preparing and/or cooking foods:

- Avoid thawing frozen food in the temperature danger zone where bacteria can grow or cook immediately after defrosting if using a microwave/oven's defrosting settings to defrost.
- Do not allow prepared foods to remain at room temperature for more than two hours before eating.
- Make sure that cooked food reaches a temperature of at least 75°C, which can be checked using a thermometer at the thickest part.
- Cook white fish until it flakes easily with a fork.
- Cook poultry until all the meat is white and the juices run clear, which can be checked by slicing at the thickest section.
- Cook hamburgers, minced meat, sausages and rolled roasts right through until the juices are clear (no red).
- When reheating meals, make sure to heat thoroughly as per cooking instructions to at least 75°C or steaming hot throughout. Only reheat meals once to reduce exposure to the danger zone.

Food storage

For food to be stored safely, the following precautions should be observed.

- Separate raw and cooked food, storing raw food at the bottom of the fridge to avoid juices dripping onto other foods. Always store raw food in sealed or covered containers.
- Under ideal conditions, cooked food can be stored in the fridge for a few days. If you want to keep cooked food longer, freeze the food immediately after cooling in the fridge..
- Ensure fridge temperature is below 5°C (4°C) and freezer below -15°C (-18°C).
- Allow cooked foods to cool quickly (less than two hours) to around room temperature. No steam should be rising off the food and the food should not be very hot to the touch before storing in the fridge. Cool food quicker by separating it into smaller containers.

- Use the 2-hour/4-hour guide (as shown in Table 2.4.2), which is substantiated on food poisoning bacteria generally taking more than four hours to reach dangerous numbers in ready-to-eat food. It is important to note that the times refer to total time the food has been in the danger zone – including before and after cooking.
- Avoid re-freezing any food that has been thawed.

Table 2.4.2: 2-hour/4-hour food safety guide.

Total time limit between 5°C and 60°C	Action
Less than 2 hours	Refrigerate or use immediately
Between 2 and 4 hours	Use immediately or discard
More than 4 hours	Discard

Key terms

2-hour/4-hour rule	Danger zone	Hygiene/sanitisation
Aerobic microorganisms	Facultative microorganisms	Microorganism/microbe
Anaerobic microorganisms	Food Business	Pathogenic
Bacteria	Food contamination	Physical contaminant
Binary fission	Food poisoning/foodborne illness	Virus
Biological contaminant	Food spoilage	Water activity/availability
Chemical contaminant	Food wastage	
Cross-contamination	Fungi	
	Gastroenteritis	

Review questions: 2.4 Safe food: FSANZ and Contamination

1. Identify the government organisation that produced the food standards code, and state three additional roles of this consumer protection authority.

(4 marks) (KA1)

2. Discuss a similarity and a difference between food poisoning and food spoilage.

(2 marks) (KA1)

3. Identify the following examples of contaminants as either physical, chemical, or biological.

Contaminant	Classification
Hand sanitizer	
Rat poo	
Human nail clipping	
Salmonella	

(4 marks) (KA1)

4. Complete the table by filling in the optimal conditions for bacteria.

Factor allowing bacterial growth	Optimal conditions preferred by most bacteria
pH	
Temperature	
Nutrient	
Water activity	

(4 marks) (KA1)

5. 28-year-old Val left his food shopping (bread rolls, milk, tomatoes, and roast chicken) in the car for five hours at 40°C. Upon retrieving it, he noticed some of the foods had begun to spoil.

- (a) State what Val may have noticed to indicate his food had begun to spoil.

(1 mark) (KA2)

- (b) Identify and explain how three conditions would have favoured contamination of Val's food shopping.

Condition one:

Condition two:

Condition three:

(6 marks) (KA2)

- (c) Select a food and name a pathogenic microbe that may now be present in dangerous numbers in Val's groceries.

(1 mark) (KA2)

- (d) Val decides to risk eating his chicken, but he firstly reheats it above 80°C to ensure any bacteria that may be present are completely killed. Discuss why this process is not sufficient for eliminating the food-poisoning potential of this chicken.

(2 marks) (KA2)

- (e) Val is quite lucky; he does not get any gastroenteritis from consuming the reheated chicken. Name a group of people who have a greater risk of food poisoning and provide reasons why they are at a greater risk.

(2 marks) (KA1)

6. Microbes can be grouped as acidophiles, neutrophiles or alkaliphiles based on the range of pH they survive in. Similarly, bacteria can be termed psychrophiles, mesophiles and thermophiles (to name a few groupings) based on their preferred temperature for growth.

The following questions refer to the data from Figures A and B below.

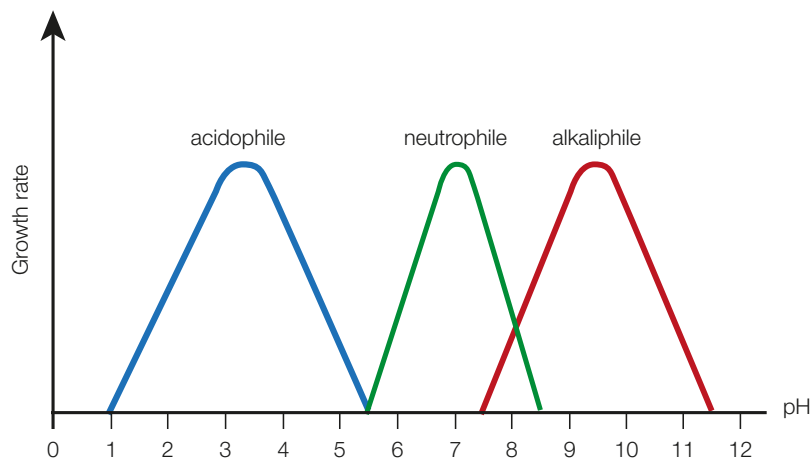


Figure A: pH range for acidophiles, neutrophiles and alkaphiles.

- (a) With reference to Figure A above, name the type of microbe that thrives best in foods with a neutral pH.
(1 mark) (IAE3)
- (b) With reference to Figure A above, identify the type of microbe with the largest pH range, using data to justify your response.
(2 marks) (IAE3)

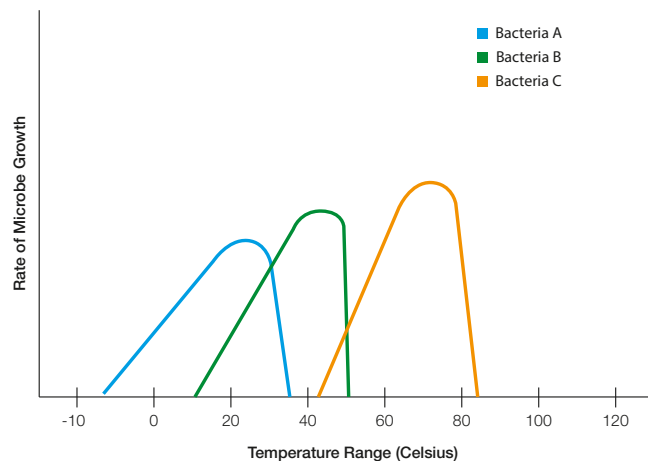
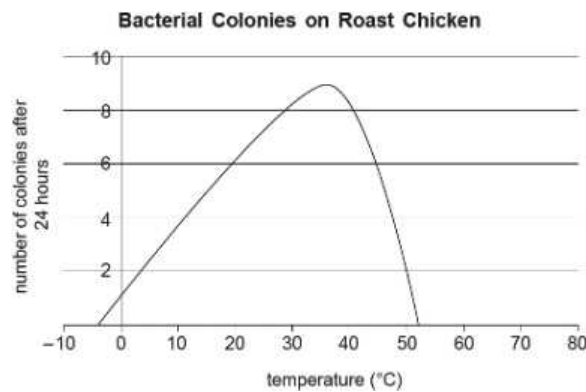


Figure B: Temperature ranges for 3 types of bacteria

- (c) With reference to Figure B above, identify the temperature at which Bacteria C grows the best.
(1 mark) (IAE3)
- (d) If thermophiles reproduce best above 50°C, mesophiles in a range of 20-45°C, and psychrophiles at 0-15°C, then:
- Identify which bacteria; A, B or C in Figure B is most likely to be classified as a thermophile
(1 mark) (IAE3)
 - Identify which grouping of bacteria: thermo-, meso- or psychro- phile, grows best in the danger zone.
(1 mark) (IAE3)

7. Chicken is a common source of food poisoning. Laboratory staff counted the number of bacterial colonies on roast chicken after 24 hours at different temperatures.

Refer to the following graph, which shows the results of laboratory testing.



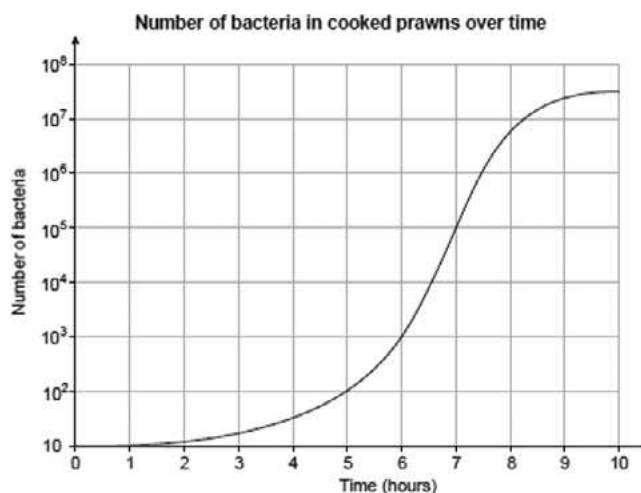
- (a) State the independent variable of the investigation. (1 mark) (IAE1)
- (b) State two variables that the laboratory staff will need to keep constant so that the results can be compared. (2 marks) (IAE1)
- (c) Using data from the graph above, describe the effect of temperature on the number of bacterial colonies on the roast chicken over the 24-hour period. (2 marks) (IAE3)
- (d) Explain why there was a change in the trend of bacteria growth on the roast chicken at 37°C. (2 marks) (IAE2)
- (e) Several people became severely ill 24 hours after eating roast chicken from a catering company for lunch. The roast chicken was prepared as follows:
- 1) The raw chickens were roasted in the oven on the morning they were used
 - 2) The roast chicken was removed from the oven and left on a bench at room temperature until it was served at lunch.
 - 3) After lunch, left over chicken was supplied to diners in takeaway food containers.
- Use this information to make a recommendation to the catering company about how to improve their food preparation procedures to minimise the risk to consumers. Justify this recommendation.

(2 marks) (KA2)

8. Sally telephones Harry's Pizzeria and orders a prawn pizza to be delivered to her home. Harry's pizzas are cooked in a wood-fired oven.
- (a) Explain the relationship between food poisoning and the temperature of food.

(2 marks) (KA2)

- (b) Refer to the following graph, which shows bacterial growth in cooked prawns, stored at 30°C, over time:



- (i) With reference to the graph, describe the trend of bacterial growth in cooked prawns, stored at 30°C over time and use nutrition knowledge to justify why this trend may have been obtained.

(4 marks) (IAE3, KA2)

- (ii) From the graph above, identify when the number of bacteria is 10^5 .

(1 mark) (IAE3)

- (c) Sally does not eat all the pizza that evening, but she plans to eat the leftovers the next day. Explain two ways in which she could ensure that the leftovers are safe to eat.

(4 marks) (KA2)

9. Describe the best way of cooling five litres of hot soup and storing it for four weeks to limit the amount of bacterial contamination that occurs.

(2 marks) (KA2)

10. A beef steak can be served to be eaten with red to the middle, yet a minced beef hamburger patty should be cooked through with no red to the middle. Explain why these meat products, despite both being beef, have different cooking requirements.

(2 marks) (KA2)

11. Outline why steaming hot food is not refrigerated immediately, but instead allowed to reach room temperature quickly before being sealed and stored in the fridge.

(2 marks) (KA2)

12. Undercooked chicken is considered a 'high risk' food in relation to food poisoning. Explain why undercooked chicken has been categorised in this way.

(2 marks) (KA2)

Total: / 60 marks

Case Study

Poor Hygiene and Food Preparation Practices

David's case worker was asked to make detailed notes about David's actions before and during food preparation to find out why he was frequently getting food poisoning and experiencing gastroenteritis symptoms. The following daily observations were made:

Before preparing his lunch, David washed his hands with soap after going to the toilet and dried them on the kitchen tea towel, which is washed weekly. He took his lunch out of the fridge – leftover pizza, some cheese slices that were stored directly under a packet of raw steak, plus some lettuce from the crisper section. David also decided he wanted to eat the scrambled eggs leftover from breakfast sitting in the frying pan on the stove top. He scratched his head while considering what to prepare first. He decided to firstly re-heat his pizza. While this was reheating, he cut the fat off the steak on a chopping board. Those trimmings were passed to his cat, which was sitting on the kitchen bench. He then sliced up the lettuce with the same knife on the same chopping board. In the meantime, his pizza has gone cold while he has been preparing his other food, so he reheated it again before eating it.

- Identify a likely cause of biological contamination contributing to David's gastroenteritis symptoms and any unsafe food practices that could be behind it.
- Explain why each practice is unsafe and give recommendations to improve David's food safety.

(10 marks) (KA2)

Case Study

Menu Modifications for Pregnancy

A group of colleagues dine together for a work function. The provided menu for their dinner is shown below:

Appetizer

Sashimi and sushi samples

Mains

Pastrami wrapped chicken breast served over mash potato

Dessert

Soft-serve ice cream and seasonal fruit

After dinner servings

Shared platter of cheeses (brie, camembert, gouda) and crackers. Coffee and tea

A week later, Margorie falls quite ill and upon going to the doctor she tests positive for listeriosis and unbeknown to her, pregnancy.

- Identify a reason for Margorie falling ill despite her colleagues suffering no symptoms and identify a danger of listeriosis to both Margorie and her growing foetus.
- Provide suitable modifications to the menu for Margorie. These modifications should also consider the additional nutritional needs of pregnancy and provide reasoning for their inclusion.

(10 marks) (KA2)



Science as a human endeavour

A bacterial mechanism causing food poisoning uncovered.

The following article has been condensed from the following source:
<https://phys.org/news/2018-12-food-poisoning.html>

Food poisoning is estimated to affect 4.1 million Australians each year and *Bacillus cereus*—one of the most common types of stomach bug—is responsible for producing toxins that cause vomiting and diarrhea. It may not be a household name, but *Bacillus cereus* can be found in vegetables, meat, fish, rice, and pasta, and will grow in these foods if they are not stored properly.

Lead researcher Ms Anukriti Mathur, from the Australian National University (ANU), has found how the bacteria works and how to combat it. “We knew the toxin would have to attack the cells, triggering an immune reaction, but we now know how it does it,” said Ms Mathur. “We discovered the toxin directly binds to the cell and punches holes to kill the cell, the immune system responds to the infection and has a reaction. Because we now know how the bacteria and the toxins work, we can fight it and find ways to use the immune system against it”.

Researchers say the discovery will be vital in understanding and treating serious cases of food poisoning. “This research could help patients with a compromised immune system,” said Ms Mathur. “We might be able to save patients by weakening the toxin, or in the case of sepsis, dampening inflammatory responses. “It also means we have therapeutic drug options to further support antibiotic therapies, especially in the face of rising antibiotic resistance.”

1. Suggest how this advance in scientific knowledge has been **influenced** by society.

(2 marks)/(KA3)

2. Explain one **application** of this bacterial mechanism to society

(2 marks)/(KA3)

2

? Science Inquiry Skills

The Science Behind the 20 Seconds of Hand Washing

Introduction:

The promotion of improved hand hygiene has been recognised as an important public health measure. At least 20 seconds with soap and water is currently recommended for washing one's hands. Most hand soaps have a pH between 8-10, making it alkaline. As well as being alkaline, a condition which does not favour bacterial growth, soap disrupts the sticky bond between pathogenic bacteria and your skin, allowing them to slide right off!

Hypothesis:

If the time of washing hands is increased, then number of bacterial colonies will be reduced.

Materials:

• Hand Soap	• 100ml measuring cylinder	• Heat protective gloves
• Agar Mixture	• Hot water	• Marker
• Beef Stock	• Bunsen burner	• Ruler
• 50ml Beaker	• Stirring rod	• Tape
• Electronic Scales	• 3x petri dishes	• Incubator

Method:

1. Working as a group of 3. Wash your hands with soap.
2. Measure 1.8 – 1.9 g of agar and 0.1 g of beef stock into a 50ml beaker.
3. Add 60mL of hot water to the same beaker.
4. Using a Bunsen burner, heat 60mL of water with the beef extract and agar until it is *nearly boiling*.
5. Use a stirring rod to continually stir the mixture while heating, to ensure the ingredients are mixed evenly and dissolved.
6. Once you notice *large bubbles* rising from the bottom of the beaker **immediately stop heating and turn your Bunsen burner off**.
7. While the mixture is still hot (allow to cool somewhat), pour it into the 3 petri dishes provided (very thin layer around 0.5cm thick). **Make sure you pour the mixture into the base, not the lid.** Lid is only to be opened AJAR and immediately close once poured. For added safety it is ideal to use heat protective gloves during this step.
8. Wait for about 5-15 minutes to allow the mixture to cool and set into a firm jelly.
9. After the elapsed time, move to the area where your agar plates have set and invert them (lids down). **Do not remove lids and keep inverted unless inoculating the plate.**
10. On the underside (base) of the 3 plates draw a straight line with a marker and rule to bisect it into 2 halves, and on the edge of the plates in small writing label one half 'T' and one half 'C'. You will not touch the side of the plate with the 'C', this side of the plate acts as a control, indicating whether the agar is sterile. Therefore, any growth on the other (test) side of the plate (T) is due to the treatment you give it. You will conduct your inoculation on this side of the plate.
11. Each member of your group is to place one hand in your pocket, then down your clothes, across the bench top, on a door handle, etc.!
12. PLATE 1. On the test side, one student is to lightly press the fingers of their unwashed hand onto the agar plate, ensuring to only lift lid ajar and invert as soon as possible. Tape the lid closed.
13. PLATE 2. On the test side, one student is to wash their hands with soap for 5 seconds, and then lightly press the fingers of their washed hand into the agar plate, ensuring to only lift lid ajar and invert as soon as possible. Tape the lid closed.
14. PLATE 3. On the test side, one student is to wash their hands with soap for 20 seconds, and then lightly press the fingers of their washed hand into the agar plate, ensuring to only lift lid ajar and invert as soon as possible. Tape the lid closed.
15. **Keep plates inverted** and incubate them at 30 degrees for 48 hours.
16. Examine the plates after 48 hours for colonies of bacteria growing on the surface. **DO NOT take the lids off. Wash hands with soap at completion.**

? Science Inquiry Skills

Results:

1. Draw images or print photos taken of your three plates after 48 hours in the spaces below.

PLATE ONE	PLATE TWO	PLATE THREE

Analysis & Discussion:

1. Describe the trend in bacterial growth as observed in your results (consider thickness, coverage, types of bacteria evident).

2. Give a concluding statement about the length of time recommended for washing one's hands before preparing food for consumption based on your experimental results.

3. In school laboratories, growth is often found on the control side of the agar plates. Give a possible reason for this finding.

4. Soap is commonly used to wash hands, having a pH of around 9-10. Explain why soap is used to wash hands before meal preparation.

? Science Inquiry Skills

5. Use the table and images below to identify the bacterial colonies present (if any) on the agar plates.

Name of Bacteria	Appearance	Located	Symptoms
<i>Escherichia coli</i> (E coli)	Translucent, white, glossy, round, smooth	Intestines, faeces	Diarrhoea, abdominal cramps
<i>Staphylococcus aureus</i>	Opaque, golden-yellow-orange, smooth, round, raised	Skin surface, inside nose	Diarrhoea, vomiting, nausea, abdominal cramps
<i>Staphylococcus albus</i>	Opaque, white, smooth, round	Skin surface	Diarrhoea, vomiting, nausea, abdominal cramps
<i>Micrococcus roseus</i>	Opaque, pink, irregular in shape, smooth	Skin, meat, water, dairy products	Diarrhoea, vomiting, nausea
Yeast species	Opaque, rough textured surface, irregular edges, can be coloured or colourless	Mouth, intestines, Skin surface	Oral and genital infections
Moulds & Fungi	Furry or hairy, black/grey/white, irregular edges	Spoiled food, organic material	Respiratory infections



Agar Plate	Type of Bacteria Present
Plate 1	
Plate 2	
Plate 3	

? Science Inquiry Skills

The Effect of Temperature on Microbial Growth

Introduction:

Temperature can be a favourable condition for bacterial growth if within the danger zone of 5°C-60°C. Therefore, the storage of food is crucial in extending the shelf life of food by preventing bacterial growth and making it safe for consumption. Foods at home are generally stored in the pantry, a fridge which generally has a temperature of 4°C or a freezer which is set at -18°C.

Hypothesis:

If the temperature of storage is reduced, then the percentage of bacteria coverage will also reduce.

Materials:

- Hand soap
- 3 agar plates
- Marking pen
- Bunsen burner
- Heat proof mat
- Matches
- Bacterial culture
- Glass rod spreader
- 70% ethanol
- Tape
- Incubator, science fridge & freezer
- Disinfectant tub

Method:

1. Wash hands thoroughly with soap
2. Place 3 agar plates on bench and ensure they are inverted (lids down). **Do not remove lids and keep inverted unless inoculating the plate.** Label the plate on the underside with your initial towards the edge.
3. Set-up and turn on Bunsen burner using required safety pre-cautions and leave on safety flame until ready to use
4. Flip the petri dish and the teacher will introduce 3-4 drops of the bacterial culture to the agar plate. **Lid to be opened ajar and step to be performed quickly.** Close the lid.
5. Turn Bunsen burner to blue flame. Dip the glass rod spreader into the alcohol (70% ethanol) and allow excess to remove. Burn off (ignite) the residual ethanol with a brief insertion (back and fro movement) into the Bunsen burner under the blue flame. **Do not leave in the flame or overheat to avoid melting/breaking.**
6. Allow the spreader to cool near the flame vicinity and turn flame back to orange
7. Take off the petri dish lid and cool the spreader by touching the side of the agar away from the bacterial broth.
8. Immediately use the sterile spreader to spread the culture evenly over the agar. Do not press hard enough to damage agar surface.
9. Close the lid and allow 5mins for the bacterial lawn to absorb into the agar
10. Place the spreader back in the alcohol
11. Repeat steps 4-10 for a further 2 plates.
12. After the allowed 5 mins, tape the petri lids closed and invert
13. Keep plates inverted, and incubate one plate at around 30 degrees in an incubator, another in the fridge and the last one in the freezer for 48 hours
14. Place all equipment used into the provided disinfectant tub/biohazard area at completion of practical and wash hands with soap.
15. Examine the plates after 48 hours for colonies of bacteria growing on the surface. **DO NOT take the lids off. Wash hands with soap at completion.**

? Science Inquiry Skills

Results:

1. Use the following grid to determine the percentage of bacteria coverage on each of the agar plates. Record your results in the table below.

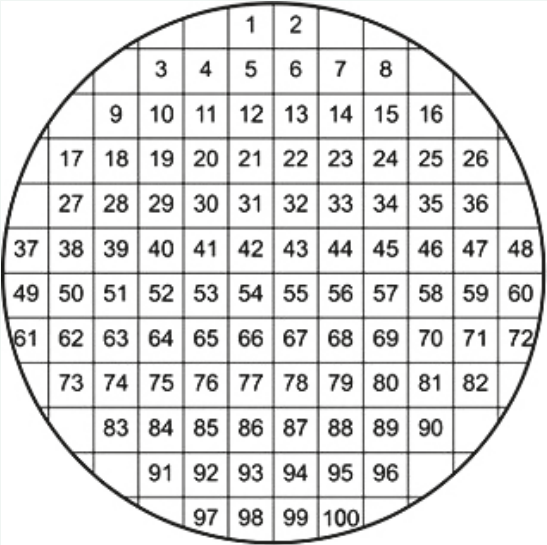


Plate	Coverage of Bacterial Colonies (%)
Incubator set at 30°C	
Fridge set at 4°C	
Freezer set at -18°C	

Analysis & Discussion:

1. Provide a reason for the agar plates needing to go into scientific storage spaces and not in communal fridges or freezers used for lunches.

2. Estimate the water activity (a_w) level (0-1.0) in the agar plate stored in the freezer and use this to explain the bacterial growth found in this plate.

3. Identify which plate resulted in the greater bacterial growth and justify using nutrition knowledge why this trend may have occurred.

Extension Activities

- Complete the table below, by researching the pH, nutrients, temperature, and water activity fungi (mould and yeast) functions best at and compare them to bacterial favourable conditions.

Favourable Condition	Bacteria	Fungi (mould and yeast)
pH		
Nutrients		
Temperature		
Water Activity		

- Complete the table below by researching some additional common causes of foodborne illness in Australia.

Microbe	Common means of transfer to food	Foods/ places most contaminated	Food poisoning toxins produced (Y/N)	Symptom onset and duration	Symptoms	Other
Norovirus						
Campylobacter						
Staphylococcus						
Bacillus cereus						

- Define immunocompromised and give some examples of people who would be classified this way.

2.5 Safe Food: Food Processing

Science understanding

In Australia, the sale of food is regulated, and consumers are protected by government legislation and regulation.

- Food processing techniques: freezing, canning/bottling and pasteurisation.
- The role of FSANZ in mandatory fortification (specifics- folate, thiamine, iodine, vitamin D).
- The role of FSANZ in using additives including emulsifiers, antioxidants, artificial colours and sweeteners.

SACE Subject Outline, 2024.

Food processing involves any method that turns fresh or raw agricultural products into foods suitable for consumption, cooking, or storage, i.e., any process that changes the food's original form. Almost all food is processed in some way before it is eaten. The main reasons to process foods are to eliminate microorganisms and to extend the shelf life, although it is often used by manufacturers to create attractive and marketable food products (see Figure 2.5.1 for further purposes of food processing). Foods are freshest and of optimal quality at the time of their harvest or slaughter. A common processing method, food preservation is used to maintain the quality of foods as best as possible. Preservation can, however, alter the nutrient content of food products.



Figure 2.5.1: Purposes of food processing.

Food preservation

Food preservation methods are a type of food processing used to extend the **shelf life** of food products and prevent deterioration, spoilage, and potential food poisoning. The aim is to maintain conditions that discourage or stop microorganism growth and to prevent microorganisms from reaching the food to keep food safe for consumption. As food preservation methods can extend shelf life, they can aid in reducing the cost of food and shopping frequency. Food being able to be preserved can also increase the range of food available and even save on the preparation time of food at home.

Definition

The shelf life of a product is the time it takes for a product to deteriorate to an unacceptable level, resulting in a loss of sensory properties and nutritional quality. The food is often no longer safe to consume.

Common food preservation methods involve reversing the favourable conditions required by pathogenic microorganisms (FATTOM) by reducing temperature, applying heat treatment, controlling water activity, reducing pH and/or reducing available oxygen. They include methods such as freezing, pasteurisation and canning/bottling.

Temperature reduction

The shelf life of many foods can be extended by storing foods at temperatures below 5°C, in the refrigerator or freezer. The ideal temperature of a refrigerator should be set at 3°C, which slows both enzymatic activity involved in food spoilage and microbial growth, due to being below the temperature danger zone. The ideal temperature of a freezer should be set between -18°C and -20°C, which delays enzymatic activity that can cause food spoilage, and keeps food safe by inhibiting microorganism growth, as at very low temperatures microbes are essentially inactive (known as **dormant**). This is because during the freezing process water molecules are converted into ice, making it unavailable to microorganisms which require it for growth. However, reducing the temperature does not kill microorganisms; therefore, when food is defrosted and exposed to a temperature in the danger zone, they are able to multiply to dangerous levels once again. Therefore, foods must be handled safely prior to freezing and while being defrosted (refer to Topic 2.4 for the 2/4-hr rule). It is important to remember that refrigerators or freezers do not work properly when they are overloaded or when food is packed tightly, because the cold air cannot circulate.

The effect of temperature reduction on nutrients

Freezing is generally regarded as the best method of long-term food preservation when based on the retention of sensory attributes and nutrients. Refrigeration is essential because it increases the shelf life of perishable foods like fruits and vegetables, however the longer the food stays in the fridge, the more it loses its freshness, taste, colour, aroma and nutrient content. This is dependent on the food source, as highly perishable foods can only be stored for a few days, whereas less perishable products can be stored for several weeks (see Figure 2.5.2). Freezing foods can cause the loss of some of the flavour; however, most of the nutritional quality is maintained. A concern with nutrient loss associated with freezing seems to be related to the exposure to high temperatures and oxygen that often occurs when handling and preparing food prior to being frozen. Freezing assists in retaining the nutrient content of most foods. However, some nutrients begin to break down when frozen produce is stored for more than a year, which is why the frozen storage recommendation of foods does not usually surpass 12 months.

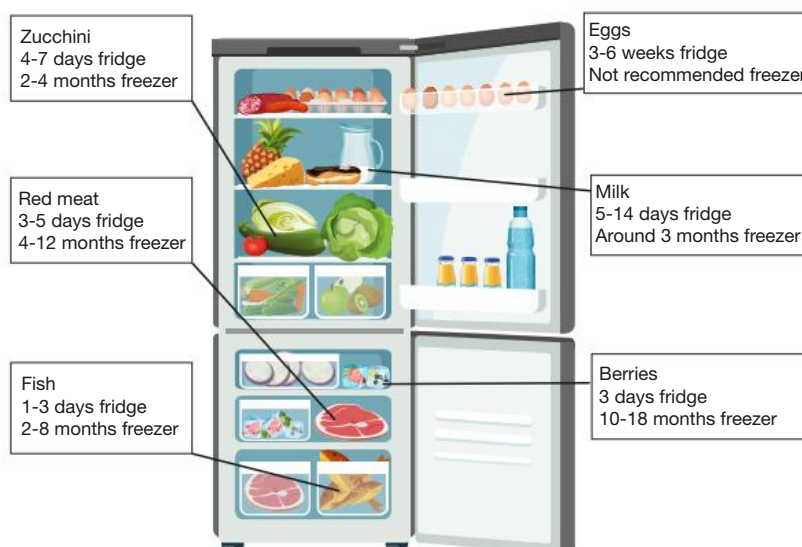


Figure 2.5.2: Recommended shelf life of some perishable foods in the fridge and freezer.

Heat treatment

Heat treatment, or thermal processing, is a combination of time and high temperatures to kill microorganisms or denature enzymes in food. **High-risk foods** must be reheated or exposed to a temperature of at least 75°C to reduce the number of bacteria to a safe level for consumption. The specific amount of time required depends upon the specific food, as exposure to heat can alter the nutritional content and texture. There are several types of heat treatments that are used in the food industry, including pasteurisation high temperature short time, HTST and canning/bottling.



Definition

High-risk foods support the growth of bacteria, where their reproduction can occur more rapidly. High-risk foods can include dairy products, eggs, meat products, poultry, and seafood.

Pasteurisation

Pasteurisation is a type of heat treatment where a low heat is applied to food and beverages to kill pathogens and inactivate spoilage enzymes. In Australia, the minimum thermal process for pasteurisation requires a holding time and temperature of 72°C for 15 seconds. This heat treatment extends the shelf life of foods by days or weeks and is commonly used for milk, eggs, fruit juices, beer, and some canned or bottled foods.

Canning/bottling

Canning or bottling is another type of heat treatment often used in preserving fruit, vegetables, meat products and other miscellaneous processed foods. Food products are placed into cans or bottles, with an accompanying liquid to replace as much air as possible, and then exposed to elevated temperatures. High-acid foods (for example, some fruit) require temperatures of around 100°C, while most foods need to be pressure canned/bottled at higher temperatures of 121°C for around 3 to 15 minutes, dependent on the foods ability to transfer heat. For example, tomatoes require less heating time than pumpkin. The application of heat can also expand the food, which expels any remaining air; therefore, after sealing and cooling, the contraction of the contents and lid produces a partial vacuum within the container. After sealing, the can or bottle is exposed to high temperatures again to destroy any microorganisms that may still be present (see Figure 2.5.3). The result of canning or bottling is a product with an extended shelf life of up to two years or more.



Figure 2.5.3: Exhaust box used in canning (top) and canning process within the exhaust box (bottom).

Vacuum sealing

In addition to the partial vacuum seal provided via the cooling process, many cans are mechanically manipulated to expel the air after heating and vacuum-sealed using industrial machinery (see step 4 of figure 2.5.3). The purpose of the expulsion of air is to reduce oxygen, which is required by pathogenic aerobic microorganisms for functioning and growth. It also protects against the degradation of food caused by oxygen, which can lead to the rancidity of fats altering their smell and taste, darkening of fresh meat and the browning of fruit and vegetables. Reducing oxygen is therefore essential to improve the shelf life of food and customer acceptability of the product's appearance and other sensory characteristics.

Liquid fill

Foods containing high concentrations of water are generally more favourable to microorganism reproduction. Therefore, the addition of the liquid fill used in canning and bottling will aim to reduce water activity by adding solutes. Common solutes added include **sugar** and **salt**, which dissolve in water and bind to free water molecules, making them unavailable for microorganisms to use. These methods prevent the growth of microorganisms and slow the action of food deterioration enzymes. An alternate or additional liquid fill involves the addition of **acids**, such as vinegar or citric acid which manipulates the pH, reducing it to below 4.5. As the pH is lowered below 7 (neutral), the food becomes more acidic, not supporting the growth of pathogenic bacteria or the production of their toxins. This reduces the heat treatment needed to extend their shelf life and make them safe for consumption.

Definition

Brine is the term given to salty water used in preservation, for example olives are bottled in brine; while sugar syrup is the name given to the sugary water often used to can fruits. The addition of an acid to a food product is known as acidification and the product can also be referred to as pickled foods.

The effect of heat treatment on nutrients

Thermal processing methods have a detrimental effect on the nutrients present in food. When foods are cooked at high temperatures or for long periods of time, heat-sensitive nutrients, including some B vitamins, Vitamin C and some of the fat-soluble vitamins are denatured and destroyed (as shown in Table 2.5.1). Heat treatments have minimal impact on minerals, these nutrients tend to remain stable when exposed to high temperatures. Water soluble nutrients, namely the water-soluble vitamins, and most minerals, can also leech out of foods when water is involved in the cooking process. For example, boiling broccoli can cause much of the broccoli's water-soluble vitamins and minerals to migrate to the boiling water and when grilling meat, iron can be lost when juices drip from the meat. However, you can still benefit from these nutrients if the liquid lost is consumed. Fat-soluble vitamins (A, D, E and K) can also leech into cooking oils if used in the cooking process.

Therefore, it can be concluded the higher the temperature, the greater the volume of water/oil present and the longer the cooking time, the greater loss of nutrients from the food source. Higher temperatures for sustained periods of time are also associated with greater changes to the food's natural flavour, texture, and appearance.

Table 2.5.1: The sensitivity of vitamins to heat.

Nutrient	Sensitivity to Heat
	• = stable ✓ = found to be sensitive with some cooking methods/times ✓✓ = highly sensitive
Vitamin B1	✓✓
Vitamin B2	•
Vitamin B3	•
Vitamin B9	✓✓
Vitamin B12	✓
Vitamin C	✓✓
Vitamin D*	✓
Vitamin K*	✓

*It is only particular forms of Vitamin D and K that have been found to be heat sensitive, but further testing and research is needed.

Food fortification

Food fortification can be considered as another type of food processing as it changes the food from its original form. **Food fortification** is when a micronutrient is added to a food in amounts above the quantity found naturally, originally in that food or after processing. FSANZ only permit certain nutrient fortifications and quantities, so long as they are aimed to improve the nutritional quality of the food supply and/or provide a public health benefit with minimal risk to health. However, FSANZ stipulates certain vitamins and minerals are added to a specified food or ingredient, which is referred to as **mandatory** (compulsory) **fortification** (refer to Table 2.5.2).

Serving size: 31g (2 biscuits)		
Servings per pack: 18	Per serve	Per 100g
Energy (kJ)	459	1480
• Energy (Cal)	110	355
Protein (g)	3.8	12.4
Fat (g)	0.4	1.3
• Saturated Fat (g)	0.1	0.3
• Polyunsaturated Fat (g)	0.2	0.8
• Monounsaturated Fat (g)	0.1	0.2
Carbohydrate (g)	20.4	65.9
• Sugars (g)	0.9	3
Dietary Fibre (g)	4	12.9
Sodium (mg)	84	270
Potassium (mg)	113	365
Thiamin (Vitamin B1) (mg)	0.55 (50% RDI)*	1.77
Riboflavin (Vitamin B2) (mg)	0.43 (25% RDI)*	1.39
Niacin (Vitamin B3) (mg)	2.5 (25% RDI)*	8.1
Folate (µg)	69 (35% RDI)**	224
Iron (mg)	3.0 (25% RDI)*	9.7
Magnesium (mg)	32 (10% RDI)*	103
* Percentage of Recommended Dietary Intake (RDI)		
** 1 serve provides 17% of the folate RDI for women of childbearing age		

Figure 2.5.4: A cereal's nutrition information panel, indicating voluntary fortification of sodium, potassium, thiamin, riboflavin, niacin, folate, iron, and magnesium.

Table 2.5.2: Nutrients which are mandatory for food manufacturers to add to a specified food or food.

Nutrient	Food Fortified	Importance
Vitamin B1 (Thiamin)	Wheat flour, which is used to make breads, excluding organic bread.	This was first mandated in January 1991 to minimise the incidence of Wernicke-Korsakoff syndrome, a potentially fatal neurological disorder caused by a Vitamin B1 deficiency. Vitamin B1 acts as a coenzyme in the metabolism of carbohydrates, providing energy to the body especially the brain.
Folic Acid (synthetic version of Folate)	Wheat flour via the milling process, which is used to make breads, excluding organic bread.	This was implemented in 2009, to ensure the healthy development of the foetus in the early stages of pregnancy, especially the neural tube which develops, closes, and fuses during this time. If the neural tube doesn't close, this can result in neural tube defects, such as spina bifida. Therefore, unplanned pregnancies were the target group of this mandate to reduce the prevalence of spina bifida in babies.
Vitamin D	Oil spreads, such as margarine.	Vitamin D has been mandated since 1987 as it enhances the absorption of calcium and phosphorus in the small intestines. This allows bones to become stronger and denser. However, a lack of Vitamin D can lead to the softening of bones, growth retardation and skeletal abnormalities in children, known as Rickets. Vitamin D also can prevent osteomalacia in adults and delay the onset of osteoporosis later in life.
Iodine	Salt, called iodised salt, which is used for bread making except organic bread and bread mixes for making bread at home.	This was implemented in 2009, which was intended to address the re-emergence of Iodine deficiency, known as goitre, in some parts of Australia and New Zealand. Iodine is required to produce a hormone in the thyroid, known as thyroxine, which is responsible for the regulation of metabolism, thermoregulation and growth. It can also cause stunted growth and impaired neurological function in babies and young children if females of childbearing age or breastfeeding mothers are deficient in this mineral.

Helpful online resources

Understanding micronutrient food fortification

<https://youtu.be/NYvxUNhOGUU?si=Tbn37Qxv03NbqyFC>



Other vitamins and minerals can be voluntarily added by food manufacturers, such as vitamin A to some milk and a range of nutrients are added to breakfast cereals. If nutrients are **voluntarily fortified**, these nutrients must appear on the nutrition information panel on a food product (as shown in Figure 2.5.4).

Food additives

Food additives are natural or synthetic chemicals intentionally added to processed foods to improve the overall appeal of the product. They can either be added to their ingredients or coated over the food to improve the taste, texture, or appearance of a processed food, improve the keeping quality or stability of a food or preserve food to extend its shelf life.

Food Standards Australia New Zealand (FSANZ) carries out safety assessment on food additives before they can be used by checking if the food additive is safe in the amount being proposed and if there is a good technological reason for using the additive. Food additives are approved only if it can be shown that no harmful effects are experienced after their safety is assessed at the conclusion of extensive testing, including animal studies. FSANZ is constantly monitoring the scientific literature relevant to the safety of permitted food additives, as are other international agencies. If any new information is made available, FSANZ will evaluate the data and make any amendments to the list of permitted food additives and their allowed amounts if required.

Fast fact

Some people can be sensitive to food additives, particularly the flavour enhancer MSG, food colourings, preservatives and the sweetener aspartame. These food additives have been known to cause allergic reaction responses including diarrhoea, insomnia, asthma, hives and/or hyperactivity in children. Symptoms, however, may be due to an underlying illness and medical diagnosis is important.

Helpful online resources

FSA Explains: Food additives

<https://youtu.be/JU51f737Obg?si=QE3db5xdwRTvOVAK>



Food additives are required to be declared in most packaged food and listed in the statement of ingredients on the food label (as shown in Figure 2.5.5). This allows consumers to make an informed decision about the product and its suitability. Food additives are listed by their class name followed by the name of the food additive or the food additive number, for example Colour (Caramel I) or Colour (150a). The class name indicates the purpose of the food additive (refer to Table 2.5.3 for some common additives used), and the additive number is based on an internationally accepted numbering system.

Ingredients

White rice (30%), glucose, candy coated choc chips (14%) [sugar, vegetable fat, cocoa, milk solids, **emulsifiers (soy lecithin)**, salt], coating [sugar, tapioca starch, **natural colours (171, 100, 120, 160c)**], **glazing agent (903, 904)**, fructose, sugar, **antioxidant (tocopherols)**, glucose solids, cocoa (1.5%), milk solids, **humectant (glycerol)**, salt, gelatin, **emulsifiers (soy lecithin, canola lecithin, 472e)**, barley malt extract, **natural flavour (chocolate)**, **antioxidant (rosemary extract)**.

Figure 2.5.5: Ingredients list of a processed food product, indicating the presence of food additives including emulsifiers, natural colours, glazing agent, antioxidant, humectant, and natural flavour.

Table 2.5.3: Common food additives and their purpose.

Food additive	Purpose	Foods commonly added to
Antioxidants	Prevent foods, particularly those with a high fat content, from oxidising by reacting with oxygen and reducing the rate of deterioration of food. This also prevents food from going rancid, which causes unpleasant flavours and odours. Antioxidants can also discourage the loss of vitamins that are easily destroyed from oxygen exposure.	Cooking oils, oil spreads like peanut butter
Colourings	Add or restore colour after processing to foods	Confectionery, cereals, jams, icing mixtures
Emulsifiers	Prevent and maintain water and oil from separating into different layers	Mayonnaise, margarine (see Figure 2.5.6).
Sweeteners	Replace the sweetness normally provided by sugars in food without significantly contributing to the kilojoules available in food	'Diet' options of soft drink, baked goods like biscuits



Figure 2.5.6: Mayonnaise with and without emulsifiers.

Key terms

Antioxidants
Canning/bottling
Colourings
Dormant
Emulsifiers
Food additives

Food fortification
Food processing
Freezing
Heat treatment
Liquid fill
Mandatory food fortification

Pasteurisation
Refrigeration
Sweeteners
Voluntary food fortification
Vacuum sealed

Review questions: 2.5 Safe Food Processing

1. Identify two mandated micronutrient fortifications in Australia. For each fortification, list a food/ingredient the micronutrient is added to, and a health concern the addition is aimed to prevent.

Micronutrient one:

Food:

Health concern:

Micronutrient two:

Food:

Health concern:

(6 marks) (KA1)

2. Food additives are added to processed foods for a variety of reasons.

- (a) Complete the following table of information related to food additives.

Type of additive	Foods/beverages used in	Benefit to consumer
Sweetener	Soft drinks, Confectionery	
		Stops rancidity in foods that contain fats, extending its shelf life
Food colouring	Confectionery, cereals, jams	
Emulsifiers		Allow products to have a smooth and creamy texture, improving the consistency.

(5 marks) (KA1)

- (b) Explain why food manufacturers would add emulsifiers to their oily spreads.

(2 marks) (KA2)

- (c) A supermarket stocks a 'diet' blueberry and choc chip muffin. Identify two food additives that may be present in the ingredients list of this food and explain their purpose of being included in these food products.

(4 marks) (KA2)

3. Contaminants such as microorganisms affect the quality of food and beverages, hence preservation methods are commonly applied to foods.

- (a) Outline three conditions needed for most food-poisoning bacteria to multiply.

(i)

(ii)

(iii)

(3 marks) (KA1)

- (b) For each of these conditions outlined above in question 3(a), explain how canning or bottling counteracts optimal conditions for microorganism growth and survival to reduce the chance of food-poisoning.

(i)

(ii)

(iii)

(6 marks) (KA2)

- (c) Discuss the impact on the nutritional content when fruits are processed to become canned fruit.

(2 marks) (KA2)

4. A remote community produces excess chicken meat, freshly milked cow's milk, and olives, and needs to preserve them to extend their shelf life and reduce food wastage.

- (a) State two aims of food processing.

(i)

(ii)

(2 marks) (KA1)

- (b) For each of the following foods, name a different method of preservation that is suitable for use in the home and describe how the identified method preserves the food.

- (i) Chicken meat

Method of Preservation:

How the method preserves the food:

(3 marks) (KA2)

- (ii) Freshly milked cow's milk

Method of Preservation:

How the method preserves the food:

(3 marks) (KA2)

- (iii) Olives

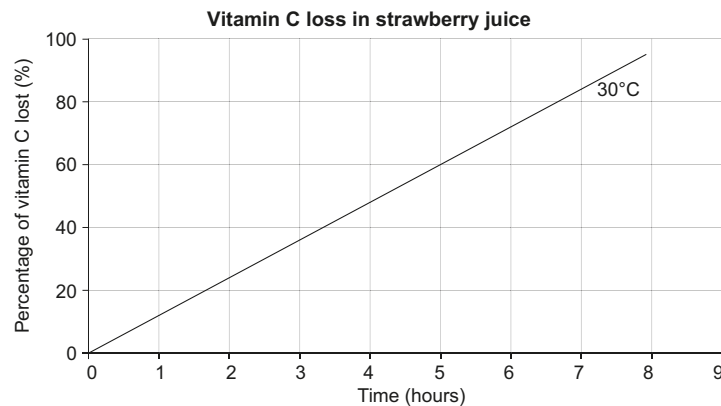
Method of Preservation:

How the method preserves the food:

(3 marks) (KA2)

5. Fresh fruit juice should be stored at 4°C and consumed within three days. Students conducted an experiment to investigate the effect of poor storage on the vitamin C content of strawberry juice. The strawberry juice was heated to 30°C and the amount of vitamin C was measured every hour for eight hours.

Refer to the following graph, which shows the percentage of vitamin C lost over time.



- (a) From the graph, identify the time taken to lose 60 per cent of vitamin C.

(1 mark) (IAE3)

- (b) State one conclusion that could be drawn from the graph.

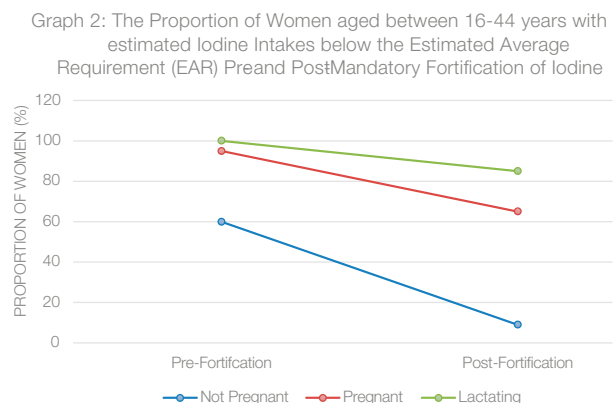
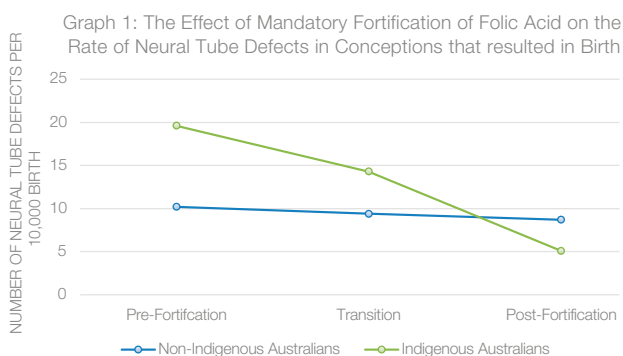
(1 mark) (IAE3)

- (c) Identify one variable that must remain constant during the experiment and explain why it must remain consistent throughout.

(2 marks) (IAE1)

6. The fortification of Folic Acid and Iodine was made mandatory in 2009 in Australia, where these nutrients were added to wheat flour and salt respectively.

The effects of these mandatory fortifications can be seen in Graph 1 and Graph 2 below.



- (a) Explain the purpose of mandatory fortification.

(2 marks) (KA2)

- (b) With reference to Graph 1 and Graph 2 on the previous page, comment on the success of the fortification of Folic Acid and Iodine that was made mandatory in Australia in 2009.

(4 marks) (IAE3)

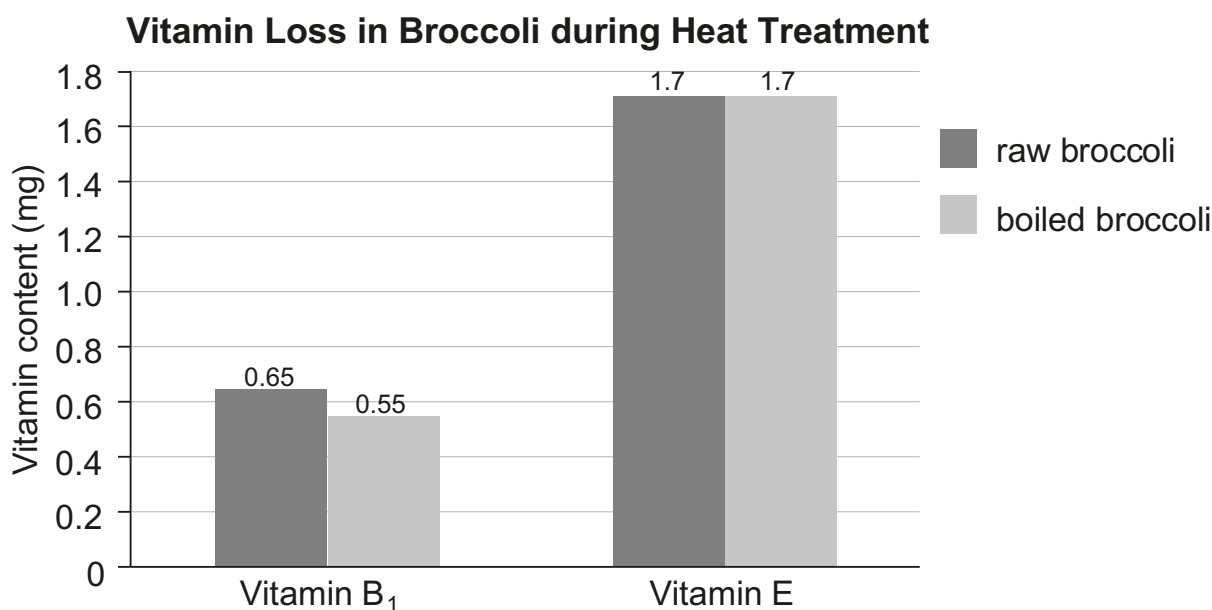
- (c) Suggest why Folic Acid was added to wheat flour used in bread making, rather than another type of food to prevent neural tube defects.

(2 marks) (KA2)

- (d) Explain the effect that the mandatory fortification of Iodine will have on future generations.

(2 marks) (KA2)

7. Students investigated the effect of heat treatment on vegetables. They compared the amount of vitamin B₁ and E content of raw broccoli with that of the broccoli after it was heated, which is shown in the graph below.



- (a) State the dependent variable of the experiment.

(1 mark) (IAE1)

- (b) Identify a factor that must remain constant during this investigation and explain why.

(2 marks) (IAE1)

- (c) With reference to the graph above, identify the effect of boiling on the Vitamin B1 and E content of broccoli. Provide justification to support this effect.

2

*(4 marks) (IAE3, KA2)***Total:** / 60 marks

Case Study

Vitamin D deficiency

A UV index of 3 or above is when sun protection is recommended. It is also the UV index that allows Australians to achieve sufficient Vitamin D when exposing their face, arms and hands to the sun for a couple of minutes a day. However, when the UV index is below 3, greater direct sunlight of at least two to three hours a week is needed to produce enough Vitamin D.

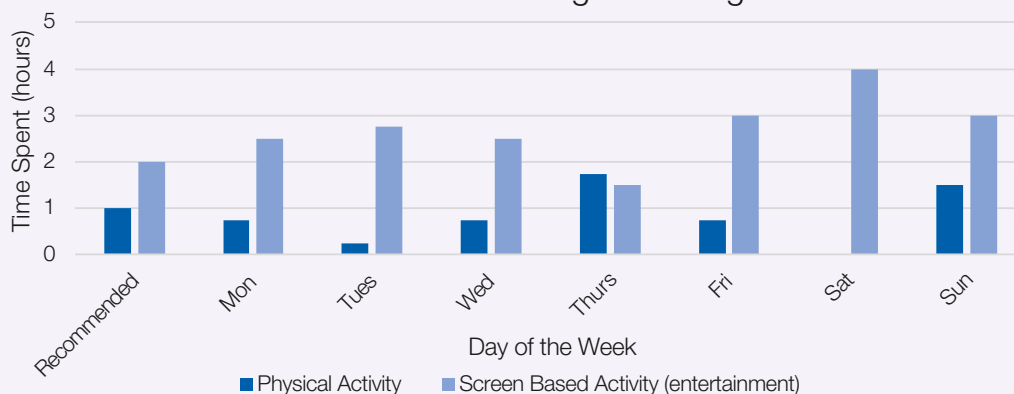
The average UV index over each day in each month across Australian cities is shown in the table below.

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Darwin	12.3	12.8	12.5	11	9.2	8.2	8.7	10.2	11.9	12.6	12.3	11.9
Brisbane	11.8	11.2	9.4	6.9	4.8	3.7	4.1	5.4	7.4	9	10.6	11.3
Perth	11.8	10.9	8.6	5.8	3.8	2.8	3	4.3	6.1	8.2	9.9	11.4
Sydney	10.6	9.6	7.5	5.2	3.2	2.3	2.5	3.7	5.4	7.2	8.8	10.1
Canberra	10.9	9.5	7.3	4.8	3	2	2.3	3.4	5.2	7.2	8.9	10.6
Adelaide	11.2	10.1	7.8	5.1	3	2.1	2.3	3.5	5.2	7.3	9.2	10.6
Melbourne	10.3	9.1	7	4.4	2.4	1.6	1.8	2.8	4.3	6.4	8.3	9.8
Hobart	9.7	8.3	5.8	3.2	1.6	1	1.2	2	3.5	5.5	7.3	9.3

The average daily eating habits and weekly time spent on physical and screen-based activities of a 6-year-old child who lives in Hobart were recorded and shown in the table and graph below respectively.

Meal	Food Items
Breakfast	Children's cereal with full cream milk
Recess	Packet of chips Muesli bar Chocolate chip muffin
Lunch	Hazelnut spread sandwich Apple Juice
Snack	Donut Flavoured milk
Dinner	Chicken nuggets Hot chips

The Time Spent on Physical Activity and Screen Based Activities During an Average Week



Case Study

- With reference to the information on the previous page, explain why this 6-year-old child is at risk of developing a Vitamin D deficiency.
- Explain how the Australian government aims to reduce the risk of a Vitamin D deficiency in the general population.
- Explain the impact of a Vitamin D deficiency on children in the short term and long term.
- Identify and describe nutrition and lifestyle related recommendations that would reduce this child's risk of being Vitamin D deficient.

(10 marks) (KA2)

2



Science as a human endeavour

Isochoric freezing – an emerging food preservation technology

Article adapted from: <https://www.foodprocessing.com/on-the-plant-floor/technology/article/11287870/four-emerging-technologies-for-processing-food-in-2022> and

<https://www.ift.org/news-and-publications/food-technology-magazine/issues/2019/november/columns/isochoric-freezing#:~:text=Isochoric%20freezing%20is%20a%20new,crysal%20formation%20inside%20the%20product>

Isochoric freezing involves putting food, either bare or sealed in flexible material, inside a rigid container. The container is filled with water and freezes, whilst the pressure inside the container keeps most of the water in food from freezing. Because the actual food doesn't freeze, this forgoes the cellular damage inside the food product that comes from ice crystal formation, improving the quality of thawed food.

Isochoric freezing was developed by Boris Rubinsky at the University of California. He and his group have been using isochoric freezing for cells, tissues, and organ transplantation. Isochoric freezing reduces ice formation in the tissues that prevents successful tissue revival, therefore allowing for greater restoration after freezing and better success with transplantation. Rubinsky started a partnership with the U.S. Department of Agriculture in 2017 to explore the potential benefits of isochoric freezing in the food industry. Isochoric freezing for food was developed by a team funded by the USDA and headed by Boris Rubinsky and Cristina Bilbao-Sainz, a USDA research food technologist.



Roberto Avena-Bustillos (left) and Cristina Bilbao-Sainz demonstrating the use of isochoric freezing chambers. Photo courtesy of U.S. Department of Agriculture.

The team has shown that freezing under certain isochoric conditions results in food products with superior quality to those preserved under conventional freezing. Many foods, especially those with delicate textures, such as fruits and vegetables, are not suitable for traditional freezing since they deteriorate significantly during freezing. Isochoric freezing offers the potential to freeze these foods and maintain their fresh-like qualities. Isochoric freezing can likely generate substantial energy savings as well 'because only a small part of the total volume is frozen - and freezing is a huge energy consumer,' Rubinsky says. "All this without actually changing the refrigeration system and only by placing the food in a closed isochoric system rather than in open air." He says that the only major change would be using rigid containers instead of running food products directly through a freezer. The team is developing isochoric storage with fisheries in Iceland and has drawn interest from other industries.

1. Discuss how this advancement in food processing technology has been **developed**.

(2 marks)(KA3)

2. Explain one **application** of isochoric freezing of food for society.

(2 marks)(KA3)

3. Discuss how the scientific research and development of isochoric freezing has relied on **collaboration**.

(2 marks)(KA3)

? Science Inquiry Skills

Preservation methods used in canning or bottling

Introduction:

Canned food undergoes several preservation techniques, including heating, vacuum sealing, and liquid filling. Liquid fill solutions are known to be antimicrobial, meaning they discourage microbe growth. Brine, which is salty water, is one such liquid fill used with a range of foods. To measure the level of antimicrobial activity of solutions used in preserving foods, zone of inhibition testing can be used in laboratories. A sample of the antimicrobial solution is introduced to a bacterial agar plate via a disc dipped in the preserving solution. After a period of incubation, a clearance zone around the disc, called the zone of inhibition becomes visible (see Figure A). The size of the zone is indicative of the effectiveness of the antimicrobial preserving solution.

Hypothesis:

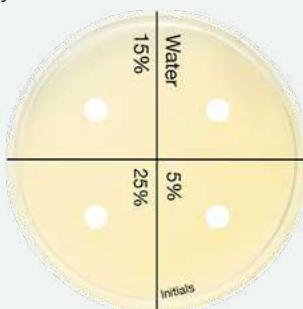
As the salt concentration of the solution increases, the zone of inhibition will increase.

Materials:

- Hand soap
- 1 agar plate
- Marking pen
- Bunsen burner
- Heat proof mat
- Matches
- Bacterial culture
- Glass rod spreader or inoculation loop
- 70% ethanol
- Sterile discs
- Forceps
- Distilled water in small beaker
- 5% salt solution in small beaker
- 15% salt solution in small beaker
- 25% salt solution in small beaker
- Tape or parafilm
- Disinfectant tub
- Incubator

Method

1. Wash hands thoroughly with hand soap.
2. Place an agar plate on bench and ensure it is inverted (lid down). **Do not remove lid and keep inverted unless inoculating the plate.**
3. Label the plate on the underside by dividing it into 4 quarters and labelling each quarter with the conditions of the practical i.e., water, 5%, 15%, 25% salt. Ensure labels are small and either towards middle or edge of the plate to not obscure vision of the zone of inhibition when obtaining results (see figure below). Label the plate with your initials towards the edge as well.



4. Set-up and turn on Bunsen burner using required safety pre-cautions and leave on safety flame until ready to use.
5. Flip the petri dish and the teacher will introduce 3-4 drops of the bacterial culture to the agar plate. **Lid to be opened ajar and step to be performed quickly.** Close the lid once the bacterial culture has been applied.
6. Turn Bunsen burner to blue flame. Dip the glass rod spreader into the alcohol (70% ethanol) and allow excess to remove. Burn off (ignite) the residual ethanol with a brief insertion (back and forth movement) into the Bunsen burner under the blue flame. **Do not leave in the flame or overheat to avoid melting/breaking.**



Figure A: Measuring the diameter of a zone of inhibition around a disc dipped in a preserving solution.

? Science Inquiry Skills

7. Allow the spreader to cool near the flame vicinity and turn flame back to safety.
8. Take off the petri dish lid and cool the spreader by touching the side of the agar away from the bacterial broth.
9. Immediately use the sterile spreader to spread the culture evenly over the agar. Do not press hard enough to damage agar surface.
10. Close the lid and allow 5mins for the bacterial culture to absorb into the agar.
11. Place the glass spreader into the disinfectant tub.
12. After the allowed 5 mins, dip the forceps into the alcohol, allow extra residue to drip off and sterilize in the Bunsen burner blue flame as performed with the spreader. Allow to cool within the vicinity of the flame and turn flame back to safety.
13. Collect a sterile filter paper disc with forceps and dip it into the beaker of distilled water.
14. Open petri dish lid ajar, and carefully position disc on the agar in the appropriately labelled quadrant (lightly press onto the agar).
15. Repeat step 12 and re-sterilize the forceps in the alcohol and the blue flame of the Bunsen burner.
16. Repeat steps 13-15 for the remaining salt solutions (5%, 15% and 25%).
17. Seal the agar plates with parafilm all the way round the lid of the agar plate. If using tape, place 3 pieces of tape at the north, east, and west side of the agar plate (as shown in the figure below).



18. Place all agar plates into an incubator set at 30 degrees, inverted (upside down).
19. Place all equipment used into the provided disinfectant tub at completion of practical and wash hands with hand soap.
20. Examine the plates after 24-48 hours for colonies. **DO NOT take the lids off.** Measure the diameter of the zone of inhibition for each disc and record results in the results table.
21. **Wash hands with hand soap at completion.**

Results:

Salt Solution (%)	Zone of inhibition (diameter in mm)
0 (distilled water)	
5	
15	
25	

Analysis & Discussion:

1. With reference to the data in the results table, provide a concluding statement about the effectiveness of using salt as a preservation method.

? Science Inquiry Skills

2. Justify your findings using nutrition terminology.

3. Select an alternate preservation method used in canning or bottling where you could conduct a similar experiment. Some ideas include liquid fill with sugar syrup, liquid fill with acids (e.g., vinegar). In groups, create a design for the alternate experiment with a testable hypothesis, identification of the independent and dependent variables, identification and discussion of three controlled variables, a material list and an altered method for the investigation. The design should be created electronically. Once the teacher has verified, this investigation could be performed, followed by a class discussion comparing the various preservation methods tested to determine which is most successful.

2

? Science Inquiry Skills

Iron fortification in cereal

Introduction:

Iron is an essential mineral for our bodies, which is a significant component of haemoglobin found in red blood cells. Although iron can be found in iron rich foods such as meat, poultry, seafood, lentils, beans, tofu, and dairy; food manufacturers may choose to add it to their cereals as it is approved by FSANZ due to its health benefits. However, unlike the iron that is naturally found in food sources, the iron in our cereals is added as a powder onto the outside of cereal flakes during production. The iron that is added is just like the iron that goes into metal screws and nails, and therefore is magnetic and can be separated using a strong magnet!

Materials:

- An iron-fortified breakfast cereal (the lighter the colour the better, although nutri-grain works well)
- Strong magnet
- A large, sealable transparent food bag (a zip-lock style bag is ideal)
- A rolling pin
- Water

Method:

1. Pour some dry breakfast cereal into the zip lock bag and then seal.
2. Crush the breakfast cereal into a powder with a rolling pin.
3. Open the bag and put your magnet into the cereal dust. Carefully lift the magnet and you should see that tiny pieces of cereal are gripping the magnet – this cereal holds iron!

Alternate Method:

1. Pour a large quantity of breakfast cereal into a zip lock bag and seal.
2. Crush the cereal up with your hands.
3. Open the zip lock bag and pour in enough water to completely cover and saturate all the cereal.
4. Seal the zip lock bag and squash all the pieces until it is a smooth consistency, like thin soup.
5. Put the magnet on a hard surface and place the bag on top.
6. Shake the bag so that all cereal has a chance to be near the magnet.
7. Leave it to rest for an hour.
8. Carefully lift the bag, taking care not to shake it, and raise the magnet to keep it touching the same spot on the bag. Look closely: you should now see a small patch of dark iron powder next to the magnet. Move the magnet across the surface of the bag to drag the iron particles around.



Helpful online resources

How to extract iron from cereal

<https://youtu.be/oQ5lzpAw2qE>



Analysis & Discussion:

1. Describe why iron is a beneficial fortification in cereal for a teenager, and especially females.

2. Explain the difference between mandatory and voluntary fortification.

? Science Inquiry Skills

- Propose one reason why manufacturers may fortify their products, including cereals, with nutrients not naturally found in them.

- Name a further nutrient that could be fortified in cereal to increase the bioavailability of fortified non-haem iron

? Science Inquiry Skills

The effectiveness of emulsifiers

Introduction:

A mixture of oil and vinegar are the predominant ingredients of an Italian salad dressing. However, these ingredients usually separate very quickly no matter how hard you shake, stir, or whisk them together, leaving an unappealing product. Oil and vinegar do not mix, as fat-soluble ingredients (such as oil) are hydrophobic, meaning they do not attract water making them insoluble. Vinegar is predominantly water, making it hydrophilic and meaning it is attracted to water. This is why it does not form a solution with the oil (as shown in the figure below with oil being poured into a glass of vinegar). Therefore, such dressings require the addition of an emulsifier, which combine fat- and water-soluble ingredients together. Emulsifiers work by having a hydrophobic end, which is attracted to the fat/oil and a hydrophilic end, which is attracted to the water/vinegar. Emulsifiers used in food manufacturing tend to be artificial, but some natural emulsifiers can be found in the home, such as an egg yolk!



Materials:

- 5ml measuring cylinder
- 3 Large test tubes with a rubber stopper
- Disposable teat pipettes
- Spatula
- Cooking oil (corn oil is ideal due to its darker and more easily visible colour)
- White vinegar
- Mustard powder
- Egg yolk

Method:

- Measure and place approximately 2cm^3 of oil into a large test tube.
- Measure and place approximately 2cm^3 of vinegar into the same large test tube.
- Put a rubber stopper into the top of the tube and shake it – not too vigorously.
- Remove the stopper and leave the mixture to stand.
- Record your observations in the results table below.
- Repeat steps 1-5 in a new test tube, while also adding a small quantity of egg yolk using the dropper.
- Repeat steps 1-5 in a new test tube, while also adding a small quantity of mustard powder using the spatula.

Results:

Test	Observations
Oil and vinegar	
Oil, vinegar, and egg yolk	
Oil, vinegar, and mustard powder	

? Science Inquiry Skills

Making natural food colourings

Introduction:

Food colourings are often man-made or artificial and added to foods to enhance their visual appeal by restoring any colour that may have been lost during processing. Artificial food colourings are often bolder in colour compared to natural food colourings and can also be favoured by food manufacturers as they don't tend to affect the taste of food. Natural food colourings, however, are still a viable substitute and can be considered a better alternative as they are wholly derived from plants. There are several natural food colourings that can be made from natural ingredients that you would find in your kitchen. Some of these options have been provided in the method, which can be selected by your teacher or class.

Method:

Pink/red food colouring:

1. Peel and grate a raw beetroot and cut into small pieces.
2. Place the small pieces into a medium pot and cover with cold water.
3. Heat over medium to high heat until the mixture begins to boil.
4. Reduce heat to medium-low and allow the water to simmer uncovered until only about $\frac{1}{4}$ of a cup of liquid remains.
5. Remove from heat and discard any pieces of beetroot.
6. Wait for it to cool and then add 1 teaspoon of the liquid from your beetroot to your frosting or cake recipe to provide a vibrant red colour.

OR

1. Cut and crush raspberries, cherries, or strawberries.
2. Squeeze the cut and crushed raspberries, cherries, or strawberries through a piece of cheesecloth or muslin into a bowl.
3. Add 1 teaspoon of the liquid from the crushed berries to your frosting or cake recipe to provide a pink/red colour (the colour won't be as vibrant as using beetroots).

Lavender/blue/purple food colouring:

1. Place and wrap a handful of blackberries or blueberries into a piece of cheesecloth or muslin.
2. Twist, and squeeze the cheesecloth or muslin, releasing any juice into a bowl.
3. Add 1 teaspoon of the liquid from the crushed berries to your frosting or cake recipe to provide a purple colour.

OR

1. Place 2 cups of blackberries or blueberries in a blender or food processor and blend until a liquid consistency is achieved.
2. Using a fine sieve, strain out the juice into a bowl and remove the skins from the mix.
3. Place the liquid from the berries and a $\frac{1}{4}$ cup of water into a small pot.
4. Heat the liquid over medium heat and simmer until it reduces to half its original volume.
5. Wait for it to cool and then add 1 teaspoon of the liquid from your berries to your frosting or cake recipe to provide a vibrant purple colour.

Blue food colouring:

1. Cut a $\frac{1}{4}$ of a head of red cabbage into shredded pieces and place in a saucepan with 1 cup of water.
2. Heat over medium heat and bring to a boil, and then reduce heat to maintain a simmer, and cook for an additional 20 minutes.
3. Allow it to sit for 15 minutes and then using a sieve, strain out the liquid and discard the cabbage pieces (the colour should be purple at this stage).
4. Return the liquid to the saucepan and add and stir 1 teaspoon of baking soda to turn the colour blue.
5. Boil to reduce to about half its original volume, or even more for a deeper and more intense blue.
6. Wait for it to cool and then add 1 teaspoon of the liquid from your cabbage to your frosting or cake recipe to provide a vibrant blue colour.

? Science Inquiry Skills

Green food colouring:

1. In a small saucepan, boil spinach or an alternate green leafy vegetable with enough water to cover for 5 minutes.
2. Drain the spinach and discard the cooking liquid.
3. Add the spinach with enough water to cover in a blender or food processor until completely smooth (add more water if clumpy).
4. Strain the purée through a fine mesh sieve.
5. Wait for it to cool and then add 1 teaspoon of the liquid from your spinach to your frosting or cake recipe to provide a green colour.

*Alternatively, add some of each food colouring to plain or vanilla yoghurt

Extension activities:

1. Complete the following table, describing the purpose of the following additional food additives and identifying what foods they are commonly added to.

Food additive	Purpose	Foods commonly added to
Anti-caking agents		
Food acids		
Foaming agents		
Mineral salts		
Stabilisers and firming agents		
Flour treatment		
Gelling agents		
Propellants		
Bulking agents		
Flavour enhancers, such as monosodium glutamate (MSG)		
Flavours (vs flavour enhancers), such as vanilla		

Food additive	Purpose	Foods commonly added to
Thickeners		
Preservatives		
Humectants		
Glazing agents, such as beeswax		
Raising agents		

2. Research and discuss the effects that the consumption of food additives may have on children (be mindful, as findings can be controversial).
3. Research and describe the difference in the processing methods of pasteurisation with high temperature and short time (HTST) and ultra-high temperature (UHT).
4. Research a food source that is fortified with a specific nutrient to enhance the health of the population in another country. Explain the reason for fortifying that specific food source and how this would benefit the general health of the population.

2.6 Safe food: labelling and packaging

Science understanding

In Australia, the sale of food is regulated, and the consumers are protected by government policy regulation.

- The role of FSANZ in:
 - Safe food packaging
 - Advantages and disadvantages of food packaging materials or medium - metal, plastic, paper, glass, and active packaging.
 - Mandatory food labelling requirements
 - Nutrition value per 100 grams to compare food products and help consumers make informed decisions.

SACE Subject Outline, 2024.

Food packaging

After food has been undergone preservation methods (should that be needed), it is presented to consumers in varying packaging types and the food package is labelled. Packaging serves a variety of purposes such as reducing damage to the product inside. However, its protective potential is dependent on the packaging material used of which there are many, including newer advances in active packaging forms.

Food packaging is another form of food processing, where food is prepared for sale by wholly or partly encasing, covering, or enclosing food in a container or wrapper. Food manufacturers, consumers, and businesses use three kinds of packaging: primary, secondary, and tertiary (as shown in Figure 2.6.1). Primary packaging is the immediate layer that is in direct contact with the product, while secondary packaging surrounds primary packaging and assists in displaying, storing, shipping, and protecting products. Tertiary packaging is primarily used for product protection, storage, and transportation.

Primary package



Secondary package



Tertiary package



Figure 2.6.1: The primary, secondary and tertiary packaging of a chocolate bar.

It is important that the materials used to package food are **food grade**, which is outlined on most packaging (as shown in Figure 2.6.2). FSANZ mandates that all food packaging must be designed and selected in a way that does not have any adverse interactions between it and the food, is fit for its intended purpose and is not likely to cause food contamination. Regulations made by FSANZ also state that any packaging must not be capable of being swallowed or obstruct any respiratory passage, or otherwise cause bodily harm, distress, or discomfort. Food manufacturers must ensure that packaging that comes into contact with food does not cause the food to exceed the permitted levels of metals (e.g., tin in canned foods), non-metal contaminants (e.g., acrylonitrile and vinyl chloride used in plastics) or natural toxicants (e.g., erucic acid found in some plants). Therefore, any substance used in packaging must not impact the safety and suitability of the contacted food and present any known hazards to the consumer even if chemicals used potentially migrate to the food source. Finally, recycled, and reused materials may be used for food packaging applications, provided they are suitable for the intended use and will not contaminate food. These regulations also apply to food that is imported in its packaging in which is intended to be sold in Australia.

Definition

Food-grade packaging is a term used to describe the type of packaging that is safe for food products. This means that the production and handling methods of packaging materials, plus the packaging material used itself, is free from harmful chemical or residues that could migrate into, contaminate, or taint the food in any way. The packaging material must also be able to be effectively sanitised.

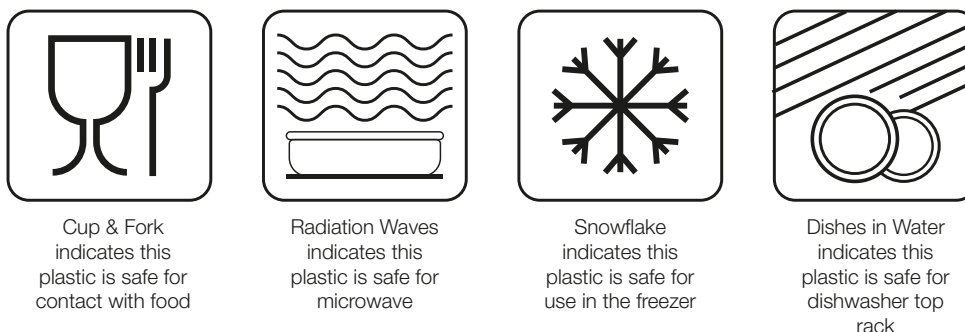


Figure 2.6.2: The labels on packaging to outline if it is food-grade and suitable for microwaving, freezing or exposure to hot water.

The Functions of Packaging

Up until the 20th century most food was sold loose, it was weighed and measured out and then placed into bags or directly into the shopper's bag to carry home. However, most of the packaging produced today is for food products. Packaging has become a massive and lucrative industry and is one of the contributing factors that persuades the consumer into purchasing the product. It serves an important role in maintaining several functions, which include:

- **Protection:** protecting the food from biological contamination agents (such as rodents, insects, and bacteria), mechanical damage (such as abrasion, fracture and/or crushing), and chemical or environmental degradation (such as oxidation, high temperatures, moisture transfer and exposure to ultraviolet light).
- **Convenience:** is important to consumers for optimum functionality, therefore packaging must come in a range of sizes, be easy to handle, open and dispense, and is often able to be resealed. Packaging should also be designed to make it easy to transport, move, lift, stack, and store.
- **Communication:** providing a surface that allows a label to be printed on or attached, for legal and marketing purposes. This allows consumers to identify the product and make an informed decision about the product and if it is suitable for them. Graphics and claims may also be included to communicate product quality, and thus increase sales.

Traditional packaging materials

The packaging materials that are primarily used in the food industry in Australia are passive, acting as a physical barrier between the food and the atmosphere surrounding the food and the external environment. They aim to protect the food product from external factors like air, light, moisture and physical damage. The most common passive packaging materials used include aluminum or tin for canning, plastic, cardboard/paper, and glass (Table 2.6.1).



Helpful online resources

Food Packaging Materials: Types and Features

<https://youtu.be/mLXfZGAV5Gw?si=fm0-mgO-nG76SZ0F>



Table 2.6.1: Advantages and disadvantages of common/traditional food packaging materials.

Food packaging material	Examples of use	Advantages	Disadvantages
Aluminium	• Drink cans • Alfoil • Foil Trays • Pull tabs • Tea • Fruit Juices • Sweets	• Inexpensive to produce • Can continually be recycled • Impermeable to light, moisture, oils and fats, oxygen and micro-organisms • Lightweight • Does not rust when exposed to moisture	• Not suitable for reuse • Some need to be cut open on one end • The product inside is not visible • Production uses non-renewable resources and releases greenhouse gas emissions • Cannot be microwaved • Can corrode when exposed to acidic foods
Tin	• Coating steel cans • Candy bars • Olive oils • Vegetables • Meat • Pet food • Fruit	• Inexpensive to produce • Recyclable • Impermeable to light, moisture, oils and fats, oxygen and microorganisms • Does not react with oxygen, therefore doesn't rust • Highly resistant to corrosion by acidic substances • Safely holds food for a longer period of time without contaminating it	• Not suitable for reuse • Some need to be cut open on one end • The product inside is not visible • Production uses non-renewable resources and releases greenhouse gas emissions • Cannot be microwaved • Heavier than aluminium
Plastic	• Sauces • Water • Soft drinks • Takeaway containers • Cling wrap • Spreads • Yoghurt • Bags in breakfast cereal boxes	• Can be moulded into any shape • Easy to handle and open • Lightweight • Inexpensive to produce • Resistant to breaking • Impermeable to oxygen, moisture, light. • They can be transparent, allowing the product placed inside to be seen.	• Produced from hydrocarbons sourced from non-renewable resources • Causes greenhouse gas emissions from production • Contributes to landfill, and pollutes ecosystems • Not biodegradable • Not always resealable • Potential of chemical migration into food • Exposure to extreme heat can cause it to melt or deform
Cardboard/ Paper	• Breakfast cereals • Pizza • Fast food • Coffee • Popcorn • Fruit juices • Milk	• Cheap • Lightweight • Excellent printing capacity for labelling • Recyclable and can be biodegradable • Made from renewable resources	• Permeable to moisture • Can be crushed from mechanical pressure • Not applicable for products that require freezing • Weak when wet
Glass	• Jams • Mustard • Instant coffee • Processed baby foods • Spreads • Wine • Mineral water	• Strong and durable • Highly recyclable • Chemically resistant • Inert • Transparent; product is visible to consumer • Can be reused and resealed • Impermeable to oxygen and moisture	• Fragile • Can be a safety hazard • Allows light exposure • Emits greenhouse gases during production • Production is energy- and resource-intensive • Heavier than alternatives, which increases transport costs

Active packaging materials

Despite the prevalence of traditional packaging, it is anticipated that there will be a shift towards **active packaging** due to consumer concerns about safety and additive content. Common types of active packaging technologies include vacuum packaging, modified atmosphere packaging, oxygen absorbers, moisture scavengers, carbon dioxide emitters and ethylene scavengers. Unlike traditional packaging which doesn't interact with the food product inside, but rather acts as a passive shield, active packaging maintains or improves the condition of packaged food by manipulating the food's **headspace**, and/or the food itself. Active packaging is designed to eliminate or reducing unwanted active components such as moisture or specific gases like oxygen. The main applications of active packaging focus on delaying oxidation, controlling moisture migration, halting or slowing microorganism growth and slowing or stopping the development of volatile flavours and aromas. As such, these types of packaging have advantages of extending the food's shelf-life in a way that reduces the need for chemical additives including antioxidants, making it an ideal preservation method for organic produce.



Definition

The inside (volume) of packaging that is not occupied by the food product itself is referred to as headspace. The atmosphere within this space is referred to as the headspace gas.

Ethylene scavengers

Ethylene (C_2H_4) is a gas produced by several fruits and vegetables as they mature, which accelerates the ripening and spoilage of packaged fruits and vegetables if not properly controlled. **Ethylene scavengers** are used to delay the ripening process in packaged fruits and vegetables by absorbing ethylene from the environment. This prevents deterioration and increases the shelf life of these products by delaying their spoilage ensuring they still look fresh when being delivered to retailers (as shown in Figure 2.6.3). These packaging materials are also particularly effective at reducing waste, which fruit and vegetables contribute approximately 50% of wasted materials. The most common ethylene scavenger is potassium permanganate, which is generally embedded in a silica gel sachet or zeolite clay and embedded into food grade packaging.

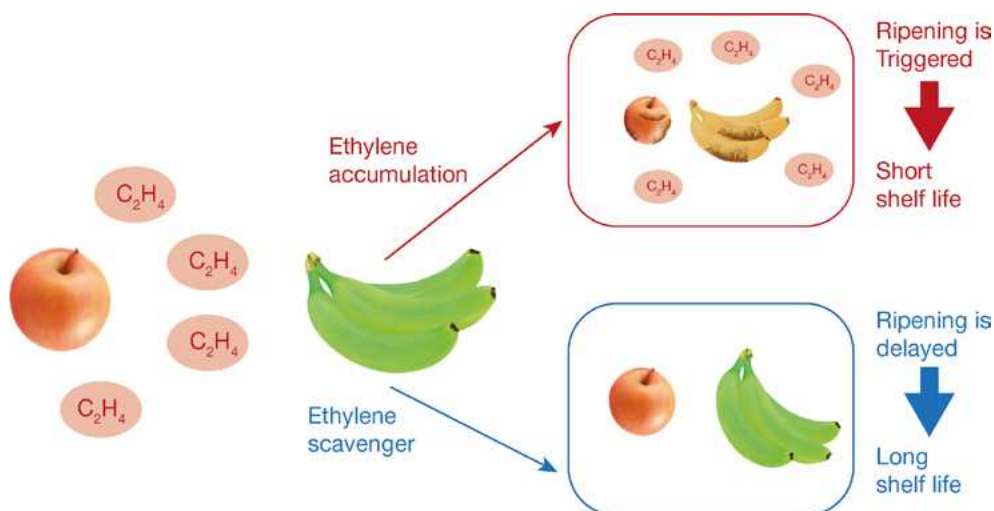


Figure 2.6.3: The effectiveness of Ethylene Scavengers in the increase in the shelf life of fruit.

Vacuum packaging

Vacuum packaging involves the evacuation of air prior to making an airtight seal. This lowers the oxygen levels present in the packaging, reducing the growth of microbes and the rate of spoilage due to oxidation. For example, the risk of spoilage and becoming rancid or foul tasting or smelling will be reduced in foods high in fat due to less oxygen being present in the packaging headspace. However, it is not possible to withdraw all air, therefore a small amount of oxygen will remain. A further limitation of vacuum packaging is that it causes the packaging material to collapse tightly around the food product. This can distort and deform the appearance of the products, which is why this product cannot be used for all food types. Commonly packaged foods with vacuum packaging include meat, seafood, vegetables, and fruit.

Modified atmosphere packaging (MAP)

Modified atmosphere packaging (MAP) manipulates the environmental gases inside the food packaging to create an optimum balance between oxygen, carbon dioxide and nitrogen. It can use oxygen absorbers and carbon dioxide emitters to do such. Carbon dioxide inhibits the growth of most aerobic bacteria and mould but can cause flavour tainting if excess levels are present. Nitrogen is an inert gas and used as a filler gas to expel oxygen, preventing the collapse of packaging and oxidative rancidity. Although oxygen causes the deterioration of foods and growth of aerobic microorganisms, some oxygen is required to maintain colour and the respiration of fruit and vegetables. As such, MAP may not slow the growth of some harmful bacteria and further preservation methods such as refrigeration may be required. The combinations of MAP and cold storage is often used to allow for fruit and vegetables to be available out of season. Meat, dairy products, fish, and seafood are additional food products MAP is commonly used with.

Helpful online resources

Modified Atmosphere Packaging

<https://youtu.be/27Pru21te2s?si=C1ywD0kaOBXLq6Km>



Oxygen absorbers

Oxygen absorbers or scavengers are small satchels filled with iron powder that are placed inside food packaging. In a sealed environment, the iron powder absorbs and uses oxygen present to produce iron rust. This process leaves primarily nitrogen in the food packaging. When all the iron powder has oxidised, the oxygen absorbers are loaded and the absorbing action stops, making the oxygen absorber unable to be reused. Due to concerns of botulism poisoning (a bacteria active in anaerobic conditions with favorable water activity levels), oxygen absorbers can only be used with dry foods such as taco shells.

Carbon dioxide emitters

CO₂ emitters actively produce and release this gas within the package to inhibit spoilage and control harmful microorganism growth (see figure 2.6.4). These technologies can also be used with oxygen scavengers, whereby oxygen is absorbed and replaced with CO₂. Excess CO₂ accumulation, however, can be detrimental to the quality of the product and/or the integrity of the package, particularly in the case of CO₂-producing foods, such as fermented foods and fresh produce like fruit. Carbon emitters are therefore mostly used with snack foods, nuts, bakery items, dried and fresh meats, and fish.

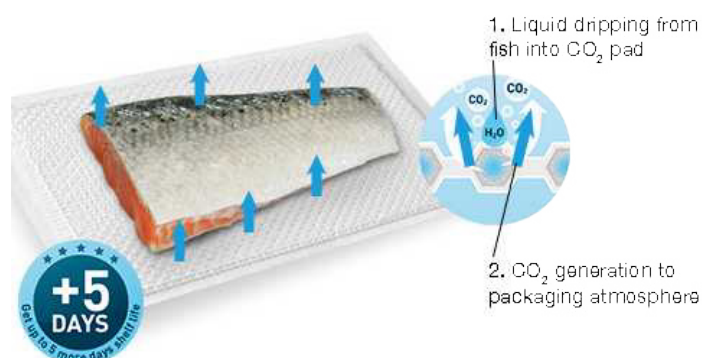


Figure 2.6.4: CO₂ emitter pad used in fish packaging

Moisture scavengers

Moisture scavengers are an effective way of controlling excess water accumulation in a food package, thereby inhibiting spoilage and microorganism growth. Moisture scavengers can come in the form of a pad or sheet that absorbs and holds moisture (see pad of figure 2.6.4 which double as CO₂ emitter and water absorber), or as a regulator which sustains a state of dryness by absorbing moisture from the air and controlling humidity in the headspace of the package. These regulators can come in the form of a sachet and contain calcium chloride, which is an example of a compound that can effectively absorb moisture from the air. Like oxygen absorbers, moisture scavengers tend to be single use only. They are commonly used in cereals, nuts, snack foods, fresh fish, and meat.

The effect of Packaging on Nutrients

Almost all food processing methods reduce the amount of nutrients present in food, after harvest or slaughter. Once foods, especially fruits and vegetables, are separated from their source of nutrients (tree, plant, or vine), they undergo higher rates of respiration, resulting in moisture loss, quality and nutrient degradation, and the growth of pathogenic bacteria. Packaging materials that expose foods to high levels of light, water and/or oxygen cause the greatest nutrient loss, especially sensitive water-soluble vitamins. For example, packaging materials such as glass and transparent plastic results in greater nutrient loss than translucent and opaque materials due to allowing light to pass through.

Mandatory food labelling

Food labels are placed onto the food packaging to carry essential information that allows consumers to make informed choices about their food selections.

Food Safety of Australia and New Zealand (FSANZ) have set the labelling requirements through the Food Standards Code. The food labelling requirements (see detailed labelling legislations in figure 2.6.6) set by FSANZ include:

- Date marking (use by and best before date)
- Food identification
- Net weight
- Warning and advisory statements
- Nutrition information panel (NIP)
- Ingredients list
- Percentage labelling
- Food additives
- Food recall information
- Directions for use and storage

Apart from labelling requirements, labels must not be misleading and be legible. Label information must be legible, for example, warning statements must be at least 3 mm high for most packaging types. It must also be prominent and distinct from the background, and in English. Should the label be in another language, the essential information must also be given in English.

Not all foods are required to have all food labelling requirements that have been set by FSANZ. However, the retailer must be able to provide labelling information for these foods if asked, including allergens, storage instructions, etc.

Foods that are exempt from any labelling includes:

- Unpackaged food or food packaged at its point of sale, such as from a bakery, butcher, fast food outlets and restaurants.
- Food delivered at the customer's request, for example, pizza.
- Smaller individual packets within larger labelled packaging, such as single packets of chips.
- Single-ingredient foods, such as fresh fruit and vegetables.
- Foods sold at fundraising events.
- Very small packaged foods and foods without significant nutritional value, such as herbs, spices and coffee.

Another mandatory label which is overseen by Australian consumer laws, rather than FSANZ, is country of origin. All packaged food and some unpackaged food such as meat, fruit, and vegetables, must be identified as being made from imported or local ingredients (or a mixture of both). Country of origin labelling can indicate where the food was grown, produced, made/ manufactured or packaged (see Figure 2.6.5).

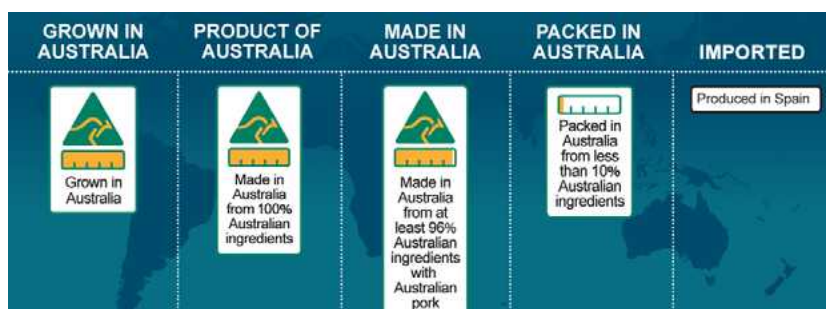


Figure 2.6.5: Country of origin labelling types.

Definition

See Figure 2.6.6. A compound or composite ingredient is itself made of a few ingredients. For example, in a can of spaghetti in tomato sauce, spaghetti is a compound ingredient that is made of flour and egg. The flour and egg must therefore be listed in brackets next to the spaghetti ingredient listing.

Use-by date:

Food that has potential to cause food poisoning or other health concerns must have a use-by-date to indicate when the food needs to be consumed by, to reduce this risk.

Best-before date:

Products with a shelf-life of less than two years that don't pose these health risks if eaten after its date marking (but may have lost quality), must be labelled with a best before date. Although it may be safe to consume after its best before date, it may have lost quality and some nutritional value.

Name and/or description of the food/beverage:

The name and description of the food needs to indicate the true nature of the food. For example, 'Strawberry Yoghurt' should contain strawberries whereas if the yoghurt contained strawberry flavouring rather than real fruit, then the name would need to indicate that it is strawberry flavoured.. It should not misinform consumers through false, misleading or deceptive representations.

Net weight:

Manufacturers must label food products with accurate weights and/or measures (quantities of servings contained in a package).

Warning and advisory statements:

If the food contains any known **allergens** which can cause severe allergic reactions, they must be declared (typically in bold or in brackets). These include peanuts, tree nuts (e.g. cashews, almonds, walnuts), milk, soybeans shellfish, eggs, fish, sesame, wheat and lupin. The preservative: sulphite that may trigger asthma, must be declared in the ingredients list if added at 10mg or more per kg of food. Foods, such as cereals, containing gluten (e.g. wheat, oats, rye and barley) must also be declared. Some food manufacturers also choose to use a 'may contain' statement should processing equipment in their foods be used for other foods with known allergens

Advisory statements appear under the ingredients list when the food contains ingredients that may pose a health risk to some consumers, such as 'contains caffeine'.

Nutrition information panel (NIP):

The NIP must list energy (kJ) and key nutrients: protein, total fat and the quantity that comes from saturated fat, total carbohydrate and the quantity that comes from sugars, plus sodium. If the product has a nutrient claim displayed anywhere on the label such as 'high in fibre', this must also appear in the NIP, to substantiate the claim.

The quantities of the nutrients are given per serving (and sometimes also displayed as % daily intake), to allow the consumer to keep track of what they are eating, and per 100g (or 100 mL if liquid), to allow comparison to similar products.

List of ingredients:

The ingredients of the food are listed in order from the one contributing the highest quantity first through to the least (according to weight). **Individual ingredients that make up a compound or composite ingredient** of significant contribution to the food (>5%), and any added water, must also be listed. If an ingredient (other than an additive or known allergen) is less than 5%, it does not have to be listed.

Percentage labelling:

The key/characterising ingredients (or the ingredient the manufacturer advertises/claims the product to contain) must be presented with the percentage of it in the food to allow comparisons to similar products. For example, strawberry is the key ingredient in this yoghurt, which contains 7% strawberries.

Food additives:

Food additives are listed in the ingredients list, displayed according to their type or class, followed by their chemical name or number, e.g. colour (tartrazine) or colour (102).

Food recall and identification information:

Name and address (PO box not sufficient) of the food supplier plus identification of the lot number is listed to allow for effective recall of batches of food that may have a potential contaminant.

Directions for use and storage:

If a product poses a risk of microbial growth or deterioration, instructions on how to specifically store the food to maintain its quality and safety until its date mark need to be included. Manufacturers also have to provide preparation directions for any products that are unsafe to eat unless prepared as directed.

Country of origin:

All packaged food and some unpackaged food such as meat, fruit and vegetables, must be identified as being made from imported or local ingredients (or a mixture of both). Country of origin labelling can indicate where the food was grown, produced, made/ manufactured or packaged (see Figure 2.5.6 for additional country of origin labelling types).



Figure 2.6.6: Food labelling requirements in Australia.

Key terms

Active packaging

Allergen

Best-before date

Carbon dioxide emitters

Country of origin

Ethylene scavengers

Ingredients list

Mandatory food labelling

Modified atmosphere packaging (MAP)

Moisture scavengers

Nutrition Information Panel (NIP)

Oxygen absorbers

Percentage labelling

Use-by date

Vacuum packaging

Warning and advisory statements

Review questions: 2.6 Safe food: labelling and packaging

1. The value of packaging produced in Australia is estimated to be approximately \$10 billion. The food and beverage sector uses almost 70% of all Australian-produced packaging.

(a) Suggest and explain a reason why the packaging industry in Australia continues to grow.

(2 marks) (KA2)

(b) The packaging used in Australia must be food grade.

(i) Define food grade packaging.

(1 mark) (KA1)

(ii) Identify the government authority that develops the regulations for food packaging.

(1 mark) (KA1)

(iii) Suggest two ways that food packaging could contaminate food, making it unsafe for consumption.

1.

2.

(2 marks) (KA1)

(c) Suggest a reason why consumers are preferring their packaged food to rely on active packaging rather than traditional packaging mediums.

(2 marks) (KA2)

2. Give two reasons why milk is no longer routinely packaged in glass bottles.

Reason 1:

Reason 2:

(4 marks) (KA2)

3. Describe two disadvantages of using aluminium cans to package food.

Disadvantage 1:

Disadvantage 2:

(4 marks) (KA1)

4. A pre-packaged, ready to eat meal was packaged in plastic.

(a) Describe one advantage for the consumer of using plastic as a packaging material.

(2 marks) (KA2)

(b) Describe one environmental disadvantage of using plastic as a packaging material.

(2 marks) (KA2)

(c) Discuss one type of active packaging that could be added to the food packaging.

(2 marks) (KA2)

5. The following questions refer to the labelling on a can of preserved mangoes.



(a) Name the predominant ingredient in this can of preserved mangoes.

(1 mark) (IAE3)

(b) Name the key or characterising ingredient in this can of preserved mangoes.

(1 mark) (IAE3)

(c) List three mandatory requirements missing from the preserved mangoes.

- 1.
- 2.
- 3.

(3 marks) (KA2)

6. Identify whether buying 'Product of Australia' or 'Made in Australia' would support the Australian economy the best and justify your response.

(2 marks) (KA2)

7. Packaging protects food from damage, spoilage, or contamination that would reduce its quality. For each of the foods listed below:

- Identify one risk factor that could reduce the quality of the product.
- Suggest packaging material (s) that manufacturers could use to reduce this risk factor.
- Explain how the suggested packaging material reduces the risk factor.

- (a) Breakfast cereal

Risk factor:

Packaging material:

Explanation:

(4 marks) (KA2)

- (b) Fresh Eggs

Packaging material:

Explanation:

(4 marks) (KA2)

- (c) Orange juice

Packaging material:

Explanation:

(4 marks) (KA2)

8. Australia has several mandatory labelling requirements.

- (a) Match the mandatory labelling law with its description:

(8 marks) (KA1)

Percentage labelling		For food with a shelf life of less than two years
Name/description		Needs to indicate the true composition of the food
NIP		Allows recall of potential batches of food that could be contaminated
Date marking		Provides quantities of nutrients per serve and per 100 g
Ingredients list		Allows the characterising ingredient to be compared to alike products
Recall information		Where allergens and food additives are found
Food additives		Must be provided if food poses gastroenteritis risk after opening
Storage instructions		Must be listed in ingredients, even if in small amounts <5%

- (b) Identify a food that does not need to be labelled and provide reasoning why it doesn't require one.

(2 marks) (KA2)

- (c) Explain the importance of sodium being mandated and included on the nutrition information panel.

(2 marks) (KA2)

- (d) Describe a difference between a best-before date and a use-by date.

(2 marks) (KA2)

2

9. Refer to the following table, which provides nutritional information for 100g of a range of foods:

Food	Energy (kJ)	Protein (g)	Total Fat (g)	Saturated Fat (g)	Carbohydrates (g)	Sugar (g)
Broccoli	101	4.7	0.3	0.0	7.2	1.4
Canned steak and vegetables in sauce	293	3.7	2.5	1.1	14.4	5.0
Dried rice cereal	1510	8.0	2.8	0.6	77.6	0.1
Lamb chop	625	21.0	17.2	3.5	0	0
Salami	1782	21.7	37.6	12.3	2.25	0

- (a) Name the food that contains most protein per 100 grams.

(1 mark) (IAE3)

- (b) Name the food that contains the greatest quantity of simple sugars.

(1 mark) (IAE3)

- (c) Name a food that would be an appropriate choice for someone with cardiovascular disease and provide reasoning using data from the table above.

(2 marks) (IAE3)

- (d) Describe the purpose of nutrition information panels presenting nutritional information per 100g.

(1 mark) (KA1)

Total: / 60 marks

Case Study

Butter Food Recall

A food recall case was reported across various social media sites during 2021-2022 as seen below.

△

FOOD RECALL

Saputo Dairy Australia Pty Ltd (SDA) is conducting a recall of the following butter and spreadable butter blend products due to a potential microbial contamination.

Devondale Salted Butter 250g  BEST BEFORE: 18 MAY 22, 04 JUN 22	Devondale Salted Butter 500g  BEST BEFORE: 30 APR 22, 01 MAY 22, 24 JUN 22	Devondale Salted Butter 3 x 500g  BEST BEFORE: 01 MAY 22	Woolworths Butter Salted 250g  BEST BEFORE: 16 OCT 21, 21 APR 22, 12 MAY 22, 13 MAY 22
Devondale Unsalted Butter 500g  BEST BEFORE: 30 APR 22	Devondale Dairy Soft Original 500g  BEST BEFORE: 06 JAN 22, 06 APR 22, 11 MAY 22, 12 MAY 22, 26 MAY 22	Devondale Dairy Soft Salt Reduced 500g  BEST BEFORE: 10 MAY 22	Woolworths Butter Unsalted 250g  BEST BEFORE: 16 OCT 21, 11 MAY 22, 12 MAY 22

The recalled products have been available for sale nationally in various outlets including Woolworths, Coles, ALDI, independent supermarkets and Costco.

Problem:
Potential microbial contamination.

What to do:
Consumers should not eat these products. Any consumers concerned about their health should seek medical advice. Consumers should return the products to the place of purchase for a full refund.

Contact Details:
For further information, contact the Saputo Dairy Australia customer service team on **1800 032 479**

With reference to the food recall information above:

- Identify the government organisation that would have created the publication of the food recall shown above, and a reason for its importance to be circulated on social media.
- Discuss two favourable conditions of the butter products that may have supported microbial multiplication after its potential contamination, and one mandatory food label that safeguards against potential microbe ingestion.
- Identify a form of active packaging that could be incorporated into the plastic packaged butter product's headspace and explain how it would slow microbe growth.

(10 marks) (KA2)



Science as a human endeavour

Laboratory testing to confirm Nutrition Information Panels

Article adapted from:

<https://nmr.oxinst.com/assets/uploads/documents/Determination-of-Fat-and-Oil-Content-in-Foodstuffs.pdf>

<https://nmr.oxinst.com/assets/uploads/documents/Using-Nuclear-Magnetic-Resonance-to-Test-Fat-Content-in-Foods.pdf>

Routine and accurate measurement of the nutrients in food is necessary to ensure that food manufacturer's food products comply with their Nutrition Information Panels. Total fat is commonly found using a standard solvent extraction/acid hydrolysis method, called the Soxhlet or wet chemistry method. However, these solvent extraction techniques tend to be slow (taking up to 6 hours), cumbersome and inaccurate, and require highly skilled personnel. In addition, many of the chemicals used in Soxhlet testing are becoming increasingly unacceptable according to international environmental standards. Despite these issues, solvent extraction continues to be used as a reference measurement for quality control.

Nuclear magnetic resonance (NMR), a newly developed technology in the food sector, offers an alternate method to test for fat content in foods but is not yet widely used. In contrast to Soxhlet test, NMR provides a fast, direct, and user-friendly method for determination of the fat and oil content in foodstuffs that can be operated by a non-NMR expert user. The sample measurement time is short, typically only 20 seconds, and minimal sample preparation from the food is required, giving the possibility to test multiple food samples. The NMR technique is non-destructive to the food, so repeatability measurements can be made conveniently.

1. Discuss how the **development** in fat testing methods meets the following SHE concept:

'New technologies improve the efficiency of scientific procedures and data collection and analysis. This can reveal new evidence that may modify or replace models, theories, and processes'.

(4 marks) (KA3)

2

? Science Inquiry Skills

What does a serving size look like?

Introduction:

A serving size is considered by food manufacturers to be the amount of food that is typically eaten at one time. Food manufacturers can select the serving size to use and convey the nutrients in that serving size via the nutrition information panel. This choice in selection of serving size can explain why some foods such as cereals, despite possibly having a very similar serving size by customers, differ across cereal varieties and brands.

Materials:

- Kitchen scales
- Range of cereals
- Bowls of similar size

Method:

1. Turn on the kitchen scales and place an empty bowl onto the scales.
2. Ensure the scales read 0grams.
3. From any of the cereals, pour how much you would typically eat in one sitting into the bowl sitting on the kitchen scales.
4. Record this measurement in the results table below.
5. Repeat steps 1-2.
6. Weigh out the serving size specified in grams on the nutrition information panel of the cereal box label into the bowl.
7. Record this mass in the results table below.
8. Repeat 1-7 for several cereals and line up the bowls to allow comparison of serving sizes.

Raw Data:

Name of Cereal	Serving Size listed on the NIP (g)	Actual Amount Consumed (g)

Analysis & Discussion:

1. Compare how the serving size compares to your typical breakfast consumption for each cereal.

2. List the cereal with the smallest serving size.

3. List the cereal with the largest serving size.

4. Identify any trend between the cereal type and its serving serve and discuss possible reasons why a food manufacturer could select a smaller serving size to list on the nutrition information panel.

? Science Inquiry Skills

Nutrition Information Panel Creation

Introduction:

A nutrition information panel (NIP) is one of the mandatory food labels. It conveys nutritional quantity information so that consumers can make informed purchases and/or comparisons to alike foods to find the better suited food to their dietary requirements. Food manufacturers must comply and add a NIP to their products.

Method:

1. Modify the following recipe to make it more suitable for someone who has an allergy to gluten.

Ingredients of Australian Biscuits	Ingredient Modifications
1 cup desiccated coconut	
$\frac{2}{3}$ cup raw sugar	
125g butter	
1 cup plain flour	
$\frac{1}{2}$ tsp bicarbonate of soda	
$\frac{3}{4}$ cup golden syrup	
1 cup rolled oats	

2. Simulate part of the food manufacturing process by creating a NIP for your new Australian biscuit recipe, by using the FSANZ 'Build recipe and NIP' (see helpful online resource). Enter each ingredient to create your NIP, and then print and display your NIP in the space given below.



Helpful online resources

Nutrition Panel Calculator

<https://www.foodstandards.gov.au/business/labelling/nutrition-panel-calculator>



? Science Inquiry Skills

The Effectiveness of Active Packaging

Introduction:

Bread has a low moisture content, making it less suitable for bacteria, which need high-water activity for growth. However, bread is susceptible to the biological contaminants mould and yeast, collectively called fungi, that can function in foods with lower water activity. Bread also supplies nutrients in a preferred form by fungi, carbohydrates. Therefore, especially when left in warm, humid storage areas, bread can often be found with fuzzy mouldy spots on it after a few days! Active packaging has been designed to delay oxidation, control moisture levels and slow microorganism growth. It could therefore offer a means to allow bread to be conveniently stored on a bench in warm or humid conditions for longer periods of time. The active packaging types that could be used in bread headspaces include oxygen absorbers, moisture scavengers and carbon dioxide emitters.

Materials:

- Oxygen absorbers for food
- Moisture absorbing pads for food
- Bread
- Zip lock bags
- Water in a spray bottle
- Marking pens
- Incubator (set around 20 degrees)
- Gloves

Method:

1. Label 2 zip lock bags – oxygen absorber and no oxygen absorber, ensuring labelling is to the side of bag to allow bread to be viewed once it is placed inside the bag.
2. Place 2 pieces of bread onto a clean bench and spray each piece of bread around 5-10 times with the water spray bottle (on one or both sides).
3. Place each piece of bread into its zip lock bag, one with an oxygen absorber sachet underneath and the other without, and seal in a similar manner.
4. Place zip lock bags into the incubator for 2-3 days.
5. Repeat steps 1-4 for moisture absorber and no moisture absorber.
6. Take images of the bread samples once substantial fungal growth is observed. Keep zip lock bags **CLOSED** and handle them with gloves.
7. Ensure hands are washed with soap at the conclusion of the collection of data.
8. Print images and glue them into the results tables.

Results:

Without Oxygen Absorber	With Oxygen Absorber

? Science Inquiry Skills

Without Moisture Absorber	With Moisture Absorber

Analysis and discussion:

1. With reference to the results, describe the effect of the active packaging materials upon fungal growth in bread.

2. The water sprayed onto the bread to encourage mould growth was not applied in a well-controlled manner. Describe how this procedural step could lead to random errors and discuss its potential impact. Suggest a possible improvement to this step of the experiment.

3. Another variable that was not controlled well in the experimental procedure was the sealing of the zip lock bags. Describe how the sealing of bags could lead to random errors and provide an improvement for this procedural step.

Extension Activities

- Discuss the differences between the terms: 'Grown in Australia', 'Product of Australia', 'Made in Australia' and 'Packed in Australia'. Research extending beyond the information provided in figure 2.6.5 will be of benefit.
- Beyond mandated fortifications, food manufacturers can add nutrients voluntarily (additions of saturated fat, sugar and salt are not permitted) and make associated nutrition and/or health claims on their product labelling. Nutrient additions are typically in an effort to make their product more appealing to the consumer, for example, 'added calcium to help healthy bones'. The nutrients added to the food and the claim advertised must be included in the NIP; however, some claims that appeal to customers can be deceiving. For example:
 - 'Light/lite' – may not be referring to the fat or energy level, but the texture/colour/taste of the food!
 - 'No/low cholesterol' on plant foods – these foods naturally have virtually no cholesterol!
 - '93% fat free' – it still has 7% fat but sounds better saying the opposite!
 - 'Baked not fried' – but it may still contain the same levels of fat/energy!

Therefore, always read the nutrition information panel when these claims are made!

- Investigate some of the foods in your pantry with claims, or as you peruse items at the grocery store, and report findings back to the class to hold a discussion over foods with food marketing methods.
- Food manufacturers can also include other FSANZ approved voluntary food labels, such as those seen in the table below. Complete the table below to find out more about some possible voluntary food labels.

Type of labelling	Illustration of the labelling	Description	Examples of foods that commonly use this labelling	Requirements to obtain the labelling
Organic				
Halal				
Heart foundation tick				
Fair trade				

3. The Health Star Rating is label that provides a quick, easy way to compare food by giving a rating from $\frac{1}{2}$ a star to 5 stars on the overall nutritional content of food. The more stars, the healthier the choice.
- (a) Select, find, and fill out the Nutritional information panel for a 2–3-star health star rating (HSR) muesli snack bar compared to a 4–5-star health rating muesli snack bar.

2-3 HSR muesli bar	Average Quantity per Serving (___ g)	Average Quantity per 100g
Energy	kJ	kJ
Protein	g	g
Fat, total	g	g
- saturated	g	g
Carbohydrate	g	g
- sugars	g	g
Dietary fibre	g	g
Sodium	mg	mg

4-5 HSR muesli bar	Average Quantity per Serving (___ g)	Average Quantity per 100g
Energy	kJ	kJ
Protein	g	g
Fat, total	g	g
- saturated	g	g
Carbohydrate	g	g
- sugars	g	g
Dietary fibre	g	g
Sodium	mg	mg

- (b) Identify which muesli bar is a better choice for someone with hypertension and provide reasoning.
- (c) Identify which muesli bar is a better choice for someone with diverticular disease and provide reasoning.
- (d) Some museli bars have a high HSR rating of around 3-4.5, despite being quite high in simple sugars. Observe the NIP of high HSR rated bars to identify and explain how they qualify for its rating (further research may also be useful).

Topic Two Summary Test

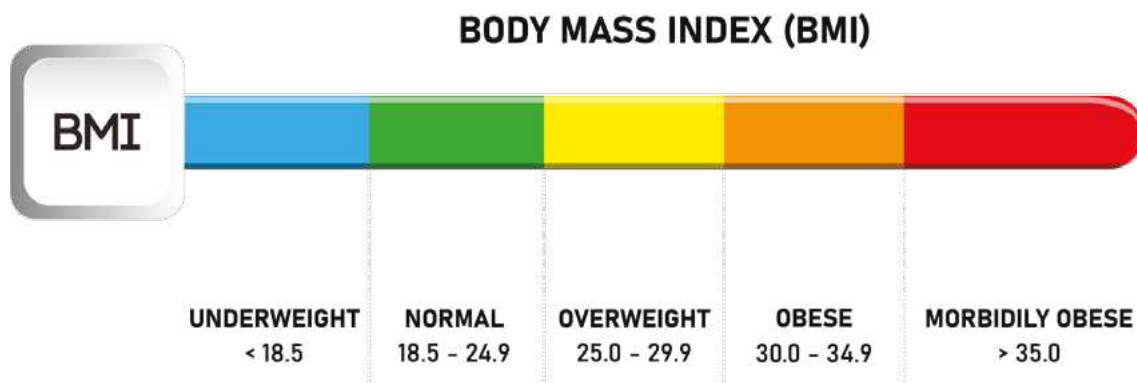
1. (a) Define what a diagnostic tool is.

(1 mark) (KA1)

- (b) Calculate the body mass index (BMI) of an individual with a height of 153 centimeters and weight of 76 kilograms. *Make sure to state the formula, show all your working out and round your final answer to the nearest whole number.*

(2 marks) (KA2, KA4)

- (c) With reference to the image below, categorise the weight classification of this individual.



(1 mark) (IAE3)

- (d) The BMI of an athlete is classified as obese, yet when this same athlete measures his waist-circumference, his classification is normal (not obese or at risk of overnutrition disease). Provide reasoning for this anomaly in findings.

(1 mark) (KA2)

- (e) Identify a further diagnostic tool often used by doctors or dieticians, not involving anthropometry measurements.

(1 mark) (KA2)

- (f) Identify a disadvantage of using the BMI as a diagnostic tool for obesity in comparison to the diagnostic tool identified in part (e).

(1 mark) (KA1)

2. Most South Australian (SA) school canteens use the Right Bite policy to classify foods and drinks according to their nutritional value.

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) Discuss the importance of healthy-eating initiatives, like Right Bite, for children aged 5 to 12 years.

(2 marks) (KA2)

- (b) The Australian Guide to Healthy Eating (AGHE) (NHMRC, 2017) separates discretionary food choices from the five food groups recommended for daily consumption. These discretionary foods are classified as red according to the Right Bite policy. Explain one nutritional reason why parents should limit discretionary or 'red' food choices for children aged 4 to 8 years.

(2 marks) (KA2)

- (c) Canteen staff need to determine the traffic light colouring of their foods when following the SA Rite Bite policy. When a food item is assessed as having less than (or equal to) the specified energy, saturated fat, and sodium amount, or more than (or equal to) the specified fibre quantity, it is able to be sold in canteens as an amber food. If the food item is found to be over the threshold for energy, saturated fat, or sodium or under the quantity needed for fibre, the food is categorised as red and unable to be sold in canteens. Refer to the table below, which demonstrates the nutrient amounts used to categorise foods.

Food Category	Nutrient content per serve			
	Energy (kJ)	Saturated fat (g)	Sodium (mg)	Fibre (g)
Sweet snack food, bars, and biscuits	600kJ or less	3g or less	-	1g or more
Savoury snack food, biscuits, crispbreads, and crisps	600kJ or less (Energy must be 1800kJ or less per 100g)	2g or less	200mg or less	
Ice creams, milk-based ice, and dairy desserts	600kJ or less	3g or less (Milk must be listed as first ingredient)	-	-
Un-iced cakes, muffins, and sweet pastries	900kJ or less	3g or less	-	1.5g or more

With reference to the information in the table above, identify if the following foods can be sold in school canteens across South Australia or not.

- (i) Per 40g serving, a muesli or granola bar has 773 kJ, 6.2g saturated fat and 2.6g fibre.

(1 mark) (IAE3)

- (ii) Per 35g serving, a nut bar has 581 kJ, 1.4g saturated fat and 3.1g fibre.

(1 mark) (IAE3)

3. Australians don't tend to eat enough vegetables.

- (a) Name one social marketing campaign that encourages people to eat the recommended number of serves of vegetables each day and discuss how it does this.

Advertising campaign:

(1 mark) (KA1)

Discussion:

(2 marks) (KA2)

- (b) Describe an environmental and/or social factor parents may encounter that would lead to children consuming fewer serves of vegetables per day.

(2 marks) (KA2)

- (c) Vegetables do not tend to be the food turned to when comfort eating. Define comfort eating and identify how it can be recognised.

(2 marks) (KA2)

4. Food labels provide a wide range of information to help consumers make food choices. The nutritional information panel (NIP), ingredients and warning statements from two different cereals are shown below (Cereal A left, Cereal B right):

Cereal A

Nutrition Information (AVERAGE)				
Serving size: 30g (3/4 metric cup)				
	quantity per serving	% daily intake ▲ per serving	per serve with 1/2 cup reduced fat milk	quantity per 100g
ENERGY	510 kJ	6%	790 kJ	1690 kJ
PROTEIN	1.6 g	3%	6.8 g	5.3 g
FAT, TOTAL	1.2 g	2%	3.3 g	4.1 g
- SATURATED	0.4 g	2%	1.7 g	1.4 g
CARBOHYDRATE	25.2 g	8%	32.2 g	83.9 g
- SUGARS	10.5 g	12%	17.5 g	35.0 g
DIETARY FIBRE	0.7 g	2%	0.7 g	2.4 g
SODIUM	102 mg	4%	170 mg	340 mg
% RDI*				
RIBOFLAVIN (VIT B2)	0.42 mg	25%	0.66 mg	1.42 mg
NIACIN	2.5 mg	25%	3.7 mg	8.3 mg
VITAMIN B6	0.4 mg	25%	0.4 mg	1.3 mg
FOLATE	50 µg	25%	58 µg	166 µg
IRON	3.0 mg	25%	3.0 mg	10.0 mg
ZINC	1.8 mg	15%	2.3 mg	6.0 mg
Ingredients				
Cereals (55%)(maize flour, wheat flour, oat flour), sugar, natural colours (carmine, paprika, vegetable carbon, turmeric, copper chlorophyll), vegetable oil, emulsifiers (E471), salt, dextrose, minerals (iron, zinc oxide), vitamins (niacin, vitamin B6, riboflavin, folate), natural flavours (orange, lemon, lime).				
CONTAINS CEREALS CONTAINING GLUTEN.				
MAY CONTAIN TRACES OF PEANUTS AND/OR TREE NUTS.				

Cereal B

Serving size: 45g (1/2 metric cup)				
	quantity per serving	% daily intake ▲ per serving	per serve with 1/2 cup skim milk	quantity per 100g
ENERGY	620 kJ	7%	820 kJ	1380 kJ
PROTEIN	6.3 g	13%	10.9 g	13.9 g
FAT, TOTAL	1.2 g	2%	1.3 g	2.7 g
- SATURATED	0.2 g	0.9%	0.4 g	0.5 g
CARBOHYDRATE	21.7 g	7%	28.2 g	48.3 g
- SUGARS	7.5 g	8%	14.0 g	16.7 g
DIETARY FIBRE	12.6 g	42%	12.6 g	28.0 g
- SOLUBLE	2.1 g	-	2.1 g	4.7 g
- INSOLUBLE	10.5 g	-	10.5 g	23.3 g
SODIUM	162 mg	7%	218 mg	360 mg
% RDI*				
RIBOFLAVIN (VIT B2)	0.42 mg	25%	0.68 mg	0.94 mg
NIACIN	2.5 mg	25%	2.6 mg	5.6 mg
VITAMIN B6	0.4 mg	25%	0.4 mg	0.9 mg
FOLATE	50 µg	25%	56 µg	111 µg
IRON	3.0 mg	25%	3.1 mg	6.7 mg
MAGNESIUM	108 mg	34%	124 mg	241 mg
ZINC	1.8 mg	15%	2.3 mg	4.0 mg

Ingredients

Wheat bran (85%), sugar, barley malt extract, salt, minerals (iron, zinc oxide), vitamins (niacin, vitamin B6, riboflavin, folate). (Natural source of magnesium).

CONTAINS CEREALS CONTAINING GLUTEN.

MAY CONTAIN TRACES OF PEANUTS AND/OR TREE NUTS.

- (a) Identify the cereal that meets the Australian Dietary Guidelines (ADGs) the best, and provide reasoning that utilises data from the cereal boxes in your response:

(3 marks) (KA2)

- (b) Identify a nutrient that both cereals have been fortified with.

(1 mark) (KA2)

- (c) The NIP, ingredients and warning statement are visible on the packaging of both cereal A and B. Name another label requirement that must be included on the packaging of the cereals as per FSANZ and justify the importance of this labelling.

(2 marks) (KA2)

- (d) Name two food additive groups that are used in cereal A and outline their function in this food product.

Additive group 1:

Function:

(2 marks) (KA2)

Additive group 2:

Function:

(2 marks) (KA2)

- (e) State two advantages of using cardboard as a packaging material for food manufacturers.

(1 mark) (KA1)

(1 mark) (KA1)

- (f) State a reason for plastic packaging to be used in cereal boxes, rather than just cardboard packaging alone.

(1 mark) (KA2)

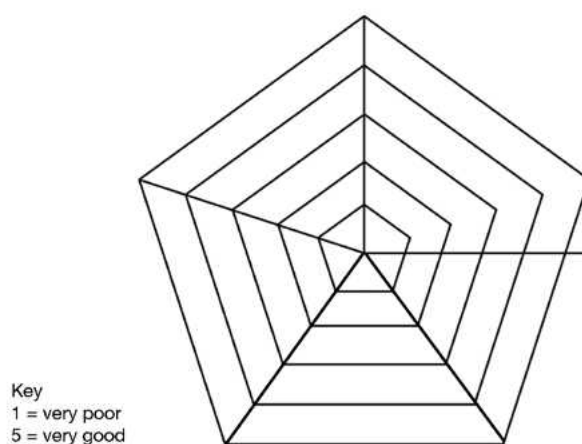
- (g) Identify and describe one possible active packaging form that could be utilised within the cereal plastic packaging and explain how this type of active packaging can extend the cereal's shelf life further.

(3 marks) (KA2)

5. A sensory evaluation was performed on two different types of potato chips. The results are recorded in the table below.

Potato chip type	Sensory characteristic	Mode
Cooked in animal lard	Saltiness	5
	Flavour	4
	Appearance	4
	Texture	4
	Aroma	2
Cooked in canola oil	Saltiness	5
	Flavour	3
	Appearance	3
	Texture	4
	Aroma	2

- (a) Represent the results in the table onto the axes of the radar graph below. Make sure to include the appropriate features on the graph, including the optimal results.



(5 marks) (IAE2)

- (b) Name the independent variable of the chip sensory evaluation.

(1 mark) (IAE1)

- (c) Identify two factors that must be kept constant when conducting the sensory evaluation and discuss why it is important to keep these factors the same.

Factor one:

(2 marks) (IAE1)

Factor two:

(2 marks) (IAE1)

- (d) With reference to the graph and/or table above, identify the:
highest ranking characteristic:
lowest ranking characteristic:

(2 marks) (IAE3)

- (e) Describe a weakness or limitation of using sensory evaluation tests to collect data.

(2 marks) (IAE4)

- (f) With reference to the characteristics tested in the sensory test of the chips, explain why testers with a cold were excluded.

(3 marks) (IAE1)

- (g) The sensory test on the chips was conducted using 100 taste testers. Explain the importance of testing a large sample size of individuals.

(2 marks) (IAE4)

6. Food safety refers to the handling, preparing, and storing of food in such a way as to best reduce the risk of individuals becoming sick from foodborne illnesses.

- (a) Giuseppe is a student who works part time in a restaurant. He often brings leftover food home. He takes this food with him in his backpack on a 1-hour bus ride to university to eat between 3 hour lectures and reheats it in a microwave.

- (i) Describe why it is safer for Giuseppe to eat the food after heating it in the microwave, rather than having it without any heating.

(2 marks) (KA2)

- (ii) Explain why re-heating the food is unfortunately not sufficient to ensure Giuseppe doesn't get food poisoning and discuss whether Giuseppe is following the 2-hour/4-hour food safety guide.

(4 marks) (KA2)

- (b) The restaurant Giuseppe works for makes their own fish cakes to be used in fish burgers. The main ingredients in the fish cakes are fish, eggs, capers, breadcrumbs, potatoes, onions, parsley, and wheat flour. Refer to the following stages in the production of these fish cakes:

Stage	Production Process
A	Storing the fish cakes
B	Cooking the fish cakes
C	Serving the fish cakes

- (i) Choose two of the key stages above (A, B or C), and for each stage, outline one hazard that could lead to food poisoning and describe one food safety practice that could be used to overcome the hazard you have outlined.

Stage:

Hazard

(1 mark) (KA2)

Food safety practice:

(2 marks) (KA2)

Stage:

Hazard

(1 mark) (KA2)

Food safety practice:

(2 marks) (KA2)

- (ii) Name a bacteria that may cause food poisoning should the restaurant not follow your recommended food safety practices:

(1 mark) (KA1)

- (iii) Outline three conditions needed for most food-poisoning bacteria to multiply.

1.

2.

3.

(3 marks) (KA1)

- (c) Refer to the table below, which demonstrates the reported number of food poisoning outbreaks by city and year between 2017-2019 to answer the following questions.

Year	City A	City B	City C
2017	2300	7900	3600
2018	2690	5900	3820
2019	2450	5910	4040

- (i) Suggest one possible reason for the change in the number of reported cases of food poisoning in City B between 2017 and 2019.

(1 mark) (IAE3)

- (ii) Name one group of people who are at high risk of developing food poisoning and explain why they are at high risk.

Group:

Explanation:

(2 marks) (KA1)

- (d) Distinguish between food spoilage and food poisoning.

(2 marks) (KA2)

- (e) Explain why it is a good practice when preparing food on a chopping board to cut cooked meat first and then to cut raw meat.

(2 marks) (KA2)

2

7. The Abdella family live quite isolated on a farm in outback Australia, visiting their closest town once a month to buy groceries. They would like to cook the following fish stir-fry recipe as one of their meals but find fresh food is difficult to come by and often expensive.

<i>400 g fresh fish</i>	<i>2 tbs soy sauce</i>
<i>3 spring onions</i>	<i>2 tbs sweet chilli sauce</i>
<i>2 bunches bok choy</i>	<i>¼ bunch of flat-leaf parsley</i>
<i>1 cup of refrigerated ready-to-cook noodles</i>	

- (a) Suggest two modifications to the ingredients of the fish stir-fry above to cater for the difficulty this family has in accessing fresh foods.

Modification one:

(1 mark) (KA2)

Modification two:

(1 mark) (KA2)

- (b) Identify and discuss how two methods of preservation could be utilised to allow the Abdella family to keep a 2kg fish caught in the river for longer than the recommended 1-2 days when refrigerated.

Method one:

(2 marks) (KA2)

Method two:

(2 marks) (KA2)

- (c) The family has recently come into financial hardship, brought about by drought. Suggest two ways the family can save on grocery bills each time they visit town to shop.

(2 marks) (KA2)

- (d) The Abdella's are of Islam belief. Discuss the nutritional impact of not consuming pork or pork products on the health of family members.

(4 marks) (KA2)

Total: / 90 marks

Topic 3

3.1 Food systems & their impact on the environment

Science understanding

The food system involves the stages of production, distribution, and research and development. Each stage affects the nutrition quality and accessibility of the food product:

- Production and distribution
 - The impact of food production methods:
 - Monoculture – soil quality, land availability, use of fertilisers and pesticides
 - Livestock farming – soil quality, land availability, use of antibiotics
 - Organic farming methods of intercropping/crop rotation/mixed farming – crop yield, biodiversity
 - Aquaculture – eutrophication, water quality and contamination
 - Commercial fishing – biodiversity
 - The impact of food production on:
 - Global warming
 - Food distribution and mileage
 - Water availability
 - Food wastage
 - The impact of food packaging materials on:
 - Natural resources – oil, mining, deforestation
 - Environment and pollution – plastics/microplastics, habitats
 - Food waste – landfill, compostable packaging
- Strategies that consumers, producers and retailers can do to reduce food wastage and its impact on the environment.

SACE Subject Outline, 2024.

Food systems

Our **food system** includes all the stages involved in providing food for our population. The stages include growing and harvesting food (called agriculture), food processing, food packaging, transporting, retail, consumption, and the disposal of food and food packaging. Infrastructure is also a part of food systems, which refers to all the structures and facilities needed to provide food. For example, storage buildings, refrigerated transport vehicles and harvesting machinery. Finally, it involves humans: to operate each process of the food system and explore its advancements through research and education. In short, our food system includes every process to get food from paddock to plate!

Nowadays our food systems are facing several challenges including **food security** for growing populations and the issues created by climate change. But the way our food systems are currently run has contributed to these issues and further environmental impacts. Behind the concerns created by food systems is the fact that it is a heavy user of many of Earth's resources, especially water, land and our depleting fossil fuels that create greenhouse gases (see figure 3.1.1).



Reminder

Food security refers to populations having access to enough food to meet their dietary needs.

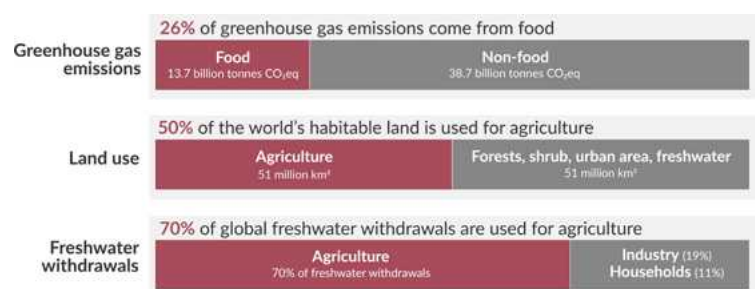


Figure 3.1.1: Our World in Data statistics on global food systems heavy use of Earth's resources

Earth's Resources

Water

Australia is a very dry continent and water shortage, or availability, can be an issue. Our only inland river system noteworthy of mentioning is the Murray-Darling, which is quite small compared to the world's great rivers (see Figure 3.1.2)! Although water is a renewable resource, the amount available for use in Australia is limited due to insufficient river systems and periods of low rainfall such as during drought. Over-use along the food systems, particularly in farming or primary food production, and issues that reduce water quality are also playing a part in water scarcity.

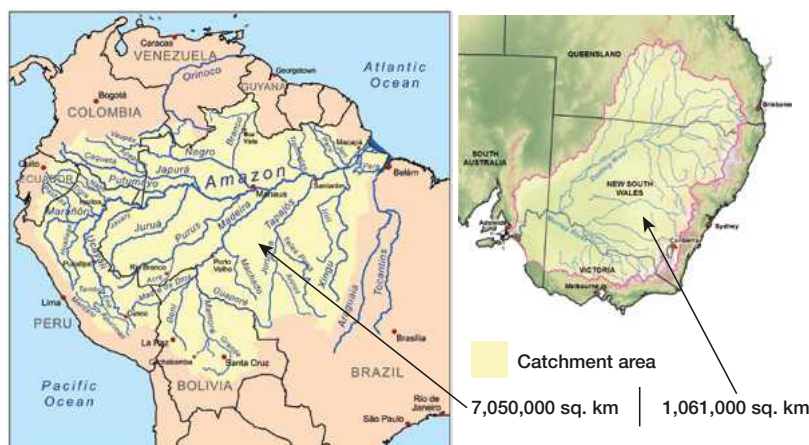


Figure 3.1.2: At 3672km long, the Murray-Darling basin (right) is about half the length of the longest continuous river in South America, the Amazon (left) (6992km).

Land

Australia's landscape is hugely diverse, with vast areas of desert in the centre, rich rainforests in the north and everything in between! Despite our country being arid and mostly desert or semidesert, our landscapes can still support a wide range of land use activities, such as farming, cities, forestry, and nature conservation. Each of our land uses by food system processes can impact upon factors such as water availability, soil quality, global warming, and biodiversity.

Fossil fuels

Fossil fuels, such as coal, oil and natural gas are found in the Earth's crust and contain carbon and hydrogen. They can be burned for energy, which our food systems are very reliant on to power farming machinery, make fertilisers, transport food products, run food processing plants, make food packaging, and more! Of concern is that our fossil fuel reserves are limited and facing depletion. When fossil fuels are used to create energy, it leads to the production of greenhouse gases. The major greenhouse gases released along the food system chain are carbon dioxide (CO₂), methane (CH₄) and nitrous oxide (N₂O) (see Figure 3.1.3).

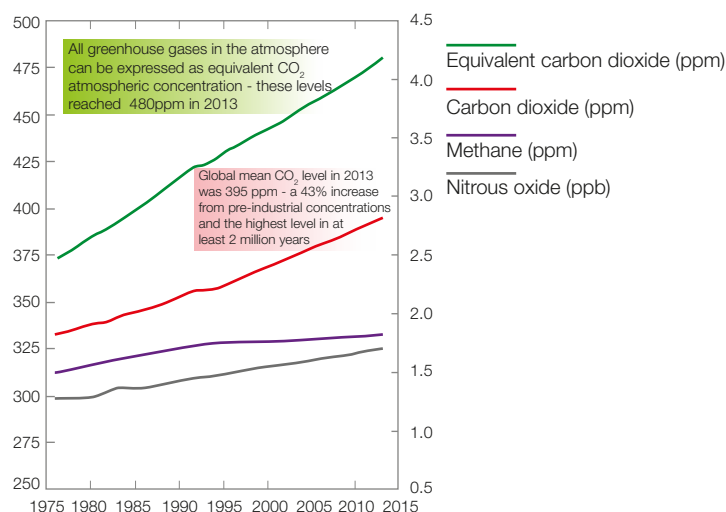


Figure 3.1.3: Increasing greenhouse gases in Australia.

Greenhouse gases can trap heat radiation from the sun and keep the earth warm (much like a greenhouse, hence their name). Climbing levels of greenhouse gases can therefore result in greater heat retention, meaning the Earth has, and is, becoming warmer. This is known as the 'Greenhouse effect' or '**Global warming**' (see Figure 3.1.4). Global warming is contributing to the world's weather patterns being more extreme and unpredictable, which is defined as **climate change**. For example, in Australia this can mean increased prevalence of drought or floods. These weather events can have dire consequences on farming areas and food security, biodiversity, and human populations.

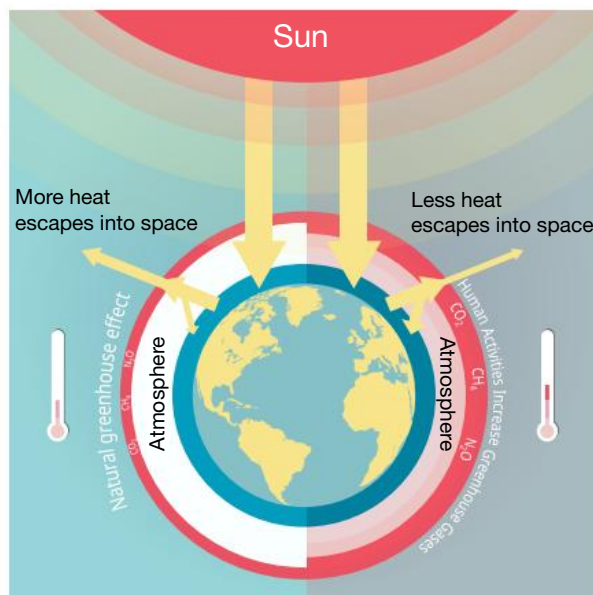


Figure 3.1.4: Natural greenhouse effect (left) and global warming (right).

Primary food production environmental impacts

The first stage of our modern food systems is called **primary food production or agriculture**. It refers to the growing or cultivation of crops or pastures, plants for human or livestock consumption respectively. It also refers to the raising, collecting, or catching of animals or animal products used as food sources, for example eggs, milk and honey, and the picking or harvesting of plant produce. There are a multitude of food production methods including monoculture, livestock farming, organic farming, aquaculture, and commercial fishing.

Monoculture crops

Monoculture cropping refers to growing a single plant or crop across all fields at the same time (see Figure 3.1.5). It is widely used in conventional farming across Australia as it allows simultaneous seeding and harvesting, pest care, nutrient application, and water supply. Better efficiency when specialising and caring for one crop also tends to lower costs and give higher yields. However, the detrimental environmental impacts of monoculture are numerous.



Figure 3.1.5: Corn being harvested on a monoculture farm.

Land availability

Only a small portion of Australia's land is lush arable land, with plentiful rainfall and fertile soils that are rich in nutrients. Arable land is located along Australia's coastline, but as populations have grown and cities have expanded, farmlands have been pushed into areas that are arid, which are not as arable. Farming in areas with less fertile soils and lower rainfall patterns leads to lower yields, which requires farms to expand in size to stay economically viable. Agricultural cropping land now currently occupies around 5% of Australia's land (see purple of Figure 3.1.6). Clearing further land for crops enhances the rate of **deforestation**, which is the clearing of forestland for a specific purpose. This reduces land availability for Australia's **biodiversity**, our variety and prevalence of plants and animals, or flora (plant life) and fauna (animals) respectively, and their interwoven food chains and habitats suffer.

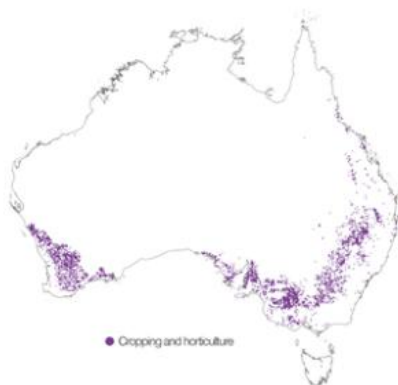


Figure 3.1.6: Land taken by agricultural cropping

Soil quality

Deforestation or clearing of native vegetation for monoculture crops can lead to dryland salinity, whilst monoculture crops reaching harvesting point at the same time, is associated with soil erosion. Both soil erosion and salinity are types of **soil degradation**, which refers to any kind of decline in soil quality.

Dryland salinity

Dryland salinity refers to an increase in the salinity or saltiness of the land. This occurs when the **water table or groundwater** rises from its usual location deep below the soil surface. It rises when rainwater penetrates or leaks down through the soil and adds to the water table. As it rises, the groundwater dissolves naturally occurring salts in the soil, in particular sodium chloride, thereby increasing the saltiness of the water and land as it reaches the Earth's surface. Ordinarily, minimal rainwater will penetrate the soil to reach the water table because large, sparse tree roots utilise the rainwater before it can reach the water table (see Figure 3.1.7 A). However, monoculture replaces native vegetation, particularly trees, with shallow-rooted crops which allows rainwater to penetrate down to the water table and therefore rise (see Figure 3.1.7 B).



Definition

The water table or groundwater refers to an underground area where the Earth's surface is saturated with water.

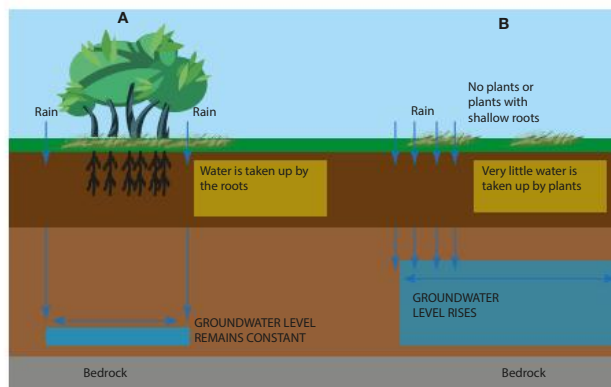


Figure 3.1.7: Stable water table (A – left) and the processes of dryland salinity (B – right)

Once saline waters reach the Earth's surface, it can pass directly into our wetlands, streams, and river systems, reducing water availability by making these bodies of water too salty to provide hydration for native flora and fauna, and too salty for native vegetation or crops and pastures to grow. Areas of Australia with poor soil quality due to salinity concerns are shown in Figure 3.1.8 below.

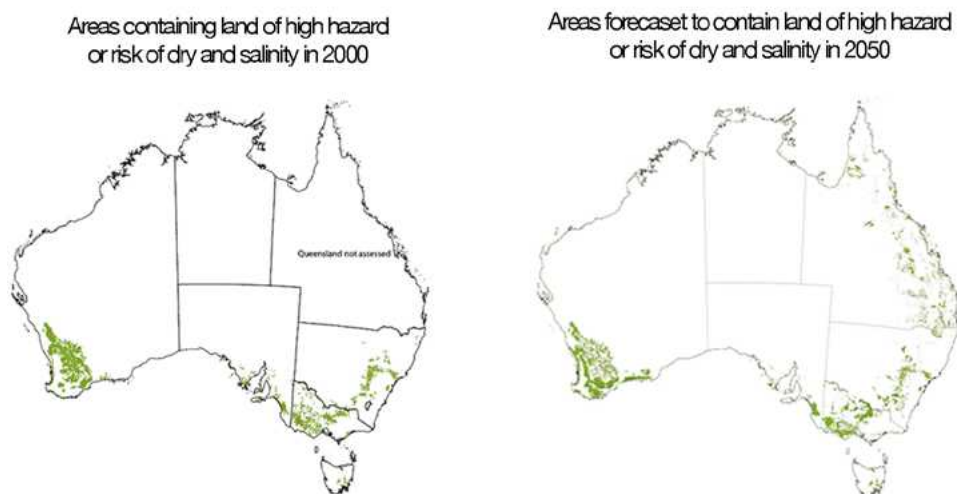


Figure 3.1.8: Areas of Australia with high risk of dryland salinity (left) and areas that could be affected by 2050 should effective reversal solutions not be implemented (right)

Helpful online resources

Salinity and the Murray River

<https://www.youtube.com/watch?v=gi6r2lpGoBY>



Soil erosion

When crops are cleared or harvested for human consumption, fields of land can be left bare or uncovered by vegetation (see Figure 3.1.5 earlier). It is the uppermost layer of soil, called the **topsoil**, that is left uncovered. Without crop roots to hold and bind the topsoil in place, it is subject to being washed away by rain or blown away by the wind. The removal of topsoil by wind and water is termed **soil erosion** (see Figure 3.1.9).



Figure 3.1.9: Soil erosion by wind (left) and water (right) upon the topsoil of empty crop areas.

It is the topsoil that stores the largest percentage of nutrients and a wealth of life such as earthworms and many microorganisms. Therefore, erosion can impact negatively upon biodiversity as well as soil quality by lowering soil nutrient levels. Continual tillage by large tractors, or the digging and over-turning of the topsoil after each growing season to help control weeds, accelerates these issues. As a result, crop yields can also suffer, as their shallow roots rely on drawing nutrients for growth from the uppermost soil layers.

Even if not subject to erosion, if shallow-rooted monoculture crops are continually planted time after time, or season after season, using the same nutrients for growth, they can deplete the topsoil of these nutrients, resulting in infertile or nutrient-poor soils. Infertile soils from crop growth nutrient depletion or topsoil erosion can have further implications upon a food's nutritional quality. For example, in certain areas of Australia (such as Tasmania and the ACT), the soil has been found to be depleted or low in a mineral called iodine. Crops grown in this soil will therefore be low in iodine levels and this can be linked to iodine deficiency causing Goitre in its consumers (see Figure 3.1.10).



Figure 3.1.10: Enlargement of the thyroid gland seen in Goitre.

3

Helpful online resources

Soil erosion:

<https://www.youtube.com/watch?v=MSbbl5lpmik&t=124s>



Soil acidification

To overcome issues of infertile soils, fertilisers are often applied intensively in monoculture farming practices. A **fertiliser** is a chemical that adds nutrients to the soil that are essential to plant growth, thereby enhancing crop yield. Nitrogen, phosphorus, and potassium are always present in fertilisers as they are the main nutrients required for plant growth. Although fertilisers are beneficial to crop yield and food availability, they are associated with a form of soil degradation called soil acidification.

When absorbed into the soil, fertilisers, especially the over-use of high-ammonium nitrogen fertilisers, can leach down through the soil. This fertiliser will add hydrogen ions (H^+) to the soil, decreasing the pH and making the soil more acidic, which is called **soil acidification**. Normally the natural alkalinity of plants counteracts this affect to some extent, but when monoculture crops are all harvested at once, this affect is lost, leaving the soil more acidic. This is a major concern as it causes a decline in crop and pasture growth due to decreasing the available nutrients to plants needed for growth (see Figure 3.1.11). A further concern of changes in soil nutrients and acidic soils is the impact on soil biodiversity. Many microbial processes such as nutrient cycling and the breakdown of organic matter, like harvest remains, are reduced in acidic soils because many microorganisms, primarily bacteria and fungi, can be sensitive to pH changes and their reproduction is hindered.

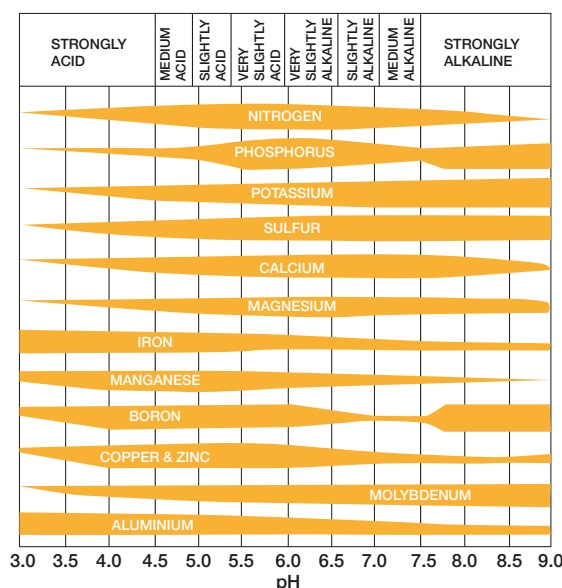


Figure 3.1.11: Availability of nutrients in changing pH.

Water availability

Of all the freshwater available for human use, irrigating or watering crops demands about a third of this water! That third of all available water equates to millions of megaliters each year, with the amount varying per food crop and per season, which is dependent on rainfall (see water footprint of different food crops in Figure 3.1.12).



Figure 3.1.12: Examples of water footprints to produce just one item from a food crop.

Unfortunately, the water applied to crops is not always effectively delivered. It can penetrate down to the water table, causing irrigation salinity, with similar principles to dryland salinity and concerns over water contamination with salt. Water availability is further jeopardised by monoculture practices, such as fertiliser and pesticide use which can cause eutrophication and groundwater pollution, reducing water quality to the point where water can no longer be used as a safe water drinking source.

Eutrophication

Fertiliser application can be via a variety of methods including injected into the topsoil or sprayed from the air above the crops (aerial spraying). No matter the application style, the fertiliser is not always well-absorbed into the soil. Fertiliser not absorbed into the soil can be washed away with rain or with excess water from irrigating fields. It will run-off into and accumulate in nearby rivers, lakes, or other bodies of water. This results in **eutrophication**: an increase in the concentration of nutrients in a body of water. The increased nutrient concentration provides excellent conditions for blue-green algal growth, especially if the water is stagnant or only flowing slowly. Blue-green algae grows rapidly using the nutrients in the water until an intensive area of growth, called **algal bloom** results (refer to Figure 3.1.13). The algal bloom at the water's surface can block sunlight needed for photosynthesis, which provides oxygen and simple sugars needed by water plants to fuel their growth. Therefore, a decline in the rate of photosynthesis results in the death of water plants. Dead plants, including algae, are broken down by decomposers (bacteria) which use up remaining oxygen in the water. This results in the death of organisms in the water due to a lack of oxygen availability used to support respiration, and hence, a decrease in biodiversity. In addition, blue-green algae can produce toxins which are poisonous to animals, including humans, rendering the body of water useless, thereby reducing water availability.

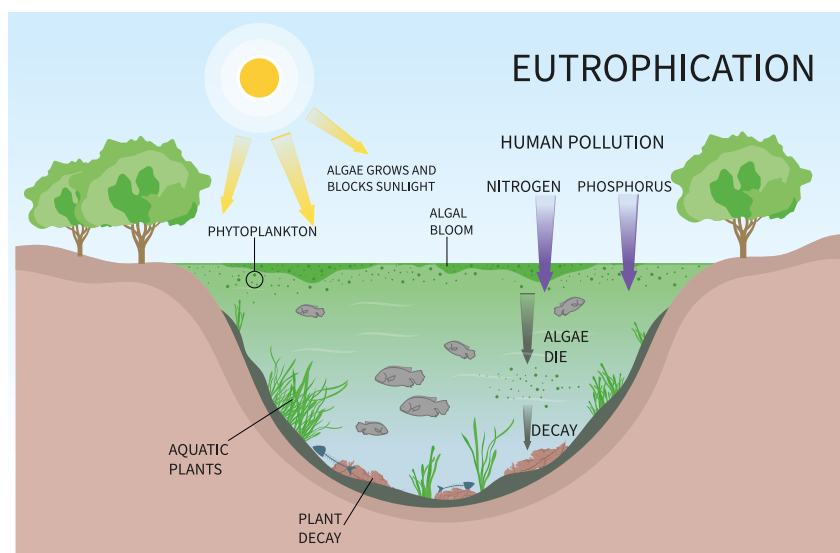


Figure 3.1.13: The process of Eutrophication



Helpful online resources

Eutrophication:

<https://www.youtube.com/watch?v=6LAT1gLMPu4>



Groundwater pollution

Some fertiliser nutrients can even leach far down through the soil, especially through permeable sandy soils and enter the water table, reducing water quality and availability. Should this groundwater be a source of domestic water, the nitrogen of fertilisers (which become nitrates) can be a serious health hazard. Excess nitrates in drinking water can cause health risks such as depleting oxygen levels because they disrupt the functioning of haemoglobin. Nitrates have also been shown to combine with food to make cancer-forming compounds which has been linked to the increased incidence of many types of cancer.

Another form of groundwater pollution arises through pesticide use. **Pesticides** are chemicals aimed to eradicate pests. They can be further categorised into groups such as those shown in figure 3.1.14.

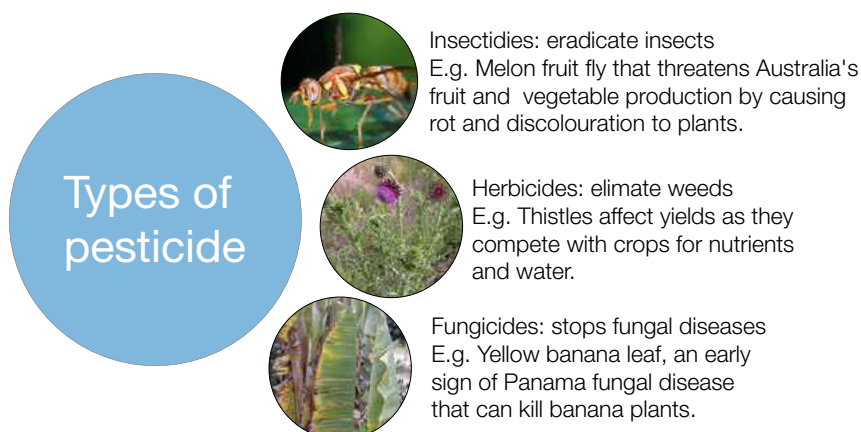


Figure 3.1.14: Types of pesticides and examples of common pests/pathogens in Australia

The production of one crop in monoculture, season after season, can allow pests of that crop to flourish and spread. Should a plant be susceptible to a particular pathogen or pest that reaches the crop, the disease spread from that pathogen, or destruction from that pest, can quickly move through uniform monoculture fields. Both factors jeopardise yields and are reasons why monoculture farmers rely heavily on pesticides.

Pesticides are typically sprayed over large monoculture crops. Of this spray, some reaches its intended farming pests. However, a significant amount reaches other non-target destinations via means such as spray drift and land run-off, caused by wind and rain or excess irrigation respectively (see Figure 3.1.15). Pesticides reaching non-target areas can create air and water pollution, or can even harm non-target native species, affecting Australia's biodiversity. Additionally, soluble pesticides can leach through the soil layers and eventually reach groundwater (see figure 3.1.15), degrading water quality and hence adversely impacting water availability.



Figure 3.1.15: The movement of pesticides, including run-off, drift and leaching after tractor application.

Pesticides will also settle on the fruit and vegetables that we eventually eat. However, FSANZ safeguard us by setting maximum allowed limits for pesticide residues in the food supply in Australia (this includes imported foods as well). The levels of residue allowed in foods are considered safe to eat. For most pesticides, a minimum time between spraying and harvesting of produce is set to ensure safe food as pesticides degrade or break down over time. Levels of pesticide residue in Australia are consistently found to be very low and well within safe limits. In addition, government monitoring programs are put in place to regulate the proper use of all farm chemicals including pesticides. For example, the government body called the Environmental Protection Agency (EPA) deters improper pesticide use by fining farmers for incorrect use.

Global warming

All forms of agriculture in Australia make it the fourth most energy-intensive industry in Australia. Although monoculture cropping is not the predominant form of agriculture, with only 5% of all land use, it still requires significant amounts of fossil fuel inputs such as for the use of harvesters, tractors, and irrigation systems. A notable contribution to greenhouse gases is also via the large amounts of energy needed to produce farming chemicals such as fertilisers and pesticides. In addition, deforestation which involves the clearing of trees, is conducted to expand cropping areas. This reduces the ability of native trees and vegetation to remove carbon dioxide via photosynthesis from the atmosphere and store it as carbon in branches and leaves as they grow (as shown in figure 3.1.16). That stored carbon is released as carbon dioxide when native vegetation is cleared. More concerning is that our soils, especially the topsoil, is an even larger carbon sink than vegetation, meaning it has a greater capacity to capture and store carbon dioxide from the air. Monoculture cropping practices that result in soil degradation are negating the ability of soil to act as a carbon sink. Collectively, the result is increased greenhouse gases that absorb the sun's heat which radiates from the Earth's surface, trapping it in the atmosphere and preventing it from escaping into space. This is known as the greenhouse effect and contributes to an increase in the Earth's temperature, which is known as global warming.

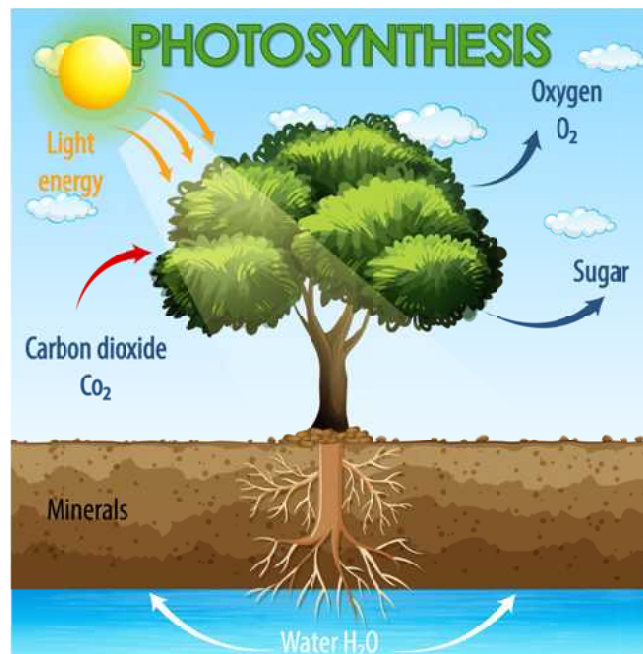


Figure 3.1.16: The process of photosynthesis allowing trees to absorb and store carbon dioxide from the atmosphere.

Livestock farming

Livestock farming refers to the practice of raising and managing agricultural animals on farms for meat and animal products that give a profit such as dairy, wool, eggs, and honey. The top livestock farming commodities of Australia are shown in Figure 3.1.17 and the dominant three are summarised in Table 3.1.1.

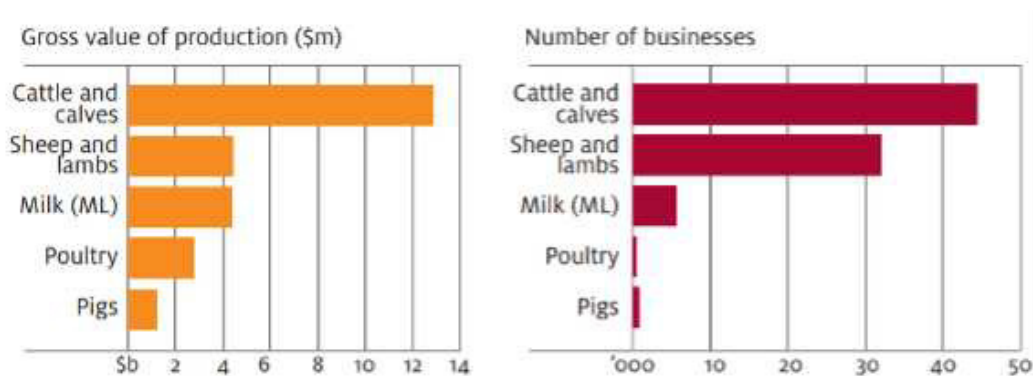


Figure 3.1.17: 2018-19 Australian Bureau of Statistics data on the top 5 livestock commodities

Table 3.1.1: Dominant livestock farming of Australia

Farming type	Description
Beef cattle farming  <i>Beef cattle feedlot</i>	Beef cattle farming refers to the breeding and raising of cattle until of market age. Whilst increasing in size from calf to market age, beef cattle graze for food upon pastures, or from native land and grasses. They may also have a final feeding stage in feedlots where they are fed supplement grains to allow for more muscle or meat weight gain.
Sheep farming  <i>Sheep shearing</i>	In Australia, sheep farming for both wool and meat is a common practice, although some farms specialise in only the one aspect. Sheep farming holds similarities to beef cattle meat farming in how they are fed, whilst sheep also tend to be shorn twice a year, with the wool that is removed by clippers or shears, being used for various products like clothing and blankets.
Dairy farming  <i>Automatic milking machines</i>	Dairy farming is for the purpose of milk production. Milk is collected from cows that have delivered a calf in the months following the birth. During milking, which typically takes place twice a day, cows enter a milking parlour. The milking parlour is often highly mechanised, where cows can be milked with automatic milking machines! Milking machines have allowed for more efficient milk collection and the ability to milk more cows in a shorter space of time, thereby allowing farmers to increase cattle herd sizes and milk yields. Dairy cattle typically graze on pastures; however, farmers may use supplementary grain feeding as well.

Land availability

Pasture grazing for cattle and sheep farming is preferred over native vegetation by farmers, because plants grown in pastures are of high yield, which allows for a greater number of sheep or cattle, and therefore better meat or milk yield. However, pastures tend to only grow well in the southern states and south-east Queensland due to these regions having more arable land that is supported by their cooler climates (see lime green regions of Figure 3.1.18). Areas suitable for pastures are primarily occupied by monoculture cropping and dairy farms, leaving land availability issues a concern mostly for the beef cattle and sheep industries. The result is that most sheep and beef cattle farms get pushed into the western and northern states, plus the middle of Australia (see grey regions of Figure 3.1.18) where weather patterns tend to be hotter and dryer. Pastures don't fare well in these conditions, so farmers rely on resilient native grasses found across these regions. Native grasses do not tend to grow densely or give high yields like pastures and can be quite sparse. This results in expansion of farming areas over vast amounts of land to support the large daily food needs of sheep and especially cattle. As such, livestock farming occupies close to 50% of all Australia's land! Sheep and cattle foraging over vast areas of native vegetation poses a threat to Australia's biodiversity due to these farming animals competing with wildlife such as kangaroos for native grasses as feed.

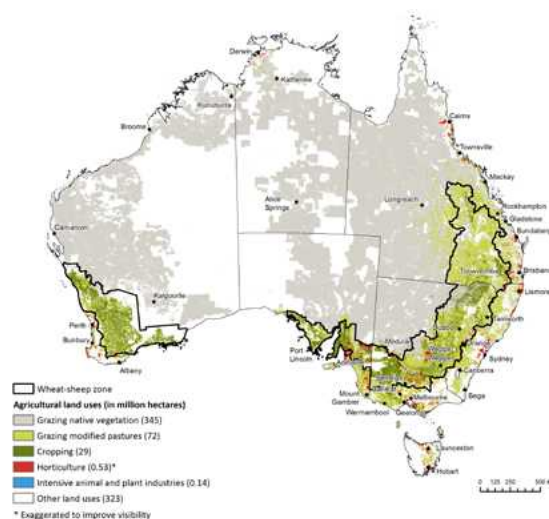


Figure 3.1.18: Agricultural production zones

Soil quality

For livestock to graze upon pastures, land must first be cleared, which results in similar biodiversity concerns plus soil quality concerns as growing monoculture crops. In addition, should poor livestock farming methods be used, or animals not be monitored regularly due to being spread over vast areas of land, land can be overgrazed. Overgrazing means livestock consume plants to the point where it's difficult for them to regenerate or grow quickly causing the land to become bare. Further heightening soil degradation concerns are livestock hooves and sheer animal weight compacting soil, increasing the topsoil lost with run-off, as rain (water) cannot penetrate the soil as effectively (as shown in figure 3.1.19). In addition, fertilisers are often used to increase the yield and quality of pastures which adds to soil acidification.

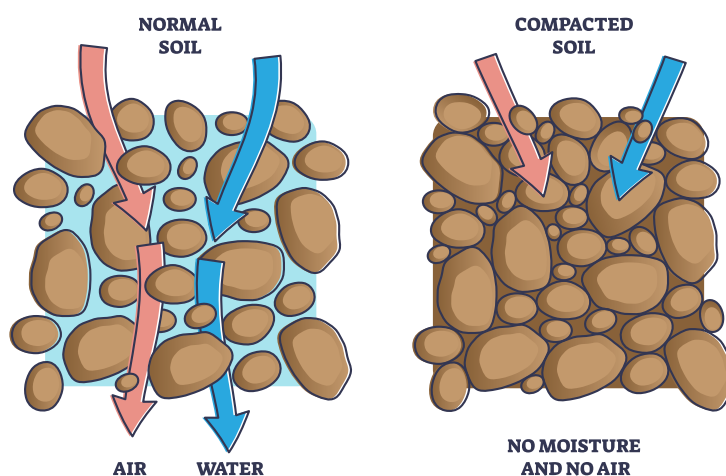


Figure 3.1.19: A comparison between normal soil and compacted soil, where water and air cannot penetrate.

Water availability

Like growing crops, livestock farming has immense water demands to grow livestock pastures and for animal consumption. For example, a milking cow can drink up to 200L per day of water! When considering how much water an animal drinks until of market age, plus the water needed to grow animal feed, the water footprint of animal products is very high (see figure 3.1.20) compared to plant crops (refer back to figure 3.1.12). For example, about 900L of water is used for every 1kg of corn grown, whilst close to 9000L is needed for 1kg of meat from sheep or goats! Currently animal agriculture is responsible for up to one third of all freshwater consumption in the world today, reducing water availability.

In livestock farming the main issue that decreases water quality and impacts upon water availability is the run-off from cleaning livestock handling, milking, and feeding areas, especially urine and faeces. This run-off leads to eutrophication issues as it adds additional nutrients to water ways.

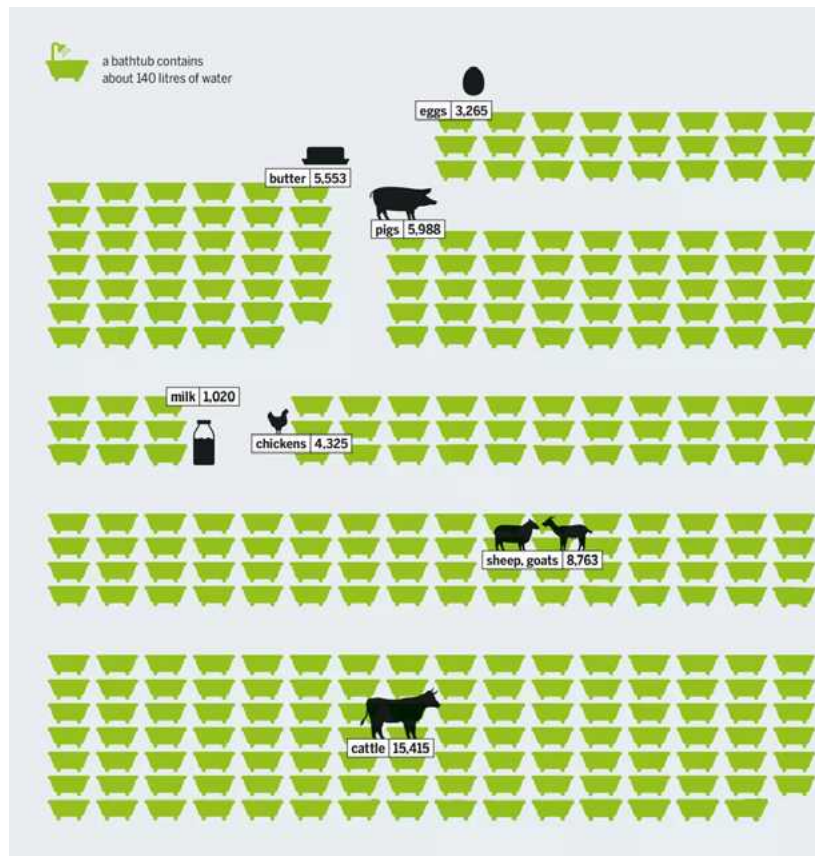
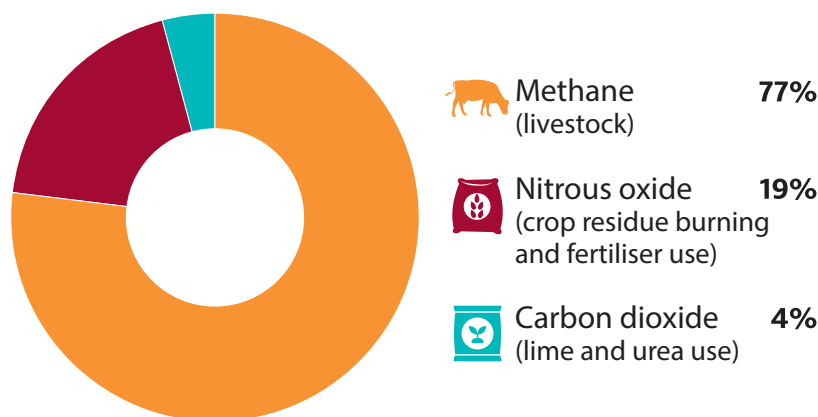


Figure 3.1.20: Global averages of water used in litres/kilogram and bathtub equivalent to obtain 1kg.

3

Global warming

Livestock farming is the predominant form of agriculture across Australian land, making it the largest agricultural contributor to greenhouse gas emissions. Agriculture contributes to about 14% of all greenhouse gas emissions. As per monoculture cropping, deforestation, and its connection to increased atmospheric carbon dioxide is at play again to create pastures, as is the reliance on fossil fuels to power operational machinery, for example automatic milking parlour machinery. However, it is the methane that is produced from livestock digestion processes and manure decomposition, especially from cattle, that adds a major concern to climate change. Methane is a potent greenhouse gas, much stronger than carbon dioxide. Every 1kg of methane released into the atmosphere is equivalent to around 25kg of carbon dioxide. Considering a single cow on average produces between 70 and 120 kg of methane per year, it is clear how methane is a major contributor to agriculture's greenhouse gas emissions (see figure 3.1.21). In addition, nitrous oxide emissions are released from livestock manure and nitrogen-based fertilisers used on pastures, and, and can be 300 times more potent than carbon dioxide at heating the Earth's atmosphere.



Source: DISER 2020

Figure 3.1.21: Predominant greenhouse gas emission sources across all agricultural farming methods in Australia

Use of antibiotics

Antibiotics are used widely across all types of livestock to keep animals healthy by killing bacterial infections. Antibiotic use in livestock can have implications upon food accessibility as antibiotic residue can be present in meat and animal products. This can be hazardous; for example, antibiotic residue in milk may cause sensitivity and allergic reactions in humans. Another concern is that if antibiotic residue or low levels are continually consumed by humans, our bacteria may build up resistance to the antibiotic. Antibiotic-resistant bacteria may also have developed in livestock that are over-exposed to antibiotics and pass directly to humans when present in contaminated meat that is consumed. This would have repercussions on human health dependent on the type of bacterial infection that could no longer be controlled by its usual antibiotics. A similar effect would occur in livestock as well, and an uncontrolled bacterial infection amongst livestock could have negative implications upon food security. Strict regulations are therefore put in place to ensure that animals are not given any antibiotics in the few weeks leading up to slaughter and strict limits on the amount and frequency of antibiotic use exist. This helps reduce the chance of antibiotic-resistant bacteria developing, and the amount of antibiotic residue left behind in the meat. Additionally, rules and regulations around animal products consumed are extensive. For example, milk is tested for antibiotics and must be discarded if residues are found.

Organic farming

Organic farming offers alternate farming methods to conventional livestock farming and monoculture cropping.

Organic farming is the primary production of food without the use of genetic modification and synthetic or artificial chemicals, including pesticides and fertilisers for crops and antibiotics for animal health. Organic farms are not completely chemical free, animals can be treated with vaccines to prevent disease, and pesticides and fertilisers can be used, but they are limited to those naturally derived, not synthetically. For example, a plant extract from chrysanthemum flowers called Pyrethrum that can kill pest insects, is permitted on organic farms as it degrades by sunlight into non-toxic byproducts quickly. Organic fertilisers tend to be derived from livestock manure, and plant matter or compost, with the ability to release nutrients slowly into the soil. A slower release of nutrients into the soil from organic fertilisers can reduce the need for repeated applications, whilst quick destruction of naturally derived pesticides reduces the time toxic pesticides can harm non-target organisms, both of which are beneficial to the environment and our biodiversity, which is at the heart of organic farming.

Organic farming practices aim to mirror nature, protect the natural environment, and reduce the environmental impacts of agriculture. Creation or protection of water ways and native vegetation, for example corridors, throughout an organic farm is a common practice, as is diversity in crops being grown (see examples of organic farming methods plus the corridor of native trees surrounding the intercropping field in figure 3.1.22). Diversity in crops and maintaining native vegetation has many benefits including reducing the need for farming chemicals, controlling soil erosion, boosting soil quality, attracting pollinators, and providing areas of shelter and travel to preserve our biodiversity. Unfortunately, diversity means there is less specialised care of one crop, and naturally derived farming chemicals are generally not as effective, so organic farming comes at the cost of crop yields, often producing less than or equal to 25% of conventional farming practices like monoculture cropping.



Crop rotation

The practice of growing different crops sequentially on the same field. E.g. Corn is planted season one, followed by soybeans the next season, a legume that returns nitrogen to the soil.



Intercropping

The practice of growing two or more crops in the same field at the same time. E.g. Sugar cane and cabbage being grown in the alternate rows during the same season (note native tree corridor in background).



Mixed farming

The practice of rearing livestock and growing crops on the same farm. E.g. Sheep grazing on wheat stubble after it has been harvested.

Figure 3.1.22: Some organic farming practices

Fisheries

A fishery is an area where fish are caught for commercial or recreational purposes. Australia's seafood industry relies on both commercial fishing and aquaculture to meet our consumption needs. **Commercial fishing** involves capturing wild fish and other aquatic organisms from waterways such as oceans and rivers. Methods to catch wild fish from their natural habitats include trawling and longlining (see figure 3.1.23).

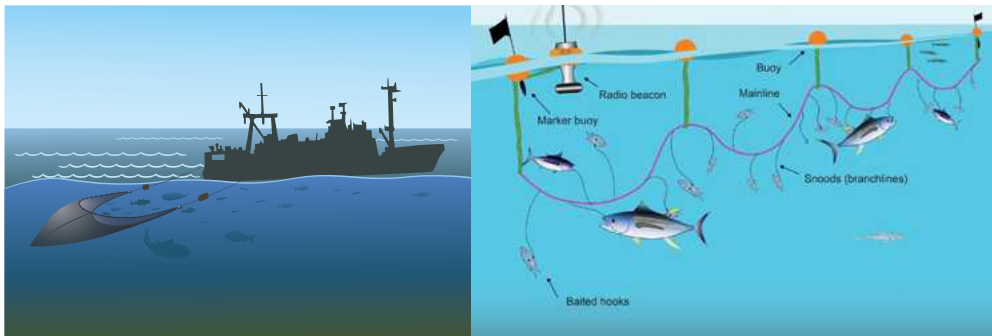


Figure 3.1.23: Commercial fishing methods of trawling (left) and longlining (right)

Commercial fishing methods are often connected to overfishing concerns with large numbers of aquatic life being able to be caught at once. Fish and other seafood can be captured at a higher rate than the population can reproduce and replace themselves, even leading to some species being listed as threatened species. This not only jeopardises food accessibility, but it can negatively affect biodiversity by disrupting food chains, as captured fish may be an integral food source for other aquatic life. Bottom trawling nets can further affect aquatic biodiversity as nets can damage ocean floors by removing soft mud seafloors and disturbing sediments to expose underlying rock. This can lead to reductions in fauna biomass, numbers, and species richness. Bycatch is another environmental issue associated with commercial fishing. Bycatch refers to fish or other marine species such as dolphins, turtles, and sawfish or even seabirds that are caught unintentionally. Sadly, many bycatch animals are either protected, vulnerable or endangered.

Aquaculture is an alternate fishery method heavily relied on in Australia. Its practice is increasing as it provides a method of sourcing seafood more sustainably by preventing the overfishing of native seafood. **Aquaculture**, or fish farming, is rearing aquatic organisms including fish, molluscs (e.g., mussels, octopus), crustaceans (e.g., crabs and prawns) and aquatic plants, in a defined marine (saltwater), estuary (mix of salt/fresh) or freshwater area (see Figure 3.1.24). Because aquaculture seafood receives controlled feedings, and fish farms are protected from predators by barricading off portions of natural bodies of water to rear marine life intensively, yields are enhanced. However, for rearing larger aquaculture fish, the diet is typically of high-protein feed pellet often sourced from smaller wild fish populations. Using native fish to make feed pellets creates similar over-fishing concerns as commercial fishing. Aquaculture is also associated with several other environmental concerns.



Fast fact

Aboriginals have practiced (and continue to practice) small-scale aquaculture methods utilising fish traps to capture and hold aquatic life for food. Fisheries have expanded this traditional method to large scale operations and now provide close to half of all seafood consumption needs.



Figure 3.1.24: Marine aquaculture utilising ocean areas (left) and an underwater view of the intensive rearing of aquaculture fish (right).

Water availability

In open water aquaculture systems, wastes can escape netted fish holding areas resulting in water bodies becoming contaminated. Contaminated water can reduce water quality, leaving water unsafe for wildlife and human consumption. The wastes that can contaminate include concentrated aquatic wastes like fish faeces, chemicals used such as antibiotics and uneaten feed pellets that introduce extra nutrients directly into the water, which also leads to eutrophication concerns.

The proximity of fish farming organisms in conjunction with water contamination can also amplify disease and parasite spread, including to wild populations sharing the same bodies of water. The bodies of water used in aquaculture are also over significant areas, thereby making it a practice that adds to agriculture's water-scarcity issue. Even if fish farms don't section off water in natural water bodies, and instead build ponds or tanks or large aquariums, water is required to fill and maintain these artificial habitats, adding to water availability concerns. The land used to create artificial fish farms, or the open water farms encroaching on natural habitats are further involved in biodiversity reductions.



Helpful online resources

Which seafood is better for the environment: farmed or caught wild?

<https://www.youtube.com/watch?v=zn6AD3khu1U>



The impacts of food processing and food miles

After harvest, collection or slaughter, raw products from primary production can be transported to food manufacturing plants for food processing and/or distributed to places of sale.

Food processing

Food processing or manufacturing turns raw products from primary production into the foods we eat. Most foods undergo some type of processing, such as preservation and packaging, carried out in workplaces including:

- Bakeries
- Dairies
- Food manufacturing plants or factories
- Mills, e.g., grain processing

Food miles

Transport of raw or processed food products is called **food miles**. It is a measure of the distance food travels between production and consumption. Australian domestic food products require distribution across the country while imported or international products need to be firstly transported over air or water before distribution across Australia. Whether international imports or domestically sourced foods, food can **travel over vast distances** to reach consumers, particularly those in remote populations.



Fast fact

Our shopping basket has travelled an average of 21 073km, almost the whole way around Australia's coastline. Should four imported items be added to the shopping basket, this equates to approximately an additional 50 000km! The resulting fossil fuel use for all food transporting trucks carrying one shopping basket of 25 items on any given day is the equivalent of 2,830 cars driving for a whole year (Community Environment Park's Food Miles Report, 2008).

Global warming

High food miles equate to high petroleum needs to create petrol, which contributes to the depletion of fossil fuel reserves. Petrol is combusted to power motor vehicles, with exhaust emissions creating greenhouse gases. In addition, food processing workplaces often utilise power-driven machinery requiring a lot of energy (see Figure 3.1.25), again placing demands on our depleting fossil fuel reserves. Food processing workplaces also rely on other resources such as water, for example, in the cleaning and cooking of raw food products before sale.



Figure 3.1.25: Highly mechanized biscuit manufacturing plant

The packaging of food, a final step of food processing, contributes to global warming in a few ways. Firstly, the processing or creation of packaging materials requires resources like water and is powered by the extraction and processing of fossil fuels like oil. For example, the manufacture of plastic food packaging relies on fossil fuels, such as natural gas or crude oil refining for its production. These fossil fuels are burnt, releasing greenhouse gases, and contributing to global warming.

Another problem that stems from the packaging of food is that much of the packaging ends up in landfill (see Figure 3.1.26) which can take hundreds of years to decompose completely, if at all (as shown in Table 3.1.2). For the packaging materials that can decompose, greenhouse gases, such as methane and carbon dioxide, are released into the atmosphere further contributing to global warming.



Fast fact

Australians throw away around 1.9 million tonnes of packaging each year – enough to fill the Melbourne cricket ground nine times over!



Figure 3.1.26: Packaging materials in landfill.

Table 3.1.2: The time it takes for packaging types to decompose in landfill.

Rubbish	Paper	Milk carton	Plastic bag	Tin can	Beer can	Plastic bottle	Styrofoam	Glass bottle/jar
Time to decompose (years)	0.25	0.25-5	10-50	100	200-500	450	Never	Never

Pollution

Decomposition can also result in chemicals from packaging materials, such as labelling inks and dyes, leaching into and polluting the groundwater and soil. Packaging can also make its way into our environment, instead of landfill, becoming litter that contaminates our water and soil, and exposes our wildlife to risks associated with eating or becoming entangled in it. When plastic debris is left to decompose as litter in the environment, it's gradually broken down into smaller and smaller fragments, until it forms particles smaller than 5 mm, known as **microplastics** (refer to figure 3.1.27). Microplastics range from a fraction of a millimeter (0.1mm) to 5mm. Nanoplastics will be formed with further plastic degradation, into tiny particles around 1000 times smaller than microplastics, which will likely never biodegrade! Due to their small size, both microplastics and nanoplastics can be ingested by organisms. Their presence in ecosystems has raised concerns about their impact on wildlife and potential transfer through food chains to humans. They could potentially have long-term adverse health effects due to both absorbing and giving off harmful toxic chemicals. There is, however, scientific uncertainty about the hazards surrounding them.

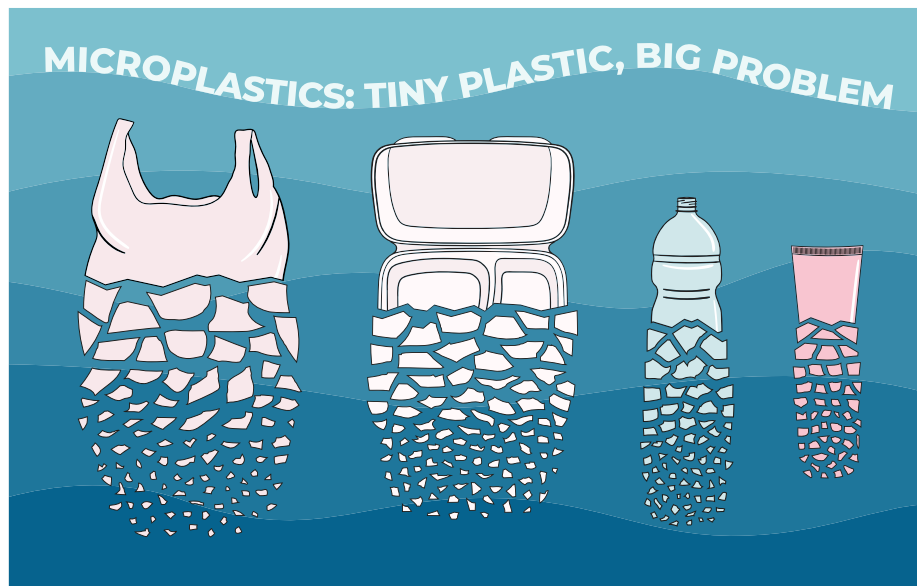


Figure 3.1.27: The breakdown of plastic packaging into microplastics

The packaging materials themselves place a burden on Earth's natural resources as well. Over the past few decades, the quantity of natural resources Australians use, including aluminium, tin, and steel for cans for example, sand for glass and trees for paper and cardboard, has doubled! Sourcing these resources, whether it be via clearing land, or via **mining** and extracting them from the ground, comes with environmental concerns of deforestation and habitat destruction (see Figure 3.1.28). Similarly, mining is a technique often used to extract fossil fuels. In addition, landfill sites and food manufacturing workplaces also require land space and deforestation to firstly occur.



Figure 3.1.28: Aluminium ore mining (left) and coal mining in an open pit following prior deforestation (right)

Food systems impact on food waste

The final step of our modern food systems is food waste management, with all food system stages contributing to food waste (see Figure 3.1.29). Of all the food that is produced globally, at least one third of it is lost or wasted! Sadly, Australians contribute significantly to this high average, with around 40% of food produced here being either lost or wasted. Both food loss and food waste refer to food that is discarded and not eaten. However, it is important to note that there is a slight difference between food loss and waste. The definition of each varies, with **food loss** predominantly considered food that is discarded before it reaches the consumption stage of households and food businesses, whilst **food waste** refers to food discarded at the consumption stage of our food systems.

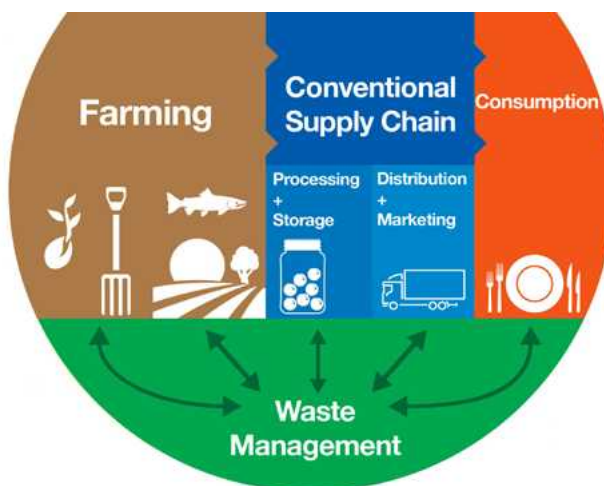


Figure 3.1.29: The main components of our food system, which all contribute to food loss and waste

Primary food production

Food loss begins at the first stage of the food systems supply chain: on farms. Agricultural food production losses occur for many reasons, including:

- Severe weather, disease, pest destruction, poor soil, and water scarcity
- Damage during production, harvesting, packing, or handling.
- Poor storage infrastructure.
- Rejection of produce due to food safety concerns or by supermarket chains and other retail markets for not meeting aesthetically pleasing contractual specifications such as quantity, colour, or size (see figure 3.1.30).
- Unharvested crops due to low demand (changes in consumer tastes and preferences), labour shortages, fall in market prices, or contractual supply arrangements*.

*In developed countries like Australia, supermarket chains can create farmer-buyer sales agreements, whereby farmers will grow and supply the quantities of produce expected to sell. Should there be unexpected change in market trends, and quantities sold or expected to sell fall, farmers are still obligated to deliver the original quantity to the supermarket chain. This can result in surplus produce, that is contractually unable to be sold by farmers to other buyers, donated to charity, or used for alternate purposes. These contractual agreements can therefore lead to large scale food destruction. In addition, overproduction is a normal practice to counteract any risks to produce loss to ensure supermarket supply needs can be met. For example, in Australia, up to 25 per cent of all vegetables produced don't leave the farm!



Figure 3.1.30: Examples of 'ugly' fruit and vegetables that can be rejected by retailers.

Food processing

After leaving farms and on reaching food manufacturing workplaces, food loss can be attributed to a variety of causes such as:

- Poor storage infrastructure.
- Excessive trimming of meat, vegetables, fruit for processed foods.
- Spillage e.g., milk.
- Changes in production due to consumer demand e.g., failure to predict demand and over-producing.
- Technical inefficiency or malfunction in processing that leads to defects in the final product such as incorrect shape or weight, or spoilage due to contamination (chemical, physical or biological).

Distribution and marketing

The distributing and marketing stage of our food systems includes the transport of food, for example from farm, processing workplaces, storage, retail or wholesale venues, that allows consumers to access food produce.

Once produce leaves farms, food or livestock can be lost via:

- Poor temperature control.
- Physical damage during transportation.
- Inappropriate primary and/or secondary packaging.
- Food approaching use-by dates due to large food mileage of long transport times.

Once produce reaches retailers, many retailers refuse to buy food close to their expiry dates, returning orders, resulting in food waste of safe foods. Other reasons for food waste at the retail level include:

- Poor stock management, including over-ordering to stock shelves for customer satisfaction.
- Improper stock rotation, storage, and handling practices.
- Customers buying later expiry date products from the back of stock rotations, leaving earlier dated products to expire more readily.
- Produce no longer meets quality standards, not as aesthetically appealing, and is discarded.
- Retailers stocking 'convenience' foods to meet consumer needs e.g., ready-made sandwiches and pre-sliced fruit and vegetables, often with a short shelf-life increasing the chance of being discarded before sale.
- Limited access to facilities to recycle or repurpose food waste.

Consumption

In general terms, the consumption stage refers to places where foods are prepared to eat. This translates to food waste from households or food businesses such as restaurants. Causes of food waste at this stage include:

- Poor stock management, handling, and storage.
- Over-purchasing or over-cooking of food that is then thrown away.
- Commercial pressure from the marketing stage to over-purchase e.g., promotional activities such as 'buy three, get one free.'
- Limited knowledge of how to safely repurpose or store food leftovers.
- Confusion over 'use-by' and 'best-before' date labelling.
- Limited access to food waste collection systems.

Australians are very wasteful, throwing away around 2.5 million tonnes of food a year per, equivalent to more than 4kg per week per household. Lunch box waste typically contributes to about one quarter of this waste. An additional 2.2million tonnes is discarded from the commercial and industrial sector (includes food processing, marketing e.g., supermarkets and food preparation premises e.g., restaurants).

In summary, around 14% of all food is lost globally during the initial food systems stages of agriculture, processing, and distribution, but most, 17% is wasted at the retail and consumption levels (see Figure 3.1.31 for examples of food loss and waste along the food system stages).

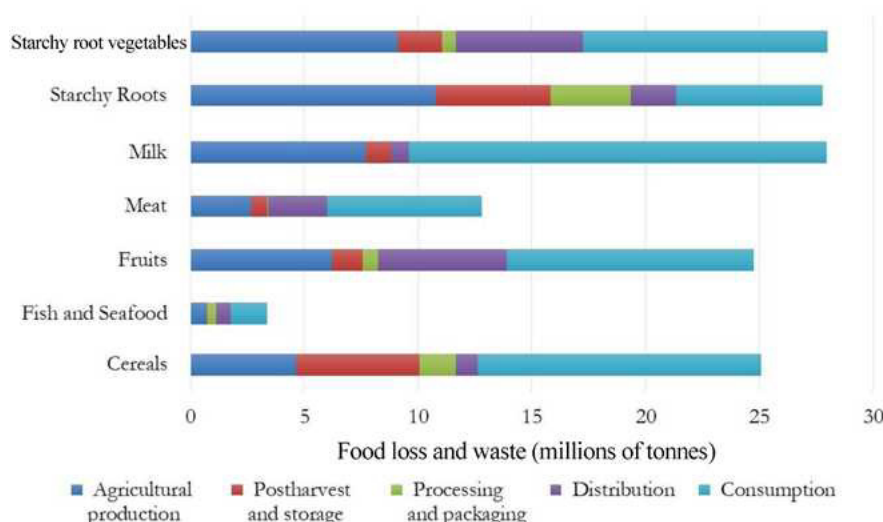


Figure 3.1.31: Estimated food loss and waste of a variety of foods in regions with very good food security (includes Australia)

3

Strategies to reduce food loss and wastage

An issue surrounding food being discarded is that it is not just the food that is wasted, it's the energy and fossil fuels, **land**, **water**, farming labour, chemicals such as fertiliser, and many other resources that were invested in its production, not to mention the countless associated futile repercussions on the environment from the foods' production! Furthermore, discarded food is sent to landfill where it rots and releases methane gas, adding to climate change concerns. Another issue is that if just a third of discarded food was saved, it would be enough food to feed the over 800 million people that go to sleep hungry nightly. With such grave issues surrounding food loss and waste, it is on the world's political agenda, with many government initiatives being run to globally reduce food being discarded in half by 2030.



Fast fact

The amount of land used to grow wasted food in Australia covers a landmass larger than the state of Victoria, and throwing out one burger wastes the same amount of water as a 90-minute shower! (Source: <https://www.dcceew.gov.au/environment/protection/waste/food-waste>)

Food packaging

Packaging waste is responsible for polluting our environment and it takes a lot of energy, water, and other natural resources to produce. Plastics are a predominant source of litter, and this can be attributed to single-use plastic packaging and the increase of convenience snacks and ready-made meals using it. In response to environmental concerns, single-use plastic bags have been banned in all Australian states and territories and some states, led by South Australia, have banned single-use cutlery, straws and polystyrene cups and plates. Australian governments have also endorsed the Australasian recycling label (see figure 3.1.32) and states and territories are implementing legislation and container deposit schemes that specifically address packaging litter issues. An incentive of money for returning containers to be recycled is helping to keep plastic out of the environment and landfill.

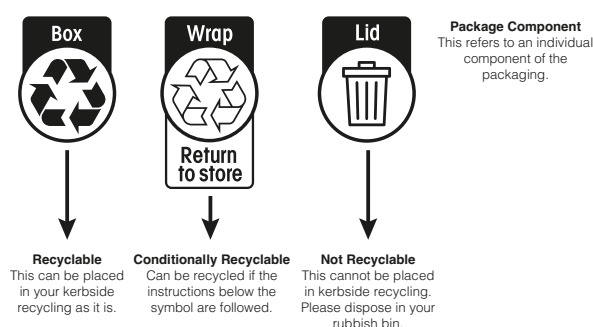


Figure 3.1.32: The three variations of the Australasian recycling label.

There is also a push for food manufacturers to reduce packaging. However, simply banning and reducing packaging to counteract environmental impacts is a complex issue because of packaging's role in reducing food waste. Food waste is just as concerning an issue, if not more, so a balance between packaging reduction and food protection is needed. Food packaging is important in reducing food contamination risks, the chance of physical damage during transportation and the extension of the shelf-life of produce. In fact, packaging may be unavoidable if we want to reduce food waste! Therefore, there is an increasing need for environmentally friendly sustainable packaging materials that maintain the desired physical barrier properties as conventional packaging. Innovative biodegradable and compostable packaging types are currently entering the market in response to this need.

Compostable packaging

Compostable packaging is growing in popularity because it breaks down naturally within a few months into a nutrient-rich compost that should leave no harmful substances behind in the environment. Compostable materials are usually made from plant-based substances (see Figure 3.1.33). Some of these packaging materials can be composted through food waste bin processes, whilst others must be composted through explicit industrial processes which are not yet widely available.

	Bagasse packaging - A type of fibrous food packaging. Bagasse is the fibrous waste material that remains after the juice is extracted from sugarcane production. - Examples of use: cups, plates, containers.
	Polyactic acid (PLA) - PLA is a type of bioplastic made from any starchy plant with fermentable sugar like corn, sugarcane and potato. - Examples of use: cups, plates, containers.
	Mushroom (or mycelium) packaging - Packaging made from the root structure of mushrooms and other agricultural waste such as straw or rice hulls. - Examples of use: food containers.
	Cellulose packaging - Cellulose is created into thin plastic-like material from the cellulose taken from cotton, wood and hemp. - Examples of use: wrapping for fruits and vegetables.

Figure 3.1.33: Examples of compostable packaging materials

Helpful online resources

'Mushroom packaging'

<https://www.youtube.com/watch?v=zw2O1PhrzA0&t=2s>



Biodegradable packaging

Biodegradable packaging materials can also break down naturally, reducing environmental impact, but over an undefined period. It can either be a shorter or longer timeframe and materials are not necessarily broken down into completely harmless substances or leave behind nutrient-rich compost. For example, biodegradable plastics break down quickly into microplastics, the harm of which is still largely unknown. However, biodegradable packaging is more versatile and will break down in many different environments or conditions such as soil or water. It doesn't have the same breakdown constraints, or specific environmental needs provided by industrial businesses, as most compostable packaging. For these reasons, the most common practices today are for food manufacturers to use a combination of compostable and biodegradable materials for sustainable food packaging.

Broad categories of environmentally or eco-friendly packaging types include:

- Fiber food packaging, like bagasse packaging, which uses fibrous waste materials or sustainable natural fibers such as wood pulp, bamboo, and wheat straw alone or in conjunction. Bagasse and bamboo fibers for example are often used together in food packaging.
- Bioplastics, an alternative to PLA made from avocado waste, corn starch, or vegetable oils.
- Biofilms, like cellulose packaging but utilising alternate sources like corn starch.

Despite innovative food packaging types entering the food supply chain, larger impacts on food waste will come through changing the methods, behaviours and habits of producers, retailers, and consumers.

Producers

Farmers can take several steps to reduce food loss. Some of the strategies they can employ include:

- Improving technology to sense crop or livestock distress or to harvest/collect produce more efficiently (see digital farming in chapter 3.2).
- Invest in storage infrastructure with adequate ventilation, controlled temperature, and humidity to optimise produce shelf-life.
- Donating surplus produce to the food rescue sector, including organisations like Food Bank, Ozharvest & SecondBite, so that it can be redistributed (see Figure 3.1.34). Food recovery charities redirect surplus food to community food programs for those with food insecurity, such as the homeless. Donating surplus food to organisations like these means that food can be redistributed to people who need it, instead of going to landfill.
- Sell imperfect or 'ugly' fruit and vegetables directly to consumers at reduced prices.
- Process excess or imperfect produce into foods such as jams or juices.
- Improve collaboration and communication – strong relationships with retailers can help farmers better understand market demands and therefore adjust production accordingly to achieve a closer match between supply and demand, rather than overproduce. Farmers could also strive to build relationships with alternate markets to diversify sales for left-over produce.
- Utilise crop waste to produce compost, animal feed, chemicals, other materials such as biodegradable packaging and biofuels, or even to rear insects that could be used for example, in aquaculture feed pellets, thereby decreasing the potential environmental impact of sourcing pellets from wild fish populations.
- Converting to biogas, made from anaerobic digestion of organic farming wastes, for electricity generation.



Figure 3.1.34: Logos of food recovery charities in Australia.

Retailers

Like producers, retailers can also reduce food loss by ensuring proper storage conditions are provided, collaborating with farmers or suppliers, and donating surplus produce to food banks and charitable organisations. Retailers can further play their part by:

- Investing in proficient technology and appropriate employee training to monitor stock levels, expiration dates, and sales data to help avoid overstocking produce and food expiring on shelves.
- Offer discounts on foods approaching expiry dates such as 'half price' with clear labelling to promote sale, rather than encouraging customers to bulk buy e.g., buy two, get one free, which increases the likelihood of perishable items only then being wasted at the consumer level.
- Negate the need to keep shelves full for customer satisfaction and instead adjust produce placement and rotation to reduce the chances of older items being overlooked by customers.
- Implement food waste tracking systems so that data can provide targeted areas of frequent food loss to address.
- Accept and sell imperfect produce at a lower cost e.g., Woolworths' 'The Odd Bunch' variety of fruits and vegetables, or utilisation of imperfect produce as convenience fresh cut produce such as salads.
- Ensuring organic waste products are collected for industrial composting facilities.
- Retailers, especially large supermarkets can help create awareness of food waste and how consumers can cut down on waste through publications plus sharing tips in sections around stores.

Consumers

It is at the end of the food supply chain where the most significant reductions in food waste can be made. Households, you, can make a difference by:

- Being open to purchasing and consuming 'ugly' or imperfect fruit and vegetables.
- Storing food correctly.
- Checking food labels date markings and having an awareness that food can be consumed after its best before date (if the food has not been opened).
- Still cooking and storing food safely when additional take-away food is purchased when a meal was planned to be cooked before expiry.
- Freezing food you know you won't get a chance to eat before it passes its use-by date.
- Using leftovers.
- Donating unwanted food.
- Checking the fridge before shopping.
- Not shopping hungry.
- Planning meals and writing shopping lists so that you stick to buying only the food you need and don't cook too much food.
- Avoiding buying perishable items in bulk e.g., buy only the single fruits needed vs pre-bagged.
- Taking food in the correct order of stocking (the front).
- Removing visibly aging produce to use immediately or compost, as it can emit gases that speed the ripening of other produce.
- Eating parts of produce that usually get discarded e.g., potato peel or using them elsewhere e.g., lemon skins incorporated into desserts or sauces with fish.
- Disposing of organic wastes in the correct 'green' bin or even composting your own food scraps.
- And more!



Helpful online resources

Additional tips to reduce household waste:

https://www.youtube.com/watch?v=KZf9_GdDff0



How to make your own compost:

<https://www.bhg.com/gardening/yard/compost/diy-indoor-compost-bin/>



Summary of the causes and management of food loss and wastage:

<https://www.youtube.com/watch?v=ishA6kry8nc>



Key terms

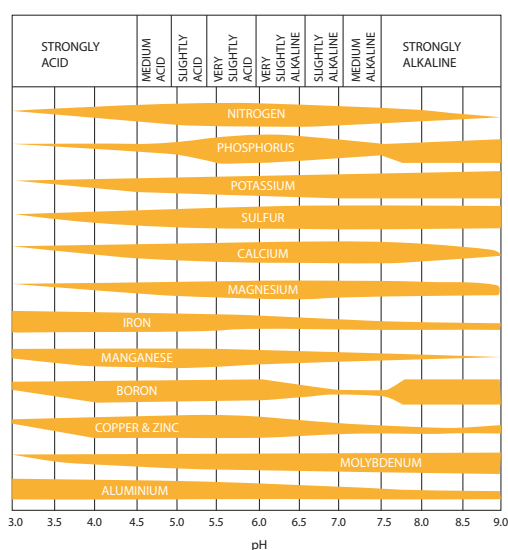
Algal bloom	Dryland salinity	Monoculture
Antibiotics	Eutrophication	Microplastics
Aquaculture	Fertiliser	Mining
Biodegradable packaging	Food loss	Organic farming
Biodiversity	Food miles	Overgrazing
Climate change	Food system	Pesticides
Commercial fishing	Food waste	Primary food production (agriculture)
Compostable packaging	Global warming	Soil acidification
Crop rotation	Greenhouse gases	Soil degradation
Deforestation	Intercropping	Soil erosion
	Livestock farming	Topsoil

Review questions: 3.1 – Food systems and their impact on the environment

1. Crop rotation is a practice used in organic farming.
 - (a) Crop rotation is advantageous in reducing the risk of soil acidification.
 - (i) Explain how crop rotation can reduce soil acidification.

(3 marks) (KA2)

- (ii) Refer to the figure below to answer the following questions about soil acidification.



- 1) State the pH range that classifies soil as being strongly acidic.

(1 mark) (IAE3)
- 2) Identify a primary nutrient required for plant growth and the pH range that is necessary for this nutrient to be available in larger amounts.

(2 marks) (IAE3)
- 3) Using data from the figure above, provide a concluding statement about iron's availability to plants as the pH changes.

(2 marks) (IAE3)

(2 marks) (IAE3)

- (b) Describe the difference between intercropping and crop rotation.

(2 marks) (KA2)

- (c) Apart from intercropping and crop rotation, name another type of practice used in organic farming.

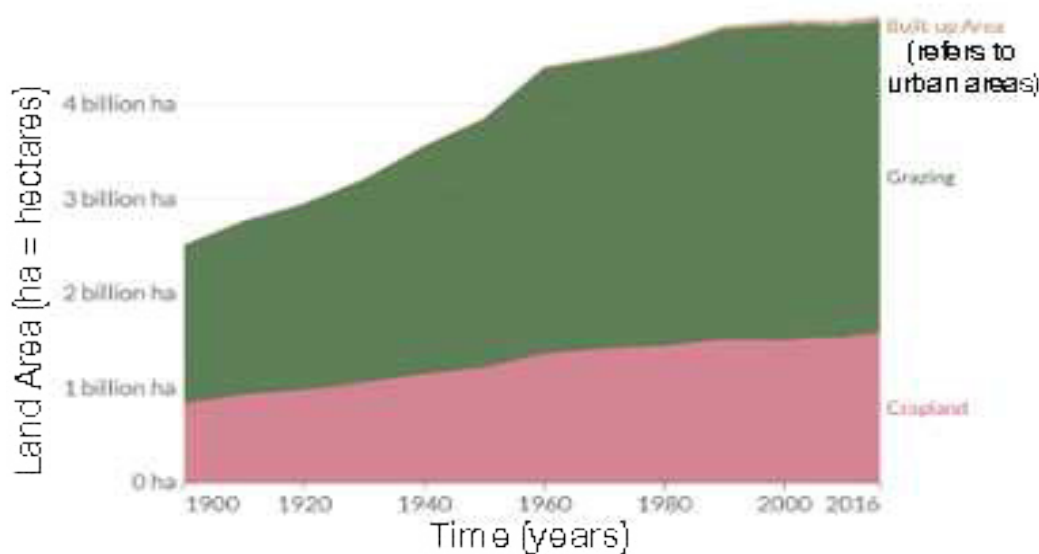
(1 mark) (KA1)

- (d) Complete the following table that compares typical methods when growing crops using crop rotation or monoculture. Place a tick or cross under each type of farming.

Practice	Crop rotation	Monoculture
Uses synthetic pesticides		
Typically produces higher yields		
Uses manure as fertiliser		

(3 marks) (KA1)

2. Refer to the following graph below which shows global trends in some of the uses of land.



- (a) Using data from the graph above, describe the trend in grazing areas from the 1900s to 2016.

(1 mark) (AE3)

- (b) Provide a reason for the trend described in part (a).

(2 marks) (KA2)

- (c) Explain how both the trends in land use for cropland and grazing have been a contributing factor to climate change in different ways.

(4 marks) (KA2)

3. Food waste is a pressing issue in Australia, with all food system stages contributing to this issue.

(a) Provide two reasons for food loss or food waste in the following sectors along the food supply chain.

Food systems stage	Reasons for food loss or food waste
Primary food production	
Processing	
Distribution	
Retail	
Households	

(10 marks) (KA1)

(b) Explain how food waste could be contributing to the increased frequency of floods and drought in Australia.

(3 marks) (KA1)

(c) Complete the following table by providing two strategies to reduce food loss or food waste at each level of the food supply chain indicated:

Level	Strategies to reduce food waste
Producers	
Retail	
Households	

(6 marks) (KA1)

(d) State a similarity and difference between food waste and food loss.

(2 marks) (KU2)

4. Polyhydroxyalkanoates (PHAs) are a class of biodegradable packaging plastics and polylactic acid (PLA) is a compostable plastic that is non-biodegradable. Both are packaging types entering the food market to reduce food waste.

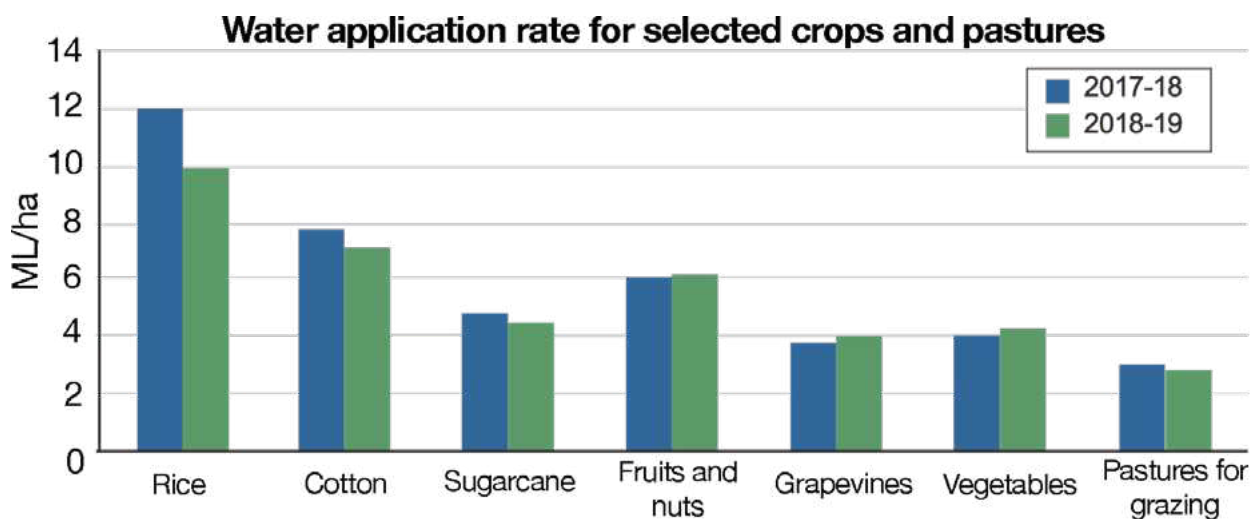
(a) Identify which plastic is more environmentally friendly and provide reasoning to justify your selection.

(2 marks) (KA2)

(b) Discuss why PHAs are utilised in packaging more frequently, and an environmental concern over their use.

(3 marks) (KA2)

5. Refer to the following graph, which shows the water application rate on various crops between 2017-2019.



(a) List a crop that reduced its water use over the 2018-19 period:

(1 mark) (IAE3)

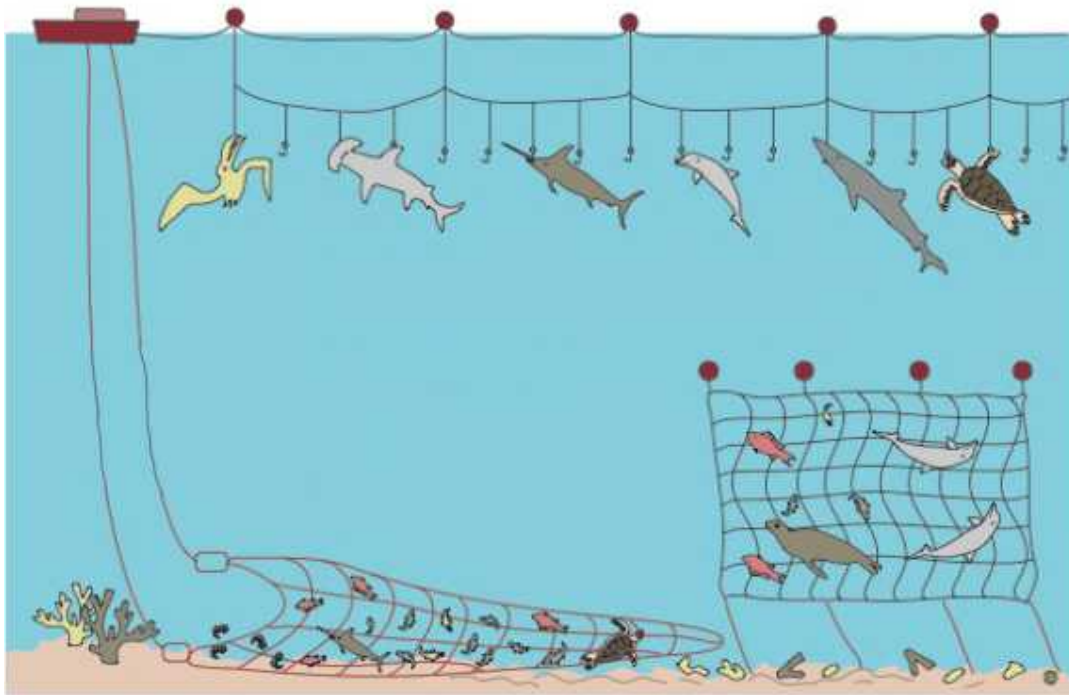
(b) Identify the crop contributing most to water scarcity issues:

(1 mark) (IAE3)

(c) Vegetables received greater water application rates than necessary in 2018-19. Explain how this may impact food availability or accessibility.

(3 marks) (KA2)

6. Bycatch is estimated to kill around 250,000 loggerhead and leatherback turtles, 1 million sharks, 300,000 small whales and dolphins, and thousands of other animal life such as seabirds, as visualised in the image below.



- (a) Identify one of the fishing techniques shown in the image above and describe an environmental concern, other than bycatch, of this technique.

(3 marks) (KA2)

- (b) Identify an alternate way to rear fish and describe a comparative advantage and a disadvantage of this alternate method.

(5 marks) (KA2)

Total: / 60 marks

Case Study

Suitable Garden Crops

This case study works in conjunction with the science inquiry skill task titled 'Testing for soil salinity' and/or 'Soil pH testing' which need to be completed prior to the case study being answered.

A saline soil is one that contains sufficient soluble salts (most commonly sodium chloride) to adversely affect the growth of most plants. Salinity reduces a plant's ability to extract water from the soil and can cause toxicities from specific ions. A salinity threshold indicates soil salinity levels where plants begin to experience yield reducing effects. Crops have a specific salinity threshold (as shown in the table below on the left), where it is expected that if the salinity is above this threshold, then yield losses are expected.

The pH of soil is a measure of acidity and alkalinity. Most soils have a pH value between 3.5 and 10. However, most crops have an optimum pH range (as shown in the table below on the right).

Crop	Salinity Threshold (ds/m)
Asparagus	4.1
Bean	1.0
Broccoli	2.8
Carrot	1.0
Cauliflower	-
Celery	1.8
Eggplant	1.1
Lettuce	2.0
Muskmelon	1.0
Okra	1.2
Onion	1.2
Pea	1.5
Pepper	1.5
Potato	1.7
Purslane	6.3
Red beet	4.0
Spinach	2.0
Strawberry	1.0
Tomato	2.5

Crop	Range of soil pH optimum for selected crops				
	5	5.5	6	6.5	7
Asparagus					
Bean					
Cabbage					
Carrot					
Corn					
Cucumber					
Kale					
Lettuce					
Mustards					
Onions					
Parsnips					
Peas					
Pepper					
Potatoes					
Radishes					
Spinach					
Squash					
Tomatoes					

(Source for salt tolerance of vegetables: https://www.researchgate.net/figure/Salt-tolerance-of-vegetable-crops-as-determined-by-soil-salinity-EC-e-and-irrigation_tbl2_316655080 and pH optimums: <https://hortnews.extension.iastate.edu/2016/04-08/soilpH.html>)



Helpful online resources

Salt tolerance levels of additional vegetables and fruits:

https://ucanr.edu/sites/Salinity/Salinity_Management/Effect_of_soil_salinity_on_crop_growth/Crop_salinity_tolerance_and_yield_function/

Preferred soil pH ranges of additional vegetables and fruit:

<https://www.acurite.com/blog/soil-ph-recommendations-and-tips-for-fruits-vegetables-trees-shrubs.html>



Case Study

- With reference to the soil salinity and pH test results (obtained from the completion of the soil testing science as an inquiry skill task) and the tables above, which indicate the salinity threshold and soil pH range of different crops, select and list two garden crop plants that you would recommend being grown in your potential school garden. Justify your recommendations by using data. Additional research or use of the online resources provided, may be needed for fruits or vegetables that are suitable to be grown but not given in the tables above.
- Discuss a method you could employ to reduce food wastage when you harvest your garden crop if you find you have too much of your vegetable or fruit to eat before it spoils.
- Discuss how you would replace soil nutrient loss after you harvest your garden crop in a manner that reduces the impact to the environment.
- Describe one nutritional benefit of each chosen garden crop plants for adolescents.

(10 marks) (IAE3, KA2)



Science as a human endeavour

Microplastics – just how much plastic are we consuming?

The article has been adapted from the following source:

<https://www.sciencealert.com/humans-consume-over-74-000-microplastic-particles-each-year-without-knowing-it>

From what little we know about microplastics in air, food and water, Canadian researchers have now estimated that the average person consumes more than 74,000 particles of plastic each year. Likely, the authors admit, this undervalues reality. Due to a lack of data, the research was limited to only a few categories, including fish, shellfish, added sugars, salts, alcohol, tap or bottled water, and—of course—the air we breathe. Based on a thorough review of the literature, including 26 peer-reviewed studies, the team created a microplastics database which they then compared to US dietary data. Depending on a person's age and sex, the number of particles consumed yearly sat somewhere between 74,000 and 121,000 particles. Of all the items in the database, air, bottled water, and seafood accounted for most of the microplastic intake, although these also had the most variation depending on your location and food intake.

While the results might sound scary at first, the authors themselves admit that there's a lot of variation in the underlying data. They also remind readers that their estimates are based solely on the average American's daily food consumption, and only 14 percent of the caloric intake at that. "Extrapolating the number of microplastics consumed with the remaining 85 percent of calories is not possible," the authors write, "however, if our findings are remotely representative, annual microplastic consumption could exceed several hundred thousand."

Without including cultural differences in diet, or staples like meat, dairy, grains, and vegetables (data which does not yet exist), these results are more of a ballpark figure. What's more, the research says nothing about the costs, if any, to human health. Today, the effects of consuming microplastics are largely unknown, and yet there's little doubt that it's going on right now at unprecedented volumes. The potential pathways for harm are many, and scientists have only proposed a few. Once microplastics enter the gut, they could release toxic substances causing oxidative stress or even cancer, according to the researchers. Particles small enough could be taken up by cells in the lungs and gut; while larger ones might be absorbed in the digestive tract. What happens from here is anyone's guess. Many questions for the scientist to try to answer in a short period of time because this is urgent."

While more direct research needs to be done, the trend so far suggests that microplastics will continue to be found in many, if not all, items intended for human consumption. "If the precautionary principle were to be followed, the most effective way to reduce human consumption of microplastics will likely be to reduce the production and use of plastics," the authors conclude.

1. Outline the **communication** and **collaboration** used to arrive at the findings in the article.

(2 marks) (KA3)

2. Discuss **limitations** of the research used to arrive at findings in the article.

(4 marks) (KA3)

? Science Inquiry Skills

Testing for soil salinity

Introduction:

Monoculture cropping methods are known to increase the risk of soil becoming too salty to support plant growth. Before growing your own fruit and vegetables, it is important to know how much salt is in soil as it will determine what can be grown well in it.

Materials:

- EC/Salinity meter
- 3 x soil samples (about a trowel full)
- 3 x containers to hold soil
- Spoon
- Trowel
- 3 x heat-proof oven dish
- Aluminum foil
- 9 x 100 ml beaker
- Electronic scales
- Mortar and pestle
- Distilled water
- Stirring rod
- Standard calibration solution (1413 or 12880 EC)

Method:

1. Select three potential garden areas around your school.
2. Collect 3 separate samples of soil from each chosen area (9 soil samples altogether) and place in a container. **Note: the 3 samples at each area should be at alternate ends of the garden space.**
3. Thoroughly mix the three samples from the one garden area with a spoon in its container, then transfer soil into a heat-proof oven dish, by using aluminium foil to separate the samples.
4. Repeat step 3 for the other two garden area samples.
5. Dry the soil in an oven for about one hour at 150 °C if possible (for more accurate results).
6. Weigh out 10 grams of each dry soil sample using the electronic scales, and place in a 100ml beaker.
7. Grind the soil with a mortar and pestle or rolling pin until all the lumps are gone.
8. Remove any gravel.
9. Put the 10 grams of soil into a 100ml beaker with 50ml of distilled water in it.
10. Stir thoroughly with a stirring rod then let it stand for 5 minutes.
11. Calibrate the salinity meter using a standard calibration solution.
12. Rinse the meter probe with distilled water.
13. Stir the soil and water sample again with the stirring rod.
14. Immerse the salinity meter probe into the soil and water sample and record the reading in the results table below.
15. Rinse the meter probe and repeat steps 7-14 for each soil sample.

Results:

1. Record the salinity reading for each of the soil samples from the three potential garden sites in the table below.

Potential Garden Site	Salinity level EC (dS/m)		
	Sample 1	Sample 2	Sample 3
1			
2			
3			

*Case study: suitable garden crops - utilises the salinity readings of this investigation.

? Science Inquiry Skills

Analysis & Discussion:

1. Identify which garden site has the greatest potential for growing your own fruits and vegetables.

2. Provide a reason for collecting 3 soil samples from alternate corners of a potential garden area and mixing them, rather than only one.

? Science Inquiry Skills

Soil pH testing

Introduction:

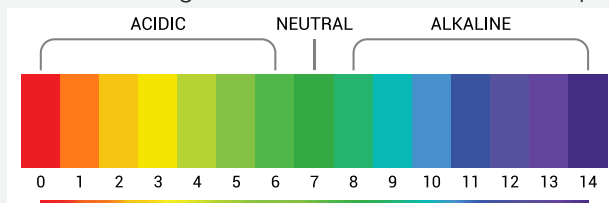
Overuse of fertilisers can affect the pH of soil, which in turn affects nutrient availability to growing plants. In this investigation you will measure the pH of several soils to investigate how nutrient availability can change in differing pH.

Materials:

- Large test tubes
- Containers
- Teaspoon
- Trowel
- Soil samples
- Stirring rod
- Universal pH indicator paper and pH indicator colour chart (or calibrated pH meter)

Method:

1. Collect various soil samples including sandy and clay soils from different areas around Adelaide. The soil samples from the 3 potential garden sites collected in the testing for soil salinity science skills inquiry can also be utilised.
2. Record the soil types that you are testing in the first row of the results table below.
3. Add approximately 1 teaspoon of soil and 1 teaspoon of water to a large test tube and mix (these quantities can be manipulated to suit the soil type)
4. Dip the indicator paper into the soil mixture (or pour mixture into a beaker if using a pH meter) and compare with the indicator chart diagram below to determine the soil's pH.



5. Record the pH of the soil.

Raw Data:

Record the soil type and the pH of the soil in the results table below.

Soil type						
pH						

*Case study: suitable garden crops - utilises the pH readings of this investigation.

? Science Inquiry Skills

Analysis & Discussion:

1. With reference to the results, identify which soil type would best support the growth of crops. Use scientific terminology to justify your answer.

2. Identify the error type and discuss the effect it would have on results if the soil samples were not mixed.

? Science Inquiry Skills

Design investigation into the effect of fertiliser

Introduction:

Fertilisers are commonly relied on in primary food production, especially monoculture practices. There is an abundance of choice over fertiliser types as well as a variety of methods to add it to soils. In this investigation you will explore the effect of fertilisers to better understand how they are used in agriculture.

Some ideas for the design of an investigation into the effect of fertilisers are:

- Effect of fertiliser in different soil types
- Organic fertiliser vs conventional fertiliser
- Varying fertiliser quantities
- Varying fertiliser brands or types e.g., pellets vs liquid; high ammonia vs general fertiliser
- Varying fertiliser application e.g., spray vs drip irrigation
- Effect of fertiliser on different plants

Design:

1. In groups, decide whether your dependent variable will be upon plant growth or soil pH and which aspect of fertiliser use will become your independent variable. Record these in the space provided below by making clear how the independent variable will be manipulated and how the dependent variable will be measured.

Independent variable:

Dependent variable:

? Science Inquiry Skills

2. Identify at least three factors you will need to control to create a fair investigation and explain the effect if these factors are not controlled.

Controlled variable	Effect of variable if not controlled and how you will control it

3. Develop a testable hypothesis which incorporates the dependent and independent variable.

4. Compile a material list in the space below of all necessary equipment needed to conduct your investigation.

•	•
•	•
•	•
•	•
•	•
•	•
•	•
•	•
•	•
•	•

5. Create a method for your investigation in the space below. Aspects to consider are:

- How often and time of day will you water and apply fertiliser and over what length of time will you run the investigation.
- Steps to ensure constant variables are being met.
- Steps to ensure you have a control set up to compare fertiliser effectiveness to.
- How you will collect your results.

** Design, materials & method to be verified for suitability by your teacher before commencing experimental procedures. Be sure to follow all safety procedures specified on fertiliser applicators. Risk assessments of practical designs should be completed.*

? Science Inquiry Skills

6. Design a suitable table to compile the results, whether that be images of plant growth, or values of changing pH, height of plants.

Analysis & Discussion:

1. With reference to the results, describe the trend of the data and whether this supports or refutes the hypothesis. Provide justification to support these trends.

2. Identify two possible sources of random error and discuss the effect of these errors on the data. Use examples of raw data to support the presence of these random errors.

Extension Activities

1. For this activity you will need 20-30 balls (tennis or soft small balls) dependent on class size and a large flat grassed area or oval.

Procedure:

1. Get $\frac{3}{4}$ of the class to spread out and pretend they are trees (remember trees cannot move, their roots: student legs, are attached to the ground; trees also can't talk!).
2. The remaining $\frac{1}{4}$ of the class are to stand in a line in front of the trees. Give each of these students 4 balls (depending on class size). These students represent the clouds, and the balls represent raindrops. The trees are to catch as many balls as possible without moving their feet! The clouds are to lob the balls gently, one at a time, into the air above the trees on the count of three. All clouds are to throw their raindrops simultaneously.
3. Count the number of balls on the ground and remember it. Repeat the process if you wish!
4. Now remove half of the trees. Get the clouds to lob the same number of balls as above over the remaining trees.
5. Count the number of balls on the ground and remember it.
- (a) What was the difference in the number of balls on the ground? What does this mean? What will happen to the water?

- (b) Discuss how the activity performed simulates primary production practices and the environment impact(s) it is associated with.

2. List several ways your household could reduce your environmental impact through your use of packaging.

3. Research and discuss:
- (a) A method to reduce soil acidification resulting from fertiliser over-use.
 - (b) A method to reduce dryland salinity created by deforestation.
4. Using the image below as a stimulus, research and discuss some of the consequences and impacts of global warming on society and food accessibility. For example, a decrease in global ocean oxygen would create greater no-go zones for aquatic life leaving them with fewer areas to eat and reproduce. This would decrease food accessibility as it would reduce commercial fishing seafood supplies.



5. There are many different fishing techniques used in commercial fishing. Each technique employed is aimed at capturing certain species of aquatic life for consumption. Find out what seafood is predominately caught with each fishing technique in the table below. You may find the helpful online resource to be of use in table completion.

Commercial fishing technique	Seafood predominantly captured
Pelagic longlining	
Bottom trawling	
Harvestors	
Purse seine	
Gillnets	



Helpful online resources

Australian Fisheries Management Authority - Methods and Gear

<https://www.afma.gov.au/methods-and-gear>



3.2 Research and development

Science understanding

The role of research and development in reducing the impact of food production on the environment and enhancing food security by increasing food availability and meeting nutritional needs of society.

- digital farming
- vertical farming
- genetically modified organisms (GMOs)
- entomophagy
- algae
- lab grown meat
- 3D printed food

SACE Subject Outline, 2024.

Future farming innovations

Consumer trends over food choices are moving towards produce whose primary production places significance on animal welfare and environmental sustainability. Organic farming does just this and as a result, there has been and continues to be an increase in organic produce by around 20-30% per year in Australia. However, without the help of artificial chemicals such as pesticides, it is disputed as to whether current organic methods can produce the required yields to support a growing consumer demand for food as our population increases. It is also disputed as to whether higher yielding conventional farming methods such as monoculture can support consumer demand for food due to its negative impact on the environment. Humanity will be challenged worldwide to feed the rapidly growing human population, which is predicted to reach around 9.5 billion people by 2050. Food distribution and waste are a significant part of food insecurity today; however, even improvements in these areas by 2050 will not suffice to feed millions of additional people, most of them in populated developing countries. Farming methods will need to expand to meet the food demands of the growing population. However, expansion of either organic or conventional farming methods is questionable, considering most land suitable for farming, is already being farmed! If farms are unable to increase in size to match food demands, yields will need to increase. To significantly intensify the output of food production, research and development is integral to finding solutions. Applied research needs to explore how agriculture can be immersed with technology to improve current food production methods (see digital farming). In addition, research and development needs to seek innovative blending of organic and conventional agricultural methods with technological advances. An example of this is vertical farming. Beyond adapting and improving food production methods that are already being used in agriculture, research and development needs to explore entirely **new food production innovations** that have potential to meet consumer demands whilst simultaneously reducing detrimental impacts on the environment. This includes 3D printing of food, cellular agriculture, algae cultivation, entomophagy, and the genetic modification of new foods. In addition, for any new food production method or current method with added technological advancements to be successful in facilitating future food product development, it must actively find ways to reduce food waste and reduce or replace food packaging with environmentally friendly options. They must also incorporate the use of alternate or reduced energy and water sources to ensure environmental sustainability.



Definition

Food produced via new means are called novel foods. **Novel foods** are those that are produced by a method that has not previously been used by humans and must be approved by FSANZ before being marketable. The definition for novel foods also extends to foods that have not been consumed to a significant degree in the past.

Digital farming

Digital farming refers to the use of digital technology integrated into agricultural production methods. It refers to technological tools that:

- digitally collect data, for example soil moisture sensors.
- store and analyse data to then share this electronic data and/or information, for example soil moisture detected by sensors is analysed against norms to detect poor soil moisture which is then delivered as a notification to a farmer's mobile app.

Data results are then used to make farming productivity adjustments. Adjustments can be carried out autonomously, without human or farmer assistance, for example by self-driving tractors and robotic farming aids (see Figure 3.2.1).



Figure 3.2.1: An example of digital farming components.

There are a multitude of technology advances that can be used on existing farms including:

- Moisture sensors in soils connected to irrigation-drip systems to ensure optimal water for plant growth.
- Robotic devices, called agrobots, equipped to run farming labour jobs such as: sowing or planting seeds, watering, applying fertiliser, harvesting crops, and identifying and destroying weeds (see Figure 3.2.2).
- Drones fitted with high-resolution cameras, infra-red light and/or heat sensors combined with GPS technology to monitor and map an array of farming necessities such as harvesting, water, pesticide and fertiliser needs, crop growth, and livestock wellbeing.
- Electronic identification devices for livestock and biometric sensors which monitor animal behavior and body changes, to enable rapid response to cases of animal stress or disease.



Figure 3.2.2: Australian centre for field robotics (University of Sydney) robot called RIPPA (Robot for Intelligent Perception and Precision Application) for spraying individual weeds with herbicide, and a farming drone monitoring plant health and overseeing RIPPA movements.

These high-tech advances in agriculture could give crops and livestock exceptional levels of attention to help maximise yields and minimise food wastage, or poor animal health. By increasing yields, digital farming could help address challenges of future consumer food demands. Precise and necessary application of chemicals and water would also reduce the negative environmental impact of overuse typically seen in conventional farming.

Helpful online resources

Overview of digital farming:

https://www.youtube.com/watch?v=nsnpEmr1q_k

Examples of future farming robots:

<https://www.youtube.com/watch?v=uD4mJCgsmdM>



Vertical farming

Vertical farming refers to the practice of crops being grown in vertically stacked layers with soilless farming techniques. There are several vertical farming types (see Figure 3.2.3) including:

- **Hydroponics:** plants grown or cultivated in water without soil.
- **Aeroponics:** growing plants in an air/mist environment with no soil and very little water.
- **Aquaponics:** plants are cultivated in water without soil as per hydroponics, but in combination with aquaculture. However, unlike aquaculture where aquatic animal waste can accumulate in the water and create eutrophication concerns, the waste in the water is converted into nutrients required by plants for growth. The water is then recycled and used in the hydroponic water system, thereby reducing water needs.

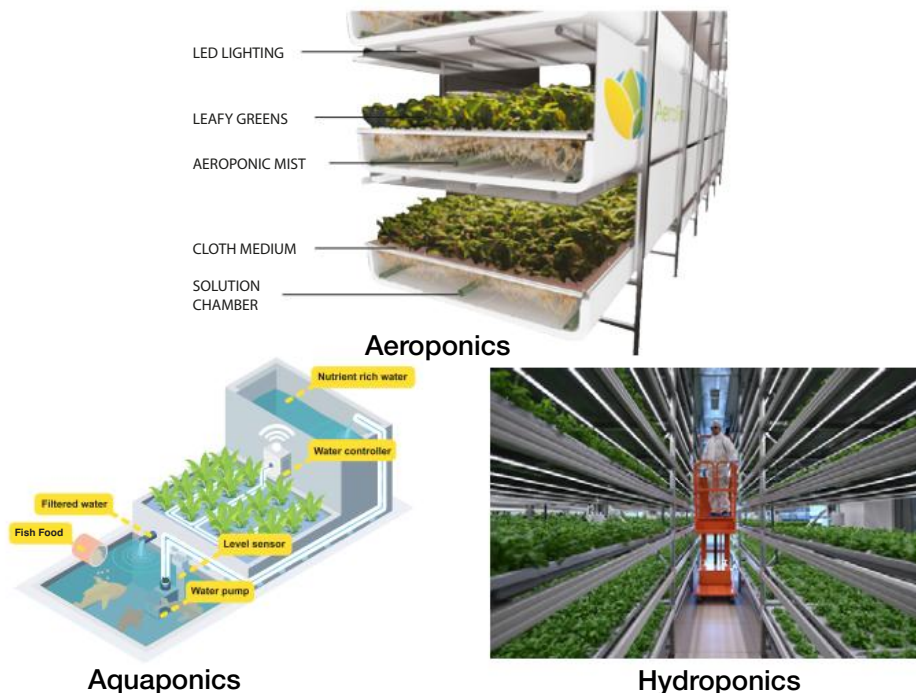


Figure 3.2.3: Different types of vertical farming (please note: the aquaponics system would function with each level above the other, the image has moved the levels horizontally for easier viewing).

Vertical farms are often started-up in urban areas or cities, in climate-controlled indoor areas termed by some farmers as 'plant scrapers!' They can function all-year around due to environmental conditions like light (often LED light for energy-saving purposes), temperature and water, being controlled. Vertical farming is an emerging food production innovation with benefits to food availability and environmental impact such as:

- Vertical farms can grow in urban or city areas, which reduces the issues of urbanisation impacting upon land availability of arable land for farms. Smaller pockets of land requirements in comparison to vast fields comes with improvements in land degradation and biodiversity issues, and urban locations can also mean a heavy reduction in food miles before produce reaches consumers.
- Water not trapped by plant roots is able to be reused rather than leaching through the soil to the water table as it does in conventional farming. Dependent on the type of vertical farming employed, they can use approximately 50-90% less water than field farming.
- Farms being indoors allow crops to grow in all seasons and in challenging weather, like droughts, brought on by climate change and its associated changes in weather patterns.

- Vertical crop yields have been found to be higher in comparison to crops on traditional fields and therefore could also be a solution to growing consumer demands for food as our population inflates.
- The ability to cultivate or grow a larger variety of crops at once because plants are not sharing the same plot of land, is another reason for the occurrence of vertical farms increasing. A variety of crop plants growing ensures food security if disease was to affect single crops.
- There has also been some scientific evidence of better nutrient absorption by crops grown using aeroponics. This could be the pinnacle in producing more nutrient-dense foods to meet nutritional needs of societies.

Genetically modified (GM) foods

The **genetic modification (GM) or genetic engineering of foods** refers to foods that have been derived from an organism, in particular a crop or animal/livestock, which has had a gene introduced into its genetic make-up that results in that gene expressing a desirable trait. The genes used for genetic modification may come from a range of unrelated organisms including bacteria, plant, or animal species. For example, in Australia, canola has been approved to be genetically modified with a bacterial gene exhibiting herbicide resistance. This results in the canola expressing resistance to a particular type of herbicide (glyphosate herbicides). GM canola is not actually a GM food as such, merely an ingredient. Canola crops are grown for their seeds which are crushed for the oil that is used in margarine and cooking oils. Another GM ingredient used in Australia is cottonseed oil from GM cotton. The cotton plant has been genetically modified to be resistance to specific types of cotton pests. At present, these are the only GM food crops able to be grown in Australia that are intended for human consumption. Other GM ingredients do, however, exist in Australian foods, imported from GM global crops. These crops include GM soy, maize (or corn) and sugar beet (see Figure 3.2.4).



Figure 3.2.4: Soybean pods from a soya plantation (left) and sugar beet root crop (right).

The introduction of a gene from an unrelated organism has created controversy and resistance to GM foods being a solution to enhancing food production. Rather than introduce an unrelated organism's gene, the way forward for GM in food could be by turning a particular gene on or off from expressing its trait. A new method of genetic engineering called CRISPR (clustered regularly interspaced short palindromic repeats) focuses on gene editing: the cutting and deleting or replacing the DNA of a gene (as shown in figure 3.2.5). When DNA is replaced, it is by mirroring an improved genetic code that naturally exists in the plant or animal family being modified, it does not use conventional GM production techniques which insert foreign genetic material. Only minor manipulations in gene sequences are made to produce the gene with its desired trait.

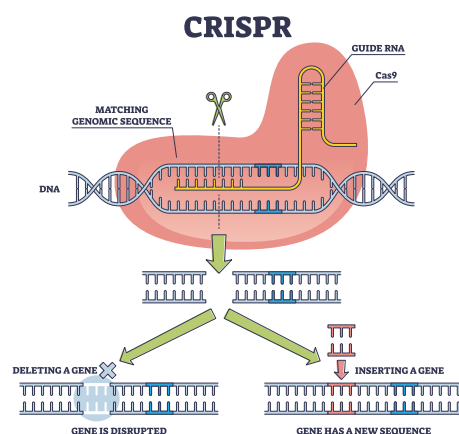


Figure 3.2.5: CRISPR Gene Editing, where genes can be deleted (left) or inserted (right)

Helpful online resources

CRISPR explained with seed health example:

<https://www.youtube.com/watch?v=KUAp4RIU1M>



The current foods available for consumption with GM are from plants that have been engineered to be more tolerant to disease or herbicides, or to improve yield. In future, new foods plus foods derived from GM microorganisms and GM animals, could be introduced into our food market. Driving the creation of new GM foods are the following potential benefits (see Table 3.2.1):

Table 3.2.1: Possible benefits of GM foods to improve food security or reduce environmental damage.

Benefit	Examples
Reducing a food's allergen potential.	Wheat could be developed to be free of gluten, a major factor in Coeliac Disease.
Improving the efficiency of the modern food systems to match a growing population and consumer demands.	- Black tiger prawns (or other aquaculture species) could have their conventional breeding time sped up. - Salmon that can grow to market size in half the time as conventionally farmed salmon.
Enabling agriculturally unproductive or arid land to become viable for crop cultivation.	Wheat could be advanced to be resistant to salinity, resulting in crop yields being increased for better food security.
A focus on sustainability and reducing the food systems environmental damage.	- Crops could be genetically manipulated to be more efficient at utilising soil nitrogen. This modification could decrease the need for added fertilisers, with prospective reductions in environmental concerns such as eutrophication and soil acidification. - Corn is technically advanced to contain a gene for a bacterial pesticide that kills larval pests when they try to eat the corn plant, therefore potentially minimising pesticide use and its impact on contaminating waterways and soils. - Soybeans can be altered by an inserted gene to render them herbicide resistant. When herbicide is sprayed it can effectively wipe out weeds, leaving crops intact, thereby reducing the need to loosen or turn the soils to control weeds. This can help decrease soil degradation issues such as soil erosion.
Improving yield in weather extremes that can be brought on more frequently by climate change, for example drought.	Chickpeas are being trialed to tolerate drought conditions thanks to some biotechnological changes.
Creating functional foods , which are foods with an improved nutritional content to better meet nutritional needs of society and/or alleviate prevalent nutritional diseases.	- Wheat could be engineered to have improved nutrition with a higher protein and soluble fibre content. - CSIRO researchers are working on a wheat that might improve nutritional properties such as the glycaemic index (GI). - An evolving 'golden rice' being genetically modified to contain vitamin A and iron to prevent common nutritional deficiencies.

GM foods on the market, including products containing GM ingredients must comply with FSANZ codes. All GM foods are considered novel foods and are therefore safety assessed by FSANZ before being allowed on the market to be consumed. Assessment investigates aspects such as toxicity, tendency to provoke allergic reactions, unintended effects of the gene insertion and stability of the inserted genetic material. A GM food will only be approved for sale if it is assessed as safe and as nutritious as its conventional counterpart.



Helpful online resources

GM crops:

<https://www.youtube.com/watch?v=kZIYkYNpnP0>



Entomophagy

Entomophagy is the practice of consuming insects, which is traditional in many continents, including Asia and Africa, as well as within Australia by Indigenous Australians. **Edible insects** can include crickets, grasshoppers, mealworms, caterpillars, or various fly larvae (as shown in figure 3.2.6). Insects, however, are not a traditional part of western diets and can therefore be considered a novel food in Australia. Risk assessment and approval by FSANZ is mandatory as allergic reactions to insects may be possible in those allergic to crustaceans. For populations around the world where insects have not been a traditional part of the diet, the thought of eating insects can be unappealing or unappetizing, and commonly thought of as a dietary option in dire survival circumstances. Therefore, the future of entomophagy could be in the form of crushed insects or powdered insect flours incorporated into new food innovations like biscuits and pasta. Entomophagy's future may also expand into alternate 'bush tucker' protein sources, especially considering they have fed populations of indigenous communities in the past and would be well-adapted to Australian climates.

Fast fact

There are around 1900-2000 edible insects known to exist!



Figure 3.2.6: Traditional entomophagy dishes – crispy salted silkworm pupae (left) and crickets (right).

Entomophagy has captured media attention and been an area of research and development due to their nutritional composition, ability to meet consumer demands and their potentially lower environmental footprint. The benefits of entomophagy include:

- The nutritional composition of insects can vary widely based on the species and life stage consumed, but in general, insects have similar energy and quantities of protein to meat and fish. They are also a good source of fibre and micronutrients such as iron. Many insect species can also be a good source of unsaturated fats, including omega 3 and omega 6 essential fatty acids. It should, however, be noted that data on nutritional composition and the bioavailability, or absorbability of these nutrients, is still limited.
- Traditional sources of protein, particularly meat and dairy products, are recognised as having a large environmental footprint. Insects are reported to emit fewer greenhouse gases than conventional livestock, including cattle and pigs, reducing the impact of global warming. For example, pigs produce 10-100 times more greenhouse gases per kg of weight than mealworms.
- Insects reproduce rapidly, grow quickly, and can convert the food they eat into body growth and weight effectively. For example, insects can convert 2kg of feed into 1kg of insect mass, whereas cattle require 8kg of feed to produce 1kg of body weight gain. These abilities mean they require significantly less water and land to grow feed resources in comparison to rearing livestock, which reduces the strain on finite resources, and enhances food security to cater for the growing population.
- Feed sources for insects can also be organic food wastes, which additionally lowers entomophagy's environmental footprint as it means less food waste being left in landfill to decompose and release methane gas, a potent greenhouse gas adding to global warming.

Algae

Humans have eaten macroalgae, like nori seaweed for thousands of years, but recent attention has turned to single-celled algae or **microalgae** as another possible solution to increase food production to meet the projected population growth. Microalgae, namely *Chlorella vulgaris* and *Arthrospira platensis*, commercially known as *Spirulina*, can be grown in freshwater and more commonly, in seawater-fed aquaculture systems (see Figure 3.2.7).



Fast fact

Spirulina, a blue-green algae, is scientifically classified as a type of bacterium known as cyanobacteria. Cyanobacteria and algae are often grouped together because they both grow on water, photosynthesise and can provide many of the same nutrients.



Figure 3.2.7: Microalgae cultivation facility in Hawaii (left) and a water jet to aid in growing microalgae (right)

Although there are some concerns over production, such as energy needs, algae-based aquaculture may enhance food security and meet societal nutritional needs, whilst reducing the current impact of food production on the environment by:

- Providing a high protein content with high biological value as algae holds essential amino acids as well as a range of vitamins and minerals found in animal products, and omega-3 fatty acids from seafood. This makes algae a suitable protein alternative for vegans also.
- Growing approximately 10 times faster than traditional crops. This has the potential to increase the removal of carbon dioxide from the atmosphere as algae needs it to conduct photosynthesis.
- More efficient use of fertiliser due to being grown in relatively enclosed facilities enabling the ability to re-use any excess nutrients rather than allowing run-off into nearby waterways, contributing to eutrophication.
- Growing in seawater means algae doesn't require soil, irrigation, or vast amounts of land, thereby reducing the need for already limited arable land, fresh water, and deforestation with its associated impact on climate change.

A handful of algae in its natural form is comparable to a handful of green slime! Therefore, microalgae has predominantly entered the food market as an added ingredient. For example, *Chlorella vulgaris* and other microalgae has been incorporated into gluten-free bread to increase its protein, lipid, and mineral (Ca, Mg, Cu, Zn, K, P) contents. Unfortunately, such food products have had very limited success due to taste and other sensory attributes being negatively affected. However, research and development into ways to incorporate algae into the diet is in its early stages. Startup companies are still trialing new novel foods such as a smoked salmon substitute made of spirulina. Keys to improved commercial success are further studies in combination with marketing campaigns to increase consumers' awareness of the positives of producing microalgae.



Helpful online resources

Is algae the food of the future:

<https://www.youtube.com/watch?v=tAdrNQNP8ew>



Lab-grown meat

Cellular agriculture is the name given to the process of growing a collection of cells, or cell culture, that is used in the production of novel foods. Primary research and development have focused on using cell cultures to grow cultured meat, called lab-grown meat, as an alternate to livestock farming. In this new and innovative method of food production, muscle cells are taken from a living animal in a relatively painless procedure due to it being performed under anesthetic. The muscle cells taken are the stem cells of muscles, called myosatellite cells. The myosatellite cells are placed into labware containing a medium or mixture of nutrients, including glucose, oxygen, water, and amino acids, and naturally occurring growth factors. Myosatellite cells function in animals to create new muscle tissue when an animal's muscle is injured. Under favourably controlled laboratory conditions, the muscle stem cells perform the same functions they do in injured animal muscles, and they create new muscle cells. Myosatellite cells are left to multiply and create new cells until there are trillions of cells. Growth factor is then no longer given to the myosatellite cells, which then naturally form muscle fibres (called myotubes) and go on to become muscle tissue. Muscle fibres or tissues are then combined to create a piece of meat (see Figure 3.2.8). The meat tissue from cell culture is biologically the same as meat tissue that comes from the animal!

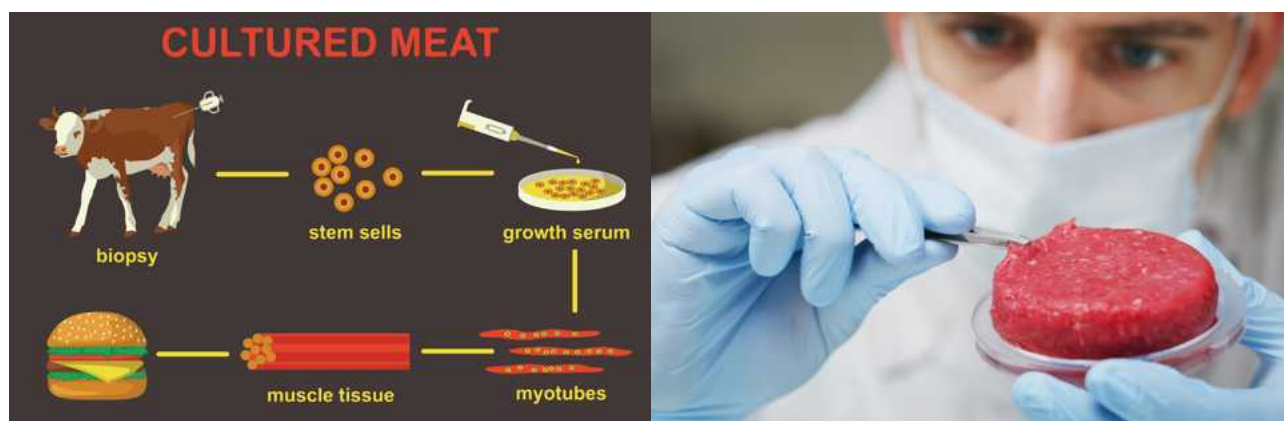


Figure 3.2.8: Process of creating cultured meat (left) and the final cultured meat product (right).

Helpful online resources

How lab-grown meat is made:

<https://www.youtube.com/watch?v=u468xY1T8fw>



One sample of muscle cells taken from a cow can produce 800 million strands of muscle tissue, equivalent to around 80 000 hamburger patties! This capability of manufacturing large amounts of produce from a small cell sample from one animal makes this innovative food production method a promising solution to increasing demands for food in the future. Although lab-grown meat production could be more energy-dependent (to power the process itself and the creation of resources for the growth medium), a shift in meat consumption sources to lab-grown meat could see lower populations of livestock animals needed, and therefore reductions in other environmental impacts such as:

- Livestock methane gas production and its associated impacts on global warming and climate change.
- Vast reductions in land needs considering cultured meat would be produced in laboratory settings. In addition, for land that is cleared for pastures to provide feed for livestock, this would also mean the environmental destruction that comes with deforestation, for example soil degradation and releasing carbon dioxide into the atmosphere, is minimised.
- Laboratories could also be situated within urban areas, cutting down on food miles.
- Considering lab-grown meat will not have similar demands on water such as irrigation for crops that become animal feed, or for daily functioning of a large-sized animal, water can be conserved more readily.

Not only can cultured meat offer environmental benefits and prospective food supply increases, but it also has the potential to diminish or even eliminate the need for slaughtering livestock, addressing concerns relating to animal welfare and consumer trends favoring the ethical treatment of animals in the food industry.

3D food printing

3D food printing is the process of manufacturing food from syringes that hold food pastes. The food pastes are deposited or pushed through a nozzle, layer by layer, following instructions from a computer program to create a food or even a meal! The novel food that is made can be in a range of shapes, colours, textures and flavours (see Figure 3.2.9). The food pastes need to be soft enough to pass through a syringe and nozzle yet possess a thick viscosity to hold their shape. For example, purees of vegetables, fruit, and legumes are suitable options. Powdered ingredients can be used to thicken liquids or increase viscosity. For example, flour could be mixed with milk to create a paste. Food pastes can also be created from melted solid ingredients such as cheese and chocolate.



Figure 3.2.9: 3D printed cupcake.

The benefits of creating new foods from 3D printing include:

- The nutrient content can be customised in food, by controlling the amount of protein, sugar, vitamins, and minerals through the addition of these to pastes. This can be done at an individual level, based on one's health and nutritional needs, making 3D food production suitable for meeting societal nutritional needs and the prevention of dietary diseases. This is an especially applicable way to produce aesthetically pleasing nutritious food for fussy children, or for the elderly who require softer foods.
- In conjunction with entomophagy, 3D printing using cricket flour to make pastes, offers an environmentally sustainable solution to meet growing consumer demands for food. It also offers a way insects can be presented so they don't resemble insects, to improve appeal.
- A form of 3D printing called **meat bioprinting** takes the mixture of muscle stem cells and growth factors from lab-grown meat procedures and 3D prints it into a layered structure which becomes a piece of muscle tissue or meat replica (see Figure 3.2.10). Being an extension of lab-grown meat, it offers similar reductions in environmental concerns aforementioned.
- 3D printing called '**meat analogue**' can print plant-based steaks that mimic the texture and appearance of meat. The potential benefit of this is on the environment considering growing crops is known to be less taxing on the environment than raising livestock.
- 3D printing can use foods or parts of foods which typically end up as food loss or waste. Discarded food being re-distributed from landfill to 3D printing could help address growing food demands as well as reducing the impact to the environment by reducing greenhouse gas emissions during the decomposition of food. 'Ugly' fruit and vegetables and meat off-cuts can also be turned into purees and used to create new foods.
- Although not food, 3D printing could also reduce what ends up as landfill by printing edible utensils such as straws and cutlery. Less single-use packaging being discarded decreases pollution commonly clogging food chains and harming biodiversity.

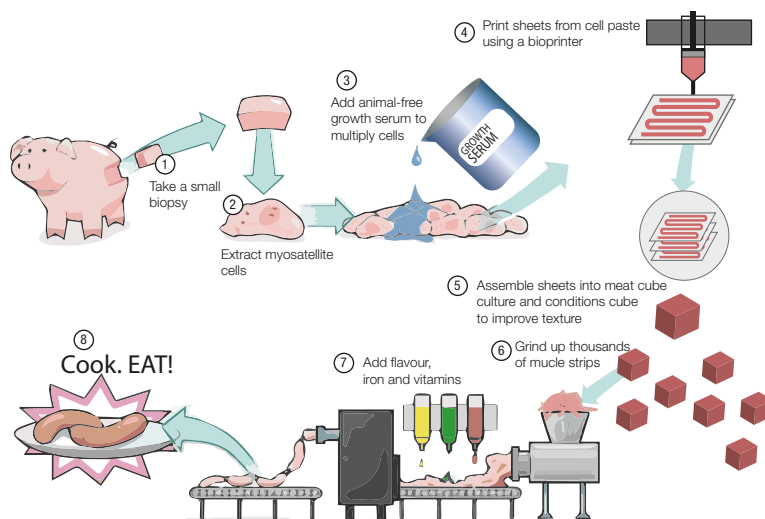


Figure 3.2.10: Cultured meat process (steps 1-3) followed by 3D printing (step 4) and further traditional processing steps can also be added to the meat production (steps 6-8).

Key terms

3D food printing

Acellular agriculture

Aeroponics

Aquaponics

Cellular agriculture

Digital farming

Functional foods

Genetically modified foods

Hydroponics

Meat analogue

Meat bioprinting

Microalgae cultivation

Novel foods

Vertical farming

Review questions: 3.2 Research and development

1. Match the innovative developments in food production to their definitions or examples.

Food production method	Definition or example
Digital farming	Cultivating barramundi in conjunction with lettuce grown without soil in a vertical farming system
Aeroponics	Foods derived from a crop or animal that has had a gene that will express a desirable trait introduced into its genetic make-up
Lab-grown meat	Food manufactured from syringes that hold food pastes
Entomophagy	Myosatellite cells producing muscle tissue
3D printing of food	Novel foods that have not been consumed to a significant degree in the past in Australia
Genetically modified food	Robotic egg collection and sorting by weights
Meat bioprinting	Smoked salmon made from Spirulina
Microalgae cultivation	Cell cultured meat transformed into a 'steak' via 3D printing
Aquaponics	Method of crop production that uses soilless techniques
Vertical farming	Vertical farming system where crop roots are suspended in air, receiving water and nutrient needs via a mist spray onto their roots

(10 marks) (KA1)

2. Farmer Ezra claims she can grow kale with 90% less water than that of a conventional farmer. Identify a possible innovative farming technique Ezra has employed and explain how it can reduce water use so drastically.

(4 marks) (KA2)

3. Innovative food production methods are being developed to reduce the impact of food production on the environment and enhance food security by increasing food availability and meeting the nutritional needs of society.

(a) Identify two future food production methods and explain how they could meet the nutritional needs of society.

(4 marks) (KA2)

- (b) Identify two future food production methods that address food waste issues and discuss how this is achieved.

(4 marks) (KA2)

- (c) Discuss two future food production methods that may provide better food security during periods of drought brought on by climate change.

3

(4 marks) (KA2)

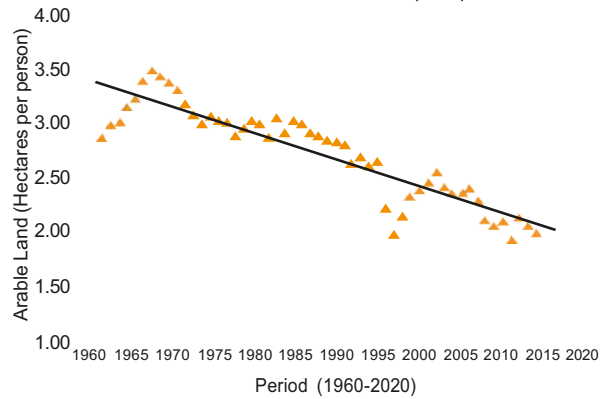
- (d) Discuss two innovative food production methods that reduce the potential impact of eutrophication.

(4 marks) (KA2)

- (e) Name an innovative food production method for growing crops able to reduce food miles and discuss how it addresses food mileage issues.

(2 marks) (KA2)

4. The following graph demonstrates the amount of arable land per person from the 1960s to 2000s.



- (a) State what is meant when land is described as arable.

(1 mark) (KA1)

- (b) Using data from the graph, describe the trend in the amount of available arable land over time.

(2 marks) (IAE3)

- (c) Compare the scatter of the data between 1965-1970 and between 1985-1990 and discuss types of errors behind each data section and how this affects reliability.

(2 marks) (IAE3)

- (d) The increase in cattle grazing has been found to be a leading cause in the decline of arable land.

- (i) Identify an alternate animal that could be farmed as a source of protein-rich food that would reduce farming land needs.

(1 mark) (KA1)

- (ii) Describe an environmental benefit of rearing the animal identified in part (i) in comparison to rearing cattle.

(2 marks) (KA2)

- (iii) Describe two nutritional benefits of rearing the animal identified in part (i) in comparison to rearing cattle.

(4 marks) (KA2)

- (iv) Identify an alternative innovative food production method for animal-sourced protein foods and describe how it would reduce land use in comparison to cattle grazing.

(2 marks) (KA2)

5. The following questions refer to the passage of information below on dysphagia:

Dysphagia is a swallowing disorder affecting just under 10% of the world's population. It is a disorder that can develop in several conditions such as throat cancer or dementia. The main symptom of this disorder, finding swallowing difficult, can affect quality of life including mental health. It can also impact quite drastically on nutritional health. It's often recommended that those suffering from dysphagia eat texture-modified foods, which include soft, bite-sized, minced, and liquified foods. It's also generally advised that those suffering from dysphagia avoid any food that can be stringy, chewy, crunchy, or solid. The problem with these modified meals is that they are often considered to be mushy and unappealing, which leads to food refusal and poor nutrition. Loss of control over one's meal choices can also result in anger and depression.

- (a) Identify an innovative food production method that could be of assistance to someone with dysphagia and outline how the food produced is suitable.

(3 marks) (KA2)

- (b) Explain how the application of the innovative food production method identified in part (b) could improve mental health.

(4 marks) (KA3)

6. In Australia, cotton and canola has been genetically modified to be resistant to herbicides, such as glyphosate and glufosinate.

- (a) Identify the governing body that approves the use of GM foods in Australia.

(1 mark) (KA1)

- (b) Explain what is meant when a crop becomes herbicide resistant.

(2 marks) (KA2)

- (c) Discuss how a crop being herbicide resistant can cater to the expected growing population and reduce negative impacts on the environment.

(4 marks) (KA2)

Total: / 60 marks

Case Study

Crop damage by flood

Farmer Jones is feeling defeated. For the second time in 5 years his tomato crops have been destroyed by floods. In the most recent floods, over half his fields were destroyed by the torrential rain or aggression of the fast-moving water. The fields of plants that survived then became susceptible to phytophthora root rot, a water mould prevalent in wet conditions that causes the root to soften, blacken and die. This eventually spreads to the parts of the plant above the ground, making his produce unable to be sold for human consumption.

- Suggest and discuss advances in farming research and development farmer Jones could adopt to reduce the chances of crop loss should flooding occur again.
- Describe the additional environmental advantages of the suggestions made.

(10 marks) (KA2)



Science as a human endeavour

New golden bananas could solve vitamin A deficiency!

Adapted from: <https://www.sbs.com.au/food/article/2017/07/19/these-new-golden-bananas-could-help-solve-vitamin-deficiency-around-world>

In a world first, Queensland University of Technology has developed new-and-improved, “biofortified” bananas that are densely packed with pro-vitamin A which is important for many bodily functions including vision, skin health and the proper working of your immune system. The extra vitamin A content in the banana results in a golden-orange flesh (as opposed to regular, cream-coloured bananas). But these golden bananas are more than just easy on the eye – they’re expected to help as many as 750,000 worldwide suffering from pro-vitamin A deficiency annually. Many of these children are in Uganda, where bananas are a major diet staple. This is more than just a scientific breakthrough – it’s a humanitarian one, too.

Research led by Professor James Dale and involving PhD candidates from Uganda has been ongoing for the past 10 years. “What we’ve done is take a gene from a banana that originated in Papua New Guinea and is naturally very high in pro-vitamin A but has small bunches and inserted it into a Cavendish banana” (the “everyday” banana you see at your local supermarket). These new bananas, grown in field tests in north Queensland and in Uganda, are a huge step in the direction of alleviating vitamin A deficiency around the world.

The results of the research, which was supported by the Bill and Miranda Gates Foundation, were published in Plant Biotechnology Journal. The researchers involved included Ugandan students studying at QUT, with some of them now overseeing field trials in Uganda.

1. Discuss the **communication and collaboration** evident in developing the pro-vitamin A biofortified banana.

(3 marks) (KA3)

2. Discuss the **development** of the pro-vitamin A biofortified banana.

(2 marks) (KA3)



Science as a human endeavour

Biotechnology to help soil and crops.

Adapted from: <https://www.economist.com/technology-quarterly/2016-06-09/factory-fresh>

Understanding and exploiting microbes for farming is a rapidly developing part of agricultural biotechnology. Of particular interest in research and development is the symbiotic relationship microbes can form with plants. For example, the natural partnerships formed with nitrogen-fixing bacteria by legumes such as soya beans. In legumes, the plants' roots grow special nodules that become homes for the bacteria. The bacteria fix nitrogen from the air into soluble nitrates that act as natural fertiliser. The big prize, however, would be to persuade the roots of crops such as wheat to form partnerships with nitrogen-fixing soil bacteria. If wheat rhizomes could be persuaded, by genomic breeding or genome editing, to behave likewise, everyone except fertiliser companies would reap enormous benefits.

1. Discuss the potential benefits of the **application** of the symbiotic relationship between nitrogen-fixing bacteria and wheat crops.

(4 marks) (KA3)

2. Discuss how society may be **influencing** the research into symbiotic microbial agricultural biotechnology.

(2 marks) (KA3)

? Science Inquiry Skills

The future of entomophagy

Introduction:

Currently for many Australians, the thought of eating insects is unappealing, or unappetizing. Hence, the future of entomophagy being successful could see insects being ground into a flour replacement and used in foods such as pasta and breads. Taste tests will be important in detecting whether insect flour modifications to food affect the sensory perceptions of the food.

Materials (should make 20 cookies):

Recipe 1

- Kitchen scales
- 180g unsalted butter (room temperature)
- 180g caster sugar
- 1 medium egg
- 360g plain flour
- ½ tsp vanilla extract
- Mixing bowls and utensils
- Electric beater or wooden spoon
- Baking tray
- Grease proof paper
- Oven
- Spatula
- Rolling pin
- Round cookie cutter
- Knife

Recipe 2

- Kitchen scales
- 180g unsalted butter (room temperature)
- 180g caster sugar
- 1 medium egg
- 360g flour with cricket powder (e.g., circle harvest)
- ½ tsp vanilla extract
- Mixing bowls and utensils
- Electric beater or wooden spoon
- Baking tray
- Grease proof paper
- Oven
- Spatula
- Rolling pin
- Round cookie cutter
- Knife

Method (for each recipe):

1. Add the butter and sugar to a large mixing bowl and beat with an electric mixer, or wooden spoon to cream the butter and sugar together until pale and fluffy.
2. Beat in the egg, followed by the flour and vanilla. Bring together with your hands to form a ball of biscuit dough.
3. Wrap the dough in clingfilm and chill in the fridge for one hour (this step can be skipped; cookies will simply flatten and be harder instead of being chewier and holding their texture better).
4. Preheat the oven to 160°C/180°C fan and line two baking trays with baking paper (this step to be completed earlier if skipping refrigeration step)
5. Remove the dough from the fridge and roll out onto a floured surface until the dough is about 0.5cm thick.
6. Use a medium-sized round cutter to cut cookies out of the dough and space them out on the trays.
7. Bake for 10-12 minutes, or until lightly golden.
8. Remove from the oven and cool on their trays for 10 minutes before transferring to a wire rack to cool completely.
9. Repeat steps 1-8 but replace the plain flour with cricket powder flour.
10. Once the cookies are cooled, cut them in half and conduct a triangle taste test by randomly assigning 3 cookie samples to the taste testing subject/s (including ½ a cricket cookie alongside 2 x ½ normal cookies OR ½ a normal cookie alongside 2 x ½ cricket cookies).
11. Get taste testing subject/s to complete the results table in the raw data section by identifying the odd sample and leaving a comment describing what is different about the sample and whether it was liked or disliked.

? Science Inquiry Skills

Raw Data:

Name:	Product:
Panelist Number:	Date:

Instructions: You are presented with three coded samples of . Two of these samples are identical or alike, while the third is different or odd. Taste and smell each sample, and then place an X in the second column next to the sample code that you identify as being odd. Write any comments below describing what is different about the sample. You may test each sample several times if required.

SAMPLE CODE	ODD SAMPLE

Comments:

Analysis & discussion

1. Calculate the percentage of taste testers who correctly identified the cookie sample that contained the flour with cricket powder.
2. Using data from above, give a concluding statement on whether you believe entomophagy will expand in popularity as a food source via grounding into flour.

3. Discuss 3 factors that need to be controlled during the taste testing.

Extension Activities

1. Research foods that include the ingredients outlined in the table below:

International GM crop	Australian foods found in (as an ingredient)
Soy	
Corn (maize)	
Sugar beet	

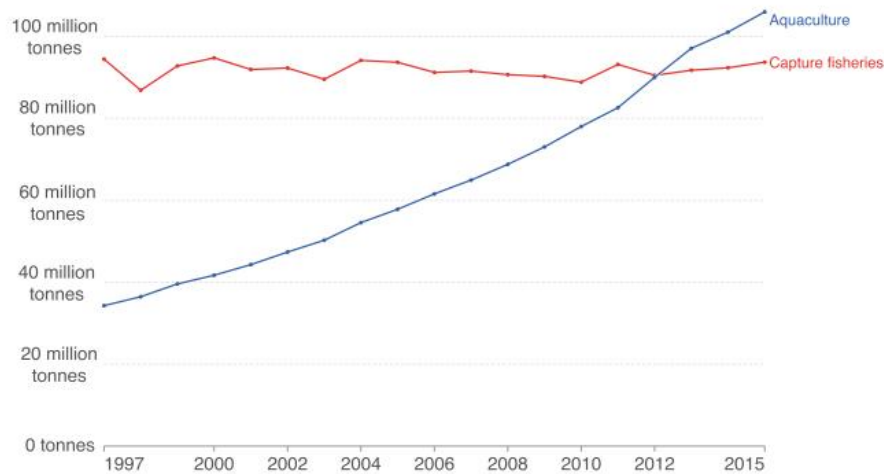
2. Research new foods being created and trialed using both traditional and CRISPR biotechnologies both in Australia and internationally, and state the modification being made.

3. Run a class debate on the benefits and concerns of introducing further GM foods into Australia, in relation to food security and environmental damage. Include the benefits and concerns in the table below.

Benefits	Concerns

Topic Three Summary Test

1. Sourcing of seafood to meet human consumption needs have shifted to rely more on aquaculture. Refer to the following graph, which demonstrates the quantity of aquaculture and capture fisheries from 1997 to 2015.



Data source: Food and Agriculture Organization of the United Nations (via World Bank)
OurWorldInData.org/fish-and-overfishing | CC BY

- (a) With reference to the graph above, identify the approximate year when Aquaculture overtook commercial fishing as our primary method to source seafood.

(1 mark) (IAE3)

- (b) Discuss two reasons for the aquaculture industry overtaking commercial fishing in providing seafood for human consumption.

(4 marks) (KA2)

- (c) An aquaculture farm for large predatory carnivorous barramundi has recently received negative media attention for wiping out surrounding small wild fish populations. Describe two ways aquaculture could have contributed to this environmental issue.

(4 marks) (KA2)

2. A vertical farming technique incorporates aquaculture and the growing of lettuce.

- (a) State the type of vertical farming incorporating aquaculture.

(1 mark) (KA1)

- (b) Describe three ways growing lettuce using vertical farming methods is advantageous in comparison to monoculture cropping.

(6 marks) (KA2)

3. On average, food travels approximately 4,000 km every time it is delivered to the consumer.

- (a) Define the term food miles.

(1 mark) (KA1)

- (b) Discuss the following statement and provide justification to support: *'Foods with lower food miles do not necessarily have a lower environmental footprint'*.

(4 marks) (KA2)

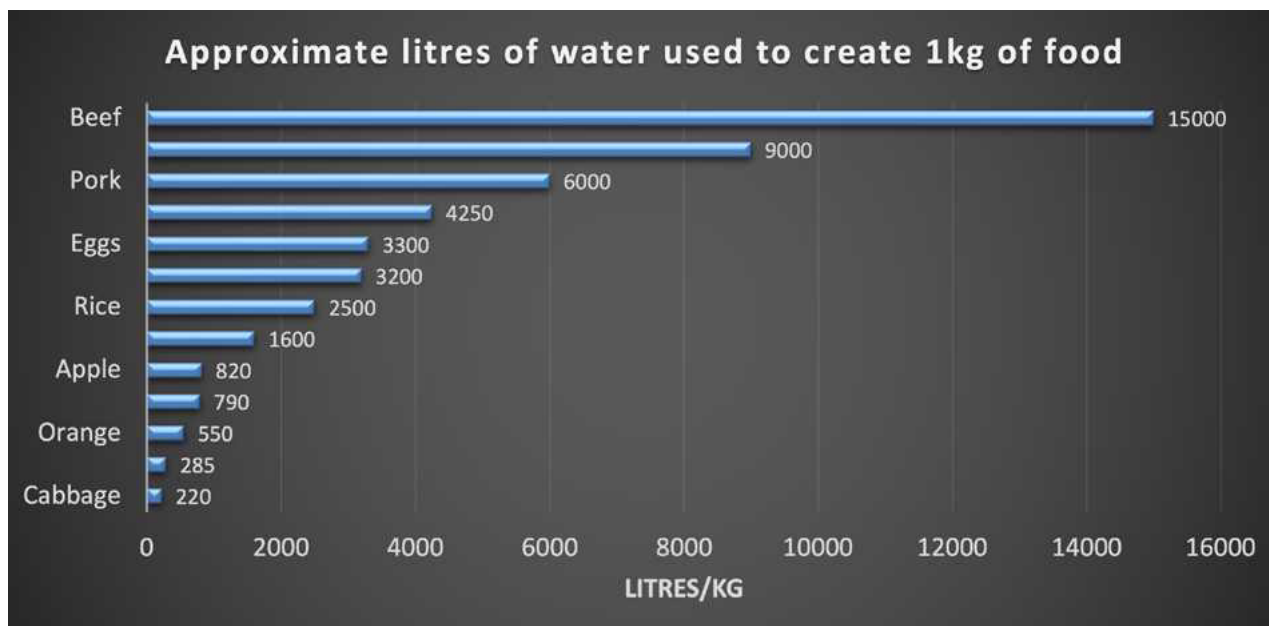
- (c) List two strategies consumers could adopt to reduce food miles of their food purchases.

(2 marks) (KA2)

- (d) Bob notices some of his food products being delivered are packaged with bioplastics. Discuss one potential benefit and one concern of using bioplastics as a packaging material.

(4 marks) (KA2)

4. The water footprint of food production varies dependent on the type of food, which is shown in the graph below.



- (a) Using data from the graph above, identify whether fruit or vegetables have a larger water footprint.

(2 marks) (IAE3)

- (b) With reference to the graph above, provide a concluding statement about the general trend of water use in plant-based produce compared to animal-based produce, and provide two possible reasons for the trend.

(5 marks) (IAE3)

- (c) Identify an anomaly to the statement made in part (b) above and identify an innovative farming method you could employ to reduce water use for this product and discuss how it does this.

Anomaly:

(1 mark) (IAE3)

Innovative farming method:

(2 marks) (KA2)

- (d) With reference to the graph, beef has the greatest water requirements.
- (i) Apart from improving water availability, discuss two ways how removing beef from our diets would help to lower agriculture's environmental footprint.

(4 marks) (KA2)

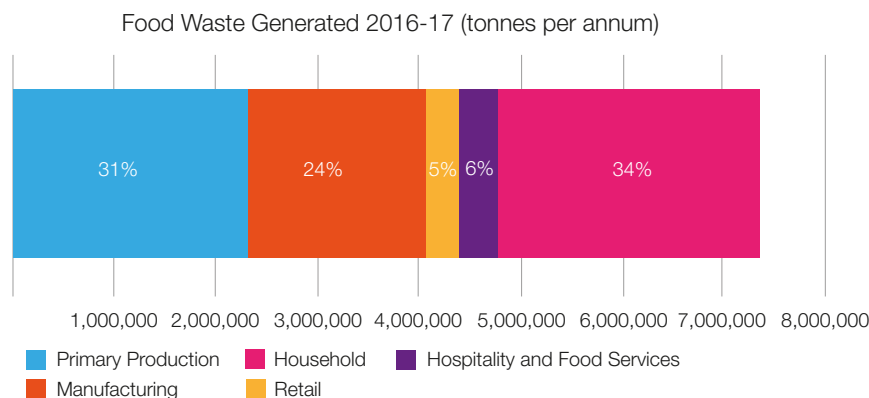
- (ii) Identify an innovative food production method to produce beef that could reduce beef's large water requirements and explain how the production method can improve food availability.

Innovative food production method:

Explanation:

(2 marks) (KA2)

5. In Australia, 7.3 million tonnes of food is lost or wasted each year! The following figure demonstrates the National food waste generation by sector for 2016 and 2017.



- (a) With reference to the figure above, identify which sector wasted the most food over the 2016-2017 period.
- (b) Provide two reasons why the sector identified in part (a) wastes so much food.

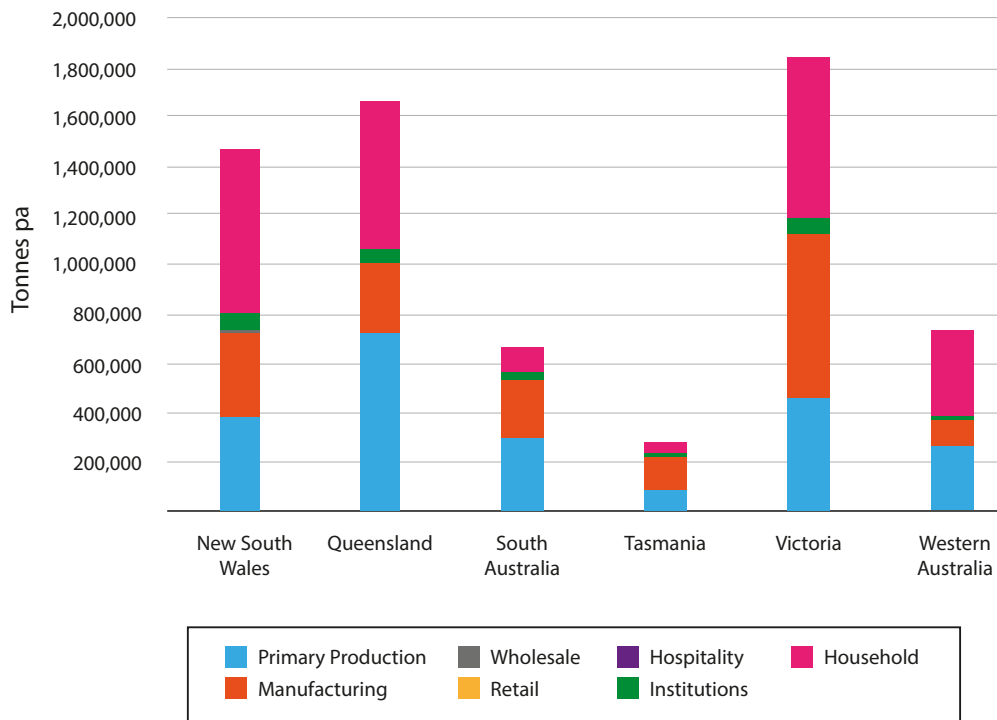
(1 mark) (IAE3)

(2 marks) (KA2)

- (c) Using data from the graph, provide a concluding statement comparing sectors that contribute to food waste versus food loss.

(3 marks) (IAE3)

- (d) Refer to the graph below, which demonstrates the food loss and food waste contributions by sector and state for 2016 and 2017.



- (i) With reference to the graph above, identify the state whose agriculture sector contributes the most to food loss.
- (1 mark) (IAE3)
- (ii) Identify the state whose primary production sector contributes the least to food loss.
- (1 mark) (IAE3)
- (iii) Suggest two initiatives of state identified in part ii. that may account for it having the least food loss from primary production.

(2 marks) (KA2)

6. The following article on Aeroponics has been modified from: <https://interestingengineering.com/13-vertical-farming-innovations-that-could-revolutionize-agriculture>.

The innovation of Aeroponics in the field of vertical farming was made by 'The National Aeronautical and Space Administration' (NASA). This sustainable growing technique was invented by NASA in the 1990s when it was looking for efficient techniques to grow plants in space. This technique was then coined Aeroponics and involves growing plants without soil and with very little water.

It is undoubtedly the most efficient way in vertical farming as it uses a staggering 90% less amount of water than the most efficient hydroponics systems too. It has also been observed that the plants that are grown with the aeroponics system uptake more vitamins and minerals, thus making the plants potentially healthier and more nutritious.

- (a) Describe the **development** of aeroponics in vertical farming.

(4 marks) (KA3)

7. Monoculture practices have been linked to issues with dryland salinity.

(a) Define monoculture cropping.

(1 mark) (KA1)

(b) Place the following steps of dryland salinity development into their correct order by numbering them from 1 (first) to 5 (last).

Rainwater seeps through the soil, unable to be trapped and used by tree roots	
Crops planted in topsoil perish in saline soils	
Food supply dwindles	
Deforestation removes natural habitats to allow for agricultural crops to be planted	
Water table rises dissolving saltwater as it rises	

(5 marks) (KA1)

(c) Identify and discuss how an innovative food production method that could be utilised to maintain food availability should many farmers face dryland salinity.

(2 marks) (KA2)

(d) Aside from dryland salinity, discuss two ways monoculture cropping can affect soil quality.

(4 marks) (KA2)

8. Discuss two ways food manufacturing or processing can negatively affect biodiversity.

(4 marks) (KA2)

9. CSIRO is undertaking a series of projects designed to kick-start an Australian insect industry:

The following article has been modified from: <https://www.sustainabilitymatters.net.au/content/sustainability/article/csiro-developing-nation-s-insect-industry-472464035>.

Boosting libido in flies

One project involves the development of a recipe to get Black Soldier Flies in the mood to mate. Partnering with Canberra-based start-up Goterra (a food waste industry), farming experts from CSIRO have been searching for the perfect combination of conditions that will encourage flies to mate — testing lighting, temperature, moisture, surface texture and diet. Boosting egg laying will enable Goterra to breed more insects to eat through food waste and turn it into compost.

Farming insects for food

Sustainable insect farming requires less land and water than raising cattle or pigs, while still producing a high-protein end product for consumption. Working alongside the University of Adelaide, CSIRO is expanding its partnership with Goterra to investigate which native Australian insects are the best nutritional options for human consumption. The agency's Australian National Insect Collection will help identify native species of insects that are potential candidates for Australia's edible insect industry. The organisation is also working with local Aboriginal communities to understand traditions around witjuti grubs, bogong moths and green tree ants, which are known for their zesty citrus-tasting abdomens.

To get the industry roadmap underway, CSIRO is hosting an international conference on edible insects in Brisbane, to help guide the development of the insect industry in Australia.

- (a) Using the information provided above, discuss how this study highlights the interaction between science and society using two different Science as a Human Endeavour (SHE) key concepts.

SHE key concept one:

(4 marks) (KA3)

SHE key concept two:

(4 marks) (KA3)

- (b) If flies can be encouraged to mate, they will produce eggs and therefore larvae at a more frequent rate. Larvae utilise food waste, converting it into compost. To determine the best conditions that will encourage flies to mate, researchers manipulated the temperature of 4 different aquarium-style containers. The following results were recorded after one week.

Temperature (°C)	20	25	30	35
Food waste consumed (g)	346	442	488	435

- (i) Identify the independent variable in this experiment.
(1 mark) (IAE1)
- (ii) Identify the dependent variable in this experiment.
(1 mark) (IAE1)
- (iii) Identify two factors that need to be controlled in the experiment and explain the importance of keeping these factors controlled.
(4 marks) (IAE1)
- (iv) With reference to the data in the table above, identify the temperature where flies are frequently mating.
(1 mark) (KA1)
- (c) State the term given for the 'farming of insects for food'.
(1 mark) (IAE3)
- (d) The consumption of insects may not gain popularity due to the thought of their consumption being unappetizing. List an alternate innovative food production method that could change the appearance of insect produce to make it more appetizing to the consumer.
(1 mark) (KA1)

Total: / 90 marks

Answers

Topic One Solutions

1.1: Determining energy and nutrient requirements

Review Questions

1. **Snack A: Small packet (20g) of Original Popcorn**

Carbohydrates: $8.4\text{g} \times 16.7\text{kJ/g} = 140.28\text{kJ}$

Protein: $1.8\text{g} \times 16.7\text{kJ/g} = 30.06\text{kJ}$

Lipids: $5.1\text{g} \times 37.7\text{kJ/g} = 192.27\text{kJ}$

Total = $362.61\text{kJ} \approx 363\text{kJ}$

Snack B: Fruit & Nut Muesli Bar (45g)

Carbohydrates: $25.1\text{g} \times 16.7\text{kJ/g} = 419.17\text{kJ}$

Protein: $4.1\text{g} \times 16.7\text{kJ/g} = 68.47\text{kJ}$

Lipids: $6.7\text{g} \times 37.7\text{kJ/g} = 252.59\text{kJ}$

Total = $740.23\text{kJ} \approx 740\text{kJ}$

Snack C: Mini Blueberry Muffin (40g)

Carbohydrates: $17\text{g} \times 16.7\text{kJ/g} = 283.9\text{kJ}$

Protein: $1.7\text{g} \times 16.7\text{kJ/g} = 28.39\text{kJ}$

Lipids: $6.2\text{g} \times 37.7\text{kJ/g} = 233.74\text{kJ}$

Total = $547.3\text{kJ} \approx 546.03\text{kJ} \approx 546\text{kJ}$

Based on the recommendation that snacks in children's lunchbox should be below 600kJ per serving, Snack A: Small packet of Original Popcorn would be the most suitable snack as it provides the lowest kilojoules per serve (*however mini blueberry muffin would also be suitable as it is below 600kJ also*).

2. (a) Carbohydrate distribution = $\frac{484.3}{1246} \times 100 = 38.9\% \approx 39\%$

Protein distribution = $\frac{233.8}{1246} \times 100 = 18.8\% \approx 19\%$

Lipid distribution = $\frac{527.8}{1246} \times 100 = 42.4\% \approx 42\%$

A majority (42%) of the energy provided by this meal is being provided by the macronutrient: lipids. This alerts the manufacturer to reduce the lipid content to meet the recommended range of 20-35%. On the other hand, only 39% of the kilojoules are being provided by carbohydrates. Therefore, this alerts the manufacturer to increase the content of carbohydrates in this meal to fall within the recommended range of 45-65%. The energy provided by protein in this pasta meal (19%) falls within the recommended range of 15-25%, therefore is suitable.

(b) To reduce the lipid content: using low fat cheese, low fat cream, egg whites only or low-fat butter will ensure the energy provided by lipids falls within the recommended range of 20-35%. As well as this, vegetables (e.g., spinach) can be added to the pasta recipe to increase the amount of energy provided by carbohydrates to ensure it is within the recommended range of 45-65%.

3. (a) Aaron.

(b) Any one of the following reasons:

- Males body composition is composed of greater lean body tissue (muscle), which is a faster metabolising tissue than adipose tissue.
- Males expend more calories per kilogram per hour than females, where males burn 1.0 calorie and females burn 0.9.

- (c) i. 10%
- ii. Energy expenditure = BMR + Physical Activity + Thermic Effect
 Energy Expenditure = $(77 \times 1 \times 24 \times 4.2) + 2210 + (12300 \times 0.1)$
 Energy Expenditure = $7761.6 + 2210 + 1230$
 Energy Expenditure = 11201.6kJ/day
- iii. Energy Balance = Energy Intake – Energy Expenditure
 Energy Balance = $12300 - 11201.6$
 Energy Balance = +1098.4kJ
 Therefore, this is a positive energy balance.
- iv. If these eating patterns continued for a long time, Aaron would gain weight. This would put him at risk of developing obesity, and some of its associated health related consequences, including type II diabetes, cardiovascular disease, and hypertension.

4. (a) Carbohydrates: $58\text{g} \times 16.7\text{kJ/g} = 968.6\text{kJ}$
 Protein: $15\text{g} \times 16.7\text{kJ/g} = 250.5\text{kJ}$
 Lipids: $31\text{g} \times 37.7\text{kJ/g} = 1168.7\text{kJ}$
 Total: $968.6 + 250.5 + 1168.7 = 2387.8\text{kJ} \approx 2388\text{kJ}$

- (b) $\frac{2387.8}{7600} \times 100 = 31.4\% \approx 31\%$

This meal would provide approximately 31% of an elderly female's estimated energy requirements for the day.

	AI	EAR	RDI	UL
Calcium (mg)		1100	1300	2500
Iron (mg)		5	8	45
Vitamin C (mg)		30	45	
Dietary Fibre (g)	25			

5. An advantage of using RDI to evaluate an individual's diet and health is that it is set high enough to meet the nutritional requirements of nearly all (approximately 98%) of healthy individuals. As well as this, it is specific to individuals in different life stages (age groups) and genders.
6. (a) The average BMR of individuals decreased by 2970kJ throughout their weight loss journey.
- (b) Fad diets can be kilojoule restrictive and result in weight loss by significantly reducing the energy intake of individuals who follow them. This leads to a negative energy balance, causing the body's BMR to decrease to conserve energy due to the deficiency in energy being consumed. As well as this, the body obtains energy from its stores, involving the break down of muscles to increase the glucose available. A decreased amount of muscle reduces the amount of energy the body expends.
- (c) Basal metabolic rate had permanently decreased; therefore, these individuals were not burning as many kilojoules at rest. This causes the excess kilojoules consumed from their original diet to be stored as triglycerides in their adipose tissue stores, leading to weight gain.
7. Carbohydrates: $2.6\text{g} \times 16.7\text{kJ/g} = 43.42\text{kJ}$
 Protein: $1\text{g} \times 16.7\text{kJ/g} = 16.7\text{kJ}$
 Total: $43.42 + 16.7 = 60.12\text{kJ}$
 Alcohol: $520 = 60.12 = 459.88\text{kJ}$
 Alcohol provides 460kJ of energy in a glass of wine.
8. (a) A: 38-41 units per day, C: 55-58units per day
- (b) Individual C may require higher units of nutrient X each day due:
- To being malnourished.
 - To having a medical problem/chronic disease.
 - To being pregnant.
 - To experiencing rapid growth.

- (c) False. An RDI is set at the level of meeting the needs of 98% of the population it is targeting. Most people require less than this, but a small number require more.
- (d) The EAR value is established to meet the nutritional needs of at least half of the population of healthy individuals, whereas the RDI is set higher than this value to meet the requirements of approximately 98% of the population.
9. (a) An individual's intake of a nutrient would be inadequate if consuming below the EAR or consuming above the UL.
- (b) Individual's nutrient requirements vary and fall within a range, where toxicity and deficiency can occur if a specific nutrient is consumed in excess or below this range. It is inaccurate to think a nutrient requirement is only one set value for everyone, and not consuming this specific amount will result in toxicity or deficiency symptoms.
10. A majority (49%) of this adolescent's energy intake is being provided by the macronutrient: lipids. This alerts an individual to the need to make lower lipid selections during the day to meet the recommended range of 20-35%. On the other hand, approximately 35% and 16% of the kilojoules are being provided by carbohydrates and protein respectively. Therefore, this alerts an individual to make higher carbohydrate and protein selections during the day to fall within the recommended ranges of 45-65% and 15-25% respectively.
11. *Calculating the % of 8820:*

$$\text{Carbohydrates: } \frac{55}{100} \times 8820 = 4851 \text{ kJ}$$

$$\text{Protein: } \frac{25}{100} \times 8820 = 2205 \text{ kJ}$$

$$\text{Lipids: } \frac{20}{100} \times 8820 = 1764 \text{ kJ}$$

Calculating the quantity of macronutrients:

$$\text{Carbohydrates: } 4851 \div 16.7 \text{ kJ/g} = 290.5 \approx 291 \text{ g}$$

$$\text{Protein: } 2205 \div 16.7 \text{ kJ/g} = 132.0 \approx 132 \text{ g}$$

$$\text{Lipids: } 1764 \div 37.7 \text{ kJ/g} = 46.8 \approx 47 \text{ g}$$

To achieve the recommended energy intake and macronutrient energy distributions, Giuseppe would need to consume 291g of carbohydrates, 132g of protein and 47g of lipids throughout the day.

Case Study

Samantha's current diet provides her with 11,989kJ, however her Estimated Energy Requirement for her age is 10,700kJ (*to calculate the EER, determine the physical activity level (PAL) and then multiply that value by 1000 to get it into kJ = 10.7 x 1000*). This results in a positive energy balance of 1,289kJ. If this pattern continues, Samantha is at risk of gaining weight due to her consuming more energy than she is expending, and therefore at risk of being identified as Obese later in life.

Most of her energy intake is being provided by carbohydrates (50%), which is suitable as it falls within the recommended range of 45-65%. On the other hand, only 11% of her kilojoules are provided by protein, indicating she needs to make higher protein selections throughout the day to meet the recommended range of 15-25%. Her daily diet provides 37% of her kilojoules as lipids, which suggests she needs to make lower lipid selections at other times of the day to keep within the recommended range of 20-35%. As lipids are the most energy dense macronutrient, this can also contribute to her positive energy balance, which can later contribute to an obese category.

Samantha consumes a total of 19g of fibre, which is slightly below the NHMRC recommendation for daily fibre intake of 22g. Although, she is marginally below the recommendation, Samantha should increase her fibre intake slightly to ensure the excretion of soft bulky stool, preventing constipation and diverticulosis.

The NHMRC recommends a diet containing between 460-920mg of sodium per day, whilst Samantha's sodium intake is over triple this amount, with 2566mg. This number is highly concerning as high levels of sodium have been found to directly cause a high blood pressure, which is a further risk factor to developing Atherosclerosis.

Samantha almost meets the recommended daily intake of Calcium (1300mg) a day, as she consumes 1154mg daily. However, she does exceed the estimated average requirement of 1050mg, which meets the nutrient requirements of half of the population. Therefore, her consumption of Calcium is not a concern; however, it is essential that she meets this requirement to ensure a strong peak bone mass delaying the onset of osteoporosis later in life.

The recommended daily intake of Iron for a female between the ages of 14-18 is 15mg, whereas the estimated average requirement is 8mg. Therefore, Samantha's current intake falls within these values where she currently consumes 9.72mg. Iron is responsible for the production of red blood cells, which transport oxygen around the body. If Samantha is deficient in Iron, she may be feeling fatigued due to a lack of healthy red blood cells, putting her at risk of being diagnosed as anaemic. Iron is especially important for a 16-year-old female as they undergo menstruation each month where red blood cells are lost.

**When answering a Case study, ensure data is used to identify the differences between the recommended intake and the individual's current intake. These differences should then be used to justify the diagnosis of the relevant diet related disorders they are at risk of developing. You may not have a deep understanding of the diet related disorders just yet and may need to look ahead at Chapter 1.9 and 1.10 to assist in answering this Case Study. To achieve the 10 marks, you need to identify 5 key differences and make a recommendation to improve her intake of the identified nutrients. An extension could be identifying what the deficiency or excess of this nutrient may lead to.*

Science as a Human Endeavour

How to count macros for weight loss and why registered dietitians often consider it a better method than calorie counting.

1. Limitations:

- Macro counting can be confusing at first and can take time to adjust. Even the most experienced calorie counters can find it difficult as you need to first identify the amount of energy required to be consumed in comparison to the amount of energy you expend daily.
- It takes time and energy to count macros, and therefore people may not have time to record and calculate their macronutrient intake.
- Learning to count macros is a behaviour change and can be overwhelming to establish a whole new way of looking at food. Behaviours are difficult to change once they have been established in childhood.

2. Applications:

- Macronutrients contribute calories, so by tracking macronutrients, you are essentially counting total calories intake as well. Therefore, if more people were educated on how to count macros, they could ensure that they were consuming the same number of calories as expended or a deficit in calories to lose weight. This could reduce the number of people who are classified as being obese, and the associated diet related disorders that you are at risk of developing. This eventually could reduce the strain on the health care system.
- A strength-training athlete can increase their protein and carbohydrate intake, by understanding how much of each of these macronutrients they need to consume. Therefore, macro counting can be applied to athletes to ensure they consume the correct ratio of macronutrients to repair muscles and replenish energy levels that were used during training.
- Macro counting can be applied to diabetics who are wanting to monitor their blood sugar by reducing their carbohydrate percentage and increase their fat intake instead. This can reduce the risk of hyperglycaemia and the associated consequences of diabetes.

1.2: Carbohydrates

Review Questions

- (a) Polysaccharide
(b) Monosaccharide
(c) Disaccharide
- Any of the following: sucrose, lactose, or maltose
- Monosaccharides are composed of a single sugar unit (either glucose, fructose, or galactose) and a disaccharide is made of two monosaccharide units, which are bonded together through a condensation reaction.
- As most sports drinks have a high GI, energy levels would rapidly increase followed by a rapid decrease, therefore energy levels would not be sustained for the first few hours after consumption.

	Food A	Food B	Food C
Time from consumption to blood glucose peak	18 minutes	90 minutes	20 minutes
Type of carbohydrate	Glucose	Starch	Sucrose

6.

Function	Type of Carbohydrate
Provides bulk to stools due to not being broken down	Insoluble Fibre (IF)
Slows stomach emptying	Soluble Fibre (SF), Oligosaccharides (O), Resistant Starch (RS)
Binds to water, producing soft and bulky stools	Soluble Fibre (SF), Oligosaccharides (O), Resistant Starch (RS)
Foods high in this carbohydrate create a low GI response	Starch (S)
These carbohydrates undergo fermentation in the colon, providing energy and a food source to beneficial bacteria	Soluble Fibre (SF), Oligosaccharides (O), Resistant Starch (RS)
Foods high in this carbohydrate create a high GI response	Simple Carbohydrates (SC), Glucose (G)
Assists in the functioning of the immune system	Soluble Fibre (SF), Oligosaccharides (O), Resistant Starch (RS)
Carbohydrates that provide the body with energy	Simple Carbohydrates, (SC), Glucose (G), Starch (S)
Simple carbohydrates and starch are broken down into this molecule	Glucose (G)
Slows down initial digestion, maximizing nutrient absorption	Soluble Fibre (SF), Oligosaccharides (O), Resistant Starch (RS)
The only type of carbohydrate the brain can utilize to create energy	Glucose (G)
Creates satiety	Soluble Fibre (SF), Oligosaccharides (O), Resistant Starch (RS)
Reduces cholesterol levels, by binding to bile acids	Soluble Fibre (SF)
Provides bulk to stools through the bacteria that die during fermentation	Soluble Fibre (SF), Oligosaccharides (O), Resistant Starch (RS)

7.

Ingredient	Saccharide grouping
Whole wheat flakes	Polysaccharide
Corn flakes	Poly (processing = mono/di as well)
Apricots	Monosaccharide
Almonds	-
Raw sugar	Disaccharide
Milk	Disaccharide

8. (a) Soluble fibre is broken down in the large intestines by bacteria through a process of fermentation.

(b) Soluble fibre can prevent constipation:

- As it binds to water, which produces soft bulky stools which are easy to expel from the body.
- As the bacteria which die during the fermentation process are added to stools, producing bulky stools which allows an easy passage through the large intestine.
- By increases the transit time of stools through the intestine preventing constipation/diverticular disease/bowel cancer/haemorrhoids/varicose veins

(c) Any two of the following, but make sure to provide a food source from different food groups to demonstrate your extensive knowledge and avoid double dipping:

• Wheat bread	• Carrots	• Beans
• Whole wheat/grain pasta	• Banana	• Green leafy vegetables
• Whole grain cereals	• Apple	• Flesh of the vegetables
• Oatmeal	• Pear	• Linseed
• Brown rice	• Strawberries	• Legumes
• Broccoli	• Nuts	• Seeds

9. When these starchy processed foods are consumed, they become easier to break down into glucose as their starch is partly broken down into maltose, a disaccharide. As maltose requires little digestion due to being made of only 2 sugar units, this sugar enters the bloodstream quickly, producing a similar rapid surge in blood glucose as simple carbohydrates.
10. Simple carbohydrates and starch can be broken down into monosaccharides and enter the bloodstream, therefore providing energy and cellular recognition. Whereas dietary fibre, resistant starch and oligosaccharides cannot be digested by the body to enter the bloodstream, therefore its functions are restricted to within the gastrointestinal tract, specifically the colon.
11. (a) Food A
(b) Food B ($44.3 - 2.7 = 41.6$)
(c) Food C would have the highest glycaemic index, as it is predominantly composed of simple sugars. Food C contains 40.5g of simple sugars and only contains 3.9g of complex carbohydrates; therefore approximately 91% ($40.5/44.4 \times 100$) of this food source are simple sugars and would enter the bloodstream rapidly, resulting in a high glycaemic index response. Simple sugars account for approximately 67% ($51.3/77 \times 100$) of Food A and 6% ($2.7/44.3 \times 100$) of Food C.
(d) Food B would be classified as a polysaccharide as it is made up of mostly complex carbohydrates (approximately 41.6g of a total carbohydrate content of 44.3g). Consuming this food source would therefore cause blood glucose levels to rise gradually and slowly due to taking longer to break down into its simplest form.
12. (a) Low GI foods break down slowly releasing glucose into the blood gradually (or aren't readily absorbed), causing a slow rise and fall of blood glucose levels.
(b) i. The independent variable is the method of cooking a potato.
ii. Any of the following would be accepted:

Variable	Explanation
Type of potato	Different potatoes have differing carbohydrate levels, such as starch, which will lower the GI level if a greater amount of starch is present.
Method of cooking	The way in which the potato is cooked (e.g., boiling) will affect GI levels. For example, other cooking methods may expose the potato to heat for longer periods of time which will increase the GI value further.
Size of potato	The size of the potato will affect cooking time for boiled potatoes. Smaller potato cubes will take less time to cook, increasing the GI value.
Presence of skin	The skin of the potato contains fibre, which will decrease the GI level.
Temperature of water	Cooler cooking temperatures will reduce the cooking effect and lower the GI level.
Method of measuring GI	If measure at different time periods = different effects on GI Measure from different body regions = different glucose quantities in blood

- iii. Boiling the potato for 9 minutes longer will breakdown the food further, allowing the body to break it down more quickly and resulting in a higher GI level where it increased from 49 to 56.

(c) Any of the following:

- Inappropriate title
- wrong labels for axes.
- Incorrect scale for GI (on the y axis,)
- No units for GI =1
- Treatment labelled incorrectly - only mashed - not boiled for 19 mins and mashed.

(d) i. Any of the following systematic errors:

- Incorrect calibration of timer
- Incorrect calibration of equipment used to measure GI.
- Incorrect calibration of thermometer
- Scales used to weigh potatoes.

ii. The impact of a systematic errors reduce the accuracy of the data, making it skew in the same way.

Science as a Human Endeavour:

What is Kombucha and does its hype stand up to scientific scrutiny?

1. Food sources such as Kombucha contain live beneficial bacteria which can enhance gut health by controlling harmful bacteria, protecting against colon cancer, enhancing immune function, and alleviating diarrhea and constipation by allowing an easy passage for waste.
2. Limitations:
 - A limitation of Kombucha is there is only evidence from lab bench studies and animal studies, therefore the effects on humans are unknown and further research is needed to understand if the results translate to humans.
 - The effects of drinking Kombucha are likely to be like drinking tea or fermented foods, therefore if you favour these products due to not liking the taste of Kombucha then stick with these, especially as Kombucha may be more expensive than these items also.
 - Kombuchas on the market have fruit juice added after the fermentation process, which will contribute to your overall sugar intake. Therefore, this can enhance your sugar intake contributing to diet related disorders, such as Obesity and Type II Diabetes.

1.3: Lipids

Review Questions

1.

Triglyceride classification	Structural property	Physical property
Saturated	No double bonds present between the carbon atoms, only single bonds making it saturated with hydrogen atoms	Solid at room temperature or highest melting point
Monounsaturated	One double bond present between the carbon atoms	Liquid at room temperature or lower melting point than a saturated fat
Polyunsaturated	More than one double bond present between the carbon atoms	Liquid at room temperature or lowest melting point

2. (a) Polyunsaturated Fatty Acid – specifically Omega 6
 (b) Monounsaturated Fatty Acid
 (c) Trans Fatty Acid
 (d) Saturated Fatty Acid
 (e) Polyunsaturated Fatty Acid – specifically Omega 3

3. Macadamia nuts: Monounsaturated fat

Beef: Saturated fat

Avocado: Monounsaturated fat

Chia seeds: Polyunsaturated fat (Omega 3)

Cheeseburger: Saturated fat

4. (a) Monounsaturated

(b) Melts first: sunflower oil

Melts second: Olive oil

Melts last: Butter.

(c) Oil or Spread: Flaxseed Oil

Possible functions of Omega 3 include:

- Assists in the development and functioning of the brain in a fetus and infant.
- Reduces LDL cholesterol, reducing the risk of plaque build-up.
- Reduces the risk of an abnormal heartbeat by keeping heart beat regular.
- Reduces the risk of blood clotting by thinning the blood.
- Reduces inflammation, supporting the immune system.

5. (a) i. Trans-fatty acids are more solid at room temperature, which resembles the physical property of a saturated fatty acid.

ii. Naturally occurring trans-fatty acids have at least one double bond between the carbon atoms, like an unsaturated fatty acid.

(b) *Any of the following would be accepted:*

- Improves the texture of foods by making them more solid, therefore increasing sales allowing manufacturers to make a greater profit.
- Protects fats against oxidation, which causes these products to turn rancid. This extends their shelf life making them inexpensive to produce.

6. (a) Omega 3 or Omega 6

(b) An essential fatty acid cannot be synthesised in the body, and therefore must be consumed from the diet.

Ingredients	Triglyceride category
1 zucchini (about 12–15 cm long)	
2½ tbsp olive oil	Monounsaturated
2 tbsp sesame seeds	Polyunsaturated – Omega 6
4 slices avocado	Monounsaturated
1 tbsp finely chopped basil	
200 g cherry tomatoes	
90 g (about 6 slices) smoked salmon	Polyunsaturated – Omega 3
125 g soy cheese cut into small cubes	Polyunsaturated – Omega 6

8. Adipose tissue around vital organs and joints is known as visceral fat, which provides protective cushioning and padding that absorbs any pressure placed on these sites and prevents any physical impact. Adipose tissue under the skin is known as subcutaneous fat, which provides insulation and regulating the body's temperature by reducing heat loss via the skin.

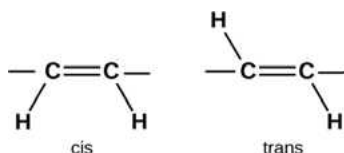
9. (a) Cholesterol is transported in the blood with the support of lipoproteins, due to being mostly hydrophobic and requiring a hydrophilic molecule due to the high-water content in the blood.

(b) Any one of the following functions would be accepted:

- Part of the cell membrane
- Assists in the production of bile, hormones, and vitamin D.

- (c) i. Low density lipoprotein (LDL) is composed of the highest proportion of cholesterol and carries cholesterol from the liver to cells around the body. High density lipoprotein (HDL) contains the lowest proportion of lipids (triglycerides, phospholipids, and cholesterol), and the highest quantity of protein, making it the smallest in size and the greatest in density.
- ii. Oil which would increase the level of LDL cholesterol the most: Coconut oil.
- Oil which would increase the level of HDL cholesterol the most: Flaxseed oil.

10. A fatty acid with a *cis* double bond is where the hydrogen atoms attached to the carbon atoms with a double bond are on the same side of the carbon chain. Whereas a fatty acid with a *trans* double bond is where the hydrogen atoms attached to the carbon atoms part of the double bond are on opposite sides of the carbon chain (as shown in the diagram below).



11. (a) Glycerol and three fatty acids.
- (b) 37kJ/g
- (c) When energy needs have been met, excess triglycerides are stored within fat cells (adipocytes) within adipose tissue. However, if triglycerides are eaten in excess, fat cells continually store excess triglycerides increasing an individual's risk of gaining weight and becoming obese.
12. (a) Myristate: Saturated
Palmitoleate: Monounsaturated
Linoleate: Polyunsaturated
Arachidonate: Polyunsaturated
- (b) Myristate: Solid
- (c) As the chain increases from 14 to 20 carbon atoms long, and the number of double bonds increases from 0 to 4, the melting point decreases from 54.4°C to -49°C. Therefore, it can be concluded that as the carbon chain is longer with greater saturated, the melting point of fatty acids decreases making them more liquid at room temperature.
- (d) Myristate: Coconut Oil
Palmitoleate: Olive or Canola Oil

Science as a Human Endeavour:

Is coconut oil actually good for you?

1. This example demonstrates the key concept of communication and collaboration, as it shows the collaboration between scientists, dietitians, and different dietary associations in researching if coconut oil is healthy or unhealthy for consumption. Examples from the source include:
- Major health heavyweights, including the Dietitians Association of Australia, the Heart Foundation, the World Health Organisation and the American Heart Association aren't so enthusiastic, advising that we only use the saturated-fat laden oil occasionally
 - Professor Barbara Meyer, director of the University of Wollongong's Lipid Research Centre states there is not enough scientific evidence to state categorically that coconut oil is good for us, nor bad for us.
 - Melanie McGrice, accredited practising dietitian and spokesperson for the Dietitians Association of Australia, agrees. "I don't think there's enough research yet.
 - Peter Clifton, a professor of nutrition at the University of South Australia, there's no doubt that LDL cholesterol is a heart risk.
 - Dr Yutang Wang, senior lecturer in biomedical science at Federation University suspects that we may not have a black and white answer as to whether coconut oil is good or bad for us, we don't need to avoid it entirely now.
 - It probably doesn't hurt to include a bit of coconut oil, maybe once a week or fortnight," advises McGrice.
 - According to Clifton, coconut oil only really becomes a concern, cholesterol-wise if you're consuming it regularly.
 - Wang recommends choosing virgin coconut oil, as the hydrogenation process that other oils go through can generate harmful trans fats.

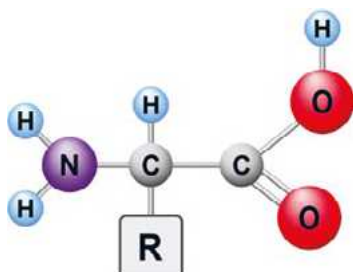
2. Hydrogenation adds Hydrogen atoms to an unsaturated fat (mono or poly), where some or all the double bonds are made saturated (broken). If any of the double bonds remain after hydrogenation, the configuration changes from cis to trans, producing a trans-fatty acid.

1.4: Proteins

Review Questions

1. (a) Nitrogen

(b) i.



- ii. Essential amino acids must be provided by the diet as the body cannot synthesise these at all or cannot produce in sufficient amounts to meet the body's requirements. Non-essential amino acids can be synthesised by the body in sufficient amounts.

2. The sequence and length of amino acids determines the shape and function of each protein in the body. The sequence and length of amino acids are determined by the order of bases on our genes, which are provided by our genetic information (DNA). This set of instructions determines the type of protein that is produced.

3. (a) *Any of the following foods are complete proteins, which have a high biological value:*

- Chicken
- Cheese
- Salmon
- Cow's Milk
- Beef
- Chicken eggs
- Chia seeds

Any of the following foods are incomplete proteins, which have a low biological value:

- Spinach
- Broccoli
- Almonds
- Walnuts
- Pumpkin seeds
- Chickpeas
- Avocado
- Legumes – black beans & white (cannellini) beans

- (b) A protein is considered to have a high biological value if they contain all essential amino acids. These proteins are classified as complete proteins.

4. Protein acts a secondary source of energy and is only used during times of starvation and insufficient carbohydrate and lipid consumption. However, if protein is relied on as the predominant energy source, protein's main functions are sacrificed, and the body will break down tissue proteins to make amino acids available to be used as an energy source. Therefore, blood glucose levels are maintained, but at the expenses of losing muscle and lean body mass.
5. An enzyme is a catalyst, which speeds up a biochemical reaction in the body. An example of an enzyme is salivary amylase, lingual lipase, or pepsin in digestion (*other examples are accepted if suitable*). A hormone is the body's chemical messenger which allows the cells to communicate with each other to implement an appropriate response to restore and maintain body conditions. An example of a hormone is insulin, growth hormone, thyroxine, or dopamine (*other examples are accepted if suitable*).

6. (a) A limiting amino acid is the essential amino acid which is not provided in adequate amounts in the diet to meet the body's requirements.
- (b) A complimentary protein.
- (c) Vegans should have a sound knowledge of complimentary proteins to ensure they consume all essential amino acids. A complementary protein improves the composition of protein in their diets by combining plant sources (incomplete protein) that contain different essential amino acids, which are limited in plant-based proteins which are part of a vegan lifestyle.
- (d) *Any of the following would be accepted:*
- Wheat based noodles with black beans.
 - Brown rice with black beans
 - Pita bread with black beans
 - Crackers with hummus
 - Wheat based noodles with vegetables.
 - Vegetables with sesame seeds
- (e) Popcorn and cashews are not an example of a complimentary protein, as they both have the same limiting amino acid: Lysine. Therefore, when consumed in combination with each other, they do not provide all essential amino acids to the consumer.
7. The body can obtain all essential amino acids from complete proteins, which are derived from animal sources, such as meats, seafood, dairy products, eggs, and egg products. All essential amino acids can also be obtained from soy products, quinoa and chia seeds which are plant based and an exception.

8.

Symptom of Protein Deficiency	Explanation
Oedema (fluid retention) and difficulty with correct fluid balance	A protein known as albumin attracts water, which controls the movement of fluids into and out of the cell. A deficiency in protein causes water to remain outside of the cell causing oedema (fluid retention).
Poor skin, nail, and hair development	Protein is the building block of the growth and development of body tissues, including skin, nails, and hair. Without sufficient protein these bodily tissues do not develop efficiently.
Stunted growth in children	Protein is the building block of the initial matrix of bones where the cells lay down a protein, known as collagen. Without the initial laying of collagen, bones can become soft and underdeveloped causing a stunted growth in children. This can also be caused by the underdevelopment of other bodily tissues also.
Greater susceptibility to bacterial and viral infections	Without sufficient protein, the body is unable to produce the required amount of a specific antibody to fight an invading pathogen. This can increase the prevalence of bacterial and viral infections.
Anaemia (lack of quality red blood cells) & Fatigue	Red blood cells contain a protein known as haemoglobin, which is responsible for transporting oxygen to the body's cells for respiration to occur, which produces energy in the form of ATP. Without sufficient haemoglobin, the quality of red blood cells is compromised leading to the development of Anaemia and the production of less energy, resulting in fatigue.
Depletion in muscle mass	If insufficient protein is consumed, protein will be taken from the muscle to be used as energy or to support other bodily functions. This will deplete the muscle mass.
Muscle pain	A muscle fibre is composed of two types of protein: actin and myosin which assist in the contraction and relaxation of muscles. Without these types of protein, the muscle cannot contract and relax successfully resulting in pain. As well as this, protein assists in the repair of the muscle after exercise, reducing the pain experienced.

9. (a) As an individual increases in age from 0 to 18 years old, their protein RDI also increases from 10-14g to 45-65g.
- (b) i. A non-essential amino acid may become essential where the body is unable to produce enough to meet the body's requirements. This can occur under certain conditions, such as illness, injury, stress, or rapid growing stages. In these cases, they are referred to as conditionally essential.
- ii. With reference to the table only, infancy or pregnancy may be life stages where Arginine becomes conditionally essential due to the rapid growth and development which occurs.

(c) Any of the following explanations would be suitable, dependent on the life stage chosen. However, a different explanation is required to obtain the full four marks.

- Life Stage: Infancy
Protein is the building block of body tissues which provides a constant supply of amino acids for the growth in length and mass of body tissues, including bones, muscles, nerves, arteries, skin, glands, hair, fingernails, teeth, ligaments, and tendons experienced in the first year of life.
- Life Stage: Childhood (1-8 years)
Protein is the building block of body tissues which provides a constant supply of amino acids for the repair of body tissues, including fatigued muscles. Fatigued muscles can result from an increase in activity levels experienced during this life stage.
- Life Stage: Childhood (9-13 years)
Protein synthesises hormones, which are the body's chemical messengers which allow the body's cells to communicate with each other. Hormone production increases during the end of this life stage due to the onset of puberty, therefore protein is required to meet these requirements.
- Life Stage: Adolescence
As blood volume increases, greater red blood cells need to be produced to cater for this increase. Haemoglobin is a protein in red blood cells, which is responsible for the transportation of oxygen. If greater red blood cells are produced, greater haemoglobin needs to be produced also to ensure the quality is maintained. Greater albumin is also needed to be produced to maintain homeostasis by attracting water and controlling the movement of liquids into and out of the cell, which maintains blood volume and fluid balance.
- Life Stage: Adulthood
By adulthood, growth and development is completed, however the maintenance of body tissues is ongoing. Our body is continuously replacing cells in the body to maintain their performance and function, which requires protein to supply the amino acids to do so during this life stage.
- Life Stage: Elderly
Proteins synthesise antibodies, which defend the body against invading pathogens that may cause disease or a virus. In the elderly, their immune system is compromised; therefore, protein can support the production of these antibodies to strengthen their declining immune function.
- Life Stage: Pregnancy
Protein is the building block of body tissues which provides a constant supply of amino acids for the development of the foetus' body tissues, including bones, muscles, nerves, arteries, skin, glands, hair, fingernails, teeth, ligaments, and tendons experienced during pregnancy.

10. (a) As the level of activity increases from sedentary to vigorously active, the recommended daily protein intake also increases from 0.8 to 2.0g/kg. This is necessary as when the body is active (especially strength-based exercise), this causes the muscles to contract and stretch repeatedly causing damage (micro tears). Therefore, greater protein is recommended as greater exercise is performed, to provide the muscles with the amino acids necessary for them to repair and rebuild.

(b) Amount of protein (g) = $1.7 \times 68 = 115.6\text{g} \approx 116\text{g}$ of protein should be consumed daily.

(c) An example of a daily diet may include (but not the only option):

Meal	Food Items	Protein Quantity (g)
Breakfast	2 slices (94g) of wholegrain sliced bread	7.9
	2 Large (120g) hard boiled eggs	14.88
Lunch	80g of cooked Lean Chicken Breast	23.84
	200g of Lentil and Couscous salad	14.20
Dinner	100g of cooked Barramundi	22.80
	½ cup of cooked Brown Rice	2.77
	240g of Green Salad (broccoli, cabbage, corn, kale, sunflower seeds)	13.4
Snacks	¼ cup (30g) of Raw Almonds	5.85
	¾ cup (200g) of Low Fat, natural dairy Yoghurt	12.75
Total Protein Quantity		118.39g

Science as a Human Endeavour:

Considering insects as food.

1. *The following influencing factors can be discussed:*
 - Insects produce the same amount of protein as conventional poultry, beef, and pork which are the most consumed protein sources. This influences the replacement of traditional protein sources as it is important to ensure that society still obtain an adequate intake of protein to prevent any deficiencies.
 - Insects may be a cheaper protein source due to cheaper production costs as they require less land, energy, and water. This influences society economically by providing an affordable protein source, enhancing food security.
 - Insects are nutrient dense being rich in protein and micronutrients, therefore further influencing their introduction into western diets as they have the potential to reduce the risk of nutrient deficiencies and obesity.
 - Insects require 25 times less land resources to raise than conventional beef, half the energy and one third of the water resources. Therefore, their sustainability is a significant influencing factor due to their ability in reducing the rate of deforestation and usage of water and non-renewable resources which will reduce the impact to global warming.
 - Insects can be made into a variety of products including powders and whole roasted snacks, therefore demonstrating their versatility, and influencing their acceptance into society.

1.5: Water

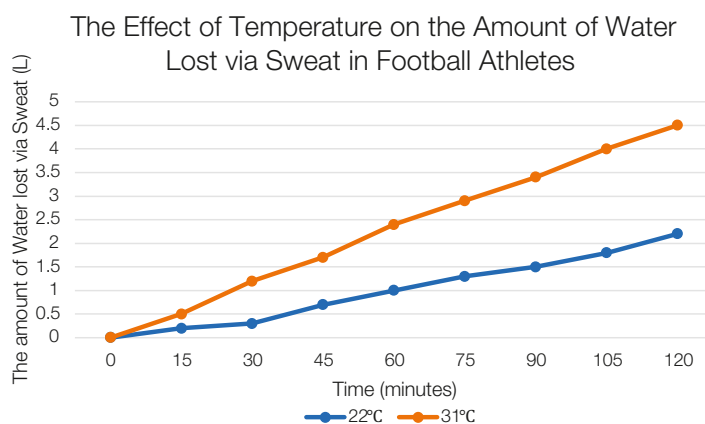
Review Questions:

1. (a) False - Water makes up 75 per cent of lean body tissue and 25 per cent of adipose tissue.
 (b) True – As we age and grow in body size, we require more water as approximately 60% of the body is composed of water.
 (c) True – Water can be lost from the body via vomiting and diarrhoea; therefore, causing dehydration.
 (d) False – Frequent dehydration may cause permanent kidney damage, which can cause a build-up of wastes in the body due to less urination.
 (e) False – Water softens stools, allowing easier evacuation from the large intestines and preventing constipation.
 (f) True – people who are active tend to sweat and lose water via perspiration.
 (g) False – Water softens food and assists with easier movement of food throughout the digestive tract.
 (h) True – Males generally require more water than females because they have a larger body size and generally have greater lean body tissue.
 (i) True – Water acts as a solvent, allowing nutrients to be transported throughout the bloodstream.
 (j) False – Water contains no kilojoules (OkJ).
2. Males require greater amounts of water daily due to having a higher percentage of lean body tissue than females and generally having a greater body size. Three quarters of lean body tissue and 60% of the body is composed of water, which is why males require 3.4 litres a day.
3. *Any one of the following are suitable options as long as from different food groups: including:* milk, watermelon, strawberries, lettuce, cabbage, celery, spinach, fruit juice, yoghurt, apples, grapes, oranges, carrots, broccoli, pears, pineapple, bananas, avocado, cottage cheese, ricotta cheese, corn prawns, baked potato, pasta, legumes, salmon, ice cream.
4. (a) Amber – Dehydrated.
 (b) Thirst is the first sign of dehydration and would indicate the need for water.
 (c) It would be recommended that this individual drink 2-3 glasses of water immediately, or at least every 15 minutes to ensure water is continually absorbed into the bloodstream.
5. The amount of water ingested is one determining factor of blood volume, as water composes approximately 90% of blood. If an individual is dehydrated, the kidneys will conserve water rather than expelling it via urine. However, if an individual is severely dehydrated the volume of blood will reduce which will decrease their blood pressure.

6. (a) As the age of individuals increases from 2 to 70+ years, the proportion of those drinking plain water decreases by approximately 15%. Possible reasons for this trend include thirst reduces with age, the body demands less water as we age or there are more beverage options available as we get older (including tea, coffee, and alcohol).
- (b) Tea and coffee are known as diuretics, which causes increased urination. Therefore, the excessive consumption of tea and coffee promote greater water loss from the body via urine, which can increase the risk of dehydration.
- (c) Milk consumption is at its greatest between the ages of 2-18. An additional benefit of drinking milk at this age is that milk is a great source of calcium, which supports the development and growth of a strong bone matrix.
7. (a) *Any of the following options are appropriate:*
- Sparkling water
 - Sports drinks
 - Lager
 - Coffee
- (b) A large sample size enhances the reliability of the data, by reducing the impact of random errors.
- (c) A control in an investigation acts as a benchmark or a point of comparison. This allows experimenters to see the effect of the independent variable (tested beverage) on the beverage hydration index.
- (d) Oral rehydration solution provides the greatest hydration with a beverage hydration index of 1.5, which indicates that more water is retained by the body. This assists in producing soft stools, which prevents them from drying out and getting stuck in the large intestines, which reduces the risk of constipation.
- (e) Beverage hydration index of coconut water = $\frac{106}{132} = 0.80$

The beverage hydration index of coconut water is less than plain drinking water, therefore the claim is not supported which states that coconut water is as hydrating as plain water.

8. (a) The dependent variable is the amount of water (L) lost via sweat during both games of football.
- (b)



(Marks allocated for labelled axes including units, even scale, plotted correctly and legend)

- (c) The amount of fluid lost from the body was greater at a higher environmental temperature (31°C) where this athlete lost 2.3L more fluid after 120 minutes of football than at 22°C. This difference could be due to greater perspiration being evaporated from the surface of the skin, attempting to cool the body due to a higher ambient temperature.
- (d) *Any two of the following:*
- Diet: Low consumption of foods with a high-water content or an excessive consumption of diuretics which promote water loss via urine, will require more water to be consumed.
 - Body size: an individual with a greater body size will have higher water requirements as 60% of the body is composed of water.
 - Activity levels: an individual who is active will have higher water requirements due to the loss of water from greater perspiration.
 - Illness/Blood loss: an individual who is ill will have higher water requirements due to greater loss of water from vomiting, diarrhoea, sweating (due to having a high temperature) or blood loss.

Science as a Human Endeavour:

Which drink is best for hydration? Hint: it isn't water.

- The findings in this recent study can be applied to endurance athletes to ensure maximum hydration during the event. The findings in this study suggest that beverages with a small content of sugar, fat, and protein (e.g., milk) may be more beneficial for an athlete to consume prior to a marathon event as they slow down the emptying of the stomach and absorption into the bloodstream, keeping individuals hydrated for a longer period. However, it would be recommended to consume water after a marathon event to allow for a quick release of water into the bloodstream to increase hydration levels as quickly as possible.

1.6: Vitamins

Review Questions

- 1 = h 2 = a 3 = b 4 = f 5 = g 6 = c 7 = e 8 = d

- Water soluble vitamins are required to be consumed more frequently. Water-soluble vitamins are not stored in the body, whereas the fat-soluble vitamins are stored in the body's adipose tissue. Excess water-soluble vitamins are excreted via mostly urine. As well as this, if the foods are cooked or processed, they have typically lost some of the water-soluble vitamins making them more important to continually have in the diet.

Vitamin characteristic	Fat soluble	Water soluble
Transportation in the body	Dissolves in fat/oil, requiring a lipoprotein for transportation	Dissolves in water, transports easily in the blood
Storage of excess in the body	Excess is stored in adipose tissue and the liver	Excess cannot be stored, and are excreted via bodily fluids daily
Absorption from the small intestines	Absorbed in the lymphatic system	Absorbed directly into the blood
Probability of deficiencies	Deficiencies are less common, and a greater risk of hypervitaminosis	Deficiencies are possible, causing hypovitaminosis
Stability in food processing	More stable and not readily lost through processing	Less stable and can easily be destroyed through exposure to heat, light, and oxygen.

- Children aged 6-7 years likely have less screen time than a 4-5-year-old, as they attend school during the day and potentially participate in extracurricular activities such as sport. Therefore, children of this age have less free time to exceed the recommended 2-hour daily limit.

- Children experience steady and consistent growth during this life stage, where bones increase in mass and density. Therefore, it is essential for children to have an adequate vitamin D intake to increase the absorption of minerals: calcium and phosphorus from the small intestines. These minerals allow bones to become denser and stronger.

Unfortunately, very few foods contain vitamin D, however sources that would improve a child's vitamin D intake include fortified margarines and eggs. Oily fish, such as salmon, herring or mackerel and liver are also sources, however, are generally not favoured by children.

Children who have a vitamin D deficiency are at greater risk of developing Rickets, which leads to the failure of bones to develop normally. This causes the softening of bones, growth retardation, skeletal abnormalities and the bending of bones when attempting to support the body's weight.

Children who exceed the recommended daily limit for screen time are at an increased risk of a vitamin D deficiency, due to a lack of sun exposure. The body can produce a precursor of vitamin D from cholesterol. However, to convert this form of vitamin D to its active form, it is dependent on ultraviolet radiation from the sun. Therefore, children who exceed the recommended daily screen time, produce a limited amount of vitamin D in its active form, which is required for it to perform its functions in the human body.

- The RDI of Folate increases with age, from birth to 18 by 100mg, and then plateaus at 200mg. The RDI of Folate then increases again at pregnancy by 200mg.

- (b) Foetus: Spina Bifida
Pregnant Female: Megaloblastic Anaemia
- (c) *Any one of the following sources:*
- Green leafy vegetables (broccoli, spinach, kale)
 - Legumes (chickpeas, kidney beans, lentils)
 - Fruit (strawberries, citrus fruit)
 - Vegemite
 - Nuts and Seeds (walnuts, flaxseeds)
 - Fortified flour used in making bread grain products.

6. (a) Water-soluble.

- (b) *Any one of the following:*
- Works as a coenzyme in DNA synthesis for RBC formation.
 - Assists in the metabolism of macronutrients to release energy.
 - Activates Folate, to allow it to perform its functions.

(c) *Any of the following food sources can be identified:*

- Beef
- Poultry
- Fish
- Eggs
- Dairy foods e.g., milk, cheese.

(d) i. Pernicious or Megaloblastic Anaemia

- ii. Fatigue may be experienced, as there is a reduced number of healthy red blood cells as they are abnormally large and carry less oxygen to the cells around the body, which is required for energy production. *This is the main sign and symptom; however, further signs and symptoms are explained in chapter 1.10.*

7. (a) The dependent variable is the vitamin (Vitamin B₁ and K) content (mg) in raw and boiled broccoli.

(b) *Any two of the following:*

- Amount/quantity of broccoli, as a smaller size of broccoli will lose its vitamin content faster as it has less to start with.
- Surface area of broccoli, as a larger surface area will lose its vitamin content faster due to greater exposure to the water when being boiled causing water-soluble vitamins to leach from the broccoli at a greater rate.
- Volume of water broccoli is boiled in, as a greater volume of water may cause more vitamin loss due to leaching.
- Age of broccoli, as older broccoli may have a lower vitamin content to begin with due to an increased risk of being exposed to light and oxygen which can denature water soluble vitamins especially.
- Temperature of the boiling water, as a greater temperature may cause greater vitamin loss as heat can denature heat sensitive vitamins.
- Parts of the broccoli e.g., stem or floret, as the stem may not be as susceptible to vitamin loss as it requires greater cooking time.

(c) i. The vitamin B₁ content decreases in the broccoli by 0.1mg after being boiled.

ii. The vitamin K content remains the same at 1.7mg in the broccoli after being boiled.

(d) Vitamin B₁ is water soluble, and therefore, sensitive to heat and water used in the cooking process. Therefore, vitamin B₁ will leach into the surrounding water, whereas vitamin K is fat soluble and therefore not as sensitive to heat or susceptible to leaching into the surrounding water.

(e) The body cannot store any excess quantities of water-soluble vitamins, including vitamin B₁ and are excreted daily from the body via bodily fluids, primarily urine. Whereas the body stores excess quantities of fat-soluble vitamins, including vitamin K in adipose tissue and the liver.

(f) Vitamin B₁ acts as a coenzyme in the metabolism of macronutrients, especially in the breakdown of glucose for energy production.

Vitamin K assists with normal blood clotting when damage occurs to a blood vessel.

(g) Vitamin B1: *Any one of the following sources:*

- Wholegrain or fortified bread and cereal products
- Meat
- Poultry
- Legumes
- dark green leafy vegetables (such as broccoli, turnip greens, asparagus, and spinach)
- yeast
- vegemite

Vitamin K: *Any one of the following sources:*

- Green leafy vegetables (such as kale, broccoli, spinach)
- Cabbage
- Brussels sprouts
- Sauerkraut
- Natto
- Cheese

8. After 2 hours, heating the orange juice at 50°C resulted in an 80% loss of vitamin C; whereas the orange juice heated at 30°C resulted in only 22% loss of vitamin C. This is because vitamin C is water soluble and sensitive to heat, causing a greater percentage of vitamin C to denature when exposed to a higher temperature.

Science as a Human Endeavour:

Folate fortification reduces neural tube defects.

1. This example demonstrates the key concept of Influence, as it explains the acceptance of mandatory folate fortification was influenced by social, cultural, and economic considerations. These considerations are evident in the article through the following examples:

Social:

- Maternal dietary folate deficiency in the first weeks of life carries a higher risk that the foetus' neural tube will not fuse, leading to the development of either spina bifida or anencephaly.
- Spina bifida results in significant lifelong physical disability and early death.
- Anencephaly almost always results in death before or within a few days of birth.

Cultural:

- Campaigns to encourage folic acid supplements were not effective in reducing NTD in the Indigenous population.
- The Indigenous population was found to be at higher risk of NTD compared to the non-Indigenous population.
- While health promotion was moderately successful in reducing the overall risk of NTD, it wasn't effective for Indigenous children, of whom a higher proportion were vulnerable.
- Pre-fortification (2007-2009) there were 2.43 cases of spina bifida per 1000 births in the Indigenous population.

Economic:

- Pre-fortification, the cost of spina bifida was calculated as \$13,535 for the first four years and \$4354 for every year after, up to the age of 43 or 84 years.
- Children with spina bifida are hospitalised 19.4 times more than the general population and have 2.9 times more outpatient visits – therefore costs associated with medical fees and time taken off work to accompany these children.
- Children with spina bifida have pharmaceutical use that is 3.1 times that of the general population and often require assistive technology.
- Loss of work productivity in carers of people with spina bifida has been estimated at 9.2 hours a week.
- People with spina bifida in the workforce lose an average of 10 days due to their disability and have reduced earning capacity (\$21,000 less than the general population).

1.7: Minerals

Review Questions

- Major minerals are required in larger amounts and are found in the body in amounts greater than 5 grams. Whereas trace minerals are required in smaller amounts and are found in the body in amounts less than 5 grams. They both just as important as each other though.
- Both men and women are exceeding the World Health Organisation (WHO) recommendation of 5g per day by 5g and 2g respectively.
 - Any two of the following:
 - Sodium maintains blood volume, which ensures blood flow to the body's cells.
 - Assists with the contraction and relaxation of muscles, preventing muscles twitches and cramps.
 - Creates a negative resting membrane potential, which is crucial for the functioning of the nervous system in transmitting nerve impulses to the brain or muscle for action.
 - Potassium
- Iron deficiency

Food or Beverage Source	Increase or Decrease intake
Orange juice	Increase
Excessive milk and yoghurt	Decrease
English Breakfast Tea	Decrease
Lamb	Increase
Fresh Salmon	Increase
Eggs	Decrease
Fortified cereals	Increase

- calcium deficiency

Food or Beverage Source	Increase or Decrease intake
Cow's Milk	Increase
Salmon	Increase
Pepsi	Decrease
Coffee	Decrease
Yoghurt	Increase
Wholegrains	Decrease
Processed Foods	Decrease

- Any two of the following:
 - Fatigue:** reduced iron intake will lead to reduced haemoglobin production, reducing the quality of red blood cells produced. Therefore, less red blood cells in circulation will reduce the transportation and delivery of oxygen to tissues and organs for cell respiration, which produces energy.
 - Paleness:** The red blood cells in iron deficient anaemia have a reduced amount of the protein haemoglobin, which is responsible for binding to oxygen molecules. When haemoglobin is attached to oxygen molecules, it provides the characteristic red colour to these cells. Therefore, if there is a lack of haemoglobin in the red blood cell, this will reduce the amount of oxygen attached, reducing its red colour, and leading to the skin becoming paler.
 - Fast Heart Rate:** As there is a lower concentration of quality red blood cells in circulation, the heart must pump harder to get oxygen around the body and to all tissues and organs. *These are further explained in chapter 1.10.*

5. (a) *Any one of the following iron functions:*

- Iron is a significant component of haemoglobin in red blood cells, which picks up oxygen when blood passes through the lungs and transports it throughout the body for aerobic respiration.
- Iron is a component of myoglobin, which stores oxygen in the muscle for times when the body's demand for oxygen is greater than the supply. Myoglobin then makes oxygen available to the muscle, preventing it from becoming damaged.

(b) The RDI of iron is 7mg greater for a female aged 14-18 years as this is the average age where females begin to menstruate, where blood is lost every month. Therefore, the body needs iron to make more red blood cells to replace the blood that has been lost.

(c) Iron is poorly absorbed, especially non-haem iron which is found in predominantly plant-based sources that make up a vegetarian diet. However, consuming foods that are high in Vitamin C, such as citrus fruits including oranges or green leafy vegetables including broccoli with non-haem iron sources in the same meal will increase the absorption of this mineral into the bloodstream by protecting it from oxidation. This will ensure that a vegetarian female aged 14-18 years will meet her RDI of this mineral.

(d) i. *Any of the following are some sources of haem iron:*

- Meat
- Poultry
- Seafood, including fish.

Any of the following are some sources of non-haem iron:

- Lentils
- Beans
- Tofu
- Nuts
- Seeds
- Eggs
- Milk
- Cheese

ii. Haem iron is more readily absorbed.

6. (a) Skim cow's milk has the lowest precision due to having the greatest range of 96mg/100mL, due to the outlier of 43mg/100mL in trial 1. This demonstrates that this sample has been affected by random errors, causing the raw data measurements to be further away from each other and therefore reducing its precision. On the other hand, Almond milk demonstrates to have the highest accuracy as the three measurements (raw data) taken are either 2mg/100mL or 0mg/100mL away from the true value of 80mg/100mL. The calculated average is also the same as the true value, further concluding the high accuracy of this milk sample's data.

(b) i. A significant outlier can be identified in trial 1 of the skim cow's milk data set, with 43mg/100mL.

ii. Average calcium concentration = $(130 + 139) \div 2 = 134.50\text{mg}/100\text{mL}$.

The removal of the outlier enhanced the data's reliability by reducing the effect of experimental errors and reducing the difference between the measurements. The removal of the outlier also increased the closeness of the average to the true value, which increases the accuracy of the data set.

(c) *Any of the following errors can be identified:*

- The units of the dependent variable have not been included on the y axis, which should read Average calculated calcium concentration (mg/100mL).
- The average of cow's milk (skim) has not been plotted. This should be 104mg/100mL but has been plotted at 130mg/100mL which is the measurement recorded in trial 2.

(d) *Any of the following groups could be identified:*

- Vegetarian/vegan – may consume soy milk as an alternative to cow's milk as this group of individuals do not consume animal products due to ethical beliefs or health reasons.
- Lactose Intolerant individuals – may consume soy milk as an alternative as they are unable to digest lactose, due to the insufficient production of lactase in their body. Soy milk is lactose free.

- (e) i. Some dietary foods and beverages, such as soft drinks, tea, spinach, coffee, wholegrains, processed foods can inhibit the absorption of calcium by binding to the mineral when consumed at the same time forming insoluble salts. The consumption of excess sodium, alcohol and caffeine can also reduce calcium bioavailability by reducing calcium reabsorption by promoting greater calcium urinary excretion by the kidneys due to being water soluble.
- ii. Calcium crystals form on a matrix of collagen during bone formation, providing a rigid bone structure. This process is continuous throughout an individual's life cycle where old bone is constantly being maintained and new bone is being produced. A long-term reduced bioavailability of calcium during the key growth and development stages, including infancy, childhood and adolescence can limit the bone's ability to reach its optimal mass and density by their late twenties. Therefore, an individual is at greater risk of age-related bone loss, fracture, and osteoporosis (discussed further in chapter 1.10) later in life.

7. (a) *Any of the following iodine functions will be accepted:*

- Component of the thyroid hormone
- Regulates growth.
- Regulates development.
- Regulates metabolism.
- thermoregulation

(b) *Any of the following food sources are some iodine sources:*

- shrimp
- oysters
- fish, including salmon, cod, tuna.
- seaweed

(c) i. The Iodine content in the soil decreases as the distance from the ocean increases. This is evident in the graph as the average content of Iodine has reduced by approximately 48µg/kg as the distance from the ocean decreases from 0km to 500km.

- ii. 1) Waikerie
- 2) If vegetables are grown in Waikerie, this may result in them having a low iodine content due to their soils potentially being low in iodine also due to being the furthest from the ocean. This can lead to a deficiency in Iodine if consumers are not consuming other foods which are naturally high in iodine including seafood. Therefore, the symptoms that may be experienced in an adult include fatigue, weight gain or feelings of coldness, due to iodine's role in the production of thyroxine which assists in the regulation of metabolism and thermoregulation and increases chemical reactions in the body such as aerobic respiration.

A

Case Study

Jimmy's current diet is deficient in Calcium by 977mg, Potassium by 479mg and Vitamin D by 4.7µg, as shown by the calculations below:

Calcium:

$$\text{Current diet} = 137 + 6 + 120 + 28 + 32 = 323\text{mg}$$

$$\text{Difference} = \text{RDI} - \text{current diet} = 1300 - 323 = 977\text{mg}$$

Potassium:

$$\text{Current diet} = 118 + 422 + 230 + 220 + 596 + 935 = 2521\text{mg}$$

$$\text{Difference} = \text{AI} - \text{current diet} = 3000 - 2521 = 479\text{mg}$$

Vitamin D:

$$\text{Current diet} = 0.1 + 0.2 = 0.3\mu\text{g}$$

$$\text{Difference} = \text{AI} - \text{current diet} = 5 - 0.3 = 4.7\mu\text{g}$$

Vitamin D and Calcium work in conjunction with each other. Vitamin D is a calcium absorption enhancer where it increases the absorption of calcium from the small intestines into the blood and reduces the amount lost via urine by enhancing its reabsorption by the kidneys. Therefore, as Jimmy's current diet is deficient in both vitamin D and calcium, his bioavailability of calcium will be low.

Jimmy's current diet needs to increase in calcium and vitamin D significantly. Therefore, some modifications (*not the only options*) can include:

- For breakfast, Jimmy can have toast with fortified margarine and a boiled egg. Both fortified margarine and eggs are a source of vitamin D. Or Jimmy can have cereal with cow's milk, which will enhance his intake of calcium.
- Swapping the juice box to a glass of plain cow's milk or flavoured cow's milk or a fortified juice to increase his calcium intake.
- Swapping the hot dog on a bun with a salad and cheese sandwich using fortified margarine. The cheese will provide a source of calcium and the fortified margarine will provide a source of vitamin D. If Jimmy likes tuna, tuna can also be added to the sandwich as an additional source of vitamin D.
- Green leafy vegetables, such as broccoli, can be added to his roast chicken dinner as a source of calcium. Or the chicken can be replaced with an oily fish, such as salmon as a source of vitamin D.
- Jimmy can introduce snacks including yoghurt with almonds to his day, which will both provide a source of calcium.

As well as the modifications to his diet, Jimmy can also increase his exposure to sunlight, which assists with the production of vitamin D in the body. This is a lifestyle modification and would require him to reduce his time watching TV or gaming in his free time.

1.8: Digestion, the microbiome & malabsorption

Review Questions

Organ or gland	Secretion	Site of release	Action
Salivary gland	Salivary amylase	Mouth	Begins the chemical break down of starch into shorter polysaccharides and disaccharides, specifically maltose.
	Lingual Lipase	Mouth	Begins the chemical breakdown of lipids into shorter fatty acid chains.
Gastric glands	Gastric Juice	Stomach	Gastric juice (hydrochloric acid) is mixed with the bolus, which uncoils proteins and activates gastric pepsin to begin the chemical breakdown of proteins into shorter polypeptide strands.
Pancreas	Pancreatic amylase	Small Intestine	Breaks down polysaccharides into shorter glucose chains and disaccharides.
	Pancreatic trypsin and chymotrypsin	Small Intestine	Breaks shorter polypeptide strands into shorter peptide chains or singular amino acids.
	Pancreatic lipase	Small Intestine	Breaks small fat droplets into singular fatty acid chains, glycerol or monoglycerides.
Gallbladder	Concentrated bile	Small intestine	Emulsifies larger fat molecules, breaking them down into small fat droplets.
2. In mechanical digestion, food is pushed along and physically broken down into smaller fragments, whereas chemical digestion results in the breakdown of all three macronutrients into their basic chemical structures, with the assistance of digestive enzymes and juices.
3. In an individual with coeliac disease or lactose intolerance, they experience a reduction in the absorption of nutrients (including glucose). This is due to the damaged and flattened intestinal walls reducing the surface area in an individual with coeliac disease or due to the incomplete digestion of lactose in lactose intolerance. Therefore, both malabsorption syndromes can result in fatigue due to a reduced availability of glucose in the blood stream, which is used in cellular respiration to produce ATP (energy).
4. (a) Any one of the following ingredients: self-raising flour, oats, or plain flour are a concern for a person with coeliac disease. All these ingredients contain the protein gluten, which is toxic to those suffering from coeliac disease.

(b) *Any of the following are possible alternatives (not the only options):*

- Coconut flour
- Chickpea flour
- Rice flour
- Sunflower seeds
- Gluten free self-raising flour or gluten free flour
- Corn flour/corn meal
- Potato flour
- Quinoa flakes
- Gluten free oats
- Gluten free muesli
- Chia seeds
- Spelt
- Buckwheat
- Almond meal flour
- Any gluten free flour or ingredients
- *No to brown flour, nuts if substituting for flour, lentils.*

(c) Gluten found in ingredients, such as wheat, oats, rye, and barley can trigger an immune response in the small intestines. This causes inflammation of the walls, where the villi become damaged and flattened. This reduces the surface area available for nutrient absorption, leading to nutrient deficiencies.

(d) *Any of the nutrient deficiencies and their subsequent diet related disorders may develop:*

- Iron – Anaemia
- Protein – Anaemia
- Calcium – osteoporosis, hypocalcaemia
- Protein – Kwashiorkor, Marasmus
- Vitamin C – scurvy
- Vitamin B1 – Beri Beri
- Vitamin B3 – Pellagra
- Vitamin B12 – Anaemia
- Folate – Anaemia
- Vitamin D – Rickets or Osteomalacia
- Potassium – hyperkalaemia
- Vitamin E – Haemolytic Anaemia

5. An individual who has undergone gastric bypass has a reduced energy intake due to the reduction of the contents in the stomach. This therefore reduces the amount of nutrients absorbed, due to a lower availability. The amount of nutrients absorbed are further reduced due to part of the small intestine being skipped. Therefore, the chemical digestion of ingested macronutrients is not completed to their monomers, preventing their absorption via the villi on the surface of the intestinal walls. Hence, the implication of this surgery is a reduced intake of nutrients and absorption of nutrients via the villi, which can enhance nutrient deficiencies.

6. (a) Liver.

(b) As time increases, the triglyceride levels decrease as lipid digestion takes place, however, the triglyceride levels are significantly reduced with the presence of bile, in comparison to no bile. After 60 minutes, the triglyceride levels drop to 0mg/dL when bile is present. Whereas after 60 minutes, triglyceride levels are 65mg/dL without bile present. Bile emulsifies larger fat molecules and converts them into smaller fat droplets. This physically breaks them down, increasing their surface area and assists with their chemical digestion by pancreatic lipase. This is why triglyceride levels are 0 with bile, as more is digestion in comparison to without bile.

7. (a) The gut microbiome is the collection of all microorganisms including bacteria, fungi and viruses that live on or within our gastrointestinal tract.

(b) i. Antibiotics reduced the diversity of Person A's microbiome as it resulted in a loss of approximately 54 bacterial species over the course of 7 days. Whereas antibiotics had a reduced effect on the diversity of Person B's microbiome as it caused the loss of only 9 bacterial species across the 7 days.



- ii. Probiotics are foods which contain living good bacteria that can make their way to the large intestines. They can assist in maintaining a healthy and diverse microbiome by restoring balance of good bacteria versus bad. This can reduce the impact of antibiotics, which can reduce the diversity of the microbiome as they don't distinguish the difference between good and bad microbes. Therefore, probiotics can maintain the diversity by supplying microorganisms that may have been cleared by the antibiotics.

iii. *Sources of probiotics may include:*

- Yoghurt
- Kombucha
- Sauerkraut
- Kimchi
- Kefir
- Miso soup
- Pickles
- Tempeh
- Buttermilk

8. (a) D (stomach)

(b) *Any of the following are functions of hydrochloric acid:*

- Prevents bacterial growth and kills most bacteria that may have been ingested with food consumption.
- Uncoils and denatures each protein strand to allow digestive enzymes to break the peptide bonds between the amino acids.
- Converts the inactive form of pepsinogen into its active form: pepsin.

(c) i. The amount of hydrochloric acid secreted declines by approximately 136mg/hr, as age increases from 11-20 to 61-70 years.

- ii. Hydrochloric acid uncoils and denatures protein strands to allow the peptide bonds to break between the amino acids by pepsin. However, if the amount of hydrochloric acid reduces then less protein strands are uncoiled and denatured to allow these peptide bonds to be broken in the stomach. This prevents the completion of protein digestion in the small intestine, reducing the number of amino acids which are absorbed in the small intestines.

9. (a) *Sources of prebiotics can include:*

- Asparagus
- Bananas
- Broccoli
- Apples
- Carrots
- Spinach
- Strawberries
- Oranges
- Tomatoes
- Nuts
- Cereals/oats

Sources of probiotics can include:

- Yoghurt
- Kombucha
- Salmon

(b) Prebiotics are known as gut fertilisers as they provide a food source for gut bacteria. This promotes their growth and enhances the diversity of the microbiome. Probiotics are foods which contain living good bacteria that can make their way to the large intestines. They can assist in maintaining a healthy and diverse microbiome by restoring balance of good bacteria versus bad.

10. In the large intestine, bacteria ferment soluble fibre producing water, gas, and small fatty acid chains, which are then used as energy for the cells of the colon and assist in enhancing the diversity of the microbiome and protecting against disease. Insoluble fibre passes through the large intestine unchanged, which assists in adding bulk to stools, preventing constipation and diarrhoea, and eliminating waste.

11. A gallstone blocking the common bile duct, would prevent the release of bile into the small intestines when lipid was present and pancreatic lipase. This would prevent the emulsification of lipids and their conversion into smaller fat droplets, which have an increased surface area. Therefore, the chemical digestion of lipids by pancreatic lipase would not occur, reducing their absorption and use of lipids in the body.

Case Study

Sibling 2 does not have lactose intolerance as their hydrogen breath test results remained under 20ppm as time increased from 0 to 135 minutes. However, sibling 1 shows signs of lactose intolerance as they recorded a rise in hydrogen over 20ppm for 2 or more consecutive readings. Each reading after 45 minutes demonstrated a hydrogen result over 20ppm. This indicates that hydrogen gas increased, due to lactose being broken down by bacteria in the large intestines instead of it being broken down by lactase in the small intestine.

The siblings may have been experiencing symptoms of bloating, abdominal discomfort, and diarrhoea. These symptoms can be caused by the amount of undigested lactose in the intestines due to the insufficient production of lactase. This undigested lactose attracts water. As well as this, the siblings may have had a significant amount of gas. This is because the undigested lactose moves to the large intestines, where it becomes a food source for the bacteria present, leading to the production of gas and an irritating acid which can cause further discomfort.

It is recommended that sibling 1 reduce their intake of lactose by reading the food label and avoiding products that contain milk, milk solids, whey, and casein. However, they can consume some products containing up to 6 grams of lactose, without experiencing any related symptoms. It is important for this individual not to eliminate all dairy products from their diet, as this may put them at risk of becoming deficient in calcium which is found in these products predominantly. Therefore, it is recommended to consume soy milk and orange juice which has been fortified with calcium, fermented dairy products, including yoghurt and cheese, and plant-based sources such as green leafy vegetables, almonds, or sesame seeds. This will ensure that this sibling does not become deficient in calcium, which can lead to reduced bone mass. It may also be beneficial to consume vitamin D sources such as eggs and fortified margarines, get at least 10 minutes of UV exposure to increase the production of vitamin D and avoid calcium absorption inhibitors to increase the intestinal absorption of calcium into the blood stream.



Science as a Human Endeavour:

Gut bacteria transplants could one day be used as a defence against Alzheimer's Disease.

- This example demonstrates the key concept of communication and collaboration, as it shows the collaboration between researchers and professors from different universities and institutes in sharing their findings about how the transplant of gut bacteria from young mice to elderly mice could protect against Alzheimer's disease. Examples from the source include:
 - "Research has shown that the aging process may be linked with age-related changes in our gut microbiota," said David Vauzour, of the University of East Anglia
 - Prof Claudio Nicoletti, from the University of Florence, Italy, said: "While it remains to be seen whether transplantation from very young donors can restore cognitive function in aged recipients, the findings demonstrate that age-related shifts in the gut microbiome can alter components of the central nervous system."
 - "Manipulating the microbiome is increasingly being seen as a way of improving or maintaining human health, and these results are an exciting indication of its potential for helping us age healthily" said Prof Arjan Narbad from the Quadram Institute.

1.9: Imbalance of nutrient intake - over nutrition disorders

Review Questions

- Android body shape, which is predominantly composed of visceral fat.
- Insulin resistance is a condition where the body's cells do not respond to insulin, thus not allowing glucose to enter the cell from the blood for energy production and/or storage.
- A similarity in the data of self-reported cardiovascular disease cases is that the prevalence in both men and women increases with age. A difference in the data is that men have a greater prevalence in self-reported cases of cardiovascular disease after the age of 45 years, whereas women have a greater prevalence between 18-44 years.
 - The dependent variable is the prevalence (%) of self-reported cases of cardiovascular disease.

- (c) A large sample size provides a better representation of the population, by reducing the effect of random errors and outliers, which allows the data to be more reliable.
- (d) *Any of the following can explain the difference in self-reported cases of cardiovascular disease between men and women:*
- Men are more prone to developing an android body shape, which stores a greater proportion of visceral fat. Visceral fat increases triglyceride and LDL cholesterol levels in the blood, which increases the risk of these depositing in the artery wall at sites which are damaged, leading to atherosclerosis and then cardiovascular disease.
 - Men have lower concentrations of the hormone: oestrogen in the blood than women. Therefore, the endothelial cells along the artery walls are at greater risk of being damaged, as this hormone offers protection. This increases the risk of LDL cholesterol from becoming trapped at these damaged sites, increasing the risk of atherosclerosis and cardiovascular disease.
 - Men naturally have a higher blood pressure than women, which can cause damage to the endothelium due to the pressure blood exerts on the artery walls. This increases the risk of LDL cholesterol becoming trapped at these sites, increasing the risk of atherosclerosis and cardiovascular disease.
 - Men naturally have higher levels of LDL cholesterol and lower levels of HDL cholesterol. This can lead to greater LDL cholesterol becoming trapped at damaged sites of the artery walls, and less LDL being cleared by HDL cholesterol. This again increases the risk of atherosclerosis and cardiovascular disease.

4. (a) *Trends demonstrated in the graph include:*

- The proportion of obesity and overweight in boys increases with age.
 - The proportion of obesity and overweight is greater in boys than girls at every age.
 - The proportion of overweight boys and girls is greater than the proportion of obesity.
 - The proportion of obesity and overweight in girls increases with age until the age of 15 years.
- (b) The proportion of children and young people who are not meeting the recommended amount of daily physical activity is increasing with age.
- (c) Children and young people not meeting the recommended amount of daily physical activity can promote a positive energy balance, where their energy intake is greater than their energy expenditure. This can lead to weight gain due to not expending as much energy than they are consuming. This weight gain can then lead to the development of children and young people being classified as overweight or obese.
- (d) Eating nutritious foods and drink to meet your energy needs promotes a neutral energy balance where energy intake is equal to energy expenditure. This prevents excess energy being stored in the fat cells of adipose tissue due to a greater energy intake than required. Therefore, eating to meet your energy needs will prevent weight gain from occurring, and therefore the development of being overweight or obese.

5. (a) *Chewy Chocolate Chip Muesli Bar:*

$$\text{Energy density} = \frac{\text{Kilojoules (kJ)}}{\text{Serving Size (g)}}$$

$$\text{Energy density} = \frac{510}{31.3}$$

$$\text{Energy density} = 16.3 \text{ kJ per gram}$$

Almond, Cashew & Cranberry Muesli Bar:

$$\text{Energy density} = \frac{\text{Kilojoules (kJ)}}{\text{Serving Size (g)}}$$

$$\text{Energy density} = \frac{692}{35}$$

$$\text{Energy density} = 19.8 \text{ kJ per gram}$$

A serving (one bar) of the almond, cashew and cranberry muesli bar has a greater energy density, as it contributes more kilojoules per gram than one serving of a chewy chocolate chip muesli bar. Further analysis of the protein, fibre, vitamin, and mineral (nutrient content) of each of these muesli bars would need to be evaluated to make a valid conclusion about their density though.

- (b) Energy dense foods are lower in beneficial nutrients, including fibre, vitamins, minerals, and protein and high in kilojoules per gram (energy). Whereas nutrient dense nutrients are high in these beneficial nutrients and lower in kilojoules (energy).

6. The level of LDL declined across the 12-month period by 1mmol/L, whereas the level of HDL increased by 0.4mmol/L. This is because as HDL levels increased, excess LDL was removed from circulation or the artery walls for removal as waste.
7. (a) Both men and women are consuming more than the WHO daily recommendation of 5g salt, by 5g and 2g respectively.
- (b) An excessive consumption of salt increases the concentration of sodium in the bloodstream. Elevated sodium levels in the bloodstream increases blood volume due to retaining water to dilute the concentration of sodium in the blood. This causes an increase in blood volume, resulting in greater pressure being exerted on artery walls, and therefore elevating an individual's blood pressure.
- (c) *Strategies to reduce an individual's daily salt intake can include:*
- Reduce your intake of processed foods.
 - Avoid adding salt while cooking.
 - Use garlic, herbs, spices, lemon juice or vinegars to flavour food instead.
 - Avoid placing the saltshaker at the dinner table to stop adding salt to food.
 - Avoid naturally salty foods including salted nuts, canned foods, cured meats etc.
 - Check the food label and choose foods labelled with low salt, salt reduced or no added salt.
 - Cook your own food, rather than purchasing takeaway or prepackaged meals.

8. *Need to use data in your response and justify why.*

Meal A would be more suitable, as it is lower in the nutrients that can increase the levels of blood LDL (contains 1g less saturated fat and 9g less of simple sugars). Meal A is also higher in dietary fibre (containing 8g more), which can decrease the amount of LDL in the blood. Meal A is also lower in kilojoules (contains 460kJ less), reducing the risk of excess kilojoules being stored in adipose tissue and developing obesity.

However, Meal B may be considered also more suitable due to containing less total fat (3g less), which would reduce overall blood triglyceride levels that can be deposited in plaque. As well as this, Meal B is lower in sodium (69mg less) which reduces the risk of developing hypertension that can cause damage to the endothelium of the artery walls.

9. (a) George had a rapid spike in blood glucose levels from 5.8-16mmol/L, whereas Paul's blood glucose levels remained steady and low at approximately 6mmol/L for the first 2 hours.
- (b) *Symptoms may include:*
- Frequent urination to excrete excess glucose in the blood and due to an increase in fluid consumption to address increased thirst.
 - Increased thirst due to an increase in water loss because of increased urination.
 - Blurred vision due to the pressure placed behind the eye causing the swelling of the lens.
 - Fatigue as glucose is not entering the cell for cellular respiration.
 - Tingling and numbness in the limbs due to excess glucose in the blood causing damage to nerve endings.
 - Hyper-glycaemia/hypo due to the fluctuation in blood glucose levels, which can cause fainting.
- (c) *Possible diet Modifications:*
- Reduce intake of Takeaway foods and processed foods, as these can be energy dense and high in sugar, which increases blood glucose levels, and high in saturated fat, which increases adipose tissue that can place pressure on the already compromised pancreas.
 - Increase consumption of fruit and vegetables by adding seasoning or blending with other foods to mask the unliked taste of them, which have a low GI and contain soluble fibre. This slows the release of glucose, which reduces the pressure placed on the pancreas. These foods can also increase satiety, which prevents overeating and a positive energy balance which can result in weight gain.
10. (a) *Possible ingredient substitutions can include:*
- Pork and veal mince could be substituted to lentils, beans, chargrilled vegetables, soya beans or tofu.
 - Grated pizza cheese or parmesan cheese could be substituted to nutritional yeast, vegan cheese substitute including cashew cheese or zucchini cheese, low fat cheeses including ricotta cheese.
 - Full cream milk could be substituted to skim milk, almond milk, soy milk.
 - Butter could be substituted for a low-fat margarine.
 - Replace salt with herbs.
- (b) *Possible modifications to the method can include:*
- Oven bake the potato wedges instead of deep frying them, as less oil is used and therefore less fat is absorbed by the potato wedges and consumed.

- Avoid sprinkling the potato wedges with salt, and season with rosemary instead. Salt is a risk factor for CVD, due to increasing the risk of hypertension which can lead to atherosclerosis.
11. (a) The first value of Angie's blood pressure reading represents the systolic blood pressure, which is when the heart muscle is contracting and pushing blood through the arteries to the body. The second value of Angie's blood pressure reading is the diastolic blood pressure, which represents when the heart is between beats and is relaxing and filling with blood.
- (b) High – Stage 1 hypertension
- (c) *The following lifestyle factors could be contributing to Angie's high blood pressure:*
- Angie smokes, which is a vasoconstrictor. This narrows the lumen of the blood vessels, which increases the pressure the blood exerts against the artery walls, thus increasing her blood pressure.
 - Angie currently works in a stressful work environment. Stress can increase an individual's blood pressure due to the release of the stress hormone: adrenaline as a way of helping your body cope with the situation.
- (d) Elevated LDL cholesterol levels in the blood can become trapped in the artery wall, causing the build-up of plaque. This narrows the lumen of the artery, which can increase blood pressure and the sheer force of blood pushing against the artery walls due to the narrowed lumen. Therefore, elevating blood pressure.

Case Study: Diagnosis of Diet Related Diseases

This patient could be suffering from Obesity, Atherosclerosis or Hypertension. It is essential you use evidence from the sources to justify your diagnosis and recommendations.

Obesity:

- He has a weight of 120kg and height of 184cm, therefore using the BMI chart, this puts him in the category of severely obese.
- He is experiencing shortness of breath, which is a symptom of obesity, as the body is working harder to pump blood/oxygen throughout the body.
- Large consumption of energy dense foods, including bacon, meat pies, alcohol chocolate donut, potato chips, coke. The consumption of energy dense foods leads to excess energy being stored in adipose tissue as fat, which can increase an individual's weight and BMI.
- His activity levels are sedentary, therefore reducing his energy expenditure, and contributing to a positive energy balance, which can contribute to weight gain and increased BMI.
- Energy dense foods, such as bacon, donuts, salted cashews, should be replaced by nutrient dense foods including fruits, vegetables and wholegrain alternatives which will reduce his energy intake and assist in contributing to a negative energy balance and weight loss.
- Exercise should be performed, including a daily 30-minute walk, which will increase his energy expenditure and result in a negative energy balance in hope of reducing weight and the risk of obesity.

Atherosclerosis:

- Diet is high in saturated fat, being sourced from bacon, fries, and donut. Saturated fat increases the production of VLDL, which is a precursor of LDL cholesterol which deposits along artery walls that are predominantly damaged. Diet is also high in cholesterol, present in animal sources and the eggs. This increases the concentration of blood cholesterol, and LDL, which deposits along the artery walls.
- This individual was a smoker, which causes damage to artery walls, encouraging LDL cholesterol to deposit at these sites, forming plaque and leading to a blockage.
- The angiogram also demonstrates that there is a blockage present in the arteries, which has developed from plaque formation caused by the depositing of cholesterol.
- Symptoms including dizziness, headaches and chest pain can be linked to atherosclerosis also. This is because not enough oxygen is reaching the brain causing headaches and dizziness. Chest pain can be associated with the heart having to work harder to push blood throughout the body and past any blockages.
- It is recommended that saturated fat consumption be reduced, which will decrease VLDL production and then LDL cholesterol. This will reduce the risk of plaque formation in the arteries.
- It is also recommended that physical activity increase, which increases energy expenditure and the burning of fat, and placing less pressure on the heart. Exercise also decreases the levels of LDL and increases the levels of HDL cholesterol in the body.

Hypertension:

- He has a blood pressure reading of 145/92, when it should be 120/80.
- Consumes foods high in salt/sodium including bacon, meat pie, chicken breast with skin, fries, potato chips, salted cashews. Sodium elevates blood pressure by increasing blood volume due to greater water retention by the kidneys.
- He experiences chest pain and irregular heart rate, which may be symptoms associated with greater pressure being placed on the arteries with each contraction of the heart.
- He works 70+ hours a week as a business manager, which may cause heightened stress levels. Stress can elevate blood pressure temporarily but can be permanent if stress continues long term.
- He used to be a chronic smoker, which acts as vasoconstrictor, narrowing arteries and increasing the pressure of blood exerted on artery walls.
- It is recommended that he reduce his sodium intake by including more fruits and vegetables. As sodium causes an increase in blood volume, leading to more pressure placed on the artery walls during contractions.
- To decrease his stress levels, it is recommended that this male should meditate daily (or adopt an alternate stress reduction method), which will naturally decrease his blood pressure.
- It is also recommended that he participates in some light physical activity, including walking, which makes the heart stronger and will increase blood flow with less effort around the body and reducing pain and discomfort which he is currently feeling.

Science as Human Endeavour:

Israeli firm develops bio-artificial pancreas that can cure diabetes.

1. This example demonstrates the key concept of Influence, as it explains the acceptance of artificial pancreas was influenced by social considerations which consider the rising prevalence of diabetes around the world. These considerations are evident in the article through the following examples:

- Cure patients who have type 1 and type 2 diabetes and are insulin dependent.
- Today, you only have ways to manage the disease. This is a cure.
- The patient should never have to inject insulin into his body again.
- There are about 500 million diabetics around the world and of them, Dr Kunicher said, about 160 million were insulin dependent.

This example demonstrates the key concept of communication and collaboration, as it shows the collaboration between professors, doctors and companies researching the development of an artificial pancreas and the success in curing diabetes. Examples from the source include:

- An Israeli company named Betalin Therapeutics has developed a bio-artificial pancreas.
- Dr Nikolai Kunicher, chief executive of the Jerusalem-based company, said in a statement that human trials were expected to begin by January 2021
- Professor Aryeh Warshel, also a Nobel Prize winner (2013 in Chemistry), is a member of the company's scientific advisory board.

This example demonstrates the key concept of development, as it explains the development of a new technology to improve the efficiency of the treatment of diabetics compromised pancreas. It also explains that data will be collected analysed through human trials.

- The artificial organ is made of pig's lung tissue and insulin secreting cells.
- It would then be able to measure the body's sugar level and secrete an optimal amount of insulin needed to balance blood sugar.
- Human trials were expected to begin by January 2021

Science as Human Endeavour:

Plaques causing heart attacks – can nanoparticles help?

2. This example demonstrates the key concept of Influence, as it explains the acceptance of nanoparticles in preventing the formation of plaque in the arteries was influenced by social considerations which consider the rising prevalence of cardiovascular disease around the world but especially in the US. This new technology has also been influenced by the limited success of previous systems used to treat this diet related disorder. These considerations are evident in the article through the following examples:

- Scientists believe the particle will be vital in developing future treatments for one of the leading causes of death in the US: atherosclerosis.



- Approximately half of all deaths in the Western world are caused by atherosclerosis.
- It is the primary cause of atherosclerotic cardiovascular disease (ASCVD), which leads to heart attacks, peripheral arterial disease, and stroke.
- Approximately 25% of deaths in the US are a result of heart disease, amounting to 610,000 people each year, and approximately 735,000 Americans suffer from heart attacks annually.
- Exploring systems that target the cell's surface, although success was limited.

This example demonstrates the key concept of communication and collaboration, as it shows the collaboration between different scientists researching the development and success of nanoparticles in preventing atherosclerosis and therefore CVD. Examples from the source include:

- In January 2020, a team of scientists from Michigan State University and Stanford University announced the creation of a nanoparticle that can destroy heart-attack-causing plaques efficiently.
- In a paper published last month in *Nature Nanotechnology*, the Michigan State and Stanford team explains that the Trojan Horse nanoparticle is effective at targeting atherosclerotic plaque.
- Scientists working on the project believe that the nanoparticle will have applications outside of atherosclerosis. However, more research is needed.

1.10: Imbalance of nutrient intake - under nutrition disorders

Review Questions

- A dietary risk factor is the consumption of processed energy-dense foods, which are low in dietary fibre and water. A Lack of these nutrients can make stools dry and hard, which can lead to constipation causing higher pressure within the gastrointestinal tract to remove stools. This increases the risk of diverticular disease developing, due to the muscles of the intestinal walls becoming weakened.
 - Any of the following would be acceptable:*
 - Exercise assists the movement of the faeces through the intestines by improving gut motility, as the intestinal walls contract pushing food and faeces through.
 - Live with family/flatmate, to increase motivation to cook nutrient-dense meals that are higher in water/fibre.
 - Avoid straining and holding faeces in the large intestines as water is reabsorbed at this site, which makes stools dry and hard.
 - Avoid the overuse of laxatives, as this can cause damage to the nerves in the large intestines and can weaken the muscles of the large intestines preventing them from being able to contract and push the faecal matter out.
 - Large Intestines – specifically the sigmoid colon
 - Any of the following symptoms:*
 - Blood in faeces caused by the pouches pushing through gastrointestinal lining, harming a blood vessel.
 - Abdominal pain/bloating caused from pouches pushing through gastrointestinal tract or becoming infected/inflamed.
 - Fever, from pouches becoming infected due to faeces becoming trapped in pouches allowing bacterial growth.
- Haem iron and non-haem iron
 - Canned steak and vegetables
 - Micronutrient: Vitamin C
Food Source: *any of the following are possible sources of vitamin C:*
 - Citrus fruits, including oranges, limes.
 - Kiwifruit
 - Strawberries
 - Green leafy vegetables, including spinach, broccoli, kale.
 - Brussel sprouts
 - Iron assists in the production of haemoglobin, which is a significant component of red blood cells. Without haemoglobin, the quality of red blood cells is compromised as this is the component that provides the red colour to these cells and attaches to oxygen, which is carried to the body's tissues and organs for aerobic respiration.

- (d) A healthy red blood cell has a concave shape on both sides, where its surface curves inwards. Its flexible disc shape increases its surface area to volume ratio, allowing for oxygen and carbon dioxide to be exchanged more readily. Its shape is also essential in its ability to move through tiny blood cells to reach all tissues in the body. In an individual with Iron Deficient Anaemia, the red blood cells appear abnormal and are unusually small (microcytic) and pale (hypochromic) in colour and have a reduced oxygen-carrying capacity.
- (e) *Any two of the following:*
- Infants and children
 - Adolescents
 - Pregnant females
 - Menstruating females
 - Cancer patients
 - Vegans and vegetarians
 - Individuals who rapidly lose a significant amount of blood
 - Individuals with infections or an autoimmune disorder
 - Endurance athletes.
3. (a) The hypothesis was supported, as the proportion of fractures caused by osteoporosis were 1% when males and females were 30, and this increased to 5% and 20% for males and females respectively at the age of 70.
- (b) An individual achieves their peak bone mass by their mid to late twenties. It is not until an individual reaches the age of 30 that bone formation is not greater than bone loss.
- (c) *Any of the following groups are acceptable:*
- Females experience a greater proportion of fractures caused by osteoporosis due to the hormonal changes that occur during menopause. This results in significant bone resorption and a decrease in calcium absorption.
 - Males also have greater bone density due to have higher muscle mass, which promotes bone strength as the muscles pull on bones when activated.
- (d) i. *Any of the following sources are acceptable, as they are calcium inhibitors which reduce the absorption of calcium, and therefore the bioavailability of this mineral, or diuretics which promote mineral loss through urine:*
- Black coffee
 - Spinach
 - Lentils
 - coke
 - lemonade
 - salted nuts
 - tea
- ii. *Any of the following nutrients are accepted, along with some possible food sources.*
- Calcium: Yoghurt, milk, broccoli, kale, spinach, fortified cereals, tofu, fortified soy milk.
 - Vitamin D: eggs, fortified margarines, oily fish, liver.
 - Protein: salmon, tofu, chicken, meat, eggs, nuts, seeds, wholegrain bread.
4. (a) Diverticula pouches
- (b) Diverticulosis
5. (a) 15 years old
- (b) His iron requirements increase by around 9mg in total, where they increase 1mg/year for 6 years and then suddenly increase by 5mg for a year, followed by smaller increase of 2mg/year for the next year.
- (c) Pregnancy or participation in a high intensity/contact sport for the year
- (d) *Any of the following:*
- Spinach/rhubarb (oxalic acid)
 - bran or wholegrain (phytic acid)
 - tea (tannins)

(e) Any one of the following can be possible symptoms:

- **Fatigue:** reduced iron intake will lead to reduced haemoglobin production, reducing the quality of red blood cells produced. Therefore, less red blood cells in circulation will reduce the transportation and delivery of oxygen to tissues and organs for cell respiration resulting in less energy being produced.
- **Paleness:** The red blood cells in iron deficient anaemia have a reduced amount of the protein haemoglobin, which is responsible for binding to oxygen molecules. When haemoglobin is attached to oxygen molecules, it provides the characteristic red colour to these cells. Therefore, if there is a lack of haemoglobin in the red blood cell, this will reduce the amount of oxygen attached, reducing its red colour and resulting in a paler complexion.
- **Fast Heart Rate:** As there is a lower concentration of quality red blood cells in circulation, the heart must pump harder to get oxygen around the body and to all tissues and organs.

6. (a) Soluble fibre is broken down in the large intestines by bacteria via a process of fermentation.

(b)

	Soluble Fibre	Insoluble Fibre
Function that prevents constipation	• Soluble fibre binds to water forming a gel-like consistency and producing soft stools, preventing constipation. • Soluble fibre also adds bulk to stools, from bacteria which die during the fermentation process. This allows for an easy passage of stools, preventing constipation.	• Insoluble fibre cannot be broken down, therefore providing bulk to stools and allows for an easy passage throughout the digestive tract and preventing constipation.
Specific Food Source	• Flesh of fruits and vegetables • Oats • Legumes e.g., lentils • Psyllium husks • Barley • Fruits containing pectin e.g., berries, apples, or citrus fruits	• Bran • Nuts • Seeds • The skins of fruit and vegetables • Wholemeal bread • Brown rice • Celery

7.

Individual at risk of iron deficient anaemia	Reason
Pregnant female	• Additional iron is needed to support the needs of the developing foetus and to compensate the increase in blood volume.
Female Marathon Athlete	• Increased demands of iron due to high energy requirements, which stimulates an increase in red blood cell production to provide adequate oxygen to the working muscles. • Iron is water soluble and therefore is lost through heavy sweating, which reduces iron stores. • Blood can be lost internally or externally from injury endured from the way the foot lands while running.
Chronic coffee consumer	• Coffee is an iron absorption inhibitor, therefore reducing the bioavailability of iron.
Vegan	• Vegans do not consume animal products which contain haem iron, which is more readily absorbed by the body.
Individual with a serious injury to the skin	• Rapid and significant blood loss causes the loss of red blood cells and iron stores.
Adolescent female	• Experiences puberty, which results in an increase in blood volume requiring an increase in red blood cell production to compensate. • Menstruates, which results in the loss of blood (red blood cells) each month which needs to be replaced.

8. (a) Vitamin D

(b) *Two reasons can include:*

- Females experience menopause, which causes a decline in the hormone oestrogen. This increases the rate of bone resorption decreasing bone density and strength.
- Males generally have greater muscle mass than women. Therefore, when these muscle tissues are activated, they place stress on the bones, encouraging osteoblasts to migrate to these stressed areas to begin laying down new bone. This increases bone strength in these areas, as a greater amount of calcium phosphate is deposited.

(c) *Any one of the following lifestyle strategies can be explained:*

- Increase weight-bearing exercise and resistance training, as these types of exercises activate large groups of muscles in the body which tug and pull on the bones, which causes stress and encourages bone formation to strengthen the bone.
- Reduce alcohol consumption, as alcohol can interfere with calcium balance in the body by disrupting the production of Vitamin D which is necessary for calcium absorption.
- Stop smoking, as smoking can reduce the rate of bone formation through slowing down the production of osteoblasts and reducing the blood supply to bones.
- Reduce caffeine consumption, as it is a calcium absorption inhibitor and therefore reduces the bioavailability of calcium in the body.
- Increase sunlight exposure especially in the winter months, as UV exposure is required to convert the precursor of Vitamin D into its active form which is necessary for calcium and phosphorus absorption.

Case Study: Diagnosis of Diet-related Disorder

It is expected that this female is suffering from diverticular disease. *Any of the following evidence can be used to support this diagnosis, it would be recommended that at least three are discussed.*

- The presence of diverticular pouches which are shown in the x-ray of the large intestines. This is where these pouches most commonly appear, especially the sigmoid colon, which is the section of the large intestines prior to rectum, which appears to be in the x-ray.
- This female appears to have hard and dry stools which is contributing to her constipation. Constipation can lead to the development of these pouches due to the increased pressure in the intestines and increased straining during defecation. This can cause the muscles of the intestinal wall to weaken, leading to the diverticula pouches forming.
- This female is experiencing abdominal pain and occasional blood in stools, which are common symptoms of diverticular disease, specifically, diverticulosis. The blood in stools indicates that a diverticula pouch has pushed through the intestinal wall near a blood vessel. Diverticulitis is when these pouches become inflamed and infected; however, there are no signs or symptoms that have been presented that indicate an infection.
- This female's sedentary lifestyle also supports the diagnosis of diverticular disease, as this is a lifestyle risk factor. Exercise promotes gut motility which encourages the contraction of intestinal muscles to move food and faeces through the digestive tract, thereby reducing the pressure in the intestines and the risk of constipation.
- Diverticular disease is also more common in adults over the age of 50 as its progression takes considerable time. Therefore, this is another contributing risk factor as this female is 65 years of age.
- Her current diet presents nutrition related risk factors, as there is a lack of dietary fibre and water being consumed. Both dietary fibre and water assist with making stools soft and bulky, which allows for their easy excretion from the body, preventing constipation.
- Her consumption of two black coffees can also contribute to constipation, as caffeine is a diuretic which promotes the loss of water via urine. This makes less water available to soften stools, which increases the risk of constipation.

Therefore, the following the recommendations would be beneficial in reducing the severity of this disease and further diverticula pouches from forming. It would be recommended that at least two are discussed.

- This female should slowly increase her intake of dietary fibre, as a sudden increase in dietary fibre can cause further bloating and cramping. It would be recommended that she add oats or a piece of wholemeal bread with her breakfast, swap white bread with wholemeal bread, replace the hot chips with steamed vegetables, such as sweet potato (skin on) and broccoli, and swapping plain salted chips with a piece of fruit or handful of nuts. These food alternatives are sources of dietary fibre, which would assist in making her stools soft and bulky, thereby reducing the risk of constipation.
- The two black coffees should be swapped for water, as caffeine is a diuretic. This modification will keep stools soft, allowing them to pass easier through the intestines and preventing constipation.



- Exercise should be introduced with at least 30 minutes of physical activity every day. Exercise promotes gut motility and directs blood flow to the digestive muscles, which allows them to contract quicker and more efficiently. This moves food and faeces through the large intestines, thereby reducing the pressure in the intestines and the risk of constipation.

Science as a Human Endeavour:

How a NASA inspired belt could treat low bone density using vibration to prevent osteoporosis.

- The vibrations tug and pull on bone, which places stress on bones, encouraging osteoblasts to migrate to the area to begin laying new bone. This increases bone strength as a greater amount of calcium phosphate is deposited.
- Development:
 - Developed to be an osteoporosis prevention tool, which was developed from findings made by NASA regarding bone loss in astronauts. This belt was developed and trialed on post-menopausal women who experience rapid bone loss, where a 14% reduction in NTX levels was found after a 30-minute treatment, which is a reliable indicator of the rate of bone resorption.

Communication & Collaboration:

- International Osteoporosis Foundation communicates the severity of the issue of osteoporosis highlighting the prevalence where 1 in 3 women and 1 in 5 men experience an osteoporotic fracture. Alongside American Journal of Managed Care who identifies that currently 54 million people experience low bone density in the US, and half of all women will have a fracture in their lifetime.
- International Osteoporosis Foundation, American Journal of Managed Care, NASA, and Bone Health Technologies are collaborating to assist in the production of a suitable prevention strategy for osteoporosis.

Influence:

- 54 million people in the US have low bone density and predicting that 3 million people by 2025 will develop osteoporosis and/or related expenditures of \$25 billion per year. This is influencing companies in successfully producing a prevention method to reduce the number of people who will develop osteoporosis in the future.
 - The fact there are currently no prevention treatments is influencing companies in producing a prevention method, rather than just treatment method. This can delay the onset and reduce the associated consequences of osteoporosis. As well as this, the current treatment has several side effects, which is another influencing factor on the development of the osteoboost.
- The following impacts could be discussed:*
 - Less fractures, which will lead to less hospitalizations and treatments required reducing the cost of health care expenditure which can then be directed to other sectors.
 - It will reduce the number of elderly people admitted to nursing homes, which can reduce the stress placed on these nursing staff members/resources meaning other elderly who require this care will be adequately looked after.

1.11 Nutrition through the life cycle

Review Questions

1.	Life stage name	Physiological characteristic
	Adolescence or Adulthood	Growth ceases
	Childhood	Aged between 1-12
	Elderly	Activity levels can decrease due to joint/muscle pain
	Infancy	Very fast growth rate (can double in height in one year)
	Childhood	Puberty begins
	Adolescence	Very rapid growth rate, but exercise may cease for some
	Adulthood	Lean muscle mass and bone density begin to decline
	Elderly	Immune system function declines

2. (a) i. 50th percentile
 ii. Between the 85th and 97th percentile
 (b) i. 50th percentile
 ii. Between the 85th and 97th percentile.
 (c) i. Iodine and Vitamin D.
 ii. Vitamin B₆, Magnesium or Iron.
3. The situation which would cause an adolescent's energy requirements to be greater are shown in the table below.

Situation 1	Situation 2
Increase in physical activity	
Being a 10-year-old female	
	Developing greater lean body tissue
	Being a 16-year-old male
The onset of puberty	

4. (a) The proportion of fat is the highest in all three fluids, where it is the highest in human breast milk (55%) compared to infant formula (49%) and cow's milk (51%). The proportion of carbohydrates is the second highest macronutrient provided by these fluids, where infant formula provides the highest percentage (42%) in comparison to human breast milk (39%) and cow's milk (29%). Protein represents the smallest proportion of all three macronutrients, where cow's milk provides the greatest proportion (20%) in comparison to human breast milk (6%) and infant formula (9%).
- (b) The implications of introducing cow's milk during the first 12 months in replacement of breastmilk, may not provide adequate fat (only 51%) and too much protein (20%). Fat is required as an energy source and provides more energy than protein (37.7kJ/g rather than 16.7kJ/g), which is required for growth. Also, a higher protein concentration can also stress the infant's kidneys (which is responsible for the removal of excess protein).
5. A lactating female is at greater risk of a diet related deficiency as her nutrient intake is provided to the baby through her breastmilk. The quality of breast milk is maintained at the expense of the mother's nutrient stores. Whereas the nutrients provided in the infant formula are not at the expense of the mother. If a lactating female fails to get enough of a specific nutrient in her diet, she may experience symptoms of nutrient deficiencies, including reduced bone density from a lack of calcium. *Other examples may be accepted if appropriate.*
6. Identifying a barrier (1 mark) and describing a strategy to overcome the barrier is 2 marks.

Barrier	Strategy
Economic: Limited Income—to purchase food	• Using senior card for discounts at supermarkets • Applying for senior services through council for transport to shops, home cleaning, exercise classes, organized elderly activities of lunch and games • Purchase foods on special, in season, canned or frozen foods, generic brands, grow own vegetables and fruits, plant-based protein. • Buy in bulk and therefore prepare meals with similar ingredients. • Buy in season and go to farmers markets or similar (online e.g., Farmers Direct). • Grow own food, cheaper meals, available

Barrier	Strategy
Psychological: Loneliness–no family and grieving, lack of desire to cook and eat alone. Lack of Education–loss of husband who was educated in cooking/ income management	• Use council services which promote and assist in social activities to attend supermarkets and lunches, apply for meals on wheels in which food is delivered and social interaction provided. • Prepare meals with foods she desired which promote happy memories. • Join social groups to find friends and social interaction
Physiological: Reduced function e.g., mobility, unable to use equipment etc. due to–osteoporosis	• Apply for medication and use of medical allotments of physio and exercise classes to help with pain management. • Meals on wheels to deliver food. • Purchase semi-prepared or fully cooked ready to reheat meals online to limit the physical pain of cooking from scratch. • Use kitchen tools which make food prep easier e.g., electric can opener. • Look for easy to use packaging such as pull lid cans

7. Any of the following modifications can be appropriate:

- The following modifications could be made as the food sources identified may be too hard and cause choking, or the infant may not have sufficient teeth to chew these foods.
 - Apple to apple puree (or cooked apple) or a softer fruit e.g., banana
 - Nuts to peanut butter paste (without added sugar/salt) or softer fruit.
- Juice and yoghurt can be high in sugar, which can cause tooth decay or develop bad habits which can lead to the development of diet related disorders later in life.
 - Juice to water
 - Yoghurt to natural or pot set yoghurt or reduced sugar alternate.
- The following modification could be made to increase iron stores in infants, which are generally low.
 - replace any of the snacks for puree meat/iron-fortified cereal.

8. The mother would need to stop consuming cow's milk and switch to alternatives, including almond milk to ensure her breastmilk is able to be consumed by the infant. However, the mother would need to ensure she is consuming enough calcium for herself and the baby, to avoid calcium being lost from her bones and developing osteoporosis earlier in life. The mother may stop breastfeeding and turn to infant formula.

9. (a) Possible answers include:

- Elderly are at greater risk of constipation due to their GI tract losing strength and elasticity, causing food and faecal matter to remain in the digestive tract instead of being excreted.
 - Elderly have reduced activity levels, which can reduce gut motility, preventing food and waste to be pushed out of the GI tract.
 - Elderly may not feel as thirsty or notice a dry mouth as they age, resulting in less water being consumed. Poor water intake can leave faecal matter dry and hard.
- (b) Iron deficient anaemia is common in elderly individuals due to commonly experiencing tooth loss and gum disease, which makes chewing hard foods difficult. Therefore, older individuals may avoid consuming red meat due to the difficulty in chewing it, reducing their intake of haem iron which is more readily absorbed by the body.
- (c) Osteoporosis is common in elderly, especially females as bone resorption is greater than bone formation as age progresses. This causes a decline in bone density, increasing the risk of fractures.

10. (a) Calcium, Vitamin D, and phosphorus are the key nutrients required to assist in the growth, length, and width of the skeleton. Calcium combines with phosphorus and forms Calcium Phosphate crystals on a matrix of the protein collagen during bone formation, which become denser providing strength and rigidity to the bones. Vitamin D is important for increasing the blood concentrations of Calcium and phosphate (phosphorus).

- (b) Protein or cholesterol are key nutrients during puberty where the development of secondary sexual characteristics occurs. Protein synthesises hormones, which increase during puberty (e.g., testosterone in males and oestrogen and progesterone in females).
- (c) Protein is the key nutrient required when muscle mass and body weight is increased during adolescence. Protein is the building blocks of all body tissues, including muscles, bones, skin, artery walls, ligaments and tendons which would all increase with body weight.
- (d) Iron is the key nutrient required to compensate with an increase in blood volume. Iron is a significant component of haemoglobin, which is found in red blood cells and responsible for transporting oxygen.

Case Study

It is likely that Amy has Iron Deficient Anaemia, which would explain her symptoms including a lack of concentration, fatigue, and irritability. A nutrition related risk factor of this disorder is a lack of iron in the diet, which is supported by her current food intake which indicates that she is deficient in iron by 11.4mg. As well as this, her haemoglobin levels are the minimum value of the healthy haemoglobin level range for her age which is 10-15.5g/dL. Amy's blood test results also indicated that her Ferritin levels were below the healthy range of 24-307µg/L by 6µg/L. Ferritin makes iron available to the body, which assists in the production of haemoglobin. Haemoglobin is a significant protein in red blood cells, which is responsible for the transportation of oxygen to the body's cells, which is necessary for cellular respiration. This produces energy, which could explain why Amy is feeling tired and irritable and is struggling to concentrate due to the lack of energy being produced in the body.

The implications of Amy's nutrient imbalances can include:

- Amy's current energy intake demonstrates a negative energy balance by 5541kJ. If this was to continue, Amy would experience significant weight loss placing her at even greater risk of a lower BMI which is currently identified as being underweight already (current BMI is 16.9). This could delay/prevent the onset of puberty and steady growth in weight and height experienced. This lack of energy could also lead to symptoms of fatigue, which can cause a lack of concentration at school or feelings of irritability and moodiness, which she is currently experiencing.
- Amy's actual intake is deficient in protein by 21.7g. The implications of a diet low in protein can lead to the poor development of body tissues as this is a significant role of proteins. As well as this, hormone levels continue to increase due to puberty experienced in adolescence. If Amy's diet is low in protein, hormone production may also decline which could impair her growth spurt, which affects the shape of her body and the function of every organ.
- Amy's diet is deficient in iron by 11.4mg, which is important to cater for her increase in blood volume which occurs due to the growth spurt experienced. Amy's iron requirements are greater than a male of her age due to menstruation, which she started at the age of 12. Amy is also a vegan, so therefore would be consuming non-haem iron which is not as readily absorbed by the body as haem iron. Therefore, these factors could be contributing to her anaemia, leaving her with a low number of quality red blood cells in circulation.
- Amy's is not consuming enough calcium for her age and gender by 988mg. Calcium is important for bone development, which occurs due to the growth spurt experienced at this life stage. A low calcium intake can compromise the development of her peak bone mass which approximately occurs by the age of 30, putting her at greater risk of osteoporosis earlier in life.

Amy's current diet needs to increase in energy, protein, iron, and calcium significantly. Therefore, an example of a meal plan could be (*not the only option*).

- For breakfast, Amy can have a slice of wholegrain toast with fortified margarine and peanut butter. This is an example of a complimentary protein, which would provide Amy with all essential amino acids. Both these sources include iron and calcium also. Fortified margarine is also a source of vitamin D, which will enhance the bioavailability of calcium in the body. By replacing a coffee with a food source for breakfast will increase Amy's kilojoule intake too. The addition of a fortified orange juice would also provide calcium and assist with the absorption of non-haem iron from the toast and peanut butter as orange juice is a source of vitamin C which is an iron absorption enhancer.
- Amy could also add tofu, quinoa, and nuts, such as walnuts to her salad at lunch. Tofu, quinoa, and walnuts are a source of protein, non-haem iron and calcium. Tofu is also an example of a complete protein, providing Amy with all essential amino acids. The apple at lunch could also be replaced with a kiwifruit, which contains a greater content of vitamin C which would assist with the absorption of non-haem iron.
- Amy could increase her serving size of brown rice had dinner. This would increase her kilojoule intake. She could also increase her serves of vegetables to 2 cups and include more green leafy vegetables including bok choy and spinach. These are a great source of incomplete protein, non-haem iron and calcium.
- For snacks throughout the day, Amy could include a handful of roasted chickpeas, kale chips, wholegrain rice crackers with hummus dip, almonds, citrus fruits including mandarins and berries or a protein ball with nuts.

These are all great sources of protein, non-haem iron and calcium. They also will provide Amy with energy to increase her overall energy intake. Citrus fruits are also a great source of vitamin C, which will assist the absorption of non-haem iron.

Breakfast	2 wholegrain slices of toast with fortified margarine and peanut butter 1 glass of fortified orange juice
Morning snack	Handful of roasted chickpeas Handful of almonds 1 cup of berries (strawberries, blueberries, blackberries)
Lunch	1 cup of mixed salad (lettuce, 1 tomato, ½ avocado, 1 cucumber, ½ green capsicum, ¼ red onion, ½ cup of tofu, ½ cup of quinoa, handful of walnuts) 1 kiwifruit
Dinner	1 medium plate of curry lentils 1 cup of brown rice 2 cups of steamed vegetables (broccoli, bok choy, spinach, carrots, and peas)
Snacks	4 Wholegrain rice crackers with hummus dip 1 protein ball 100g of kale chips 1 mandarin

Science as a Human Endeavour:

Lab-made ‘human’ breast milk may soon be an option for parents who can’t breastfeed but don’t want to use formula.

1. This example demonstrates the key concept of Influence, as it explains how the acceptance of lab made human breast milk was influenced by social, economic, and ethical considerations which consider the importance of infant nutrition and the rising prevalence of new mothers that are unable to produce enough breastmilk or have issues with latching or mastitis. These considerations are evident in the article through the following examples:

Social:

- A new mother gave birth to her son early, who had trouble latching, and she struggled to stimulate enough milk.
- She ended up “pumping constantly” and felt beat down by messaging that if breastfeeding didn’t come easily, she just had to try harder.
- It affected how I felt about myself as a woman and as a mother.
- Babies need to eat, and infant nutrition is still going to be fundamentally important for generations to come.
- The American Academy of Paediatrics and the World Health Organisation recommend babies exclusively breastfeed for the first six months of life. The guidance is based on extensive research showing that breastfeeding is linked to a host of physical and mental health benefits for both the birthing parent and baby.
- Breast milk helps protect babies from issues like childhood leukemia and obesity and is associated with a lower risk of type 2 diabetes and certain cancers in the birthing parent.
- Breastfeeding can help a new parent heal from childbirth and encourage bonding between the parent and infant.
- Formula can be harder for the baby to digest and doesn’t adapt to the infant’s changing needs like breastmilk. And formula can’t replicate all those benefits since it’s not made from human made. Instead, it comes from cows, plants, or both.
- It can come in handy for dads, non-biological parents, or parents whose babies have food allergies and can’t tolerate breast milk after their birthing parent has eaten that allergen.
- The important thing is to get fundamental nutrition right for an infant, and this is a new tool in our toolbelt that’s able to get us there faster or better than the existing options that are sold in the market today.
- She wouldn’t choose it over human breastmilk, though, due to its inability to transmit antibodies and build up the baby’s immune system.

Economic:

- Formula – while “a safe, relatively affordable, thoughtfully designed, rigorously tested, and continually improving” alternative to breast milk.
- Heather Guith, a Washington, DC, mum to a 1-and-a-half-year-old for whom nursing, said she’d only choose it if it were priced similarly to formula.
- A third option, using donor milk, is expensive Ethical.
- I think its marketing itself as something it is not and making great parents feel bad about using formula because there might be a ‘better’ option.
- Donor milk can be unregulated when accessed via a black market.

This example demonstrates the key concept of development, as it explains the development of lab made human breast milk which is better than formula and can provide adequate nutrition to infants in the crucial first six months of their life. This key concept is evident in the article through the following examples:

- Strickland and Egger say they have created the two main components in breast milk.
- In February, they announced they had reached a pivotal step in achieving their goal of creating a cultured breast milk that’s “nutritionally equivalent” to the real thing.
- Their lab-grown mammary cells made the two key components of breast milk: lactose and casein.
- We are the first company to produce vital components of milk together within the same system using a process that is sterile from start to finish and free of all contamination.
- This innovation allows us to create the full constellation of complex components in perfect proportion.
- They do expect it to produce all 2,500-some components of human breast milk since a single cell, the human mammary epithelial cell, produces them all.

Topic One Test Solutions

1. (a) $8.5 \times 16.7 = 141.95$

$0.2 \times 37.7 = 7.54$

$26.6 \times 16.7 = 444.2$

Total Energy provided by one serving: 593.71kJ

(b) i. $18.6 \times 16.7 = 310.62$

$310.62/593.71 \times 100$

Proportion of Energy provided by sugar: 52.3 %

- ii. The over consumption of sugar leads to the over working of the pancreas’ beta cells. The beta cells produce insulin in response to sugar in the blood, which signals cells to open their channels allowing glucose to enter. However, when sugar is frequently consumed, the beta cells produce ineffective insulin where the body’s cells become desensitised to insulin, leading to their channels not opening as readily, which is known as insulin resistance. This causes blood glucose levels to remain elevated after sugar consumption, leading to the development of Type II Diabetes.
- (c) i. Cereals, Wheat Flour, Oatmeal, Oat Fibre, Barley Malt Extract.
- ii. If any of the ingredients listed above are consumed by an individual with Coeliac Disease, the villi become flattened and inflamed, reducing the surface area available. Therefore, this reduces the absorption of nutrients, putting the individual at risk of nutrient deficiency disorders.

(d)

Vitamin	One Function	One Food Source	Name of Deficiency
Vitamin D	• Facilitates the absorption of calcium and phosphorus into the bone. • Ensure normal growth and development of the skeleton.	Oily Fish, (including salmon, sardines, mackerel), Fortified margarines, liver, eggs.	Rickets in children Osteomalacia in adults
Vitamin B12	• Acts as coenzyme in DNA synthesis in RBC formation. • Metabolism of macronutrients to produce energy (specifically protein).	Liver, fish, poultry, eggs, dairy products (e.g., milk), Fortified cereals and soymilk	Pernicious and Megaloblastic Anaemia

2. (a) The percentage of people with hypertension increases in both males and females as age increases. This can be seen where 0-3% of males and females between 0-34 have hypertension, in comparison to 43% of females and 47% of males over the age of 75-year-old.
- (b)
 - i. High blood pressure injures the artery endothelium via the sheer force of blood pushing through the arteries. This encourages the depositing of LDL cholesterol and accelerates plaque formation, thus initiating or worsening the progression of atherosclerosis.
 - ii. Atherosclerosis is defined as the build-up of plaque along the artery walls, which narrows the lumen of the artery. This can increase blood pressure and the sheer force of blood pushing against the artery walls due to the narrowed lumen.
- (c) *Possible ways that the DASH diet could help include:*
 - The consumption of fruits, vegetables and wholegrains would increase an individual's intake of soluble fibre. Soluble fibre binds to bile acids, which are made of cholesterol, taking them to the liver for recycling and excretion. This reduces blood cholesterol levels, preventing them from depositing along artery walls and reducing blood pressure pushed against the narrowed lumen of the arteries.
 - Reducing salt in the diet by limiting processed fats and sweets, will prevent water from being retained in the body which increases blood volume. An increased blood volume will increase the sheer pressure placed against artery walls, increasing blood pressure.
 - Consuming lean meats and low-fat dairy will reduce an individual's intake of saturated fat. Saturated fat can increase the body's production of VLDL, a precursor of LDL cholesterol. LDL cholesterol will deposit at damaged sites of artery walls, causing the lumen to narrow and increasing the pressure that blood pushes against artery walls (increasing blood pressure).
 - Presence of foods high in the unsaturated fats such as avocado and oily fish in large sections of the dash diet, promoting higher intake could increase the body's production of HDL which removes LDL plaque deposits for waste disposal into the intestines. This prevents the narrowing of the artery lumen, which can increase the pressure exerted on the artery walls.
3. (a) Type 2 Diabetes or Obesity
- (b) *Evidence may include any of the following (need to include three pieces of evidence)*
 - Obese BMI based on the BMI chart, demonstrating that he has a significant accumulation of fat stored around his body. A risk factor for type 2 diabetics as it places stress on the pancreas and increases insulin resistance.
 - Blood glucose levels are high at 16mmol/L, demonstrating that his body cells are not responding well to insulin, or his pancreas is struggling to produce enough insulin to manage blood glucose levels.
 - Experiencing symptoms of fatigue, which may be due to the physical exertion of the body carrying excessive weight.
 - Experiencing symptoms of fatigue and excessive thirst, which may be due to the body cells not being able to uptake glucose from the blood for cellular respiration (production of energy) and therefore the body frequently urinating to expel this excessive glucose.
 - Limited exercise each week, causing a positive energy balance and excessive accumulation of fat.
 - Avoidance of nutrient-dense vegetables, yet consumption of Alcohol/packageged foods/convenience foods that are energy dense kilojoules leading to the storage of excess energy in adipose tissue as fat.
- (c) *Any of the following symptoms can be discussed (no to fatigue, excessive thirst, and any consequences):*
 - Frequent urination due to an increase in fluid consumption due to increased thirst. Frequent urination may also be experienced to expel excess glucose in the blood.
 - Blurred vision due to fluid being drawn into the eye, causing it to swell.
 - Tingling in the limbs due to damage of the blood vessels and nerves caused from the pressure placed against the nerves and blood vessel walls due to high blood glucose levels.
 - UTI caused by too much glucose in urine.
- (d) *Any of the following of the following lifestyle modifications can be explained:*
 - Increase exercise, promoting a negative energy balance and therefore the loss of weight which can reduce the pressure placed on the pancreas.
 - Preparing home-cooked meals to reduce the consumption of processed/packageged/convenience foods, as these are generally high in sugar, salt and saturated fat which are energy dense encouraging the storage of fat or high GI leading to a spike in blood glucose levels, which can place pressure on the pancreas to produce insulin to manage this spike.

4. (a) Replenisher
- (b) Sample 4 in the Replenisher trial is an outlier, which could have been caused by the presence of a random error, such as cross contamination by other sports drink samples or misinterpretation of the end colour.
- (c) *Any of the following variables will need to be controlled:*
- Amount of Sports Drink tested, as a greater quantity may contain a higher concentration of simple sugars which will result in a different colour.
 - Amount of Benedict's solution, as a greater quantity may result in it remaining blue (its original colour) as the concentration of sugar may not be high enough to change its colour.
 - Number of trials conducted, so it allows for a fair and reliable comparison between sports drinks.
 - Individual determining the colour change, as everyone has a different perception of colour.
 - The solution used to measure the presence of simple sugars, as different solutions will cause different colours and therefore cannot be compared with one another fairly.
- (d) $78 \times 44 / 100 = 34.32$
High GL classification
- (e) As the GL is above 20 which is in the high range, energy is not sustained as energy levels fall quickly after rapidly spiking in the first few hours after consumption.
- (f) GL not only uses the GI of the food, but how much/ the amount of carbohydrate consumed per serve of food. GI only considers the quality of a carbohydrate (the effect on blood glucose levels).
5. (a) Vitamin D
- (b) *Any of the following lifestyle modifications can be explained:*
- Avoid smoking as it limits the absorption of vitamins and minerals and brings on menopause, which promotes bone loss. Causes bone degeneration also.
 - In social settings, drink water instead of alcohol as its consumption limits the absorption of vitamins and minerals, due to promoting urine as it is a diuretic.
 - In social settings, try de-caffeinated coffee options as excess caffeine intake limits the absorption of vitamins and minerals, due to promoting urine as it is a diuretic.
 - Do regular weight bearing and strength training activities as it activates muscles, which pull and tug on bones which encourages bone formation.
 - Exposure to sunlight, as it assists with Vitamin D production which enhances the absorption of calcium and phosphorus.
- (c) i. The EAR is the average amount of a nutrient to meet the nutrient requirements of half of a group of healthy individuals, whereas the RDI is the average dietary intake that is sufficient to meet the nutrient requirements of nearly all (approximately 98%) of healthy individuals. Therefore, the RDI is always higher as it caters for a greater proportion of the population.
- ii. It is recommended that females aged between 12-18 should consume 1300mg of Calcium daily, as their bones are growing, and they are working to achieve their peak bone mass. Beyond 50 years of age, the RDI of calcium increases again to 1300mg, as females experience menopause at this age which promotes bone loss and requires additional calcium to maintain adequate bone density.
- iii. *Any one of the following can be identified and explained:*
- Excess sodium, caffeine, caffeinated drinks, alcohol - decreases the reabsorption of calcium, as they act as a diuretic.
 - Menopause - estrogen levels drop causing a decrease in the efficiency of calcium absorption.
 - Aging causes a drop in testosterone in males, which reduces calcium absorption and promotes its excretion through urine.
 - Any applicable calcium inhibitors - decreases the absorption of calcium by binding to it, making an insoluble molecule not able to be absorbed.
6. (a) Any of the following:
- Contains one or more double bonds.
 - Less saturation of hydrogen
 - Does not have the maximum number of hydrogen atoms.

(b) Any of the following:

- Assists with the development of the brain.
- Reduces inflammation.
- Reduces blood clots, by thinning blood.
- Reduces LDL cholesterol in the blood.
- Reduces irregular heartbeat, keeping it regular.
- Reduces blood pressure.

(c) The body cannot produce these fatty acids, and therefore must be obtained through the diet.

(d) $155/610 \times 100 = 25.4\%$

(e) Saturated fats are labelled as 'bad' fats as they significantly increase the liver's production of VLDL, which is a precursor to LDL. Any LDL that remains in the blood after the cell's uptake is vulnerable in depositing on the artery walls at damaged sites. Whereas polyunsaturated fats are found to increase HDL levels in the blood, which remove excess cholesterol from the blood and take it back to the liver for recycling and excretion.

(f) i. Liver

ii. As time increases, the triglyceride levels decrease as lipid digestion takes place, however, the triglyceride levels are significantly reduced with the presence of bile, in comparison to no bile. After 60 minutes, the triglyceride levels drop to 0mg/dL when bile is present, whereas after 60 minutes, triglyceride levels are 65mg/dL without bile present. Bile emulsifies larger fat molecules and converts them into smaller fat droplets. This physically breaks them down, increasing their surface area. This assists in the chemical digestion of lipids as it increases the efficiency by pancreatic lipase. This is why triglyceride levels drop to 0mg/dL with the presence of bile, as it can complete its digestion.

7. (a) $94 \times 1 \times 24 \times 4.2 = 9475.2\text{kJ}$

BMR: 9475.2 kJ

(b) *Any of the following factors can be explained:*

- Age. Lean body mass diminishes, and physical activity declines with age, which slows BMR.
- Body Size. Larger body sizes (including greater height) have greater metabolising tissue and larger surface area, increasing their BMR.
- Growth. During childhood, adolescence and pregnancy energy demands are greater due to the growth experienced, increasing their BMR.
- Body Composition. A larger amount of lean body tissue increases BMR. This is because muscle tissue is a faster metabolising tissue (burns more kilojoules) than sluggish adipose tissue.
- Gender. Males generally have a higher BMR as their body is composed of greater lean body tissue than females. Males also expend more calories per kilogram per hour than females, where males burn 1.0 calorie and females burn 0.9.
- Amount of Physical Activity. Regular physical activity increases lean body tissue, increasing BMR as muscle tissue burns more kilojoules than adipose tissue even at rest.
- Fever, Infection, and Illness. The body must work harder to build new tissues, develop an immune response, and maintain normal body temperature, which increases BMR.
- Environmental Temperature. High and low environmental temperatures increase BMR, as the body must work harder to maintain normal body temperature.
- Fasting, Starving, Malnutrition and Crash Dieting. Consuming fewer kilojoules than the body expends reduces BMR. This is because the body's basal metabolism slows down to conserve energy. BMR can drop up to 15%, and even further if lean body tissue is lost also.
- Drugs. Drugs can increase or decrease an individual's BMR. For example, nicotine in smoking and caffeine can increase BMR; whilst some antidepressants and steroids can decrease BMR.
- Genetics, Hormonal balance. Genetics and hormone levels can increase or decrease BMR, due to their influence on the rate at which the body expends energy.

(c) $9475.2 + 430 + 1350.4 = 11255.6\text{kJ}$

Total Energy Expenditure: 11,255.6 kJ

(d) $13504 - 11256 = +2248.4\text{kJ}$

Energy Balance: +2248.4 kJ

This demonstrates a positive energy balance, which would cause excess kilojoules to be stored as fat in adipose tissue, leading to weight gain and the development of obesity.

8. (a) Prebiotics, also known as 'gut fertiliser', are non-living, indigestible carbohydrates (by humans) that gut bacteria feed on, promoting growth of that colony. Probiotics are foods that contain living 'good' bacteria and yeast cultures that can make their way into our gut to enhance the diversity. 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.
- (b) i. *Limitations could include:*
- 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* colonises 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.
- ii. *Possible applications could include:*
- 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 the 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 number of sick days these individuals take increasing productivity at work, positively affecting the economy.

Topic Two Solutions

Topic 2.1: Diagnostic Tools

Review Solutions

1. (a) BMI is a measure of weight divided by height (squared), to enable classification of someone into weight categories of underweight through to obese.
- (b) Advantages could include any of the following:
- Inexpensive
 - Non-invasive
 - Equipment is easy and straight-forward to use
 - Not very time consuming.
- Disadvantages could include any of the following:
- Requires a calculation
 - Is not entirely accurate
 - Recording of height/weight can be inaccurate/misleading
 - Only diagnostic for weight-related diseases (in comparison to other diagnostic tools with a larger range of nutritional concerns able to be tested).
- Limitations could include any of the following:
- Doesn't consider age, in particular children or elderly
 - Doesn't consider ethnicity e.g. Asians, Torres Strait Islanders
 - Doesn't consider gender
 - Doesn't consider body composition, in particular athletes or body builders with a higher lean muscle mass
 - No adjustments in measurements for pregnancy
 - No adjustments for those with physical disability e.g. those in a wheel chair.
- (c) (i) Any of the following errors with discussion are suitable:
- If the weighing scales are not calibrated properly this could be a source of systematic error as all participants may be given a weight, for example, over their actual/true weight, giving elevated BMIs.
 - Should weighing scales for measuring every participant be used on the same uneven surface, all participants measured weight would be skewed away from their true value.
 - The measuring tape may be crooked or taped with bends in it, so all participants would get a higher height than their actual height, thereby reducing accuracy.
 - The measuring tape could be stretched or pulled tight before taping to the wall, creating a source of systematic error whereby all participants would be measured shorter than their actual heights.

(ii) Any of the following random errors with associated improvements are applicable:

- Different weights of clothing for each participant provides a source of random error so participants should be instructed to change into the same provided light clothes (same weight) before being weighed.
- Subjects standing off-centre on scales (to the side, or to the back for example), would randomly skew weights. Having participants stand into pre-drawn foot share would reduce this error occurrence.
- If subjects stand with different postures against the wall, this could create random errors. Each participant should stand barefoot with light clothing to feel feet, calves, buttocks and back against the wall to stand straight. A focus point to watch to keep the head straight could also reduce head posture random errors.
- If the ruler used is not always parallel, this could create random errors. This error could be reduced by using a small leveling tool to ensure measuring height parallel from head to measuring tape.

(d) (i) Formula = $\frac{\text{Weight (kg)}}{\text{Height}^2 (\text{m}^2)}$

(ii) $\frac{88}{1.54^2} = 37.11 = 37 \text{ kg/m}^2$

(iii) Severely obese

(e) (i) $\frac{90}{1.51^2} = 39.47 = 39 \text{ kg/m}^2$

(ii) Severely obese

(f) Android (apple)

2. (a) Healthy weight range

(b) Approximately 70-95kg

(c) A calculation is not required (easier).

3. (a) A large waist size has a greatly increased risk of chronic disease as it indicates excess visceral fat. Excess visceral fat can increase the level of LDL/blood triglycerides and therefore increase risk of CVD OR excess visceral fat can deposit around and place additional pressure on the pancreas leading to increased insulin resistance and increasing the risk of Type 2 Diabetes.

(b) (i) Random errors may include:

- Measuring George with differing amounts of clothing layering or thickness could create random errors. For example, if George takes off his jumper during a measurement, to later put it back on, this could decrease then increase his waist circumference respectively.
- Measuring above or below George's halfway line between the lower rib and top of the hipbone could be a source of random error. Lower or higher waist measurements could reduce or increase the waist circumference (dependent on body shape).
- A random error could be taking the measurement when breathing in vs breathing out as breathing can change the waist circumference. For example, breathing in can increase the waist circumference.
- A random error when measuring waist circumference would be pulling the tape too tight or loose, which would decrease or increase the waist circumference respectively.

(ii) Taking 10 compared to 1 waist measurement increases sample size. A larger sample size will reduce the effect of random errors, thereby improving the precision and reliability of the measurement result.

(c) Any groups where muscle mass proportion is not considered and may affect measurements, such as:

- Athletes
- Body builders
- Ethnical groups such as Torres Strait Islanders
- Elderly and ethnicity's such as Asian are still applicable to the question (not as relevant to the question having an introduction about obesity, but the question does not specify obesity to be considered in the answer).

(d) Any of the following advantages are suitable:

- Waist circumference requires less equipment
- No calculation needed
- Able to be used by the elderly or athletes more accurately due to waist circumference focusing on visceral fat deposition and not overall weight (can be accepted if not used in part (c)).

4. (a) (i) Borderline high

(ii) A major risk for heart disease

(iii) High

(b) The total cholesterol level is not suitable as his test results are 12mg/dL above the desirable range of 200mg/dL or less.

(c) CVD (or more specifically CHD or angina)

Blood analysis result	Health concern
High LDL and triglyceride levels	Osteomalacia
Low Vitamin D	Type 2 Diabetes
Low folate	Coronary heart disease
Sustained elevated blood glucose after consumption of sugary beverage	Megaloblastic anaemia

(e) (i) Any of the following advantages of BMI at home are acceptable:

- Easy to complete (or doesn't require a lot of time and/or equipment)
- Inexpensive
- Non-invasive
- Doesn't require a lot of time/equipment
- No discomfort of needle prick or blood being withdrawn.

(ii) Any of the following advantages for blood tests at the doctors are acceptable:

- More accurate
- Can test more specifically for nutrients levels too high/low behind the man's symptoms to allow for more effective management/treatment.

(iii) A disadvantage of using the BMI at home rather than blood tests would be that further testing would still be needed to find underlying cause of the man's symptoms as BMI only gives an indication as to the risk of an over-nutrition disease, it doesn't diagnose the weight-related disease. A limitation of the BMI is that it doesn't consider loss of muscle mass with age, so it could misclassify the elderly man.

5. Any of the following advantages of using BMI in comparison to NRVs are applicable:

- Minimal costs and/or time to complete the diagnostic test vs NRVs may have the cost of dietician and few days of recording dietary intake
- BMI can be performed at home with minimal equipment, while NRVs may require travel to a dietician.

Any of the following limitations of using BMI in comparison to NRVs are applicable:

- Unlike NRV software programs that consider individualistic details to remove limitations, the BMI is limited by lean muscle mass not being distinguished in weight measurements.
- NRVs have no limitations, whereas BMI is limited by weight classifications not considering races that are naturally leaner or larger and still 'healthy'.
- BMI doesn't consider lifecycle changes such as pregnancy and elderly, whilst NRVs disease diagnosis does
- BMI diagnosis is not flexible for those unable to be weighed and measured, such as someone in a wheelchair, while NRV can still accurately diagnose disease risk in all people.

Any of the following disadvantages of BMI in comparison to NRVs are applicable:

- Due to the limitations of the BMI, it has a disadvantage of not being as accurate.
- BMI only provides one measure – a diagnosis about disease risk, whereas NRVs can cover a scope of measurements to give better insight into disease risk.

6. (a) $BMI = \frac{\text{Weight (kg)}}{\text{Height}^2 \text{ (m}^2\text{)}} = \frac{88}{170^2} = 30$. Jasper's BMI is 30 which puts him in the obese weight category.
- (b) To identify his risk of overnutrition diseases, his doctor could use waist circumference or a waist-to-hip ratio measurement.
- (c) Advantages of waist circumference in comparison to BMI include (some bullet points are applicable to WHR as well):
- These diagnostic tools can be easier to complete as they require less equipment and a calculation is not necessary
 - Waist circumference is more accurate in comparison to BMI due to higher muscle mass not increasing the weight measurement and creating misclassification of weight categories; waist circumference focuses on visceral fat being measured.
- (d) Jasper's dietitian should compare his nutrient intake levels to the Upper Intolerable Limit (ULs) to check if Jasper is overconsuming any nutrients, putting him at risk of overnutrition disorders. His dietitian should also take note of Jasper's nutrient intake compared to the Estimated Average Requirement (EAR) to confirm he is not below this level and at risk of any undernutrition diseases. For any nutrients of concern discussed with Jasper, either in low or high quantities, the RDI would give an ideal intake level that the dietitian would most likely advise to aim for in the diet to rectify imbalances.
- (e) Jasper may prefer a GP and BMI, over a dietitian and NRVs, due to the costs involved being less and diagnostic testing being more time efficient.

Case study: Evaluating Health and Diet with Diagnostic Tools

- Any three of the following answers would be acceptable*; take note the answers provided are brief, students are encouraged to extend their discussion and justification required when completing a Case Study Skills and Application assessment task. Being 48, answers may also differ in regard to Jessie being menopausal or not and the repercussion of that on vitamin B12 and osteoporosis risks.
 - BMI = 17. Jessie's BMI classifies her as underweight. Being underweight increases her risk of undernutrition diseases or malnutrition.
 - Waist circumference of 55cm is well below (25cm) the indicated risk value of 80cm (or waist to hip ratio = 0.75 is below the risk level of 0.8). Therefore, Jessie's absence of excess visceral abdomen fat gives her a low risk of developing overnutrition diseases.
 - Jessie's calcium intake is 300mg below the RDI for her age and also below the EAR by 140mg (EAR = 840mg, RDI = 1000mg). Being 48, Jessie would already be undergoing a higher rate of bone resorption than formation (i.e., bone loss). With insufficient calcium intake below the EAR, bone formation will be less proficient, putting her at even greater risk of developing an earlier onset of osteoporosis as well as a more rapid rate of disease progression.
 - Jessie's daily energy intake should be around 9550kJ which equates to 2270 calories (9550 ÷ 4.2). Her caloric intake of 1300mg is significantly under her required energy needs by close to 1000 calories! As a result, her basal metabolic rate may drop, and she could feel fatigued and sluggish with insufficient energy.
 - A vitamin B₁₂ intake of 1.85g is 0.15g below the EAR of 2.00g/day, and well below the RDI of 2.40g/day, indicating a risk of deficiency. A lack of B₁₂ increases the risk of megaloblastic anaemia, particularly for Jessie being female and still losing blood when menstruating (menopause average age is 51).
 - Hb levels for Jessie's age and gender should be around 120-160g/L. Being 15g/L below the lower level of required Hb could put her at further risk of anaemia and fatigue.
- Any two of the following answers would be suitable:
 - BMI can be inaccurate due to muscle mass not being considered and Jessie's exercise program does incorporate weight training, therefore this could provide a higher BMI. This is even more concerning for Jessie regarding being underweight and at increased risk of malnutrition diseases, so further testing would be advisable.
 - BMI, waist circumference, or waist-to-hip measurements can all be inaccurate as errors can occur in measuring. For example, if a patient is measured when breathing in, their waistline can be increased so further testing is encouraged.
 - Jessie's nutrient and energy intake have only been calculated on one day of food intake which is a misrepresentation of typical dietary patterns that may span over the course of several days. Even if over a few days, it can be difficult to determine quantities and the exact foods consumed to enter NRV nutrient calculation programs so further testing of concerning nutrient intakes should be taken
 - Hb (and other blood testing levels) can fluctuate depending on the time of the day and are affected by factors such as dehydration, so further testing to confirm a deficiency should be undertaken.

Science as a Human Endeavour:

BMI to be replaced

1. RFM should replace the BMI as its calculations are closer to their true value (found using a dual energy X-ray absorptiometry (DXA)), making the development in anthropometry diagnostic testing more accurate. RFM also accounts for limiting factors of the BMI including race, gender and muscle mass to a larger extent, indicated by fewer false obesity results, for example, obese classification for an athlete who has a high muscle mass. Fewer false results improve the reliability of data analysis using RFM.

2.2: Educational Aids for Food Selection

Review Solutions

1. (a) Possible substitutions with supportive reasoning include:
 - Replacing bacon/ham/cheese/pizza topping with mushrooms/salad/onion/ tomato/ spinach/ etc. will increase number of vegetables to address eating 'plenty of vegetables' as per guideline #2; or increase variety, in particular different types and colours of vegetables as per the guideline
 - Replace apple with mango/rock melon/pear/etc. to ensure getting some variety in fruit.
 - Replace toast/roll/pizza base with wholegrain/whole meal to ensure grains consumed are mostly whole meal or of high fibre varieties.
 - Replace bacon with beef/chicken/etc. deli slices, with fat trimmed, or beans, to ensure protein consumption is from lean meats as advocated by ADG #2.
 - Replace milk with skim milk/cheese with ricotta cheese/etc. to support the guideline specifying most that dairy products should be reduced fat.
- (b) Possible substitution that focus on limiting saturated fat, added salt and sugar, include:
 - Replace butter with margarine
 - Replace bacon with mushroom/tomato/etc.
 - Replace cheese/ham with salad/etc.
2. Food A meets the ADGs best, the Australian Dietary Guideline #3 as it has about 20g less sugar and is much lower in sodium by 114mg than Food B. As well as this, Food A is 912kJ lower than Food B, and therefore supports the Australian Dietary Guideline #1 which encourages individuals to consume foods according to their energy needs. Therefore, if an individual is categorised as being obese or at risk of being obese, then this food would be more suitable to reduce the risk or lose weight.
3. Most foods of the AGHE food groups are relatively low in kJ and hold substantial amount of micronutrients, making them nutrient-dense. Discretionary foods tend to be high in kJ and lacking in micronutrients, making them energy dense.
4. Care for your food; prepare and store it safely.
5. Answers from different food groups include (foods need to be specific though):
 - Any vegetable
 - Most fruit
 - Milk or yoghurt
 - Any meat.
 - Any grain (cereal) food that soaks water up when cooked e.g., pasta.
6. Oily fish e.g., salmon & margarine.
7. Many answers are possible, the following is an example of a model answer:

Different types and colours of vegetables will provide a range of macro and micronutrients (vitamins/minerals) and reduce the chance of developing deficiency diseases. For example, green leafy vegetables contain calcium to prevent osteoporosis and folate which is needed to produce quality red blood cells and reduce the chance of anaemia. Vegetables that can be eaten with the skin on e.g., roast pumpkin, provide insoluble fibre which reduces the chance of diverticular disease by producing bulky stools and preventing constipation.
8. (a) CVD, Type 2 Diabetes, Hypertension, or cancer.
- (b) Adults with children may wish to live longer to see their children grow up and therefore care about their health. Parents or carers can influence the long-term habits of their children, they are role models and are in control of buying the groceries/preparing meals.



(c) Either of the following answers are suitable:

- 45-60 years old is an age group that is likely to have been diagnosed with an over-nutrition disease or have a larger waistline and therefore be influenced by the campaign into making lifestyle changes, for example walking part of the way to work instead of driving/bus.
- The 45-60 age group may also be becoming less active and therefore more likely to develop an over-nutrition disease. Governments would be seeking to reduce the chances of this happening, hence the age group being a target audience.

9. Similarities include:

- Same main 5 food group
- Main food groups in the same proportions
- Both encourage water consumption
- Both allow small amounts of mono/poly oils
- Both specify discretionary foods to be in small amounts and sometimes only
- Both an initiative by the Australian government

Differences include:

- Aboriginal & Torres Strait food model focuses on Australian products while the AGHE has more foods with a multi-cultural influence (particularly in the grain food group)
- AGHE lean meats and poultry, etc. group has produce that would mostly be obtained from a supermarket, whereas the Aboriginal model includes native animals that could be hunted for food e.g., goanna.

10. Similarities include:

- Both food models encourage a variety of foods to be consumed (written words and illustrations)
- Both encourage drinking water
- Grain food groups are both predominantly wholegrain varieties
- Grains/vegetables/fruit are larger portion of the plate.

Differences include:

- The Canadian food model combines the vegetables and fruits whereas the AGHE has them as separate food groups
- The Canadian model combines the milk, yoghurt (etc.) group with the lean meat, poultry, fish (etc.) group while the AGHE has them separated
- Vegetable/fruit groups are larger portions combined in Canadian model
- Grain group is a smaller plate portion in the Canadian model in comparison to the AGHE
- Canadian model doesn't display discretionary foods or margarines/oils outside of the plate

11. (a) Rite Bite policy

(b) Like fruit, dried fruit contains some valuable nutrients (e.g., vitamin C) but unlike fruit, small servings will have moderate amounts of added sugar.

(c) Modifications include:

- White bread to be whole meal.
- Additional vegetables added to sandwich e.g., spinach leaves.
- Remove high energy processed products e.g., salami or replace with lean meat with less processing e.g., beef slices or chicken breast.
- Use reduced fat cheese.

12. (a) Monounsaturated or polyunsaturated

(b) Reduces LDL deposits or atherosclerosis/CVD/hypertension risk

13. (a) 2 eggs = 1 serve; 65g beef = 1 serve; nuts = 1 serve; chicken = 2 serves; total = 5 serves

(b) Matty's consumption of the lean meat, etc. food group is too high; he consumes double the recommended average daily number of serves, with 2.5 additional serves.

(c) Health concerns include:

- Excess protein consumption can result in dehydration/water loss from frequent urination.
- Excess protein provides kJ which can be converted to adipose tissue, resulting in weight gain/obesity.

14. (a) Possible answers include:

- Soft drink is high in simple sugars and too many simple sugars can increase insulin resistance and lead to Type 2 Diabetes
- Too many simple sugars can increase LDL/decrease HDL and increase the risk of atherosclerosis/CVD.
- Water is recommended as a replacement due to being needed in large amounts daily for functions such as aiding in digestion/circulation of oxygen and nutrients/waste removal/etc..

(b) Possible answers include:

- Discretionary foods tend to be high in kilojoules and excess kilojoules are readily stored as adipose tissue leading to weight gain. Continual weight gain leads to obesity and then increases the risk of CVD, hypertension, or diabetes Type 2.
- Discretionary foods can be high in sodium, elevated sodium levels in the blood will attract water and increase blood volume and blood pressure, leading to hypertension. Hypertension then increases the risk of CVD.
- Discretionary foods can be high in sodium, and the body will try to remove elevated sodium that enters the bloodstream via urination. Increased urination can result in a loss of water and therefore dehydration and promote the loss of water-soluble nutrients and increase the risk of under-nutrition diseases.
- Discretionary foods tend to be high in saturated fat (or simple sugars) which increases LDL production and speeds up the progression of atherosclerosis. Atherosclerosis is a precursor to CVD or hypertension.

15. (a) 49% (30% + 13% + 4% + 2%)

(b) 6%

(c) 2%

(d) 98% (100% - 2%)

16. (a) Answers may vary, dependent on the data used. For example:

- As time progressed for the running of the Measure Up campaign, it mostly maintained its effectiveness. For example, the impact on vegetable consumption only decreased by 1% whilst the impact on improving exercise slightly increased by 1%.
- There was a minimal decrease in the campaign's effectiveness, based on the behaviour of measuring waist circumference dropped by 2% from April 2009 (Wave 2) to May 2010 (wave 4) or those taking no action increasing by 4% towards the end of the waves of viewing.

(b) Increasing the amount of exercise.

Case Study: Evaluation of number of food group servings

Melissa's current diet does not meet the recommended average daily number of serves from each food group for her age and gender. Melissa is currently under consuming vegetables and legumes/beans by 2 serves, lean meats and poultry, fish, eggs, tofu, nuts and seeds, and legumes/beans by 1 serve and milk, yoghurt, cheese and /or alternatives by 1.5 serves based on her age and gender. On the other hand, based on her age and gender Melissa is over consuming fruit by 2 serves, grain (cereal) foods by 0.5 serves and discretionary choices by 2.5 serves. These differences may place Melissa at risk of any of the following diet related disorders:

- Lean meats and poultry, fish, eggs, tofu, nuts and seeds, and legumes/beans are rich in Iron and Vitamin B12. Therefore, as Melissa is currently not consuming enough serves of this food group for her age and gender; this places her at greater risk of being deficient in iron and/or Vitamin B12 which increases her risk of developing Iron Deficient Anaemia and/or Megaloblastic Anaemia. Iron is a significant component of haemoglobin, which is found within red blood cells. Haemoglobin is the component of red blood that collects oxygen from the lungs and transports it throughout the body delivering it to the cells for energy production. Vitamin B12 assists in converting Folate into its active form, therefore a deficiency of this vitamin slows down DNA synthesis producing large and immature red blood cells. Both result in fewer normal and quality red blood cells, which are unable to carry efficient oxygen, which is needed to create energy. Therefore, Melissa may experience fatigue, especially as she is a menstruating female which places her at greater risk of Anaemia due to the blood loss, she experiences every month.
- Milk, yoghurt, cheese and/or alternatives are a rich source of Calcium. Melissa is currently not consuming enough serves from this food group, therefore is at risk of not receiving enough Calcium and leading to an earlier onset of osteoporosis later in life. Calcium plays an integral part in the development of bones,

combining with phosphorus to form calcium phosphate crystals becoming a dense and strong bone matrix. This process continually occurs throughout an individual's life, when bone production is equal to bone resorption at Melissa's age. However, if Melissa's diet lacks Calcium, then greater resorption occurs resulting in bones more fragile and porous, and developing osteoporosis.

- Discretionary foods are energy dense and high in kilojoules, sugar, saturated fat, and sodium. Melissa is currently over consuming in this food group, which is recommended to consume only sometimes. The overconsumption of energy dense foods can cause Melissa to be categorised as being obese, as when more energy is consumed than expended, much of the excess energy from each macronutrient is stored in the fat cells of adipose tissue as triglycerides. This can cause the fat cells to increase in size and number, which results in weight gain and being categorised as being obese. As well as this, energy dense foods can contribute to the development of an android body shape, which can place pressure on the pancreas. This compromises the ability of the pancreas to produce effective insulin, leading to the development of Type 2 Diabetes.

Science as a Human Endeavour:

Could Australia's next social marketing campaign be – 'Rethink sugary drink'!

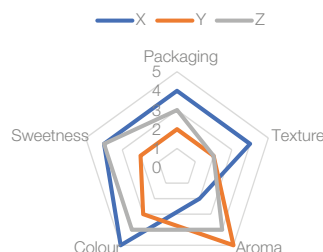
- An influence over the 'Rethink sugary drink' would be the strong link between sugar-sweetened beverages (SSBs) and increased energy intake as a cause of obesity, plus obesity being a risk factor for further over-nutrition diseases such as CVD and Type 2 Diabetes. The number of people suffering from these diseases would also have a large influence over the need for a campaign to reduce a cause of the diseases. Finally, many reputable organisations are recommending the campaign such as the Heart Foundation, Cancer Council Australia and Diabetes Australia.
- To avoid being taxed for adding sugars to beverages, manufacturers may look to limit sugars or replace them with artificial sweeteners. This may in turn result in reduced kilojoule intake from consumers and a flow on effect of lowering obesity and other obesity-related diseases. Alternately, food manufacturers may increase the price of their beverages to counteract the tax added to their food product.

2.3: Food Sociology

Review Solutions

- (a) Marks allocated for title, labelling of axes with even scale on axes, legend, and correct plotting.

The Average Sensory Scores of Different Types of Lactose Free Milks

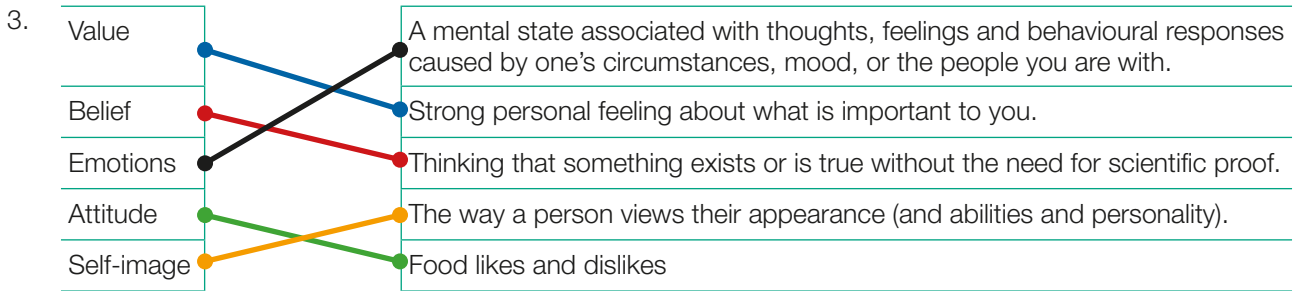


- (b) Constant factors may include:

- Amount of milk sampled.
- Temperature of milk sampled.
- Number of taste testers
- Time of testing

- (c) Milk X

- A fad diet is defined as one that is typically undertaken short term. Concerns when following a fad diet include (but are not limited to):
 - Lack of energy from restriction of kilojoules
 - Sluggish metabolism because of decrease in kilojoules
 - Dehydration from weight lost as water.
 - Muscle mass loss from weight loss
 - Under-nutrition disease development due to restriction of nutrients or entire food groups
 - Pathway to yo-yo dieting or disordered eating patterns such as bulimia and anorexia



4. Modifications include:

- Replacing bacon with a vegetarian option such as tomato
- Replacing beef with Halal beef
- Replacing cheese with rennet-free cheese
- Replacing wine with a non-alcoholic option such as water or juice
- Replacing jelly/ice-cream with a dessert that doesn't contain gelatine as an ingredient, such as cake.

5. (a) Indigenous influence: Crocodile

Distinctly Australian: Vegemite on toast

Multicultural influence: Sushi; coffee

(b) Justine's emotional state may lead her into comfort eating. This typically involves consuming energy-dense foods like chocolates to give some immediate positive feelings from eating these foods. Those positive feelings can momentarily help to alleviate her feeling upset.

6. Older people may be on the pension; therefore, their budget may not allow for expensive food items. Animal proteins are expensive to purchase due to the costs associated with their production, storage, and handling. Therefore, an elderly may not be able to afford meat, and have to rely on plant-based protein sources, such as legumes, as a substitute as these are cheaper.

7. Any one of the following:

- Peer pressure:
 - Children will model behaviours such as manners and replicate the habits observed from parents and siblings e.g., sitting at the table, trying new foods, eating in front of the TV, eating out and 'mindless eating.'
 - Parents/carers are responsible for the meals cooked and the foods purchased and therefore a child's autonomy is restricted, and food choices will be influenced by parents/carers.
 - Peer influence or lunchbox envy can create pestering power and tantrums to gain access to food choices like their peers.
 - Schools may encourage a brain food nutrient-dense snack in primary schools, increasing healthy food prevalence in the diet as parents typically abide with teacher requests.
- Media and advertising:
 - Social/Environment of the prevalence of fast-food outlets and the convenience of these foods can increase food choice for discretionary foods.
 - TV ads and social media, popular TV shows may be used as marketing ploys for food products and increase these foods in the diet e.g., use of popular Disney characters on sugary cereal boxes due to pester power, leading to children placing pressure on their parents into buying media seen products.

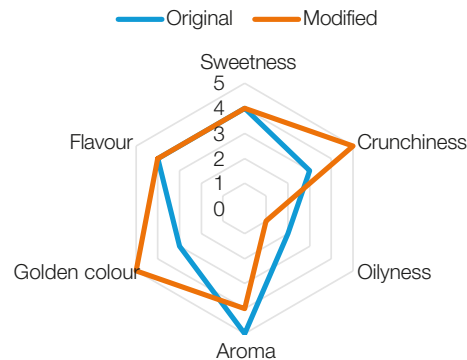
8. Any of the following factors can be accepted:

- Geographic Location: the family live in a small town, therefore there are limited supermarkets to purchase ingredients from, which generally have increased prices to accommodate for transport and refrigeration.
- Level of income: as penny's workdays have been reduced to 3 and half days, reducing income and limiting the choice of food and resorting to cheaper alternatives (e.g., fast food).
- Time available: due to caring for Penny's elderly mother, this may require greater time and leave limited time to prepare meals for their own family. Also, Fred manages a hospitality business, which may leave him with limited time to prepare food for his family. This may lead to the family relying on pre-prepared meals/ingredients to reduce the time spent on cooking and preparing meals.
- Peer Pressure: Joe's friends may influence what Joe likes to eat, therefore persuading Fred to cook these certain meals through pester power.

- Past experiences: A family member could have had a negative past experience with a specific food item, such as a case of food poisoning. This would influence Fred and Penny to avoid this food item for their family as it may trigger negative associations or unpleasant memories with that food.
 - Attitude (likes and dislikes): certain family members may evaluate a food positively or negatively, and therefore Fred and Penny will favour foods that all the family like rather than foods that are disliked.
9. (a) The greater the level of education, the lower the percentage of South Australians who are obese. There is approximately 7.5% greater prevalence of obesity in people without tertiary education.
- (b) The higher the level of income, the lower the percentage of South Australians who are in the overweight and obese weight range. Higher income earners were approximately 8% less overweight and obese than low-income earners.
- (c) Any two of the following:
- Plan the meals for the week, using ingredients that are in the fridge and pantry already.
 - Write a list of the items needed to avoid purchasing additional ingredients.
 - Buy fruits and vegetables in season.
 - Look out for supermarket specials.
 - Buy non-organic products.
 - Buy in bulk when possible.
 - Buy home brand products when possible.
 - Don't shop when hungry to avoid buying unnecessary food.
 - Purchase more plant-based protein sources instead of animal proteins.
 - Buy individual ingredients to make salads and not pre-packaged meals e.g., salads.
 - Grow your own vegetables and herbs.
 - Store leftovers appropriately to reduce food wastage.
- (d) Differences can be explained through any of the following reasons:
- Fresh peaches are more expensive in rural and remote parts of Australia due to the costs associated with refrigerated transportation or careful storage which is required as peaches are a perishable item.
 - Fewer marketplaces selling peaches, therefore the lack of competition in these areas can drive the price of these foods further up.
 - Additional handling of peaches for them to be transported further (further wages) would also increase prices.
10. (a) If the product has a decreased content of sodium, sugar and/or saturated fat, then the sensory appeal of the meal will be decreased.
- (b) The dependent variable is the consumer's sensory evaluation of the food.
- (c) Any of the following:
- The serving size of the food product must be kept consistent to provide an equal opportunity for the tasters to assess the food.
 - The taste testers must evaluate both the original and modified food product, to allow for a fair comparison between the two products.
 - The time of testing must remain the same, to ensure the consumer has the same level of hunger and desire to consume the food products.
 - The temperature of the food products, as food items which are warmer are easier to smell due to a stronger odour.
 - The number of testers must be the same to ensure a fair and reliable test and reduce the impact of random errors for both the original and modified food products.

- (d) Marks allocated for title, labelling of axes, legend, and correct plotting.

The sensory evaluation of an original and modified product



- (e) Manufacturers were just as successful in creating an appealing modified product, as flavor and sweetness were scored the same achieving a score of 4. The modified food product scored 2 points higher in crunchiness and golden colour, but 1 point lower in oiliness and aroma.
- (f) Results of a sensory evaluation are based on an individual's likes and dislikes and their pallet which differs between individuals. The likes and dislikes of food vary significantly between a person due to different habits, past experiences, emotions, and culture.

11. Any of the following:

- Buy fresh and in season fruit, rather than blueberries during June.
- Choose to make your own fruit salad, rather than paying for someone to cut and package your fruit salad.
- Buy generic brands instead of branded products, which are more expensive due to the marketing/packaging of these products.
- Buy in bulk. The toilet paper bought was only 6pkt. Buy in bulk as the rolls would be cheaper per unit. Could also split between friends to share the costs.
- Buy products with a longer shelf life. 2kg of yoghurt does not have a long shelf life and most will be wasted. Buy a smaller amount and only what you need.
- Buy local South Australian products, rather from other states to reduce the cost associated with transport.
- Buy non-organic products.
- Look for specials.

Case Study: Dietary influences

Being a Muslim, Sana's cultural influences would affect her food choices due to the food restrictions of the Islam religion. Pork or pork products, alcohol, and non-halal derived animal products/ingredients such as gelatin are prohibited as they are considered impure and harmful for human consumption. All other meat needs to be halal certified, and cheese needs to be rennet-free, Sana may find obtaining equivalent and suitable animal derived options difficult, especially when eating out. Vegan dishes may be relied on as they are void of all animal products. She may therefore find getting the required iron and vitamin B₁₂ levels more difficult. Health consequences of low iron and vitamin B12 include anaemia and its associated fatigue. There is a higher risk of Anaemia for Sana due to her age, where she would be menstruating and losing blood monthly. However, removal or avoidance of those same foods could reduce foods high in kilojoules, and saturated fat. Therefore, Sana's health could be positively affected by a lowered risk of obesity and other overnutrition diseases such as CVD.

Possible influences on Sana's idea to try the new cabbage diet could be peer pressure, self-image and/or the media. Beliefs about what other people think of a particular behaviour can influence food preferences and choices in a social setting. If her peers believe the cabbage diet is 'cool', Sana may wish to adopt it out of fear of appearing 'weird' or different to her friends. She could also have poor self-image or be dissatisfied with her image and instead idolise unrealistic thin images portrayed in the media. These factors could influence her expectations of her appearance and leave her wanting to try the cabbage diet to lose weight.

Given the opportunity to provide health advice, it is important to convey the dangers of undertaking fad diets. They often restrict kilojoules which slows the body's metabolism or BMR, so once the fad diet is ceased, this can lead to the added kilojoules of the normal dietary pattern being converted more readily to adipose tissue, as the kilojoules are not utilised as readily anymore. Furthermore, the loss of weight with fad diets is often water, which can result in dehydration, and muscle mass, which again lowers the body's ability to utilise kilojoules. As well as this, fad diets generally restrict entire food groups and limit an individual's consumption of specific nutrients which are prevalent in the eliminated food group. This can place Sana at risk of nutrient deficiencies, which could be detrimental to her due to her age, where she is currently experiencing significant growth due to puberty.

Science as a Human Endeavour:

Can you change your sensory appeal to adapt to nasty tastes?

1. Scientists have found that proteins in saliva can change based on a food repetitively eaten. Specifically, once avoided bitter foods, if continued in the diet, can become a food one can withstand more of, as salivary proteins will alter to allow taste perception to change. If scientists can apply this finding to change the expression of these proteins in humans, bitterness and other disliked tastes could be weakened. This finding could also allow for innovation in food creation: by adding salivary proteins to nutrient-dense foods with less palatable tastes, as a food additive. This could mean that it could become easier to get children to enjoy the taste of vegetables, even Brussel sprouts; in fact, any food that can be considered 'disgusting' by children. For adults, these applications could be key to making healthy foods taste better, which in turn could modify dietary choices for the better. A further positive impact of this could be a reduction in dietary diseases such as cardiovascular disease, Type 2 Diabetes, and diverticular disease. While in children it could see reduced micronutrient imbalances and a reduced incidence of obesity.

2.4: Safe food: FSANZ and Contamination

Review Solutions

1. FSANZ

Any of the following roles can be identified:

- Monitoring/approving food additive or food fortification use
- Monitoring nutrition/health/gluten claims
- Enforcing mandatory food labelling requirements
- Providing food recall information
- Providing NIP calculators

2. Food spoilage and poisoning can both be caused by microbes; poor sanitization, hygiene, improper cooking, or improper storage. Food poisoning is anything that would contaminate the food biologically and hard to detect through sight or smell; while food spoilage is typically detected by undesirable changes including unusual appearance, smell, taste, texture but is not caused by pathogenic bacteria which have the potential of causing poisoning. Food spoilage normally results in food wastage whereas poisoning is because the food is eaten and gives gastroenteritis symptoms (or worse).

3.	Contaminant	Classification
	Hand Sanitizer	Chemical
	Rat poo	Physical or Biological
	Human nail clipping	Physical
	Salmonella	Biological
4.	Factor allowing bacterial growth	Optimal conditions preferred by most bacteria
	pH	5-8
	Temperature	37°C (5-60°C)
	Nutrient	Protein
	Water activity	Greater than or equal to 0.90

5. (a) An unpleasant smell, texture, appearance, or taste e.g., bread hard/dry, tomato soft, milk sour
 (b) Any of the following conditions would be acceptable:
 - The temperature of the car at 40 degrees is in the danger zone of 5-60°C, where bacteria can multiply quickly especially as it is close to 37°C which is the favourable temperature for most bacteria.
 - Optimal pH, many of the foods, for example the milk, are around neutral pH of 7 where bacteria grow best.
 - Nutrients are present in the groceries, which provide plenty of energy for bacteria to survive and reproduce, particularly the chicken which is high in protein.
 - Water, most foods and especially the milk hold a high-water activity allowing bacteria to flourish

- Oxygen, because the food was not stored correctly, sufficient air was provided around the packaging of the foods for bacteria to utilise to make energy
 - Time, because bacteria can grow quickly, 5 hours provided more than sufficient time for bacteria to grow to large numbers as they multiply every 20 minutes.
- (b) milk – listeria; chicken – E. coli or salmonella.
- (c) Toxins produced by bacteria can be heat-resistant, and therefore may still be present regardless of the temperature that the chicken was reheated to. Therefore, these toxins can cause food poisoning.
- (d) Any of the following groups are accepted, due to having an underdeveloped or less efficient/weakened immune system:
- Infants & children
 - Elderly
 - Immunocompromised individuals, including cancer patients
 - Pregnant Females
6. (a) neutrophile
- (b) Acidophile has the largest range of 5.5 (from 1 to 5.5) while alkaliphiles have a range of 4 (7.5-11.5) or neutrophiles have a range of 3 (5.5-8.5).
- (c) around 72°C (or a few degrees above/below).
- (d) (i) Bacteria C
(ii) Mesophile
7. (a) The independent variable is the temperature (°C) the roast chicken was exposed to during the 24-hour testing period.
- (b) Any of the following constant factors are applicable:
- Swabbing site on the chicken e.g., thigh on same roast chicken.
 - Time of swabbing.
 - Incubation time (24 hours).
 - Medium for inoculating (nutrient agar plate).
 - Same exposure to environmental conditions e.g., oxygen, moisture.
 - Method used to count the bacterial colonies.
- (c) The number of bacteria colonies increased from 0 to 9 as the temperature increased from -5°C to approximately 37°C; however, the number of bacteria colonies decreased back to 0 as the temperature continued to increase to 52°C.
- (d) At 37°C, bacterial enzymes are functioning optimally, allowing for faster reproduction. Enzyme function is essential to bacterial survival, growth and reproduction but in higher temperatures, enzymes denature which explains why bacterial colony numbers begin decreasing as temperatures exceed 37°C. The higher the temperature, the more enzymes denature. In colder temperatures, enzyme activity slows down to the point the bacteria become dormant. This is represented by the decreasing trend in bacterial colonies as temperature drops below 37°C down to around -5°C where there are no bacteria reproducing and giving a colony count.
- (e) Any of the following are accepted:
- Cook to a temperature of 75°C just before lunch service, to ensure all bacteria have been killed prior to consumption, and reducing the risk of bacterial growth.
 - Place in fridge rather than bench top until lunch time, as room temperature is within the danger zone providing favourable conditions for pathogenic bacterial growth. From morning to lunch passes the 2/4-hour food safety rule, which states food left at room temperature for 4 hours needs to be discarded as bacteria could be at dangerous levels or should be refrigerated.
 - Don't give leftovers or provide instructions on storage and reheating on the takeaway container, so consumers are aware on how to store and reheat food correctly to prevent bacterial growth.
8. (a) The optimal temperature for bacterial growth is within the danger zone of 5-60°C, when food has been cooked to above this temperature then the food is considered safe, however if food is cooked, heated or kept within the danger zone temperature range, bacteria can replicate quickly to high numbers, causing food poisoning.

- (b) (i) The graph shows a rapid increase in the bacterial growth from 10 to approximately 10^7 between 2 to 9 hours before the growth plateaus between 9 and 10 hours. Time is a favourable condition for bacterial growth, therefore as time is increased, the number of bacteria continues to increase rapidly as they can reproduce every 20 minutes. However, after 9 hours the number of bacteria begins to plateau as some of the conditions available may have reduced, including the availability of nutrients, especially protein, present in the prawns causing the slowing down of bacteria reproduction.
- (ii) 7 hours
- (c) Any two of the following:
- The leftovers should be stored in the refrigerator below 5°C, which is below the danger zone, limits bacterial growth as they are dormant at this temperature
 - The leftovers could be stored in the freezer to reduce water activity as available water is converted to ice, which limits bacteria growth due to their requirement of water activity.
 - The leftovers could be reheated to above 60°C (above the danger zone) to ensure that the pizza is correctly heated to kill any microorganisms that may be present.
 - Ensure that the pizza has been entirely reheated so that there are no cold spots where bacteria can still multiply/grow within the cold spots (e.g., turn table in the microwave for even heat distribution)
 - Keep pizza in an air-sealed container or covered with glad wrap to prevent oxygen exposure needed for bacterial growth, or to prevent cross contamination from other foods and juices leaking on it.
 - Store in individual serving sizes to ensure temperature is reduced quicker to spend less time in danger zone
 - Avoid reheating more than once to limit exposure to the danger zone where bacterial can multiply
 - Avoid cross-contamination with raw and/or cooked foods by storing correctly in the fridge and above any raw meats.
9. It is important to reduce the temperature of soup. as quickly as possible. This can be achieved by storing soup in smaller individual containers, to ensure the temperature of the soup drops below the danger zone within 2 hours. Prior to storing in the freezer, ensure the soup drops to a temperature of 60°C to prevent any surrounding foods in the freezing defrosting and increasing to a temperature within the danger zone.
10. Bacterial presence from cross-contamination from poor handling and hygiene practices would be present on the outside of the meat which cooking above 60°C should destroy. However, when meat is minced, the bacteria from the outside is moved throughout the meat due to the greater surface area, which is why mincemeat requires cooking right through to the middle.
11. If food is placed into the fridge warm, it could increase the fridge temperature above 4°C-5°C, entering the danger zone where microbes could grow to dangerous numbers in all fridge foods resulting in food spoilage or poisoning.
12. If chicken is undercooked, it is likely to not have been heated above 60-75 degrees to kill bacteria, increasing the risk of food poisoning. In addition, chicken offers many of the favourable conditions of FATTOM such as an optimal pH close to neutral, a good source of protein and other nutrients, and an ideal water activity level.

Case Study: Poor Hygiene and Food Preparation Practices

David's gastroenteric symptoms could be from the ingestion of Salmonella, E. coli, or any other food poisoning bacteria. The bacteria may be passed to him via his unsafe food practices including washing his hands with a used tea towel, scratching his head while preparing food, having a pet in kitchen, using of the same chopping board for meat then lettuce, storing raw meat above cheese, consuming scrambled eggs left at room temperature for long period of time, and re-heating left-over food twice.

Microbes could be thriving in food debris wiped on the tea towel, or on his head, or in his pet hair or the used chopping board. Touching these surfaces could result in transferring the bacteria via cross-contamination to the food. Even though the raw meat may have touched a clean chopping board, the lettuce does not. It may pick up bacteria left from the raw meat. As the lettuce is not cooked after touching the board, the bacteria will not be destroyed by heat, unlike the meat, making the lettuce a high-risk food. Pet hair itself is a physical contaminant that may easily fall into the food and be a source of biological contamination as the cat is on the bench.

The raw meat is also increasing the risk of food poisoning by being stored over other foods in the fridge. Juices from the meat could drop onto the cheese and contaminate it. The cheese is not being cooked to denature bacterial enzymes and kill it, leaving it a potential to cause gastro. Food left at room temperature for a long period has been in the danger zone, while re-heated food has passed through the danger zone multiple times, both allowing bacteria to multiply rapidly to dangerous numbers, so the scrambling eggs and re-heated pizza are also foods with potential to cause foodborne illness.

David is recommended to air dry hands or use clean paper towel, wash his hands thoroughly for a minimum of 20 seconds with soap after scratching head, remove his pet from kitchen and clean surfaces the cat has been on. He should also store all food in sealed containers, with meat needing to be on the bottom shelf of the fridge. Following the 2/4hour rule, the eggs should be discarded, as should the pizza due to being left at room temperature for over 4 hours.

Case Study: Menu Modifications for Pregnancy

During pregnancy, a women's immune system can be comprised by hormonal changes, making Margorie more susceptible to food poisoning. Listeriosis could result in fever and gastrointestinal symptoms like diarrhoea and vomiting (leading to further complications e.g., dehydration) for Margorie and is dangerous for the foetus, with concerns like stillbirth and miscarriage being reported with listeriosis.

Sashimi, sushi, pastrami, soft serve ice cream, soft cheeses are all high-risk foods due to being raw foods offering favourable bacterial conditions for listeria. They could therefore be swapped for foods such as breads and oil dips to provide carbohydrates and kilojoules needed for the additional energy needs in pregnancy, vegetables, particularly green leafy vegetables e.g., spinach to provide folate and reduce the chances of Spina bifida in the baby, and nuts/legumes for additional protein needed for mother and foetus' growth of body tissues.

Science as a Human Endeavour:

A bacterial mechanism causing food poisoning uncovered

- Food poisoning affects millions of people every year. With such an expansive number in society being affected, that could influence or compel scientists to find remedies to reduce the number of people falling ill. They may also have been influenced by patients with poor immune systems who have suffered greatly from food poisoning with cases of it leading to sepsis. This creates more urgency to find solutions when vulnerable members of society fall gravely ill.
- Knowledge of the bacterial mechanism of the toxin punching holes in the cell can allow scientists to better treat food poisoning. They can treat the cause, the toxin, more directly by weakening it. This could see patients of food poisoning having reduced illness and being saved from it leading to dangerous conditions like sepsis. This is especially applicable to those in society with compromised immune systems.

2.5: Safe Food: processing

Review Solutions

- Any of the following micronutrients, foods and health concerns can be identified:
 - Vitamin B1 in wheat flour used to make bread to prevent Wernicke-Korsakoff syndrome.
 - Folic acid in wheat flour used to make bread to prevent spina bifida or neurological disorders in the foetus or megaloblastic anaemia in an adult.
 - Vitamin D in any oily spread such as margarine to prevent rickets in children, osteomalacia in adults, or osteoporosis indirectly through increasing Calcium absorption.
 - Iodine in salt added to bread to prevent goitre.

(a)	Type of additive	Foods/beverages used in	Benefit to consumer
	Sweetener	- Soft drinks - Confectionery	- Provides a sweet taste without the calories, leading to potential weight loss. - Provides a sweet taste without spiking blood glucose levels as high as simple sugars, which can benefit diabetics.
	Antioxidants	- Margarine - Chocolate	Stops rancidity in foods that contain fats, extending the shelf life.
	Food colouring	- Confectionery - Cereals - Jams	Food has a vibrant colour that is more appealing to eat.
	Emulsifier	- Salad dressing - Mayonnaise - Chocolate spread - Ice- cream	Allow products to have a smooth and creamy texture, improving the consistency.

- (b) Food manufacturers would add emulsifiers to foods to ensure an even dispersion of fat molecules rather than fat separating into an unappealing layer. The improved appearance would increase sales and profit for the manufacturer.
- (c) Any two of the following:
- Food colouring, to restore any colour lost in the cooking process, especially to the blueberries which may have lost their colour during the heating process.
 - Sweeteners, to replace the sugar in the diet muffin, to provide a sweet and appealing taste without the calories.
 - Emulsifiers within the choc chip ingredients to ensure that the fat in them doesn't separate into layers should the chocolate droplets soften with temperature.
 - Antioxidants within the chocolate chip ingredients to reduce oxygen degradation that turns fats rancid, extending the shelf life of the muffin.
3. (a) Any of the following conditions would be suitable:
- Temperature between 5-60°C
 - Presence of Oxygen
 - Water availability of 0.9 or above
 - A neutral pH (or between 5-8)
- (b) Any of the following explanations would be suitable:
- A neutral pH. Cans or bottles can be liquid filled with an acid solution. This will decrease the pH, making it unsuitable for microbes to multiply and denature any microbes present.
 - Presence of oxygen/air. Cans or bottles are exhausted, meaning the extra air is expelled to create a vacuum seal which reduces the oxygen available that microbes need to create energy for growth.
 - Temperature. Cans and bottles are heated to temperatures well above the danger zone (121°C for 3-15 minutes). These temperatures denature microbial enzymes, killing them.
 - Moisture/water availability. Cans and bottles can be liquid filled with a salt or sugar solution. These molecules bind with free water molecules in the foods, making it inaccessible for microbes to use and disallowing their reproduction to high food-poisoning numbers.
- (c) The thermal processing that canned fruits undergo is detrimental to heat-sensitive nutrients, including the B-vitamins and vitamin C. They are denatured and destroyed in high heat, reducing their presence in fruit.
4. (a) Any two of the following:
- Extends the shelf life of food products.
 - Makes food safe for consumption, reducing food poisoning cases.
 - Increases the range of food available, allowing food to be consumed out of season.
 - Reduces the shopping frequency.
 - Reduces the cost of food.
 - Saves time preparing food at home.
- (b) Any of the following preservation methods could be applied; however, make sure to provide a different processing method to each to demonstrate your understanding and avoid double dipping:
- Freezing: stops the growth of microorganisms by making them dormant and slows down enzymatic activity responsible for spoilage by exposing the food to a temperature below the danger zone. Freezing also reduces water availability by converting free water molecules into ice (*applicable to all foods*).
 - Heat treatment: exposes food items to temperatures above the danger zone, destroying bacteria and denaturing enzymes (*applicable to all foods*).
 - Pasteurisation: exposes foods to temperatures above the danger zone (72°C) for 15 seconds which kills pathogens and inactivates spoilage enzymes, extending the shelf life (*applicable to milk*).
 - Liquid fill: storing food in a sealed container in a salty brine will decrease water activity by binding to free water molecules, making them unavailable for microorganisms to use. An acid could also be used as a liquid fill, such as vinegar, which will lower the pH below 4.5 which would not support the growth or survival of microorganisms. A container which is sealed and filled with liquid to the top will also expel and reduce any oxygen present, which is required by aerobic microorganisms for growth (*applicable to olives*).

5. (a) 5 hours
- (b) The longer the juice is kept at high temperatures the more vitamin C is lost.
- (c) Any one of the following:
- The brand / type of juice, as different brands may have different vitamin C contents to begin with.
 - The volume of juice, as a greater volume may increase Vitamin C loss due to having a greater amount to begin with.
 - The temperature of juice needs to be maintained, as when temperature increases, vitamin C loss will increase due to its heat sensitivity.
 - Exposure to light needs to remain consistent, as a greater light reduces the content of Vitamin C content due to it being light sensitive.
 - The time of measurement needs to be the same, as when more time elapses, then greater vitamin C loss will occur due to additional exposure to conditions, such as light, oxygen, or heat. This will cause greater loss and denaturing of this water-soluble vitamin.
 - The same experimenter should perform the measurement step, as each experimenter may measure the amount of Vitamin C or temperature differently, therefore decreasing the reliability and precision of the results.
6. (a) Mandatory fortification is stipulated by FSANZ where specific nutrients are required to be added to certain foods or ingredients to improve the nutritional quality of the food supply and to provide a benefit to the public to minimise the risk of nutrient deficiencies.
- (b) The fortification of Folic Acid and Iodine in 2009 has been found to be successful. The number of neural tube defects decreased by around 2 per 10,000 births in non-indigenous Australians and 15 per 10,000 births in Indigenous Australians after the fortification of Folic Acid in wheat flour. As well as this, the proportion of non-pregnant, pregnant, and lactating women that were not meeting the estimated average requirement of Iodine decreased significantly by approximately 50%, 30% and 15% respectively after its fortification in salt.
- (c) Folic Acid was added to wheat flour used in bread making, as most Australians consume bread daily across multiple meals (e.g., breakfast, lunch, or dinner), which means that is accessible to the greater population. As well as this, bread is cheap, making it affordable for most of the population.
- (d) Iodine is essential in the development of the fetus' brain and nervous system, where a deficiency can cause stunted growth and impaired neurological function. Therefore, the fortification of Iodine in salt can prevent diminished intelligence and irreversible mental and physical retardation in future generations. The fortification of Iodine can also reduce the prevalence of goitre, which can result in an enlarged thyroid gland. Iodine is responsible for the production of the hormone thyroxine, which is responsible for the regulation of metabolism, thermoregulation, and growth and can therefore result in insufficient energy availability if not enough Iodine is consumed.
7. (a) The dependent variable is the Vitamin B₁/E content in mg.
- (b) Any of the following constant factors would be accepted:
- Quantity of broccoli, as a smaller quantity of broccoli will lose less of its vitamin content due to having a reduced amount to start with.
 - Volume of water used in the heat treatment broccoli is boiled in, as less water may reduce vitamin loss due to less exposure to the surrounding water.
 - Age of broccoli, as older broccoli may have been exposed to more light, heat or oxygen during transportation or storage, causing the denaturing of its vitamin content leading to a lower vitamin content to begin with.
 - Type of broccoli, as different types may have differing amounts of vitamins to begin with.
 - The temperature of the heat treatment, as a hotter temperature will result in greater vitamin loss due to more being leached from the broccoli.
 - Thickness or surface area of the broccoli, as a greater surface area/reduced thickness will result in greater vitamin loss due to having more exposure to the surrounding water or heat.
- (c) The Vitamin B₁ content in broccoli begins at a level of 0.65mg and after the heat treatment it loses 0.1mg. Heat treatment has no effect on broccoli's vitamin E content, as it remains stable at 1.7mg. Heat treatment effected Vitamin B₁ due to being a water soluble vitamin, whereas Vitamin E is fat soluble. Water soluble vitamins are a lot more sensitive to heat or water present in the cooking process, causing them to denature and leech out into the surrounding water due to their solubility.



Case Study: Vitamin D Deficiency

The 6-year-old child is at significant risk of being deficient in Vitamin D due to lifestyle and nutrition related factors. Their city of residence: Hobart can contribute to this deficiency due to the low UV index experienced between the months of May and August where they range from 1 to 2. When the UV index is below 3, the duration of sun exposure required increases from minutes to hours to ensure sufficient vitamin D production. As well as this, this child spends significant time on screen-based activities as entertainment, where they exceed the recommendation of no more than 2 hours a day, 6 days of the week. The child also does not meet the recommended 60 minutes of physical activity a day, on 5 days of the week. This would further reduce their exposure to sunlight due to being indoors. Finally, the child's average daily diet does not include natural sources of Vitamin D, including oily fish, liver and eggs. Therefore, it is unlikely this child's body is producing enough Vitamin D from sun exposure or achieving the RDI of Vitamin D from consumption.

The Australian Government stipulated the addition of Vitamin D in margarine through FSANZ in 1987 to increase the intake of this vitamin and reduce the risk to the population's health. This was made mandatory and was added to a food item, which can be easily accessed by the general population due to being affordable and commonly used daily.

In the short term, children are at risk of developing Rickets, which is the failure for bones to calcify due to impaired calcium and phosphorus absorption. This disorder can cause the softening of the bones, growth retardation and skeletal abnormalities that can be carried through to adulthood if the bones become so weak that they bend when supporting the body's weight. In the long term, this can further progress into a painful bone disease in adulthood: osteomalacia, where the bones become soft, flexible, brittle and deformed. Further to this, a significant Vitamin D deficiency can cause an earlier onset of osteoporosis in later years where the bones become porous and brittle, increasing the risk of fractures.

It would be recommended that this child engage in more physical activity outdoors, especially in the cooler months to ensure enough sun exposure to maintain adequate vitamin D levels in the body. As well as this, engaging in weight bearing exercises promotes stronger bones, which would also assist in preventing rickets, osteomalacia and osteoporosis in the short or long term. It would also be recommended that this child introduce natural sources of Vitamin D to their diet, including oily fish, such as salmon or eggs. Oily fish is not commonly consumed by children; therefore, it is essential to cook it in a way to make it appealing to young children. This could include making homemade fish fingers or salmon patties with other ingredients to add flavour. Fortified margarine could also be added to the child's sandwich to further increase their intake of Vitamin D.

Science as a Human Endeavour:

Isochoric freezing – an emerging food preservation technology!

1. The isochoric freezing method for food was **developed** from the medical field where it is used in freezing human cells, tissues and organs for transportation and transplantation. The principles of freezing the water of a container that holds the human tissues have been emulated in the food freezing technique. This technology improves the efficiency of the freezing method as the food itself is not frozen, so ice crystals are not formed and this allows for improved food quality once thawed.
2. As ice crystals are not formed in the food, this new preservation method could be **applied** to frozen foods by enhancing their quality when being thawed, which would improve the range of foods available in the frozen section of the supermarket. This **application** would allow for:
 - More foods to be available out of season.
 - Reduced food prices.
 - Reduced food wastage.
 - Improved food distribution concerns, particularly of perishable foods like meat, fish, fruit, and vegetables.

Isochoric freezing of vegetables in their raw state, rather than with prior cooking techniques as blanching, has an **application** of improving the nutritional retention of foods. This would enhance an individual's nutrient intake, reducing their risk of nutrient deficiencies.

3. For the successful development of the isochoric freezing preservation method, **collaboration** between scientists has been required, for example the collaboration between isochoric freezing developer Boris Rubinsky and a food technology researcher Christina Bilbao-Sainz, to adapt the technology of freezing human tissue samples to food products. **Collaboration** between scientists and government agencies was also needed. In this case a **collaboration** between the scientists and the U.S. Department of Agriculture enabled funding to be provided for isochoric food freezing to be developed. Further **collaboration** is also needed between scientists and food producers of the community. For example, isochoric storage containers are being developed in conjunction with fisheries in Iceland.

2.6: Safe Food: Food packaging and labelling

Review Solutions

1. (a) Population continues to grow and as lifestyles across Australian cities become faster and busier, consumers are wanting more ready-to-eat quick meals, or even single serve beverages and quick snacks while they are on the go. Rather than selecting fresh ingredients for home-cooked meals such as 2kg of potatoes without much packaging required, pre-prepared meals need to come with packaging, and often both primary and secondary packaging is required.
 - (b) (i) Food grade is a type of packaging that is safe for food products with no risk of harmful chemicals or microorganisms entering the food.
 - (ii) FSANZ
 - (iii) Food packaging could contaminate food in the following ways:
 - Releasing chemicals, such as toxins or heavy metals that are present in the packaging into the food.
 - If the packaging material contains micro-organisms, dirt or other foreign material that can be transferred to the food.
 - If parts of the packaging itself break off into the food, for example broken plastic or glass.
 - (c) Any of the following answers are suitable:
 - Consumers may prefer food packaged using active packaging as they are concerned for the environment. Traditional packaging tends to use non-renewable resources and releases greenhouse gas emissions in their production, whilst active packaging can reduce the need for traditional packaging and its impact on the environment.
 - Consumers may prefer food packaging with active packaging as they are concerned over possible adverse reactions to artificial additives in their food, or simply prefer food closer to its 'natural' state. Active packaging reduces the need for chemical additives.
2. Any two of the following:
 - Glass packaging exposes milk to light, therefore light sensitive nutrients can denature e.g., Vitamin B2.
 - Glass is fragile and easily broken, making transport and food wastage an issue as well as being a safety issue in relation to injury from broken glass.
 - Glass bottles can be awkward to pack, making them more liable to break during handling and transport.
 - Glass has a negative impact on the environment as it uses resources, e.g., water and electricity to recycle bottles.
 - The cost of glass is greater in comparison to cheaper alternatives such as plastic and cardboard, therefore resulting in greater manufacturing and customer costs.
 3. The disadvantages of using aluminium cans for packaging can include:
 - To open an aluminium can, one end needs to be cut open or the ring tab is pulled; therefore, they cannot be reused or resealed. This contributes to landfill if not recycled appropriately.
 - Aluminium cans are not transparent; therefore, the consumer is unable to view the contents inside the packaging to aid in product purchase choices.
 - Producing aluminium cans uses non-renewable resources and releases greenhouse gases into the atmosphere, contributing to global warming.
 - Aluminium cans cannot be microwaved; therefore, are not convenient for the consumer.
 - Aluminium packaging can corrode when storing acidic foods, therefore contaminating the contents inside and causing the food to taste like the metal.
 4. (a) Any one of the following:
 - Plastic packaging is cheaper to produce, therefore making the product more affordable for the consumer.
 - Plastic is lightweight and therefore easier to carry and transport from the store to home.
 - Plastic is resistant to breaking, reducing the chance of the food becoming damaged during transport to the home as well as potential food and money wastage.
 - Plastic is transparent, allowing the consumer to see the food and make an informed decision about it.



(b) Any one of the following:

- Plastic packaging contributes to landfill, this increases deforestation needs and clearing of land.
- Plastic is non-biodegradable and will contribute to landfill unable to be quickly broken down
- Plastic uses non-renewable resources in its production and releases greenhouse gases, contributing to global warming
- Plastic pollutes ecosystems, which can destroy animals' homes and causes them harm.
- There are many plastics used in food packaging, making it confusing when it comes to recycling and which plastic goes into which bin. It will contribute to landfill if not recycled properly
- Different plastics used in the packaging means different recycle methods are needed which requires additional energy

(c) Any one of the following (note that oxygen absorber is not applicable to this food as it holds substantial moisture):

- A moisture scavenger could be added to the packaging to absorb extra water emitted from the chicken or vegetables, thereby lowering water activity that favours microbe growth.
- A carbon dioxide emitter could be used to release this gas and create unfavourable conditions for aerobic microbe respiration.
- Modified atmosphere packaging would be beneficial in slowing microbe growth in the ready to eat meal by reducing the oxygen needed for microbe respiration and replacing it with carbon dioxide and nitrogen.

5. (a) Salted water

(b) Mango

(c) Any of the following requirements are missing from the food label::

- Country of origin,
- storage instructions after opening,
- NIP information per 100g.
- Energy is not provided in kJ.

6. Product of Australia would support the Australian economy best, as it is not only substantially made or manufactured in Australia like 'made in Australia' products, but additionally uses Australian grown ingredients as well.

7. The following answers do not provide an exhaustive list, other answers are possible. The answers provided is an example only, to demonstrate how double dipping should not occur across all answers.

(a) Breakfast Cereal

Risk Factor: Moisture or insects/rodents/bacteria or oxygen exposure

Packaging Material: Plastic bag and/or exterior cardboard box

Explanation: Plastic packaging is resistant to and prevents exposure to moisture (which can cause the growth of mould) or oxygen (which can cause cereal to go stale). Cardboard box can prevent contamination from insects/rodents/bacteria.

(b) Fresh Eggs

Risk Factor: Breakage

Packaging Material: Cardboard egg carton

Explanation: An egg carton separates eggs, so they do not touch each other and break during transportation.

(c) Orange Juice

Risk Factor: Light exposure

Packaging Material: Frosted plastic container or UHT packaging

Explanation: Should a packaging be provided that reduces penetration of light, this will limit the denaturing of light-sensitive nutrients.

8. (a) Match the mandatory labelling law with its description:

Percentage labelling	For food with a shelf life of less than two years
Name/description	Needs to indicate the true composition of the food
NIP	Allows recall of potential batches of food that could be contaminated
Date marking	Provides quantities of nutrients per serve and per 100g
Ingredients list	Allows the characterising ingredient to be compared to alike products
Recall information	Where allergens and food additives are found
Food additives	Must be provided if food poses gastroenteritis risk after opening
Storage instructions	Must be listed in ingredients, even if in small amounts <5%

(b) Any one of the following foods do not need labelling:

- Unpackaged food or food packaged at its point of sale, e.g., at a bakery, doesn't need to be labelled as it is prepared in front of you allowing you the opportunity to ask questions.
- Foods sold at fundraising events don't need to be labelled as they are one-off or occasional foods that are not consistently sold/part of the diet.
- Tea and coffee, and very small packaged foods like herbs, don't require food labelling as they tend to be without significant nutritional value.

(c) Excess sodium can increase blood volume and therefore blood pressure. Sodium is therefore required on nutrition information panels for someone with hypertension to be able to monitor their intake or compare to alike foods to find the one with lowest sodium which is best at managing their diet related disorder.

(d) Foods with a best-before date can still be consumed after the date marking but they may have lost quality or nutritional value. Foods with a use-by date should not be consumed after its date marking for health and safety reasons as they increase the risk of food poisoning.

9. (a) Salami

(b) Canned steak and vegetables in sauce

(c) Appropriate choices for CVD include:

- Broccoli has 0g of saturated fat which is known to increase LDL cholesterol levels in the blood, which increases the chance of it depositing in the artery wall when in excess.
- Dried rice cereal as it has less than 1g/100g of saturated fat (0.6g) and simple sugars (0.1), both of which are risk factors of atherosclerosis when consumed in high amounts.

(d) NIP presenting information per 100g allows consumers to compare foods to make informed decisions about which product to purchase, as the serving size may differ.

Case Study: Butter food recall

FSANZ monitors and coordinates food recall in Australia and in this case study, it was important to circulate the recall information to reduce the potential of any adverse health effects such as gastroenteritis from microbial ingestion.

The butter products offer some favourable conditions for microbes including (any two of the following):

- Dairy products have a pH close to neutral where microbe enzymes are functioning optimally to allow replication in numbers.
- Butter is a good source of protein, a nutrient preferred by some microbes, particularly bacteria, as a source of energy for functioning and replicating
- Water activity in the unsalted dairy products could be quite high as there would be reduced electrolytes withholding available water from microbes, supporting their functions.
- The headspace in the butter products in plastic packaging could be a source of oxygen that supports aerobic microbe respiration and reproduction.

A mandatory food label reducing the chance of food poisoning is (any of the following):

- Storage instructions, dairy is specified to be refrigerated and 4°C is below the danger zone, slowing microbe enzymes therefore reproduction.

- Food recall information, in particular the 'lot' number, and/or best before or manufacturing date can allow for more effective recall of batches that may have a potential contaminant, preventing possible purchase, ingestion, and food poisoning.

To slow or stop microbe growth, modified atmosphere packaging (MAP) could be applied to the headspace of the plastic packaged butter products. MAP would manipulate the gas concentrations to decrease oxygen and increase carbon dioxide which do not provide ideal conditions for aerobic microbe respiration, hence slowing their reproduction.

Science as a Human Endeavour:

Laboratory testing to confirm Nutrition Information Panels

- The Soxhlet method for fat quantity in food is dependent on solvent extraction techniques that require a few hours to collect test results, whilst NMR fat testing can scan food to provide measurements within 20 seconds. A more efficient scientific procedure in relation to testing time would allow for additional food samples to be tested, increasing the sample size. NMR doesn't require a qualified expert as it is easy to complete the testing. Simplicity in the testing procedure could improve data collection by minimising random errors. Additionally, in comparison to Soxhlet testing, NMR tests tends to be non-destructive and leave the food intact to allow repeat of measurements of that food item, again improving data collection. Repeat in measurements, a larger sample size, and a reduction in random errors, would then improve the analysis of results by making them more reliable. This development in testing for fat would therefore give a clearer overview of whether a food manufacturer is complying with (or misrepresenting) their total fat content conveyed on the NIP.

Topic Two Test Solutions

- A scientific or mathematical tool used by doctors, dieticians, nutritionists, scientists, or researchers to ascertain nutritional/health status and diagnose nutritional/health problems.
 - $$\text{BMI} = \frac{\text{Weight (kg)}}{\text{Height}^2 (\text{m}^2)}$$

$$\text{BMI} = \frac{76}{153^2}$$

$$\text{BMI} = 32.5 = 33$$
 - This person is not in a healthy weight range as they have a BMI > 30, indicating they are obese.
 - BMI does not consider the distribution of muscle mass on the body (muscle weighs more than fat).
 - NRVs comparisons/blood analysis (or others not mentioned in textbook such as urine testing, MRIs, etc.).
 - BMI is not as accurate as NRVs or blood analysis as they can specifically analyse kJ balance and blood nutrient levels, such as cholesterol, triglycerides etc.
- Children aged between 5-12 years old are easily influenced and during this stage is when healthy behaviours are established, which are then likely to be carried through to adulthood. This can reduce the prevalence of diet related disorders. These healthy eating initiatives can also ensure the consumption of a range of nutrients which are essential for good health, growth, and development.
 - Discretionary foods that are typically high in saturated fat, sugar, salt can become addictive and lead to young children refusing nutrient-dense foods or using pester power and tantrums to obtain 'red' foods that are linked to poor dietary habits and diet-related disorders.
 - Cannot be sold (identified as a 'Red' food)
 - Can be sold (identified as an 'Orange' food).

3. (a) Any of the following campaigns (but not limited to):

Name	Discussion
2 & 5	Vegetables presented in exciting ways which is appealing (especially to children). Or the campaign lists benefits of vegetables to health which could help encourage their consumption.
Swap it, Don't Stop it	Promotes swapping processed snacks to vegetables e.g., potato chips to carrot sticks.
Measure Up	Adults with children compelled to increase vegetable intake by strong message linking to their health benefits. Campaign aims to change the eating habits of adults and therefore their children to reduce a growing waistline.
Traffic Light Colours (Rite Bite)	Used as a guideline for children to eat less of 'red light' foods, sometimes 'orange/ amber foods' and more of 'green light' foods which include vegetables.
Stephanie Alexander program or similar	Educates children on how to grow, harvest and prepare foods that include vegetables. This engages children with eating healthier produce, such as vegetables which develops habits that they can carry with them throughout life.

- (b) Any of the following:

- Peer pressure:
 - Children and their parents can be influenced by food choices of their friends, children wanting what other children have. If a child dislikes a food, for example vegetables, then this can influence children around this child to also dislike this vegetable.
 - Family—older sibling's role modelling food choices; therefore, modelling dislikes of vegetables. Both examples could result in parent reluctance to keep trying to consume vegetables against children's wishes.
- Working parents and busy lifestyles resulting in less prepared fresh food and reliant on convenience and processed foods
- Children tend to have low attention spans and may not be interested in foods etc. that are not as appealing, such as vegetables.
- Advertising—fast foods and convenient foods and promoted more frequently, whereas vegetables are advertised the least and therefore not seen as 'normal' to consume vegetables. This can cause peer power where children pressure parents to purchase foods that are readily advertised.
- Geographical location – families may have limited access to wide variety of fresh vegetables and may cost more.
- Socioeconomic status – households may have limited income and/or limited access to resources and therefore have reduced affordability of healthier foods, including vegetables.
- Seasonal vegetables – in season, vegetables are more abundant and therefore cost is less, but when out of season more expensive and therefore harder to purchase vegetables that children prefer.
- Level of education – parents may have a low level of education and therefore food knowledge and may not be aware of the importance of children consuming nutrient high vegetables.
- Lack of cooking skills - Parents may also lack the skills and abilities to cook vegetables in a way that children enjoy them.

- (c) Comfort eating is eating to feel good, or calm, or reduce the emotion that led to the food intake e.g., eating doughnuts when depressed to feel good. It can be recognised by any of the following characteristics:

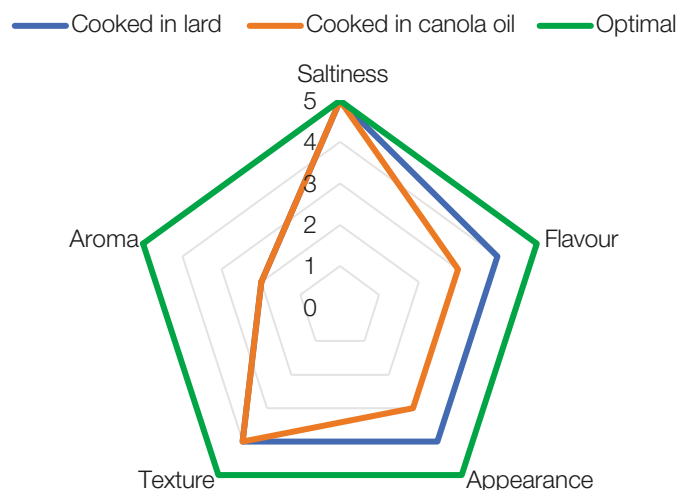
- Eating when not necessarily hungry, beyond normal levels of satiety i.e., over-eating.
- It involves a craving for a certain food, typically those that are energy dense.
- It may lead to feelings of guilt or regret after.

4. (a) Cereal B as it meets ADG 3 best which recommends to limit the intake of saturated fat, sugar, and salt. Cereal B is lower in saturated fat (by 0.2g/serve or 0.9g/100g) and sugar (by 3g/serve or 18.3g/100g).

- (b) Fibre, riboflavin, niacin, B6, folate, iron, or zinc

- (c) Label requirements may include (country of origin is not included as it is overseen by Australia consumer laws, not FSANZ):
- Date marking (specifically best before date) is important to inform the consumer of the date it is advised to consume the food before, when its nutritional value is optimal
 - Name/description of food cannot be misleading as it is valuable to inform the consumer as to the type of food, especially needed when the food cannot be seen due to opaque packaging.
 - Net weight is valuable to consumers tracking their kJ and nutrient intakes or to divide the food product into even portions for food preparation
 - Name/address of manufacturer or the barcode/batch number are important food labels allowing for more effective food recall with issues such as contamination or to contact over inferior quality concerns
 - Advisory statements carry valuable messages to allow for choice in consumption when health concerns are prevalent
- (d) 1) Colours – restore or add colouring to cereals, which may have been lost during processing.
2) Emulsifiers – prevent the oil from separating from other ingredient that hold water which improves the texture of the cereal, or keep the oil mixed uniformly amongst the cereal mixture during processing
- (e) Advantages of using cardboard for cereal boxes for food manufacturers include:
- Cheap
 - Lightweight
 - Easier printing capacity for labelling
 - Can be marketed appealingly as being recyclable/biodegradable
 - Shaped well for easier storage and transport
- (f) Cardboard is not used alone because of either of the following answers:
- It deteriorates if met with moisture, plastic provides additional protection for the food product.
 - It is not strong and can be crushed with mechanical pressure, whilst plastic packaging can be gas-filled to provide additional cushioning for the food product inside.
- (g) Active packaging forms that could be utilised within the cereal headspace include:
- Modified atmosphere packaging changes the gases inside the cereal plastic packaging, to increase the levels of carbon dioxide which inhibits the growth of most bacteria and mould.
 - Oxygen absorbers reduce the oxygen required by aerobic microbes to reproduce.
 - Moisture scavengers will absorb water, reducing the ability of microbes to reproduce.
 - Carbon dioxide emitters produce and release carbon dioxide to disallow food spoilage and aerobic microbes to function.
5. (a) 1 mark each for: title; axes labelled; correct data plotted for chips cooked in animal lard and chips cooked in canola oil chips; optimal displayed, legend included.

Sensory evaluation of chips cooked in
animal lard vs canola oil



- (b) The fat used to cook the chips in (canola vs animal lard).

(c) Factors may include:

- Sample size eaten, so that each tester is provided with an equal amount of chip to eat. e.g., receive similar amounts of the edge and the centre (edge may be crispier for example) or may taste saltier if receive a larger serving size i.e., 2 chips vs 1 chip.
- Similar times tested for each chip, so that level of satiety, which can impact taste, is similar.
- Time cooked or the temperature cooked should be the same as longer cooking times or higher temperatures may change chip appearance e.g., turn chips darker or further water loss could make them crispier.
- The potato type should be the same as different potatoes can have different nutrient quantities that may affect taste.
- Similar cooking equipment should be used, for example deep frying would allow a larger quantity of fat to be absorbed by the potato compared to oven baking.

(d) Highest ranking characteristic: Saltiness

Lowest ranking characteristic: Aroma

(e) Sensory evaluation is impacted by other factors influencing food choices, namely psychological factors. Food attitudes, beliefs, past experiences, cultural values, etc. may already predispose a taster negatively or positively towards a food. For example, chip cooked in animal lard may cause someone who has strong values about healthy food to score the chip negatively. It is also based on human response which is highly variable i.e., a subjective method.

(f) An individual with a cold has a blocked nasal cavity, therefore would not be able to score the flavor or aroma of the chips accurately. This is because odour of a product can be detected directly through the nose or after entering the mouth and flowing to the back of the throat and up into the nasal cavity. Aroma is especially important as it contributes approximately 75% to a food product's flavour. Therefore, flavour can also be affected and inaccurately scored with a cold.

(g) A large sample size reduces the impact of random errors and outliers, making the results obtained more reliable.

6. (a) i. Heating the food in the microwave can kill microbes that have been able to grow when exposed to the danger zone, possibly to food poisoning levels, before heating.
- ii. Re-heating the food may kill bacteria, but many bacteria produce heat-resistant toxins that can still cause food poisoning. Considering the food has been transported home from the restaurant, plus an hour on a bus and then 3 hours in a backpack during a lecture, it has been in the danger zone for over 4hrs. Giuseppe isn't following the 2-hour/4-hour safety guide as food that has been out of correct storage for 4 or more hours should be discarded.

(b) i.

Stage	Hazard and Food Safety Practice
A Storing the fish cakes	Fish cakes not stored in fridge/freezer: ensure these items are place in a cool environment below the danger zone until required to slow/stop bacterial growth. Not sealing fish cakes: reduce the exposure to air/oxygen by storing ingredients in airtight containers or prevent opening the packaging until required, to prevent bacteria contamination or reduce oxygen which encourages growth.
B Cooking the fish cakes	Undercooked fish cakes: check the temperature of the fish cakes with a thermometer to ensure they have reached a temperature above 75°C or until the fish is flaky. This will ensure that pathogenic bacteria have been destroyed.
C Serving the fish cakes	Cross-contamination (hands/other equipment): canteen staff to use clean surfaces/ equipment and separate hand (gloved) for food and other hand for money to avoid contamination from objects with bacteria.

ii. *Listeria*, *E. coli*, *Salmonella*, *Clostridium botulinum*.

iii. Any of the following conditions:

- Optimal temperature 5-60°C or danger zone
- Neutral pH of 7, but most can reproduce in a range of 4.5-10
- Presence of nutrients
- Water activity of 0.90 or higher
- Availability of oxygen
- Time

- (c) i. Any on the following reasons:
- The implementation of education programs targeting hospitality workers has led to better hygiene practices.
 - Better surveillance of health regulations.
 - Employment of more health inspectors.
 - More effective public campaigns educate consumers about way to care for and store food appropriately.
 - Eating out less often e.g., corona virus restrictions (assuming better food safety practices in the home).
- ii. Any of the following groups:
- People who eat out regularly: greatest risk as they are relying on the hygiene practices of other people making their food.
 - Infants and Children: immune system has not developed properly, therefore cannot fight. infection of pathogenic bacteria that are present in food
 - Elderly: weakened immune system, especially as some medications can suppress immune system function
 - Immunocompromised: weakened immune system, due to medications or treatments or genetics
 - Pregnant and Lactating Females: weakened immune system due to the changes to their metabolism and circulation, as well as sharing the nutrients with the foetus.
- (d) Food spoilage can be defined as changes in food and/or beverages that render the product undesirable for consumption, such as an unusual texture, odour, taste and appearance which develops. These signs are generally visible to the consumer. Food poisoning is typically caused by pathogenic bacteria or viruses, leading to illness. Food poisoning is generally not visible to the consumer.
- (e) It is good practice to prepare cooked meat first prior to raw meat, to reduce the risk of cross contamination. Raw meats are a good source of pathogenic bacteria as they have not been exposed to high temperatures, which kill these bacteria.
7. (a) Possible modifications include:
- 400g frozen instead of fresh fish.
 - 3 spring onions/bok choy substituted with a pickled vegetable alternate (or frozen vegetable acceptable should frozen products not have been used as an alternate answer).
 - ¼ bunch flat leaf parsley modified to dried parsley.
 - Packet/dry pasta instead of ready to cook pasta.
- (b) Methods include:
- The fish could be frozen, as this lowers the temperature to the point that microbes are dormant allowing the fish to be kept for weeks compared to a few days.
 - The fish could be frozen as this reduces the water activity to zero as water is converted to ice, zero water activity doesn't allow microbes to reproduce, allowing much longer storage of the fish.
 - The fish could be firstly cooked and then stored in jars with a cooking acid like vinegar. This method of pickling fish gives the fish a solution of storage that deters bacterial growth as they prefer a pH around neutral.
 - The fish could be firstly cooked and then stored in jars with salty water (brine). The brine solution acts to reduce water activity and deter microbe growth, allowing for an extended shelf life.
- (c) Any of the following answers could be possible options to reduce the food bill:
- Look for reduced prices/specials.
 - Use promotional coupons e.g., shopping dockets buy one get one free.
 - Buy in bulk.
 - Buy food in season.
 - Buy canned/frozen alternatives (often cheaper especially when produce is out of season).
 - Buy generic brands.
 - Look to buy legumes in replacement of meat for all meals.
- (d) Answers may include:
- Not eating pork or pork products considered suitable for health due to it being high in fat and kJ, therefore reduces the chance of excess adipose tissue/weight gain/obesity.

- With pork/pork products being high in saturated fat, removal of this food product could reduce the levels of saturated fat in the diet, thereby lowering LDL cholesterol levels and CVD risk.
- Removal of pork/pork products can remove a source of complete protein that contains all the essential amino acids needed for functions like muscle repair, therefore it is not a suitable nutritional restriction.
- Not eating pork/pork products is not a suitable health option as it they are high in haem iron (or B12), an easily absorbed form of iron that reduces the chance of anaemia.

Topic Three Solutions

Topic 3.1: Food Systems and their Impact on the Environment

Review Solutions

- Different crops use and replace different nutrients from the soil which reduces the need of fertiliser. Less fertiliser seeping through the soil means less hydrogen ions being released from fertiliser breakdown. Hydrogen being added to the soil lowers pH and creates soil acidity. Soil acidification can therefore be reduced if fertiliser use is reduced.
 - pH 3-4.5
 - Any of the following are acceptable nutrients:
 - Nitrogen with a pH anywhere between around 4.5-7.5 acceptable
 - Phosphorus with a pH range 5.5-7 & 8-9 (or greater than 8)
 - Potassium with a pH range 6.5-9.
 - Iron is available in larger amounts in an acidic pH range around 3-5.5. After 5.5, its availability slowly and constantly decreases until there are only small amounts of iron available to plants at a pH of 9.
 - Crop rotation involves replacing a farming field with a different plant or crop each season. It can rotate through two to multiple different types of crops on the same field but only one crop is grown at a time. Intercropping allows different crops to grow in the same field at the same time, often in alternating rows.
 - Mixed farming or alternate energy sources (other practices not covered in this textbook are acceptable also).
 - | Practice | Organic Farming | Monoculture |
|----------------------------------|-----------------|-------------|
| Using synthetic pesticides | x | ✓ |
| Typically produces higher yields | x | ✓ |
| Uses manure as fertiliser | ✓ | x |
- Grazing land use has increased by approximately 1.75 billion hectares from 1900 to 2016.
 - Reasoning may include:
 - Cropland and/or urbanisation land use have also increased, and they tend to occupy arable land, which pushes grazing areas into less arable regions with reduced plant yields. Grazing areas must therefore expand over even larger areas to ensure livestock can gain sufficient food supply from native grasses.
 - Urbanisation has increased, suggesting populations have risen in conjunction with the need for more meat and/or wool, leading to grazing areas expanding to raise more livestock.
 - Cropland and grazing expansion links to climate change may include (but should not repeat explanation across answers):
 - Clearing for crop or pasture expansion results in deforestation of natural habitat. Plants, especially trees, absorb carbon dioxide from the atmosphere and store it as carbon. When cleared, this carbon is released as carbon dioxide (or less trees mean less carbon dioxide being utilised by plants) resulting in increased levels of this greenhouse gas leading to global warming and climate change.
 - Increased cropland can mean heightened areas with soil degradation which disrupts the soil's ability to act as a carbon sink. Therefore, there is greater carbon dioxide present in the atmosphere, leading to global warming and climate change.



- Livestock, especially cattle, are associated with methane being released into the atmosphere via digestive processes or manure decomposition. Methane is a powerful greenhouse gas. An increase in grazing land assumes an increase in grazing animals and greenhouse gases leading to global warming and climate change.
- Machinery is required to maintain croplands and land for grazing, which uses non-renewable fossil fuels. This releases greenhouse gases, which can contribute to global warming and climate change.

3. (a) Reasons for food loss or waste will vary and may include:

Food systems stage	Reasons for food loss or food waste
Primary food production	• Pest destruction • Disease damage • Weather damage • Poor handling • Poor storage • Fall in market prices, or consumer demands, or labor shortages leading to unharvested crops. • Rejection of produce due to imperfections
Processing	• Poor handling • Food spoilage or contamination • Poor storage • Excessive trimming • Changes in consumer demands
Distribution	• Poor transportation storage • Poor handling • Inappropriate packaging • Lengthy food miles
Retail	• Poor handling • Over-ordering produce • Poor stock rotation • Improper storage • Imperfect produce rejected • Limited access to food waste disposal
Households	• Poor handling • Over-purchasing or cooking • Lack of awareness of best before date still being able to be eaten • Edible produce parts not being utilised e.g. potato skins • Poor knowledge of proper storage • Improper storage • Fussy eaters, food returned in lunch boxes • Limited access to food waste disposal

- (b) Food waste ending up in landfill can rot and decompose to produce greenhouse gases, especially methane. Greenhouse gases trap heat, warming the Earth. The increase in the Earth's temperature is linked to climate change and more frequent unpredictable extreme weather patterns such as drought and floods.

(c) Any of the following are possible answers:

Level	Strategies to reduce food waste
Producers	- Improving technology to sense crop or livestock distress or to harvest/collect produce more efficiently. - Invest in storage infrastructure to optimise produce shelf-life. - Donating surplus produce to the food rescue sector, so that it can be redistributed to those with food insecurity. - Sell imperfect or 'ugly' fruit and vegetables directly to consumers at reduced prices. - Process excess or imperfect produce into foods such as jams or juices. - Improve collaboration and communication – strong relationships with retailers can help farmers better understand market demands and therefore adjust production accordingly to achieve a closer match between supply and demand, rather than overproduce. - Utilise crop waste to produce compost, animal feed, chemicals, other materials such as biodegradable packaging and biofuels.
Retail	- Invest in proficient technology and appropriate employee training to monitor stock levels, expiration dates, and sales data to help avoid overstocking produce and food expiring on shelves. - Offer discounts on foods approaching expiry dates. - Negate the need to keep shelves full for customer satisfaction and instead adjust produce placement and rotation to reduce the chances of older items being overlooked by customers. - Implement food waste tracking systems so that data can provide targeted areas of frequent food waste to address. - Accept and sell imperfect produce at a lower cost. - Ensure organic waste products are collected for industrial composting facilities. - Create awareness of food waste and how consumers can cut down on waste through publications plus sharing tips in sections around stores.
Households	- Purchase and consume 'ugly' or imperfect fruit and vegetables. - Store food correctly to extend its shelf life. - Check food labels date markings and have an awareness that food can be consumed after its best before date (if the food has not been opened). - Cook and store food safely when additional take-away food is purchased. - Freeze food you know you won't get a chance to eat before it passes its use-by date. - Use leftovers. - Donate unwanted food. - Check the fridge before shopping. - Don't shop when hungry to prevent over purchasing. - Pan meals and write shopping lists so that you stick to buying only the food you need and don't cook too much food. - Avoid buying perishable items in bulk e.g., buy only the single fruits needed vs pre-bagged. - Take food in the correct order of stocking (the front). - Remove visible aging produce to use immediately or compost, as it can emit gases that speed the ripening of other produce. - Consume parts of produce that usually get discarded e.g., potato peel or using them elsewhere e.g., lemon skins incorporated into desserts or sauces with fish. - Dispose of organic wastes in the correct 'green' bin or even composting your own food scraps

(d) Both food loss and food waste refer to food that has been discarded. However, food that is discarded in the initial stages of our food systems (agriculture, processing, distribution, and retail) is termed food loss, whereas food discarded in the later stages (food service and households) is called food waste.

4. (a) PLA is more eco-friendly because it is compostable. That means in composting conditions, it can be broken down into substances that do not harm the environment and can provide nutrient-rich compost.
- (b) PHAs are used more frequently due to composting facilities required for plastics like PLA being limited, making PHA more convenient to use. PHA can be thrown into general waste where it can biodegrade, whereas PLA cannot. PHAs may however, decompose into microplastics which can build up in food chains, possibly harming wildlife.

5. (a) Rice, cotton, sugarcane, or pastures for grazing.
- (b) Rice
- (c) Answers possible include:
- Excess water may seep through the soil causing the water table to rise with dissolved salts, causing greater salinity in the topsoil (irrigation salinity). Salts in the topsoil will hinder crop growth, which reduces yield and food availability.
 - Excess water could wash away fertilisers into nearby waterways leading to eutrophication. Algal blooms could then result, reducing oxygen levels in the water and rendering it useless. Water scarcity issues could then impact upon future food accessibility as produce requires water for growth.
6. (a) Fishing techniques could be longlining, trawling, gillnets, or commercial fishing in general, whilst environmental concerns could include:
- Bottom trawlers damage ocean floors and ecosystems which disrupts food chains. Biodiversity could therefore be negatively affected.
 - Fishing techniques catch large numbers of marine life at once, disrupting food chains and negatively affecting biodiversity.
- (b) Aquaculture is an alternate to commercial fishing with advantages being:
- It reduces overfishing of the fish or organism being reared, as that fish is bred with the purpose of consumption rather than removing them from their natural habitat.
 - It produces high yields because seafood being bred is protected from predators in barricades such as netting and they receive controlled feedings.
- Disadvantages of aquaculture can include:
- Uneaten feed pellets or concentrated seafood excretions can introduce extra nutrients into waterbodies and lead to eutrophication.
 - Chemicals used on aquaculture such as antibiotics can contaminate water, making it unsafe for wildlife or consumption.
 - Food pellets for larger fish may still involve overfishing wild fish to process as fish pellets, impacting biodiversity negatively.
 - Proximity of fish, plus concentrated wastes can lead to hastened disease spread, affecting biodiversity should it easily reach organisms of shared water bodies.
 - Aquaculture areas take up large bodies of water, impacting negatively on natural ecosystems and negatively affecting biodiversity.
 - Fish farms on land can lead to deforestation and concerns with global warming once trees that absorb carbon dioxide are removed, or require vast amounts of water, associated with water scarcity issues.

Case study: Suitable garden crops

1. Answers will vary for selected garden plants but ensure their preferred pH and salt tolerance matches those levels found in the soil of the complete science inquiry skill practical.
2. Methods to reduce food wastage of garden produce include:
- Compost the leftover fruit/vegetables (or ensure they are disposed of in the green bin) so that they can be broken down into a nutrient source that is harmless to the environment.
 - Donate what you can't eat to food charities like OzHarvest so that it can be redistributed to those in need.
 - Preserve the fruit/vegetables in an applicable manner, for example:
 - Freeze or refrigerate the extra fruit and vegetables where microbes become dormant, increasing the shelf life.
 - Make jam where sugar is added to reduce the water activity of the food, making it inhospitable to microbes.
 - Pickle the vegetables, storing them in an acid like vinegar, which increases the shelf-life of the food as the pH is not favourable for microbial growth.

3. To replace nutrients lost from the soil you could:
 - Add compost or processed manure to the soil as they are slower to break down than fertilisers, reducing leaching through soils and the accompanied groundwater pollution or soil acidification that evolves, both with negative impacts on biodiversity.
 - Plant a crop such as a legume after harvesting the garden crop. Legumes fix and return nitrogen, a major nutrient needed by plants for growth, back into the soil.
4. Answers surrounding health benefits are many and will vary dependent on the vegetable(s) and/or fruit(s) chosen.

Science as a Human Endeavour:

Microplastics – just how much plastic are we consuming?

1. The researchers worked collaboratively to review the literature of 26 study findings communicated by other scientists, before coming up with their microplastic database.
2. An accurate average yearly microplastic consumption figure being calculated has been limited by data on microplastics only being available from a few foods and ingredients such as fish, water, alcohol and added sugars. Foods like red meats, dairy, grains, vegetables, etc. have no data on microplastic content. As such, only around 14% of all foods intake and the microplastics in them could be calculated, leaving the yearly figure to be limited to a substantial estimation. The calculation was also limited to the average American, it did not consider cultural differences in the diet. For examples, some cultures and religions avoid alcohol and may have considerably lower microplastic consumption. It also didn't consider individual differences in age, gender, etc! Females and younger children, typically consuming less food and beverages, and may potentially consume less microplastics.

3.2: Research and Development

Review Solutions

Food production method	Definition or example
Digital farming	Cultivating barramundi in conjunction with lettuce grown without soil in a vertical farming system
Aeroponics	Foods derived from a crop or animal that has had a gene that will express a desirable trait introduced into its genetic make-up
Lab-grown meat	Food manufactured from syringes that hold food pastes
Entomophagy	Myosatellite cells producing muscle tissue
3D printing of food	Novel foods that have not been consumed to a significant degree in the past in Australia
Genetically modified food	Robotic egg collection and sorting by weights
Meat bioprinting	Smoked salmon made from Spirulina
Microalgae cultivation	Cell cultured meat transformed into a 'steak' via 3D printing
Aquaponics	Method of crop production that uses soilless techniques
Vertical farming	Vertical farming system where crop roots are suspended in air, receiving water and nutrient needs via a mist spray onto their roots

2. Ezra is most likely growing her kale using aeroponics. Aeroponics heavily reduces water usage by only spraying a water mist onto plant roots as needed as well as recycling unused water compared to conventional farming where excess water leeches down through the soil.

3. Note: double dipping across different parts of question one should be avoided.

(a) Any of the following answers are acceptable:

- The genetic modification of food could meet future nutritional needs as genetic manipulation can add and/or elevate levels of nutrients in foods. For example, wheat can be made to have added protein and soluble fibre.
- Aeroponics, a form of vertical farming, has been found to improve crop uptake of nutrients. Fruit and vegetables will therefore become more nutrient-dense to aid in human nutritional health.
- Entomophagy provides a rich animal protein source with additional nutritional benefits such as fibre and mono- and poly-unsaturated fats.
- Microalgae cultivation grows a high biological value vegetarian protein source that contains minerals, fats and vitamins found in meat and seafood that could help meet nutritional needs of a growing population.
- 3D printing of food can fortify nutrients into food pastes to match individual nutritional needs and promote good health (reducing chance of deficiency diseases for example).

(b) Any of the following answers are appropriate:

- Entomophagy can potentially reduce food waste issues as insects bred for consumption can utilise food waste as a food source.
- Digital farming can detect poor animal or plant health more readily, minimising loss and therefore food waste.
- 3D printing of food can utilise foods that would ordinarily be discarded, for example, abnormal-appearing fruit and vegetables can be turned into purees that are used to 3D print visually appealing foods.
- Vertical farming can potentially reduce food waste as crops are grown in enclosed areas, protected from extreme weather patterns that can damage crops and produce food waste.
- GM foods can potentially reduce food waste as they can be manipulated to withstand environmental elements, for example, drought. Should drought occur, GM crops would not become as wilted or damaged, thereby reducing food loss.
- Lab grown meat can potentially reduce food waste as only the edible part of the animal (the meat) is cultured and produced.

(c) Applicable answers include:

- Vertical farming/cellular agriculture/3D printing food production methods are all conducted within enclosed areas and therefore growth of crops/lab-made animal products are not affected by environmental weather conditions like drought.
- In periods of drought, water supplies can dwindle. Therefore, any food production method that uses reduced water quantities could allow for better food security, such as entomophagy, microalgae cultivation and especially aeroponics (form of vertical farming).
- Genetically modified foods can have crops altered to be more tolerant of dry hot conditions. For example, genes from plants that encourage growth in periods of rain and halt growth in dry/hot conditions can be inserted into crops to allow them to survive harsh drought conditions in which they would normally perish.

(d) Answers may include:

- The waste from the fish in aquaculture has the potential to create eutrophication. However, when combined with cultivating crops in aquaponics, nutrients from the fish wastes are utilised by the growing plants. Reducing nutrients in the water reduces the potential for eutrophication to occur.
- Microalgae cultivation occurs in mostly enclosed facilities, reducing the chance of run-off into nearby waterways and potential eutrophication.
- Digital farming can use technological devices to deliver fertilisers more directly to each crop plant. This reduces potential run-off into waterways and the chances of eutrophication.

(e) Possible answers include:

- Vertical farms can be grown in buildings within areas of urbanisation. This would heavily reduce the food miles required for crop harvests to reach consumers.
- GM crops or digital farming can produce higher yields (for example, by being resistant to pests for GM), therefore the land size required to be viable would be less, reducing how far farms would need to expand away from cities, potentially reducing food miles.

4. (a) Arable land is land that can support agriculture. It is typically land with fertile soils, optimal temperatures, and plentiful rainfall.
- (b) Available arable land has decreased substantially from approximately 3.4 hectares/person to two hectares/ person over a period of about 53 years (or by around 0.1 hectares/person every 5 years).
- (c) Data values around 1965-70 fluctuate above and below the line of best fit (or average or true value) which indicates random errors may be at play. The data values are also further from the line of best fit indicating poorer precision which lowers the reliability of the results. In comparison, data values between 1985 to 1990 are all above the average which indicates systematic errors may be responsible for these findings. Systematic errors affect accuracy but as the data values are relatively close to the line of best fit, results can be said to be quite accurate during these years.
- (i) Insects (entomophagy)
- (ii) Environmental benefits include:
- Insects require less land, water, or feed resources to grow as they can convert their food to protein body mass more readily than cattle. Using less resources from the environment ensures they are not depleted for needed biodiversity.
 - Insects can use food waste as a source of nutrition which combats environmental issues surrounding food waste such as greenhouse gas production and its associated climate change with unpredictable weather patterns.
- (iii) Appropriate nutritional benefits include:
- Insects can provide a source of fibre which is useful in dietary prevention of a number of over-nutrition diseases for example Type 2 Diabetes.
 - Insects can provide unsaturated fats while meat from cattle would be high in saturated fats (when meat is not a lean cut), therefore insects would be more beneficial in prevention/management of over- nutrition diseases such as CVD.
- (iv) Possible food production methods are:
- Cellular agriculture/cultured meat/3D meat bioprinting can produce meat tissue from cell cultures in laboratory settings that do not require vast areas of farming land.
 - Genetic modification could be used to create cattle that are faster growing and with higher amounts of lean muscle tissue. This would reduce the number of cattle needed to gain the same amount of meat, thereby reducing land needs.
5. (a) 3D food printing could be useful as foods need to be converted into pastes. Pastes are of a softer texture which would be easier to swallow.
- (b) 3D printing of food can allow foods to be in a range of shapes, colours, textures and flavours. It can also be programmed to create foods that replicate pizzas, burgers, cakes, chocolates, and other meals. This would create better variety, improved appearance and allow more control and choice over one's diet for someone with dysphagia. The application of this could see a reduced negative impact on one's mental health and fewer cases of depression.
6. (a) FSANZ
- (b) Herbicides can kill plants. A plant or crop that has been modified to be herbicide resistant can be sprayed with the herbicide and not be affected, whilst nearby plants, namely weeds, will be killed.
- (c) When an herbicide is sprayed upon a crop with herbicide resistant plants, few weeds would survive meaning less competition for resources such as nutrients in the soil. This would result in a higher yield and therefore greater food availability to cater for the growing population. There would also be a reduced need for tillage of the soil to dig up weeds resulting in maintenance of the topsoil, less erosion and/or improved soil microbiome. This would reduce the need for fertilizers to restore nutrients in the soil, which can lead to soil acidification and eutrophication in nearby waterways.

Case study: Crop damage by flood

Farmer Jones could grow his tomatoes via vertical farming methods. Vertical farms tend to be indoors which would offer protection from flood damage. Additional environmental advantages of converting his field to vertically stacked layers are the reduction in water and land space needed to grow his crops. This would reduce the need for land to be cleared, reducing the rate of deforestation which contributes to greenhouse gas emissions and global warming. Needing less land space could even allow farmer Jones to relocate to be closer to cities, reducing food mileage and transport needs and its associated negative effects on increased greenhouse gases leading to global warming and climate change. Vertical farming also reduces the risk of contaminating nearby waterways, caused from the application of fertilizers to soils. This would prevent nearby waterways becoming depleted of oxygen causing the death of aquatic species.

Alternately, farmer Jones could reduce the devastation of flooding by manipulating his tomatoes using genetic modification to be more resistant to root rot. Decreasing susceptibility of crops to disease can increase crop yield and result in less land needing to be cleared and used. This reduces the rate of deforestation, which contributes to greenhouse gas emissions as their stored carbon is released and can cause global warming. This also reduces the time that land is left cleared, which can lead to soil erosion or dryland salinity. Reduced disease chances could also mean pesticide needs lessen. This is a further environmental advantage considering pesticides often reach and pollute non-target areas or harm non-target species, and cause eutrophication in nearby waterways.

Science as a Human Endeavour:

New golden bananas could solve Vitamin A deficiency!

Note: Answers are more extensive than required for the marking scheme. They may include, but may not be limited to:

1. Researchers from Australia and Uganda have worked collaboratively over 10 years at the Queensland University of Technology to develop a new banana with improved vitamin A levels. Researchers and the university have further collaborated with the Bill and Miranda Gates Foundation to gain support for the research. Effective collaboration and communication between Uganda and Australian governments would be required to permit banana testing field sites in both countries and between researchers coordinating the field studies. Findings of the research have been communicated in the Plant Biotechnology Journal.
2. Discovery of genetic modification processes have benefited the development of the pro-vitamin banana. Its development genetically modifies the cavendish banana with a gene from a Papua New Guinea banana high in vitamin A. This development allows for a type of banana with higher vitamin A that can grow in larger bunches that could feed more people, especially children in Uganda.

Science as a Human Endeavour:

Biotechnology to help soil and crops.

Note: Answers are more extensive than required for the marking scheme. They may include, but may not be limited to:

1. The environmental application of wheat crops growing nodules to home nitrogen-fixing bacteria would be the benefits of reduction in fertiliser use. These benefits include less fertiliser run-off into waterways and therefore eutrophication that leads to algal blooms and consequential harm to biodiversity would be less likely. Reduced fertilisers seeping into the soil would benefit soil pH and ensure soil microbes and fauna are not harmed by the acidic soil fertiliser breakdown products. Lower reliance on fertiliser could have applications on climate change as well, with less fossil fuels and energy needed to synthesize fertilisers.

A societal application relates to genetically engineering wheat potentially having improved yields due to better access to nutrients and growing in healthier soils, which helps to meet growing food demands of communities.

Economically, farmers could save money on fertiliser costs, and this could have further application of reducing wheat prices for customers.

2. Consumer trends for food are towards those that are environmentally sustainable. This may influence research into methods that can reduce the use of fertilisers to lessen their environmental damage, such as symbiotic microbial biotechnology in agriculture.

Society may also be influencing research into the microbial biotechnology with followings of veganism and food production that doesn't harm animals becoming more popular (especially with a large public celebrity endorsement of veganism and campaigns against animal-cruelty). This surging trend in food choices can influence methods such as microbial biotechnology of crops because of a need to improve plant (vegan) yields to match food demands.

Topic Three Test Solutions

1. (a) Around 2012
- (b) Commercial fishing often overfishes, capturing seafood at a faster rate than it can naturally replenish. Lowered natural seafood populations would mean an alternate method to meet consumption rates is needed and aquaculture has become relied upon. Aquaculture may also have surpassed commercial fishing as it can produce higher yields due to it providing controlled feedings, protection from predation and easy capture.
- (c) Aquaculture may be to blame for wiping out surrounding small wild fish populations for any two of the following reasons:
 - Aquaculture could be overfishing small wild fish populations to create barramundi feed pellets.
 - Proximity of fish can allow for disease to spread quickly amongst aquaculture fish. As aquaculture may share bodies of water with wild fish populations, it could spread to those populations as well.
 - Aquaculture rearing of fish can increase the nutrients in water bodies via fish excretions, or wasted fish pellets that are able to penetrate the netting of aquaculture farms. This eutrophication can result in algal blooms that lead to poor oxygen levels in water, and death to organisms in water needing the oxygen.
2. (a) Aquaponics
- (b) Lettuce grown using vertical farming is advantageous in several ways compared to monoculture including:
 - Lettuce can be grown out of season due to it being grown in climate-controlled indoor areas, increasing food availability.
 - Lettuce yield can be higher due to be grown in protected buildings compared to monoculture lettuce being more exposed to poor weather conditions such as frost or drought and pest invasion.
 - Vertical farms growing in vertical layers means less land is needed compared to monoculture across fields. Less land being used can be linked to benefits such as:
 - Less land being cleared for crops can reduce impacts upon biodiversity.
 - Less land being cleared for crops leaves native trees to remove carbon dioxide from air, reducing global warming and/or climate change.
 - Vertically farmed lettuces not needing to be planted directly into soil has advantages such as:
 - Improved issues with land soil acidification from overuse of fertilisers leaching through soils.
 - Improved issues with soil erosion as vast fields will not be left exposed to wind and rain.
 - Vertically farmed lettuces using water that is recycled through the vertical system is advantageous compared to irrigating monoculture lettuce fields as excess water can penetrate through soil to add to the water table and result in dryland salinity.
 - Vertically farmed produce can be located in or near cities due to less land being required. This is advantageous as food miles and associated carbon emissions are reduced.
3. (a) Food miles is the distance the food has travelled from its place of harvest, slaughter, or collection to its place of consumption.
- (b) Despite using less petroleum (and therefore fossil fuels) for travel purposes, the food may have been grown in conditions that over-use other resources such as water, energy, land. *Link to environmental concern for additional mark dependent on which resource selected.*
- (c) Any two of the following could be adopted:
 - Grow your own vegetables, fruits, and herbs.
 - Buy local, e.g., farmers markets.
 - Buy produce in season.
 - Buy 'product of Australia' as much as possible.
 - Pick food groceries/take-away rather than have it delivered to the home.
- (d) Bioplastics are biodegradable and can break down quickly to reduce environmental littering concerns such as being eaten by wildlife. However, they may break down into microplastics, with potential toxin concerns as their concentration increases along food chains.



4. (a) According to the data of the graph, fruits tend to have a larger water footprint than vegetables. *Use of data from the graph may vary but some responses may include:*
- Apples were the fruit using the most water, 535L water more than the potatoes, the vegetable using the most water.
 - Vegetables all tend to be below 300L of water per kg, whilst fruits use at least 200L/kg more water.
- (b) Plant products tend to use less water than animal products. Reasons may include:
- Crops of plant products need water to grow, just as pastures for livestock feed do. However, on top of that, livestock also consume large quantities of drinking water.
 - Additional water may also be used in cleaning livestock and livestock facilities.
 - Plants have a faster growth rate to maturation and harvesting, reducing their overall water needs, whilst some livestock may require substantially longer periods of time before slaughter, thereby using more water over that time.
- (c) Nuts are a plant product, but they use high water quantities. Nuts could be farmed in several alternate ways including:
- Digital farming, where soil moisture is monitored, and water is only applied as needed.
 - Vertical farming (for ground nuts), where water that is not trapped by plant roots is captured and re-used/recycled.
 - Genetically modified, nut crops could be modified to absorb, hold, or trap water more efficiently.
- (d) i. Answers may include, but not be limited to:
- Livestock can overgraze which exposes the soil to erosion. Reduced livestock may allow fertile topsoil to remain.
 - Livestock can compact soil, disallowing precipitation to penetrate. This can also increase rain run-off and water erosion. Reduced livestock will allow water to enter soils for improved plant growth (and maintain fertile topsoil).
 - Native grazing livestock compete with native animals for food. Reduced livestock will therefore allow native fauna (and flora) to flourish.
 - Livestock require vast areas of land and may also require additional pastures for feed. Reduced beef in the diet will therefore result in reduced deforestation and all its associated environmental impacts (for example salinity issues, reduced biodiversity, less greenhouse gas emissions).
 - Less beef could mean reduced manure and other wastes being washed away during cleaning will enter water ways where they can cause eutrophication, algal blooms, and aquatic life death.
 - Methane, a potent greenhouse gas produced by cattle, would decrease if there is a reduction in beef consumption. Therefore, global warming, climate change and associated negative impacts on environments from natural disasters may reduce.
- ii. Cultured meat (also called cellular agriculture or lab-grown meat) or meat bioprinting can produce substantial amounts of lean muscle tissue, from a small sample of cow muscle stem cells. Producing large amounts of muscle tissue means large quantities of beef can be made, resulting in food availability improving.
5. (a) Households
- (b) Any of the following:
- Confusion over 'use-by' and 'best-before' date labelling.
 - Over-purchasing or over-cooking of food that is then thrown away.
 - Limited knowledge of how to safely repurpose or store food leftovers.
 - Limited access to food waste collection systems.
- (c) Consumption sectors (hospitality and households) collectively contribute to 34% of food being discarded as waste, whilst the sectors that contribute to food loss collectively account for a higher proportion of food being discarded, at 58%.
- (d) i. Queensland
- ii. Tasmania
- iii. Answers may include but not be limited to:
- Farming businesses more readily donate surplus produce to food rescue charities.
 - Food system stage more readily accepting and consuming 'ugly' produce
 - Better food wastage infrastructure (for example composting facilities) or food storage facilities (for example cold storage) on farms.
 - More farms with digital farming, to sense and rectify crop/livestock distress more effectively.

- Farmers have built better relationships with supermarkets/retailers/etc. to ensure demand and supply are a closer match (or to allow surplus produce to be sold at alternate markets)
- Farmers are redirecting crop waste more effectively for other means such as compost, animal feeds, etc.

6. Aeroponics development was to grow plant foods for astronauts, with little water and no soil, conditions compatible with space. This development for use in space has crossed into another field of science: agriculture, as a method of vertical farming. Its development has improved the science of growing plants: in vertical farming, plants are able to take up additional nutrients as they grow compared to other methods of land or vertical farming. It has also improved scientific procedures whereby plants are able to grow with substantially reduced water needs, with aeroponics delivering water through an air/mist spray, rather than needing large amounts of water to be delivered via irrigation and much of this water not being captured by plant roots.

7. (a) Monoculture cropping refers to the growing of one type of crop only in a specified area.

(b)	Rainwater seeps through the soil, unable to be trapped and used by tree roots	2
	Crops planted in topsoil perish in saline soils	4
	Food supply dwindles	5
	Deforestation removes natural habitats to allow for agricultural crops to be planted	1
	Water table rises dissolving saltwater as it rises	3

(c) Genetic modification could be utilised and genes from salt tolerant plants could be used in crops to allow their continued growth in soils with high salinity levels, maintaining food availability.

(d) *Answers may include, but not be limited to:*

- During periods after harvest, fields can be left bare and subject to erosion which removes the fertile topsoil, reducing soil quality.
- Intensive farming methods of monoculture cropping may over-use fertiliser which can seep into the soils, making them more acidic, reducing soil quality.
- Intensive farming methods may over-use pesticides which seep into soils, reducing soil quality.
- Monoculture cropping can deplete the soil of nutrients, making soil less fertile and reducing soil quality.
- Monoculture practices of adding fertilisers can improve soil fertility and therefore soil quality.

8. *Answers may include, but not be limited to:*

- Processing plant construction sites may clear natural habitat which can destroy native flora and fauna.
- Food manufacturing relies heavily on fossil fuels. This can be linked to:
 - Mining of fossil fuels (and for packaging materials) can destroy natural habitats (as above).
 - Fossil fuel use releases greenhouse gases which lead to climate change. Climate change is associated with increased incidence of extreme weather patterns; for example, flood and drought can wipe out flora and fauna populations; OR, global warming can make it hard for biodiversity to thrive in warmer environments.
- Food packaging can end up as litter instead of in landfill (landfill also reduces natural habitat). Litter can entangle animals or be mistaken as food.
- Food packaging materials may rely on resources that need to be mined, with mining destroying habitats

9. (a) The following answers provide more detail than required for the marking scheme, with possible SHE concepts being:

- Communication and collaboration is evident in this article as CSIRO are working with a food waste company called Goterra while running experiments to increase the breeding rate of a fly that can break down food waste. This collaborative effort between scientists and food waste company members could help find a technique that breaks down food waste most efficiently. CSIRO is also collaborating with University of Adelaide to find out the nutritional composition of several insects, plus local aboriginal communities to find out information about insect palatability in order to steer Australian's entomophagy industry with which insects would be best to farm. Scientists will gather at an international conference to communicate their findings and impart knowledge to foster the prospect of Australian entomophagy becoming a successful enterprise.

- Scientific results collected from testing fly egg laying under different environmental conditions will enable scientists to develop the most effective way for flies to breakdown food waste. The application of the findings can help reduce the issues surrounding the sustainability of the environment, namely reducing food waste which rots and releases methane greenhouse gas plus adds to landfill pollution. Scientific testing discoveries could allow for effective conversion of food waste into compost which can be used as a fertiliser, offering an application of economic value. It could also see soils enriched with nutrients from compost, enabling better crop growth and food availability.
 - Through building scientific knowledge of insect nutritional composition and palatability, scientists can make reliable predictions as to farming which insects would be most successful to market. Success in this industry could see a move away from traditional animal proteins towards insects and the application of this would reduce energy, water, and land needs. Biodiversity could be positively affected as a result. A further application could see insects as a protein option on the market having added nutritional benefits that could reduce the incidence of nutritional diseases. For example, some insects being lower in saturated fats compared to beef products could reduce the incidence of CVD.
- (b) i. Temperature
- ii. Food waste consumed (g)
- iii. Answers may include, but are not limited to:
- Number of flies (including the same balance in male/females), as more flies in an aquarium enclosure could result in more eggs/larvae/food waste consumption, rather than resulting from temperature.
 - Breed/age of flies, as different species/ages may breed at faster rates.
 - Type of food waste, as some types may be converted into compost more readily.
 - Mass of beginning food waste, as a smaller mass could result in lack of food source and consumption/breeding rate slowing.
 - Lighting, as additional lighting may signal day/night and activity levels may alter based on amounts of light.
 - Moisture in the food waste, as higher levels may allow compost to be broken down more readily.
- iv. 30°C
- (c) Entomophagy.
- (d) 3D printing of food.