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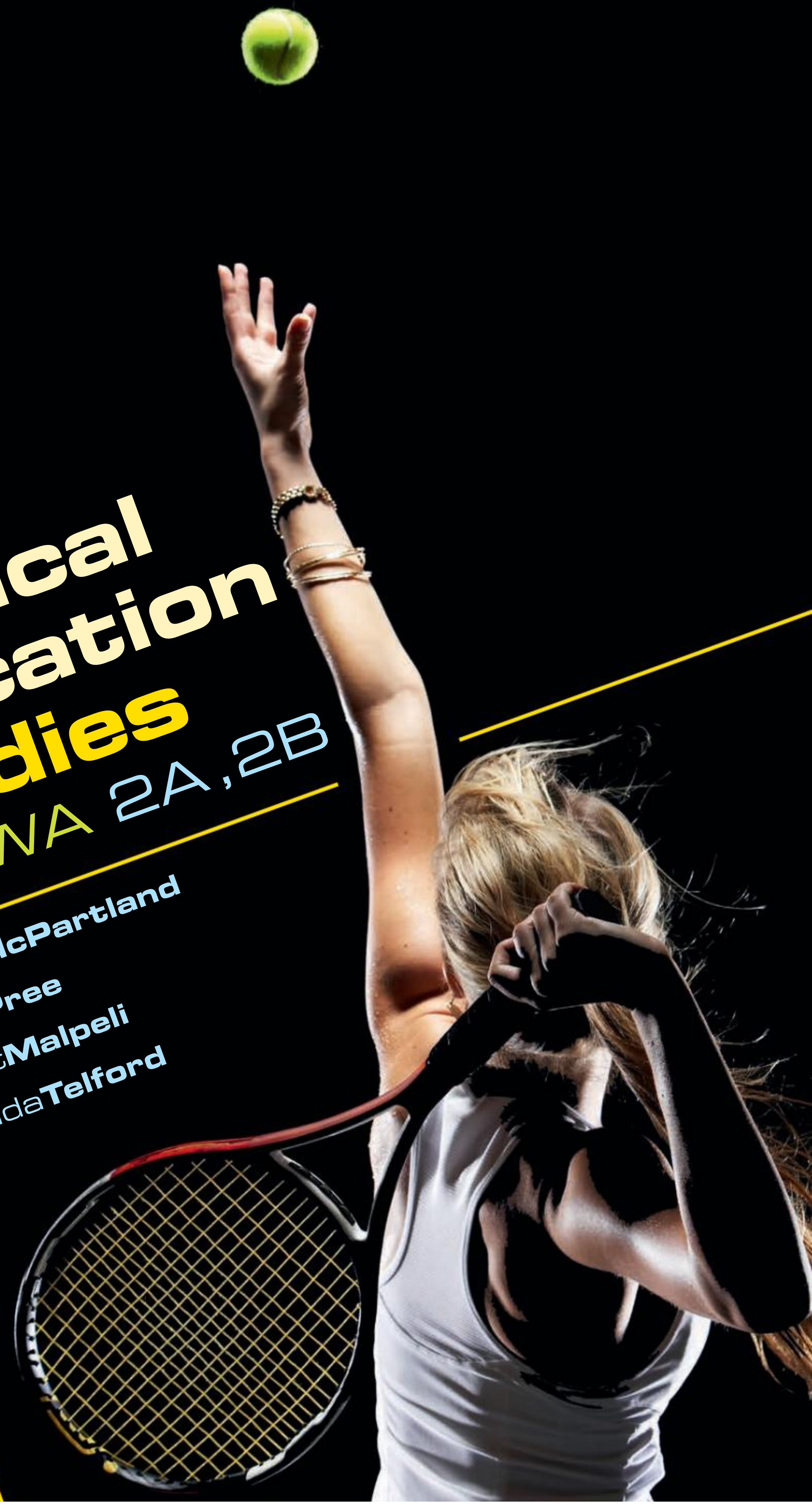
NELSON Physical Education Studies FOR WA 2A, 2B



Darren McPartland
Adrian Pree
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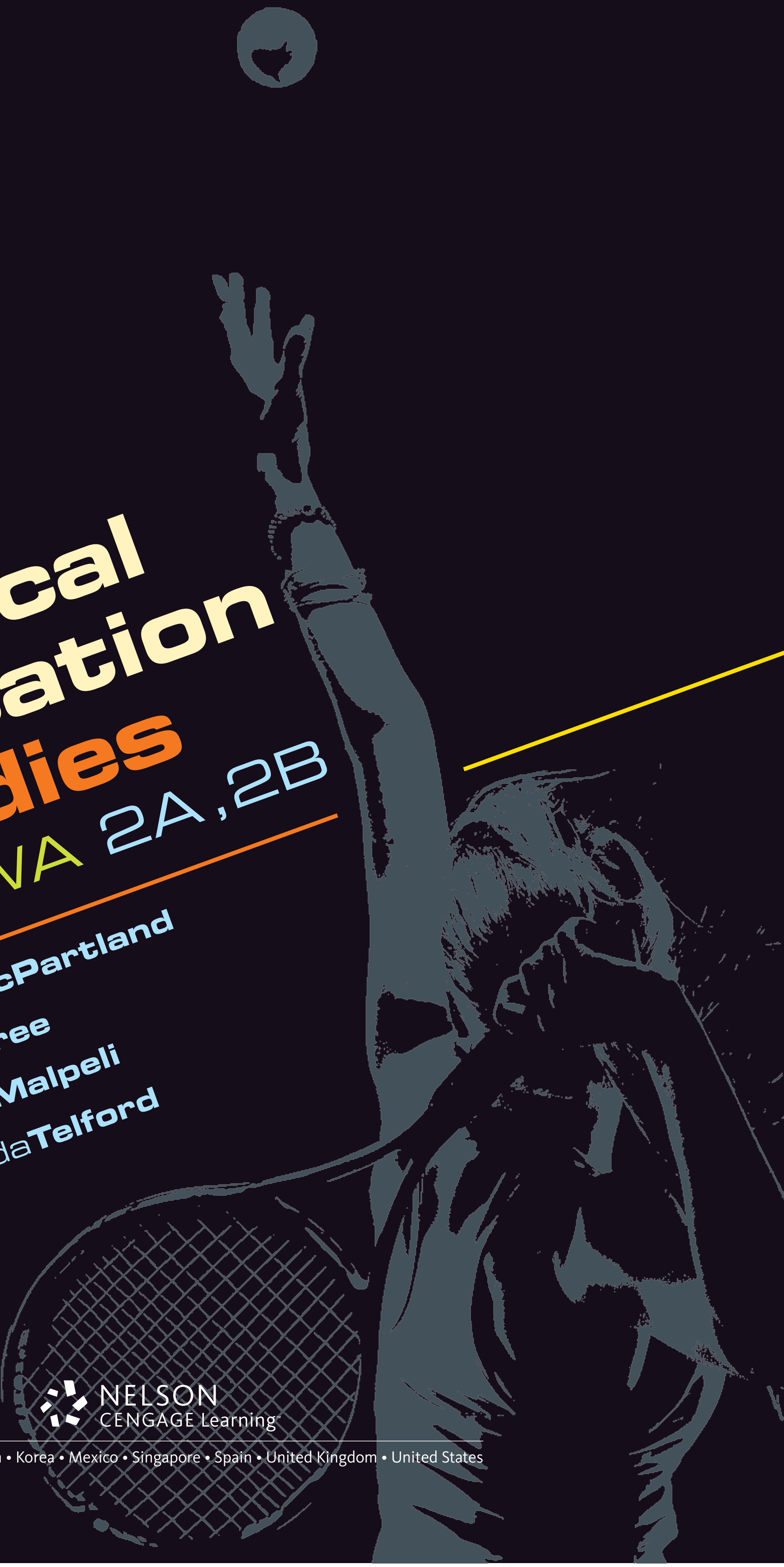

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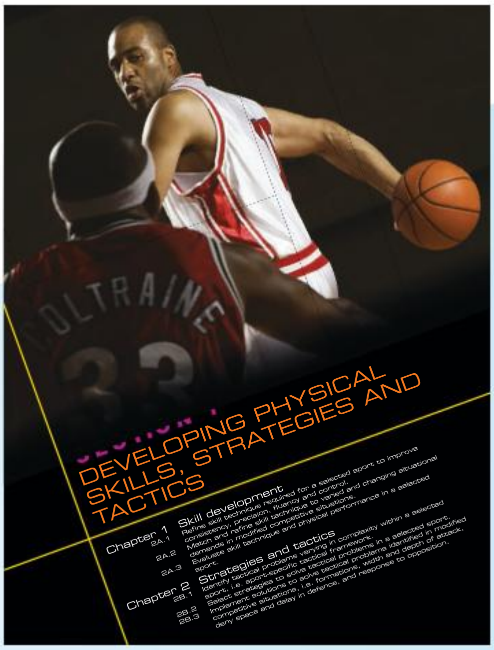
CONTENTS

About this book

Each section of *Physical Education Studies for WA 2A, 2B* lists the chapters and outcomes.



In each chapter

- Clear, easy-to-read text, with plentiful illustrations, tables and graphs to explain concepts.
- In Chapter 2, strategic principles used in all 14 sports are discussed: the tactics, with their advantages and disadvantages, and real-life examples.
- **Keep it real** case studies, articles and interviews throughout the text relate theory to real people and situations.

KEEP IT REAL!

- **Margin definitions** help students with new terms on the spot. These and other important terms are collected in a **Glossary** at the end of the book.

contractibility
muscle cells can react to a stimulus by shortening, or decreasing their overall length

- **Checkpoints** activities help students to summarise and review the section they have just completed.

Checkpoints

- **Coursework** activities and investigations throughout the chapters are perfect homework or assessment tasks. It is not expected that all students will do all the **Coursework** activities.

Coursework

- **Test your knowledge** sections at the end of chapters are exam-style, with multiple-choice, short-answer and essay-style questions. Answers are on the book's website: **www.nelsonnet.com.au.**

TEST YOUR KNOWLEDGE

- **Catchy facts** and quotations are sprinkled though the book to make reading this book a lively experience.
- There are also margin icons to alert students to weblinks and to material on the NelsonNet website.

Catchy fact
70% of lung expansion is the result of rib cage movement and 30% is a result of the movement of the diaphragm.

Muscle quiz

Worksheet 4.1

On the NelsonNet website

The NelsonNet website has:

- skills assessment checklists for all 14 Curriculum Council-assessed sports
- podcast and written interviews with WA coach Ric Charlesworth and ABC sports commentator Glen Mitchell
- worksheets
- extra material
- weblinks
- link to a sample Dartfish program (30-day free trial) that you can use with the Dartfish activities in Chapters 1 and 2 of the book.

Visit **www.nelsonnet.com.au.**

We hope you have fun using and learning from this book!

Please note: All resources listed throughout the book as available on the student CD can now be found on the NelsonNet website.

About the authors

Darren McPartland has been teaching since 1990, and has been a head of department in Western Australia, the Northern Territory, Victoria and ACT. At present he is Head of Physical and Health Education at Christ Church Grammar School. Darren has been a strong advocate of the new PE Studies Course in Western Australia, where he has had a number of jobs with the Curriculum Council, including moderator and marker. In 2007, Darren organised a very successful PD day at Christ Church for teachers of the new course, where he hosted experts from Melbourne and presented at a number of sessions himself.

Adrian Pree has taught physical education for 19 years, with 18 of those years teaching and developing physical education studies in its various forms. He has also been involved in writing assessments for the Secondary Education Authority (now the Curriculum Council of Western Australia). He has been Head of Physical Education at St Mark's Anglican Community School for 13 years and has also taught in the United Kingdom. Adrian has been heavily involved in developing local resources that directly benefit the students in his care, specifically in outdoor education, risk management, sport and martial arts.

Rb M h peli has been teaching senior physical education for more than 20 years. He has been involved in national professional development and has co-authored and produced numerous texts and resource packages for Years 11 and 12 Physical Education. He is a senior teaching fellow at the University of Ballarat and currently teaches at Balwyn High School in Victoria.

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I would like to thank my wonderful wife Kelly for all her 'extra' help with our children, Deakin and Rosie, while I was working on the book. To Ted Polglaze for his expertise. To Adrian Pree whose focus on what is best for teachers resonates throughout the book.

Darren

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Adrian

I dedicate this book to my wife Anita who breathes life into all that I do and provides me with endless inspiration and hope, as well as my children Miranda, Michael and Brittney for their constant support and understanding.

Rob

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Amanda

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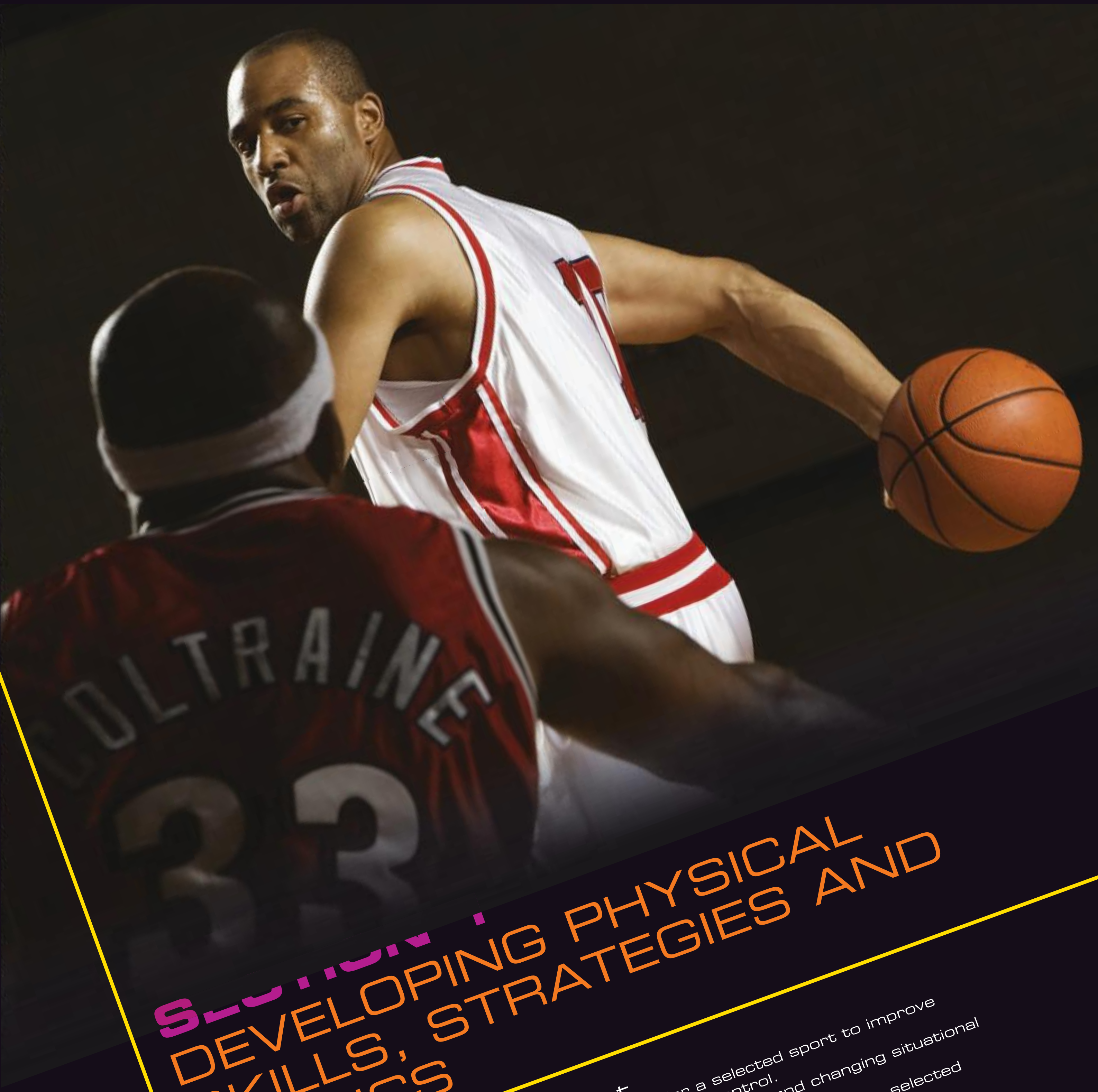

SECTION 1
DEVELOPING PHYSICAL SKILLS, STRATEGIES AND TACTICS

Chapter 1 Skill development

2A.1 Refine skill technique required for a selected sport to improve consistency, precision, fluency and control.

2A.2 Match and refine skill technique to varied and changing situational demands in modified competitive situations.

2A.3 Evaluate skill technique and physical performance in a selected sport.

Chapter 2 Strategies and tactics

2B.1 Identify tactical problems varying in complexity within a selected sport; i.e. sport-specific tactical framework.

2B.2 Select strategies to solve tactical problems in a selected sport.

2B.3 Implement solutions to solve tactical problems identified in modified competitive situations; i.e. formations, width and depth of attack, deny space and delay in defence, and response to opposition.

1 Skill development

My great concern is not whether you have failed, but whether you are content with your failure.

Abraham Lincoln, President of the United States 1861–5

Whoever said, 'It's not whether you win or lose that counts,' probably lost.

Martina Navratilova, Czech–American tennis player

Champions keep playing until they get it right.

Billie Jean King, American tennis player

What counts in sports is not the victory, but the magnificence of the struggle.

Joe Paterno, American football coach

What is skill?

skill
the degree of efficiency in performing a given task in order to achieve a predetermined outcome

Skill is the degree of efficiency in performing a given task in order to achieve a predetermined outcome. The following are common to all skills:

- They are learned.
- They are directed towards a goal of some type.
- Consistency will relate to the performer's ability.
- They require cognitive and motor inputs to occur.

According to Magill (1993), skill is defined as an act or a task that has a goal to achieve and that requires voluntary body or limb movements to be properly performed.

For an athlete to be deemed skilful, they would have a motor program that was well structured and sequenced. In technical terms, they would have good segmental interaction, temporal patterning, timing, anticipation and kinaesthetic awareness.

In simple terms, a sports commentator may refer to an athlete as highly skilled. He may use expressions such as 'He made it look easy', 'She moves so smoothly' or 'It comes naturally.' What the commentator is referring to is the idea that the movement being observed is one that has a highly refined motor pathway, combined with good decision-making, which gives the impression to a person watching that the individual has good skills.

We can all recall an athlete who we would consider to be skilled. Australian cricket captain Ricky Ponting is often described as highly skilled, well balanced and a talented sportsman. He rarely looks ungainly, averages more than 50 runs in test cricket, and is the player that most other countries would target as the key to bowling Australia out cheaply.

This may be in contrast to another sportsman whose key characteristic may be a determined fighting spirit, but with a flawed technique. Former Australian cricket captain Steve Waugh was more renowned for being a dogged fighter and an extreme competitor, without the natural gifts of Ricky Ponting.

This implies that we loosely apply the term 'highly skilled' to an athlete who just seems to 'do it easily.'

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There is no room in your mind for negative thoughts. The busier you keep yourself with the particulars of shot assessment and execution, the less chance your mind has to dwell on the emotional. This is sheer intensity.

Jack Nicklaus, American golfer

You'll miss 100% of the shots you never take.

Wayne Gretzky, Canadian ice hockey player

I have missed more than 9000 shots in my career. I have lost almost 300 games. On 26 occasions I have been entrusted to take the game winning shot … and missed. And I have failed over and over and over again in my life. And that is why … I succeed.

Michael Jordan, American basketballer

You can always become better.

Tiger Woods, American golfer

Checkpoints

1 Define what skill means to you.
2 Choose three different sports and select a performer who you would consider skilful, as opposed to one who you would describe as hard working. Give reasons as to why you would categorise these individuals in such a way.
3 Look through a selection of several days' local newspapers and try to find descriptions by the media that refer to the skill of a certain player.
4 Classify the following famous sports people as either naturally skilful or hard working.
Don Bradman (cricket)
Kelly Slater (surfing)
Ana Ivanovic (tennis)
Lleyton Hewitt (tennis)
Chris Judd (AFL)
5 Who is the most skilful sportsperson in your class? What are the key attributes that you have noticed in their performance?

What makes a skilled performer?

There are various factors that make up what we know as a skilled performer. The abilities that skilled performers display are a type of intelligence just as the abilities to do mathematics, learn a foreign language and play music are.

Skilled performers show the following traits:

- They are not affected by environmental influences and as such perform well under pressure.
- They execute simple skills perfectly on a regular basis.
- They execute complex skills to a high level when others falter.
- They make appropriate decisions on which skills to use.
- They time their movements so that they are often in the right place at the right time (reading the play).

Improving skill

Before we can begin looking at how to improve skill in any given sport, we must consider the specific demands of that sport.

In order to refine skill, it is crucial to ascertain current skill levels, potential skill levels and the time frame in which to effect change.

A good plan today is better than a perfect plan tomorrow.

General George S. Patton, American World War II leader

Consider a javelin thrower preparing for an interschool sport athletics carnival, with only four weeks of school training in which to make improvements. The coach would select a different program for this athlete than for a junior athlete who had just signed up for Little Athletics for a season's training. For the first athlete, the coach's end goal is to maximise the throwing distance in a short time period. The coach will only make minor technique changes without actually deconstructing the whole movement. For the junior athlete, the coach will be looking at their long-term development and, as such, will be willing to pull the technique apart in order to build for the long term. This may result in short-term decline in performance for overall long-term gain.

Therefore, it is necessary to consider several aspects when setting about refining the skill technique of an individual.

To design effective strategies and tactics, the following framework needs to be considered:

- Opposition strengths and weaknesses
- Your own strengths and weaknesses
- Stage of play
- Importance of fixture
- History (what worked in the past)
- Environmental concerns

KEEP IT REAL!

Glenn Mitchell is senior sports commentator at ABC Perth. A longer version of this interview can be found on the student CD.

Interview with Glenn Mitchell

Who do you feel are the best sport coaches of all time?

Look at different ways that coaches operate, and the old adage 'a coach is only as good as his players'.

The best coach I have had opportunity to spend time with and to talk with them and really analyse their strategies was Ric Charlesworth, coach with the dual hockey gold medal women's team in Atlanta [1996] and Sydney [2000], and now the coach of the men's team, the Kookaburras. He is ahead in his way of thinking of any coach I've ever met. He is very lateral. He will take what he finds in one particular sport, and then take it across to another sport. He will watch a sport like football from behind the goals. He looks at the way a team sets up on both offence and defence. He will look at things like water polo, and see what they can do. In a sport like water polo, the way that you transmit the ball from one end of the pool to the other, and he will try and find ways that you can utilise similar strategies in a sport like hockey. So for me Ric Charlesworth is the most 'catholic' coach, going right across the board. He takes into account so many different aspects.

Interview with Glenn Mitchell

The other two coaches I'd say that really fascinated me over time were Phil Jackson, who was the coach of the Michael Jordan-led team [Chicago Bulls] that won six NBA championships, three in a row, followed by three more in a row when Michael Jordan came back into the sport after having a brief flirtation with baseball.

And the other is Sir Alex Ferguson, who is the manager of Manchester United. Both those men faced a very different set of criteria than a lot of other coaches have, over time. They were working specifically with superstars…

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What Phil Jackson was able to do with personalities like Michael Jordan and Dennis Rob Scott, and what Sir Alex Ferguson has done with Manchester United, I think that underlines people management. And that's one of the key things in sport, to be able to manage personalities. What you can say to one player you can't say to another. And what you would say to a group is different from how you would tackle it with one player or another. So there are a lot of different facets which come into play about who's a good coach and who's not.

Do you utilise statistics a lot to predict the outcome?

We certainly do. History is always a good indicator of the future or the present and you can't go any further than using stats in that regard. I think that sometimes stats are used just because they are lying around. A lot of the time you will hear statistics which sound impressive, but if you analyse them they actually mean very little, if not nothing. For example, you can say that St Kilda are coming to Subiaco this week to play against the West Coast Eagles, and they haven't won there since 1995. You might then go and look at the statistics and find they have only played there three or four times since 1995, and the last time they played there might have actually been three years ago. And if you go back three years and look forward at today, there may actually only be eight players who played in that win. So you're looking at the turnover of people. So you should look at stats that are relevant to the time frame in which you are operating. I think from season to season is a good linear to look at.

Inside 50s [in AFL] is also an important statistic nowadays. It gives you an idea of the efficiency of the opposition in regard to their defence, and when a ball goes inside 50 against them, as opposed to your team, what their conversion rate is like.

Do you subscribe to a Ric Charlesworth-type theory, or do you feel that a coach does have a big influence after bounce-down?

I think a coach can have an influence to a point, but probably the most ironic thing is that where a coach doesn't have any real impact is probably when a coach wishes to have the greatest impact, and that is at the end of a clutch game. When you are in time-on at the end of the last quarter of an AFL football match there is virtually nothing a coach can do in the last 90 seconds apart from put out a message if your team's leading by two points to get the run of the stream out on the ground and say 'Hold it up, hold it up'. But there's a lot of mystique given to say 'a great coaching move'. I don't know how many great coaching moves are made during the period of a football match which actually end up influencing the outcome. Most coaches will tell you that 80–90% of the work is done before the team crosses the white line on a Saturday afternoon. The planning is done during the week; they start looking at video tape, reviewing it, each player looks at individual DVDs of the opponent he will be playing on. They come together, they have whiteboard sessions, they do specific drills with cones and the likes and various players playing certain roles in intra-club scratch matches at training. Most of that analysis is done prior to the match and there might be one key move, that perhaps a team can throw you by playing a centre half-forward who is in good form at centre half-back, you might have to come up with some way of being able to move the chess pieces on the board. But I think Ric Charlesworth is probably right; that largely, when you come up against an opponent and the game actually starts, most of the work has been done in the lead-in. If you are relying on the coach to win you the match on game day, then I think it's probably a recipe for disaster, if you haven't done the planning in advance properly.

> You can discover more about a person in an hour of play than in a year of conversation.
>
> **Plato**

Judging a highly skilled performer is not a difficult task. The way they look and move is often a good guide to someone's level of skill.

Are skilled performers solely relying on genetics for their sporting ability?

There is a saying 'Practice makes permanent, but not necessarily perfect.' When focusing on specific aspects of training in order to intervene in a technique, it is important to remember that it is quality and not quantity that is critical. Practising the wrong way leads to the development of bad habits, which may be very difficult to 'un-coach'.

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The following section covers some areas that a coach could focus on for an athlete looking to improve performance. A coach should consider consistency, control, precision and fluency in their planned training methods.

Training methods to improve consistency

Consistency refers to the reliability or uniformity of successive results or events. Performance athletes are most concerned with results that are maximal and repeatable.

Training methods need to focus on the ability of the athlete to generate good technique and basic motor pathways that they are capable of performing under the pressure of a game situation. This concept of specificity of training in order to replicate game situations, and game pressure, has been heavily researched in recent times as elite sports people seek some advantage over their competitors.

Most coaches would agree that the technique that is least likely to fail under pressure is the one that has the fewest technical deficiencies. This excludes the mental skills of the athlete to some extent, although a good coach would also implement training of the psychological skills aimed at replicating match conditions.

> Hypnotist: You will beat Shelbyville.
>
> Team: We will beat Shelbyville.
>
> Hypnotist: You will give 110%.
>
> Team: That's impossible. No one can give more than 100%. By definition, that is the most anyone can give.
>
> *The Simpsons*

Training methods to improve consistency must focus on the following:

- Safe learning environment
- Selection of correct equipment
- Massed practice in preference to distributed practice in sports where a clearly defined closed motor pathway is apparent
- Video feedback to help determine sucessful repetition of technique
- Knowledge of results and performance
- Setting of short- and long-term goals

KEEP IT REAL!

Shooting between heartbeats

Elite shooters often talk about 'shooting between heartbeats'. This is when internal blood pressure and possible tension should theoretically be at their lowest. The ability to be in tune with one's heartbeat means shooters have less muscle tension when squeezing the trigger.

When training to improve consistency, shooters need to repeat any routine that will put their minds and bodies at ease prior to executing this skill.

There are obviously many other factors that the shooter cannot control; for example, wind and their opponents' scores. Therefore, it is crucial to 'control the controllables'.

Figure 1.1 Olympic-level shooters concentrate on firing between heartbeats.

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Training methods to improve precision

Precision refers to the degree of refinement with which a movement is performed. Athletes are concerned with precision in every movement that they attempt. A tennis player aiming to hit a winning shot down the line after the rally has been going across court needs precision in the stroke in order to place the ball into the corner so that it is unreturnable. A netball player shooting at goal needs precision in her every movement in order to score. Every aspect of sport usually requires precision.

Training to improve precision has been the main focus of coaches in trying to improve performance. Skill training has dominated practice sessions, along with physical conditioning as the 'bread and butter' of coaching.

In more recent times, coaches have recognised that skill execution in practice needs to replicate match conditions if the athlete is to maximise the benefit from each session.

Aimlessly hitting a golf ball down the fairway without clearly defined goals, and some form of simulation of match conditions, is not going to improve precision during a tournament. Athletes need to recognise and respond to various stimuli that will only occur when they are put under pressure that is similar to that of competitive situations.

Principles to consider when training to improve precision include the following:

- Video feedback is critical for intervention.
- Quality of movement should be emphasised over quantity.
- Knowledge of results will guide improvement.
- Establish short-term goals to improve focus.
- Selection of correct equipment is critical.

KEEP IT REAL!

Blinking could be fatal

The late Ayrton Senna, world champion Formula One driver, used to practise controlling his blinking. At 270 km/h approaching a bend, a blink can account for 17 metres on the track. So when a car approaches a corner, the driver only has a very small area in which to brake and survive the corner at maximum speed; so they cannot blink. This need to control even instinctive bodily functions underlines the racing-car driver's necessity to have precision of *all* movements. It is not enough to just do this on race day; it must be practised repeatedly in training under race conditions.

Figure 1.2 Formula One drivers need to be able to control *all* body movements, even blinking.

Training methods to improve fluency

Fluency refers to flowing or moving smoothly – that is, gracefully. Commentators often describe elite athletes' movements as smooth, highly skilled or effortless. Even in elite sport, there are athletes who stand out from their peers by possessing some form of innate, untrainable ability. In essence, athletes such as Don Bradman and Dawn Fraser had extremely dedicated work ethics that gave them the edge over their competitors as they were prepared to 'go the extra distance'.

Don Bradman was obviously a talented natural sportsman, although few would know the hours he devoted to developing his timing and hand–eye coordination. As a young player, Don Bradman would hit a golf ball against the wall with a cricket wicket for hours at a time. He played many sports as a youngster, and steadily developed his amazing skills through enthusiasm and hard work.

'Fluency' is a word used to describe Don Bradman. It also describes Michael Jordan, Tiger Woods and Serena Williams. They move well and execute their skills with an effortless ease that inspires coaches to train the next generation.

Training to improve fluency needs to focus on:

- mental relaxation prior to effort
- thorough warm-up to ensure physical readiness
- video feedback, which will identify deficiencies that need addressing
- simulating competition at training to help avoid 'tightness' of movement
- encouraging athletes to describe 'how it felt' when completing movements. This should be tied to successful performances so they can develop a kinaesthetic memory of how a good performance was perceived internally.

Catchy fact

Legendary martial artist Bruce Lee is rumoured to have unbelievable timing and efficiency of movement. It was reported that he could suspend a piece of paper from the ceiling with string, and then punch it so that it would rip. He was so fast that he could tear the paper before the air movement from his punch began moving the paper away. This is the ultimate relationship between agonist and antagonist muscle groups (see Chapters 7 and 8). Try this one yourself.

Training methods to improve control

Control refers to the ability of an athlete to have dominance over the execution and potential outcome of a movement. The concepts of precision, fluency, consistency and control are heavily intertwined. Training methods aimed at improving control have their basis in repeating a movement with consistency. Control can refer to both the movement (performance) and the outcome (results). In most cases, athletes can really only determine what they do with their own technique. The response of their opponent may dictate the ultimate outcome, so many coaches try not to focus on this aspect.

'Control the controllables'

It is healthy to recognise the strengths of the opponent, but ultimately, most athletes can really only control their own actions. If you have a strong forehand down the line in tennis, and your opponent has a strong backhand, it would be unwise to simply eradicate that shot from your game simply because you may lose points using that tactic. It would be wiser to use the shot more selectively and, rather than hitting winners from it, using it to set up the next shot. If you have the ability to control that shot under pressure,

Figure 1.3 *Heading the ball in soccer*

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it is a poor tactical decision to try and use another skill that you do not execute as well in a competition.

Training to improve control should focus on:

- good kinaesthetic awareness of force production in order to not overplay or underplay the movement
- massed and variable skill practice that will help reinforce motor pathways, but hopefully avoid boredom
- selection of correct equipment
- using mental relaxation methods to reduce muscle tension.

Former England soccer goalkeeper Peter Bonetti used to have an unusual pre-game ritual – he would always do 500 mini-headers in a row. Bonetti would simply stand in a corner and consecutively head the ball up in the air 500 times, in order to mentally and physically prepare for the pending competition. Try this yourself to see what level of control Bonetti had. The ball only need travel 30 centimetres or so from your head.

Checkpoints

1 Using the framework described, outline the considerations you would make as coach in attempting to design a winning strategy in a sport of your choice. In a notebook, write about three lines for each of the following.

- **a** Opposition strengths and weaknesses
- **b** Your own strengths and weaknesses
- **c** Stage of play
- **d** Importance of fixture
- **e** History (strategies that worked in the past)
- **f** Environmental concerns

2 How does the mental and physical make-up of your team affect the strategies and tactics that a coach can employ? Use a sporting example.

3 Outline a key principle in training an athlete for the following sports.

- **a** Golf
- **b** Tennis
- **c** Surfing

Refining skill techniques

Sport has many variables. Coaches try and prepare their athletes as best they can for competition, and try and account for as many variables as they can foresee.

Most elite sporting teams have administrative roles within the organisation to allow adequate planning for as many 'unknowns' as possible.

In many cases, the variables will be specific to each sport. Indoor games are not usually affected by wet weather, wind, pollution, extreme heat or extreme cold. However, players in indoor venues do need to take into account length of run-offs at the end of the court, proximity of seating, lighting and ventilation; even confusion with court markings can be an issue.

Coaches need to plan and prepare their athletes to cope with all of these varied situational demands.

Environmental influences

Environmental influences are all outside forces that may cause an individual or team to change their tactics. These influences are not just weather related, but include all influences that impact on performance.

Weather conditions do have a large effect on tactics in sport. However, with indoor venues such as Etihad stadium in Melbourne becoming more common, the weather is having less impact each year. International-level netball and tennis are being played indoors more, and AFL plays a large number of games indoors at Etihad stadium.

Sports that can be played indoors include Australian Rules football, badminton, basketball, netball, squash, swimming, tennis and volleyball. A simple summary of environmental influences appears in Table 1.1.

Table 1.1 Influences on sports

	Weather	Opposition	State of the game	Stadium
Australian Rules football	Rain, wind	Speed, pace, height, strength	Opposition on a run	Surface, away crowd, size of ground
Badminton	NA	Left hander, height, court speed	Facing match point	Away crowd
Basketball	NA	Outside shooting, strength in the key, defensive structure	Time left on shot clock, time left in game	Away crowd
Cricket	Wind, rain interruption, humidity	Batting and bowling strengths and weaknesses, fielding ability	Overs left in the game, trying to win or save	Size of ground, grass length
Golf	Wind, rain	Not an impact except in match play	Whether to attack more or be conservative	Length of holes, type of rough, grass on greens (slow, fast)
Hockey	Wind, rain	Defensive and attacking structure, speed, skill	More attacking when behind, control possession when in front	New or old turf, amount of water
Netball	NA	Defensive and attacking structure, speed, skill	More attacking when behind, control possession when in front	Away crowd
Soccer	Wind, rain	Defensive and attacking structure, speed, skill	More attacking when behind, control possession when in front	Away crowd, pitch width
Softball	Wind, sun position	Pitching and hitting strengths and weakness	Attack if behind, bring on finishing pitcher late	Home-run distance
Squash	NA	Overall tactics and strategy	Facing match point	NA
Swimming	NA	Gamesmanship on blocks	Racing in heats vs finals	NA
Tennis	Wind, sun position, rain interruption	Defensive and attacking structure, speed, skill	Facing match point	Crowd
Touch football	Wind, rain	Defensive and attacking structure, speed, skill	Field position	NA
Volleyball	NA	Defensive and attacking structure, speed, skill	Attack more on serve if failing to have a number of serves in a row	Crowd size

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An example: AFL

External factors

- Playing in the rain and wind
- Playing in extreme heat
- Interstate travel
- Opposition flooding
- Opposition chipping ball around to wind down the clock
- Opposition simply kicking long into forward line

Strategies

A strategy (overall game plan) would be to deny space.

Specific tactics

- Flood (e.g. Hawthorn)
- Corridor play (e.g. Geelong – is this a response to the flood moving the ball quickly?)
- Travel early to allow recovery and acclimatisation
- Ice vests, fans on side line
- Long-sleeved jumpers

Checkpoints

1. Choose a sport and explain how the listed environmental influences (Table 1.1) will affect your tactical decisions.
2. Consider the example of the specific demands that athletes face in AFL. There are also some common suggestions that are used to combat some of these variables.
   Select two other sports and attempt to come up with a specific list of varying environmental factors, and the solution to each. Use the list from the 14 Curriculum Council-assessed sports (Table 1.1).
3. What are the advantages of using the tactics described for AFL above?

Equipment: Specialised responses to improve performance

Technology has also helped athletes maximise their athletic performance, by improving certain parameters within their sport. It may be performance, recovery, increasing or decreasing friction, or aiding physiological processes within the body.

Equipment is used in every sport today, and its design and quality affect the performance of players. Even though an athlete may be trained to peak performance, their competitiveness can be influenced by their equipment and their clothing. The following Keep it real describes some amazing innovations in equipment and clothing design.

The use of innovative equipment can cause conflict. Sport is not meant to be a test of who has the best equipment – it should be an even match between one athlete and another, and from one year to the next.

The fact that the rules of sport have been altered and manipulated over the last century to allow (or disallow) developments in equipment implies that technology certainly does influence sport.

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KEEP IT REAL!

Equipment

Javelin design

Hockey stick design

Tennis racquets

Javelin design

In 1984, the International Association of Athletics Federations (IAAF) Technical Committee changed the rules for javelin construction. Frequent flat landings and the resulting protests about whether attempts were valid or invalid caused this rethink. To ensure the point of the javelin clearly hits the ground, the centre of mass was moved 4 centimetres forward. This causes the javelin's nose to keep down, which also reduces the total distance a javelin can travel. Winning javelin throws at the Olympics are now 15 metres less than they were before the rule changed.

Tennis racquets

In 1999, ultra-lightweight tennis racquets were developed that weighed less than a can of tennis balls! The new racquet frames are made of graphite and titanium, so they are exceptionally stiff and light. Titanium is also used in strings and tennis balls. Twenty years ago, a racquet weighed about 360 grams, but today a titanium racquet weighs only 210 grams. Design changes such as wide and long bodies, and the weight being shifted from the handle to the head of the racquet to move the 'sweet spot' towards the top of the racquet, have all changed the way the game is played. For advanced players, materials are used to reduce torque and shock.

Figure 1.4 *An old wooden racquet and a new oversized graphite racquet*

Golf tee

Perimeter weighting

Golf tee

A new design of golf tee, which balances the ball on top of a small 'claw', is said to promote a more sweeping swing, and thus help to send the ball further.

Perimeter-weighted golf clubs

Perimeter-weighted golf club design is an example of an innovation resulting from a lot of physics-based research. In this club, the middle of an iron is hollowed out, so there is more weight around the edges of the club. This means the head will twist less from an off-centre hit. The less head-twisting, the further the ball will fly, for the same swing speed.

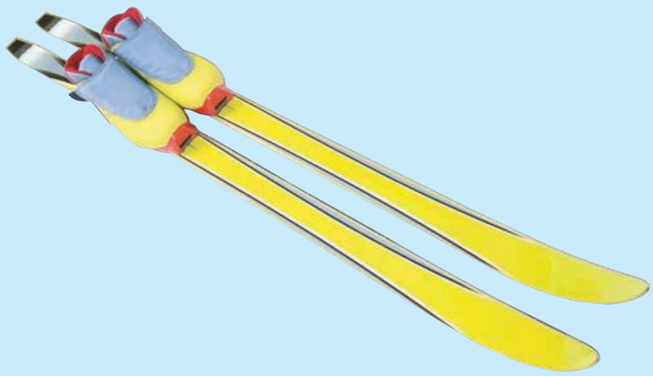

Figure 1.5 *Twin-edged skis*

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Twin-edged skis

A new concept in racing ski design is the twin-edged (parabolic) ski. The double edge on each ski means turning is much faster. These skis are much faster than snowboards. Bearings between the ski and the boot ensure stability for the feet.

Twin-edged skis

Anti-glare strips

In sports where glare is a problem, such as skiing and water sports, a lot of light is reflected from the bridge of the nose and the cheeks. Adhesive-backed No Glare strips are claimed to reduce light entering the peripheral area of the eye by about 2.5%. Adhesive-backed strips that cover both the cheek and the bridge of the nose may reduce light entering the peripheral area of the eye by about 12%. It is claimed they do a much better job than 'blacking' the area with paint, as many American footballers do.

Anti-glare strips

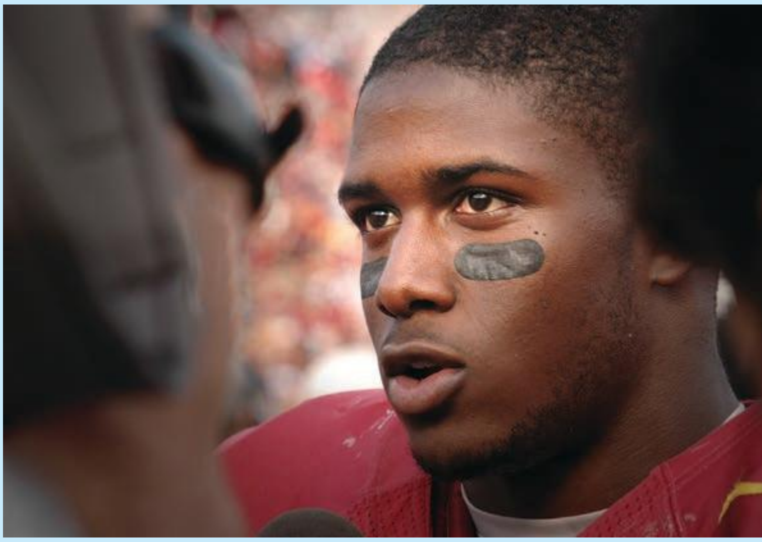

Figure 1.6 American footballers paint black marks across their cheeks to help to protect against the sun's glare.

Gender-engineered shoes

Research has shown that men and women have different styles of running. Running shoes have recently been developed for women with more flexible, deeply grooved soles. In addition, the heel has been made rounder, to lessen the chance of the ankle rolling in. It is believed that women are more susceptible to rolling their ankle because they generally have wider pelvises.

Figure 1.7 Sport shoe

Gender-engineered shoes

Compression suits

Skins™ are body-moulded compression suits, designed to provide support and muscle alignment, and change the way athletes train and play.

Testing of elite athletes has shown that Skins help reduce the build-up of lactic acid immediately after periods of sustained exercise (e.g. for 2 hours 15 minutes up to 37% reduction). They also allow faster return to normal levels (up to 38% 20 minutes later). It is claimed that athletes wearing 'skins' experience less fatigue, minimise soreness and recover faster.

Figure 1.8 Brett Lee in Skins

Compression suits

Football boots

Football boot styles remained relatively constant throughout the 1900s up to the end of the Second World War. In the first part of the 20th century, several football boot producers were established, many of whom are still making football boots today, including Gola (1905), Valsport (1920) and Hummel (1923).

In Germany in 1925, the Dassler Brothers Shoe Factory in Herzogenaurach began producing football

Figure 1.9 The Roteiro 2004 Euro Cup ball, one of many new innovative designs of soccer balls

boots with six or seven replaceable, nailed studs, which could be changed according to the weather conditions during play.

Currently there is debate about the lack of protection given by modern light football boots and what this means for player injury. In the future, boots will probably be lighter and more powerful.

Soccer balls

Developments in soccer ball design are continuing. Many companies have recently produced balls using new high-tech materials and designs. The object is to develop the optimum soccer ball that is flight accurate, waterproof and fast in flight, transfers all of the kicking force to the ball (does not absorb energy), feels soft, and is safe to head. Innovations in soccer balls must adhere to ball specifications given by governing bodies such as FIFA (Fédération Internationale de Football Association).

New balls such as Adidas' Roteiro, Finale and Fevernova, Nike's Geo Merlin, Spalding's Infusion, Puma's Shudah and Mitre's ISO use the latest design innovations and high-tech materials.

Soccer balls

Get a grip!

A paste called Grippo! helps reduce ball mishandling in wet conditions. It has been used by AFL teams for many years, and is also widely used in lawn bowls, to polish the bowls, and to give them a slight 'stickiness'.

Cycling innovations

There are many innovations in cycling. A racing bicycle today is highly engineered, and materials are stronger and lighter than in the past. In addition, there is technology available so that cyclists can monitor heart rate and power output, to optimise their ride. Carry out a quick Internet search to find your favourite cycling innovations.

Rosin powder

Baseball rosin powder

This is an old solution to a constant problem in baseball. When conditions are humid, pitchers use rosin powder, long known to ballet dancers, to enhance their grip on the ball. Designed to increase the stickiness of hands, it is also useful when lifting extreme loads or difficult shapes.

Cricket bats

Cricket bats

The Super Scoop bat is a similar concept to the golf club mentioned above. This cricket bat has a large hollow on the back, and extra wood around the edges. This redistribution of weight from the middle to the edge allowed manufacturers to increase the 'sweet spot' on the bat, making a bat that is more forgiving to slight mis-hits.

Evaluating and refining skill techniques

> The reasonable man adapts himself to the world; the unreasonable one persists in trying to adapt the world to himself. Therefore all progress depends on the unreasonable man.
>
> George Bernard Shaw, Irish playwright

When attempting to take a snapshot of an athlete's skill at any given time, it is necessary to understand the actual desired ideal goals of the movement being examined. There are several methods of gathering a profile of a player's strengths and weaknesses. They are sometimes known as skill checklists, rubrics, checkpoints, performance criteria or analysis schedules but the purpose is generally the same. It is to get a 'snapshot' of a player at any given point of time. This will help guide future training, and may help select appropriate strategies and tactics for upcoming competition.

So how do we effectively teach game play?

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KEEP IT REAL!

‘Designer games’, ‘game sense’ and ‘action method’

Primarily used in the teaching of complex sports, all three terms refer to the concept of teaching people how to play rather than being concerned with the way the ball is struck.

The term ‘designer games’ was coined by Dr Ric Charlesworth, Head Coach of the Australian Olympic Women’s Hockey Team, to describe small games designed to stimulate and teach the players how to react effectively under match conditions.

Similarly, ‘game sense’ is a teaching method/philosophy developed by English coach educator Dr Rod Thorpe and adopted enthusiastically by the Canadians who have modifi d and adapted the approach to come up with the ‘action method’. Both of these focus on teaching people how to ‘play’ rather than the traditional ‘technique’-oriented approach. Th s method promotes the use of similar activities to the ‘designer games’ mentioned above.

Source: Roger Flynn, *Tactics and Strategy in Squash*, 1999

Rubrics

The purposes of rubrics are to:

- define excellence
- help teachers and coaches plan how athletes can achieve excellence
- align the criteria and the intended outcome
- communicate the degree to which an athlete has accomplished the outcome
- make the scoring of performance more accurate and consistent
- document the procedure used in making judgements about athletic performance.

The following rubrics will allow you to develop methods to record a snapshot of current abilities in order to plan future direction.

Physical skills checklists

An example of a simple rubric for use with volleyball is shown below.

There are checklists for each of the 14 Curriculum Council sports on the accompanying CD. These rubrics are teacher and student tools. They allow you to identify your current skill levels and game performance.

Physical skills checklists

Volleyball rubric

Skill description	Teacher mark	Score
Perform a dig using correct technique. 1 Wait in the ready position with feet slightly wider than shoulder width. 2 Move quickly to get behind the ball – maintain low body position. 3 Move into the ball using your legs and contact the ball on the forearms just above the wrist. 4 Direct the ball by tilting arms towards the target. 5 Follow path of ball to its target and prepare for action of the next skill.		/6
Perform a dig using correct technique to pass to another player.		/2
Perform a set using correct technique 1 Ready position – elbows should be bent and facing out 2 Contact with the ball – finger only, not palm of the hand 3 Follow through – drive through the ball using your legs 4 Full arm extension – arms should reach as high as ball is released		/6

Skill description	Teacher mark	Score
Perform a set using correct technique.		/2
Perform a spike using correct technique. **The four-step approach** 1 Eyes on the ball 2 Begin preparation to jump – arms are moving backwards 3 Knees bent 45° 4 Arms swing forward and legs extend **Contact technique** 1 The front arm is extended; the hitting arm is prepared. 2 The hitting arm is drawn right back; back is arched. 3 As the hand contacts the ball the wrist is snapped forward over the ball. 4 The arm follows the direction of the ball after contact.		/6
Perform a spike using correct technique to attack position.		/2
Perform the serve using correct technique. • Stable stance • Loss ball toss • Firm point of contact with open hand (no spin on the ball) • Move quickly to position on court.		/6
Tactics used (include a range of basic tactics/strategies like court movement, umpiring tactics, specific to the sport)		/2
Demonstrate correct position play and rotation.		/2
Move out of position to retrieve ball then quickly return to position.		/2
Anticipate and move out of position to retrieve a difficult return.		/2
Show awareness of other positions so as not to interfere with team-mates' shots.		/2
Total		/40

Courtesy of Lumen Christi College

Quantitative analytic rubric for 2 vs 2 or 3 vs 3 volleyball game play (designed for middle or junior high learners)

Small-sided game play in volleyball **Name** ______________________	**Circle the most appropriate response for each criterion.**			
Criteria/Components/Concepts				
1 Calls for the ball when appropriate (communicates with teammates)	1	2	3	4
2 Uses the correct skill at the correct time	1	2	3	4
3 Demonstrates the correct court position when on offence	1	2	3	4
4 Demonstrates the correct court position when on defence	1	2	3	4
5 Officiates (calls ins and outs) using principles of fair play	1	2	3	4

Levels of performance

4 Criterion demonstrated 75%+ in small-sided game play.
3 Criterion demonstrated MORE than half of the time in small-sided game play.
2 Criterion demonstrated in LESS than half of the time in small-sided game play.
1 Doesn't demonstrate criterion in small-sided game play.

Quantitative analytic volleyball rubric for fair play in game play (designed for middle, junior and senior high learners)

Fair play in small-sided or full game play					
Assessor ______________________	Name of player/team ________				
Assess the game etiquette demonstrated by the player(s). Circle the most appropriate response for each criterion.					
1 Encourages others (says things like 'nice shot', 'good hustle' etc.).	1	2	3	4	5
2 Wins or loses gracefully (doesn't throw temper tantrums; shakes opponents' hands after the game).	1	2	3	4	5
3 Both partners on the team played equally (one person didn't hog the court and try to dominate play).	1	2	3	4	5
4 Correct calls were made; they didn't attempt to cheat.	1	2	3	4	5
5 Courteous to others ('We really enjoyed playing the other team because they were so nice').	1	2	3	4	5
Levels of performance 1 Student never demonstrates criterion. 2 Student demonstrates criterion in less than 50% of the opportunities presented. 3 Student demonstrates criterion in more than 50% of the opportunities presented, but less than 75%. 4 Student demonstrates criterion in more than 75% of the opportunities presented, but less than 100%. 5 Student always demonstrates criterion.					

Coursework

Apply the following rubric to the sport that your class is currently studying. Adapt it to meet the demands of this activity.

Attempt to use your modified rubric to assess a partner. Would it give a correct rank list of your whole class?

Criteria	**Never** **0**	**Sometimes** **1**	**Usually** **2**	**Always** **3**
1 Calls for the implement (ball) when appropriate (communicates with team-mates).				
2 Uses the correct skill at the correct time.				
3 Demonstrates the correct court position when on offence.				
4 Demonstrates the correct court position when on defence.				
5 Officiates (calls ins and outs) using principles of fair play.				

Coursework: Badminton overhead clear

Name ______________________________

Copy the list and check (✓) to indicate which of the critical elements are present.

1 Ready position – quick feet to position ☐

2 Shoulders perpendicular to net ☐

3 Early racquet preparation ☐

4 Contact of racquet and shuttlecock at arm's reach above head ☐

5 Snap of wrist on contact ☐

6 Balanced follow-through ☐

Performance definitions

Present: demonstrated in more than half of the student's attempts in singles game play

Absent: demonstrated in less than half of the student's attempts in singles game play

1 This checklist is rather simplified, and has a type of pass/fail scoring system. Modify the checklist so that it is more like a numerical scoring system that allows you to gain more worthwhile quantitative information.

2 Why is this new scoring system that you have developed still open to varied interpretations?

3 What does this tell you about testing athletes for skill?

Coursework: Strategy and tactics

In this task, your goal is to use video analysis to *identify* and *analyse* strategic and tactical problems in an elite-level team sport. You must identify game strategy, tactics and game phases while also differentiating between *offensive* and *defensive* play.

Use the free 30-day Dartfish program available on the Dartfish website (link directly via your CD) to complete this task.

Dartfish program

Task 1: Strategy and tactic

a Using video analysis tools, create a tagging template specific to the sport of your choice. Include in your observations the following elements:

- Offensive play
- Defensive play
- Strategy
- Tactics

b Choose 10 minutes of footage from the sport of your choice that demonstrates the above elements and use the tagging template you have created to break down the game.

c Critically analyse the effectiveness of each of your identified strategic/tactical components.

d Publish your observations and analysis in a mediabook you make on the Dartfish website.

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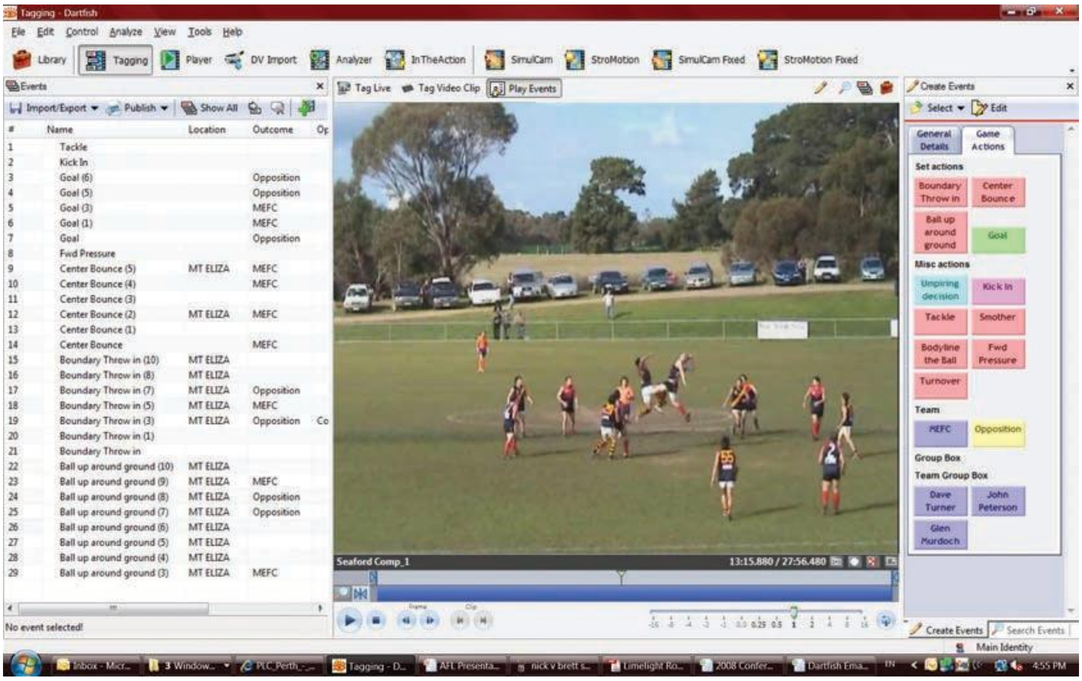

Figure 1.10

Task 2: Player tracking

a Create a tagging template that identifies the elements of individual performance in the game chosen above.

b Using the tagging template, track the performance of a player over a 20-minute period, identifying all elements of the player's involvement.

Figure 1.11 *Dartfish video analysis*

Coursework: Example assignment

Movement principles and trajectory

1 Describe the optimal sequencing of body parts involved in performing a well-coordinated tennis forehand. Integrate movement (biomechanical) principles into the optimal sequencing by creating, analysing and annotating key positions that help justify your answer.

2 Hitting the forehand with topspin can make a ball's trajectory change compared to hitting the ball with backspin or with no spin. Draw a graph showing the expected trajectories of tennis balls hit with topspin, backspin and no spin. (Assume all other factors contributing to ball trajectory are constant.)

3 Explain the different trajectories using movement (biomechanical) principles.

2 Strategies and tactics

> Coaching is about high level skill. If you don't have that, you won't be successful. My task is to develop that skill, and something which fits right alongside that is vigilance. There is a saying that the price of life is eternal vigilance. Paying attention to the details, and then being able to apply it is critical.
>
> Ric Charlesworth, coach Australian men's hockey

Introduction to strategies and tactics

Strategies and tactics in sport are used by athletes and coaches as an extension of the skills that they have already acquired, in order to be more successful in achieving a desired goal.

In some cases, a coach may not even have winning as the true goal for the team for a given time period. For example, where a club wishes to rebuild its squad after some major injuries have occurred, the coach may be focusing on bringing in new players and familiarising them with the overall team plan. The coach might be prepared to accept loss because they know that the team is incapable of winning consistently until they actually understand the overall strategies required to move forward and improve.

> My thoughts before a big race are usually pretty simple. I tell myself: Get out of the blocks, run your race, stay relaxed. If you run your race, you'll win … channel your energy. Focus.
>
> Carl Lewis, multiple Olympic gold medallist

Strategy

strategy
overall plan for achieving success

A strategy considers a long-term view of the team and overall plan. The strategies a team develops should look at the 'big picture'. Strategies are normally prepared before the commencement of competition, but coaches adjust them as the circumstances of the competition change.

Some coaches use the notion of a 'game plan' to describe their strategy. A game plan is more than just a strategy and it includes tactics, goals and team rules.

Once a strategy has been decided on, the coach and team will need to develop a range of tactics to help them to implement the strategy.

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Tactics

Tactics are the small parts a team or player plays to help move towards success – achieving the desired goal. Tactics vary with circumstances and will often change over time and in response to different environments. A tactic can be implemented as one or more tasks. For example, in international soccer, the Italians will set up a more defensive formation, take few risks and often only play one striker. They attempt to score goals on the counterattack.

tactics
the specific tools used to achieve a strategy

Catchy fact
Poland's Stella Walsh (Stanislawa Walasiewicz) won the women's 100-metre race at the 1932 Olympics in Los Angeles, becoming the first woman to break the 12-second barrier. When she was killed in 1980 as an innocent victim in a robbery attempt, an autopsy showed that she had male genitalia and both male and female chromosomes.

Checkpoints

1 Think of an elite sport you are familiar with and describe two teams that have opposite strategies.
2 What do you understand as the difference between strategies and tactics?
3 Summarise the similarities in strategies and tactics between:
   a soccer and Australian Rules football
   b netball and cricket
   c table tennis and tennis.

Sport-specific tactical frameworks

Classifying sports

In order to group strategies and tactics into similar groups, it is necessary to classify them. The criteria used for classification may differ significantly depending on the opinions of the observer.

One simple classification system would be 'ball sports versus non-ball sports'. This system defines only two categories, and very little commonalities between activities. Soccer and squash are two ball sports identified in this simple system that have very little in common, so few tactics are transferable.

Table 2.1 demonstrates a way of classifying sports but several sports are open to interpretation. Water polo is an evasion/invasion sport, but predominantly aquatic in nature. The skill and the ability to be a competent swimmer are heavily intertwined, and make its classification open to interpretation. Similarly, surfing is a water sport but the judging is heavily subjective and open to interpretation; hence its classification as an aesthetic sport.

Before we can begin looking at strategies and tactics, it is necessary to classify all sports into suitable categories.

Obviously the tactics of Australian Rules football and surfing are almost totally unrelated, as are tennis and rugby league, cricket and boxing, and gymnastics and middle distance running.

The classification will be based on the sport or activity's key features. The classification allows us to group similar activities, so that inferences can be made on the transfer of strategies and tactics.

This may be helpful for performers hoping to draw on tactical knowledge from a sport that they know, and utilise it in a new sport in order to fast-track their progress.

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Table 2.1 Classifying sports

General category	Sample tactical problems	Curriculum Council sport	Examples
Evasion/invasion games	Set plays from restart	Yes	Australian Rules football
	Set plays in offence; open plays in offence	Yes	Soccer
	Set plays in defence; open plays in defence	Yes	Hockey
	Pressuring ball carrier to force turnover	Yes	Netball
	Player-on-player pressure	Yes	Touch football
	Playing formations	Yes	Basketball
		No	Rugby league
		No	Rugby union
Net/wall games	Starting	Yes	Tennis
	Attacking from set and open plays	Yes	Badminton
	Defending from set and open plays	Yes	Squash
	Playing formations	Yes	Volleyball
Aesthetic sports	Starting	No	Gymnastics
	Gaining position	No	Surfing
	Finishing	No	Diving
	Transitions		
Aquatics	Starting	Yes	Swimming
	Finishing	No	Water polo
	Transitions	No	Rowing
	Attacking	No	Kayaking
	Defending	No	Sailing
Combat sports	Attacking	No	Boxing
	Defending	No	Wrestling
	Scoring points versus gaining advantage	No	Martial arts
	Negating opponent		
Cycling	Starting	No	Road racing
	Mid race	No	Track cycling
	Finishing	No	Mountain biking
		No	Triathlon
Target game	Beginning	Yes	Golf
	Sequences	No	Archery
	Recovery	No	Ten-pin bowling
	Conservative	No	Lawn bowls
	Finishing		
Striking/fielding	Fielding – attacking	Yes	Cricket
	Fielding – defending	Yes	Softball

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General category	Sample tactical problem	Curriculum Council sport	Examples
	Batting – attacking		
	Batting – defending		
	Last ball of innings special circumstances		
Athletics	Starting	No	Track events
	Mid-race	No	Field events
	Finishing		
	Field event planning		
Extreme sports	Speed	No	Rock climbing
	Technical sections	No	Skateboarding

General strategic principles

Table 2.1 summarises tactical problems that are common to each category. The list is by no means exhaustive, but does provide a framework to commence planning of tactics to use in order to achieve a strategy.

It is necessary to look at some of these aspects in more detail to grasp the key concepts. Each sport has unique aspects that will help guide a skilled tactician in devising a suitable game plan for varying situations.

The classifications of the activity types covered in Chapter 1 will help provide a framework that all of the various sports could be built upon.

The purpose of the following sections is to provide some samples of sport-specific strategies and tactics that can be or have been employed by various athletes in a variety of sports.

The sports chosen are the 14 recommended sports that are externally examined by the Curriculum Council as well as baseball and cycling. This will allow you to look at some of these sports in a little more detail with reference to some of the unique strategies that occur at elite levels.

Simple game plans are easy for your team to understand but may also be easy for the opposition to read. Changing tactics may only suit a team with great decision-making skills among the players.

Invasion games – a closer look

Invasion games, where teams have to get into their opponent's area in order to score, include Australian Rules football, basketball, hockey, netball, rugby, lacrosse and soccer.

Invasion games usually involve large numbers of players, which makes strategic planning very complicated, as there are so many variables. This high number of variables means that coaches need a simple framework to help them define what they are trying to accomplish. Here are some of the key features of attacking and defending principles that are transferable across invasion/evasion games.

Attack principles

Creating space

This is done by holding width or staying well forward or back. The main objective is to spread the defence to create space for your team to attack through. Having attackers spread across the field provides the opportunity to switch the angle of attack.

Holding players behind the ball

Having players behind the ball while in attack serves a number of purposes:

- They are in an outlet position should the ball player or carrier get into trouble.
- They can quickly move to an appropriate defensive position if the ball turns over (is lost to the opposition).
- They are able to move into space created by other players.

Taking a defender out of play

Once a player is not available to defend, then the attacking team effectively has an extra player. It can be achieved in a number of ways, including:

- screening a defender
- passing the ball past a defender
- performing a 'scissor' move by running forward and then doubling back to get behind the defender.

Motion offence

Motion offence is when the attacking team moves the defenders around as result of a set play or an intuitive move. Motion offence attempts to:

- make the defenders move to create space behind them. If the defender does not follow the attacker who is moving, then they are in an open position to receive the ball
- get the defender 'lost' from their direct opponent
- force the defenders as individuals and as a unit to adapt to different positions and situations.

Defence principles

Depth

Depth in defence involves having as many players as possible protect the goal by positioning themselves between the goal and the ball. The main aim is to limit the space the opposition can move into. It is important that the defending team be appropriately spread out. Defenders in a straight line are easily passed. A staggered defensive line can be beneficial, except in soccer where the offside rule is a major defensive tactic.

Zone defence

Spreading players across the major attacking areas helps to limit space and is effective against a motion offence. In this situation, players tend to look after an area on the field rather than being responsible for a direct opponent. A zone could include all players or just some. In some sports, a zone defence that includes all players is called a 'flood'.

Delay

By slowing the attacking team, a defender provides time for their team to set up an appropriate defence structure. Delaying can be achieved by:

- sending the ball out over the sideline or as far as possible down the field
- getting one or more defenders directly in front of the ball to force the attackers to go wide.

Player-on-player defence

Every player has a responsibility to cover one other player. Everyone knows their specific defensive role.

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1 Australian Rules football

Tactic	Advantage	Disadvantage	Real-life example
Defensive – tagging the opposition's best player	Limits the effectiveness of their best player	Sacrifices a player. Opposition player may go to a position to exploit tagger	Cameron Ling (Geelong)
Defensive – zone or flood	Limits the space for the opposition to move into Players are where they will deliver the ball. More numbers to help out Limits the ability of one player to dominate, especially in a one-on-one	No players forward when you get the ball Forward players need to do more running than previously Takes time to set up the zone	Hawthorn
Offensive – handball through the middle of the ground, run and carry the ball	Holds possession Quick movement Brings the defenders in and creates space behind the defenders A number of angles of attack from the middle of the ground	More possessions gives more opportunity to make mistakes Vulnerable out wide as more players are in the central corridor Requires good decision-making skills	Geelong
Offensive – quick movement – play on as much as possible	Opposition doesn't get time to set up zone Ball comes in very quickly to the forward line – difficult for defenders to help each other out	Often kicking to a contest – not precise Need a dominant forward to be successful Often gives the opposition a 50/50 chance	Essendon 2009

2 Badminton

Tactic	Advantage	Disadvantage	Real life example
Singles – offence When opposition plays net shot from net: fast push shot across court to opposite corner	Immediately puts an opponent under pressure as they scramble to the back of the court	Push shot needs to be high enough to beat opposition. If it is cut off, it will leave the attacking player vulnerable	Tiger Chen (WA) Leisha Cooper (WA)
Singles – defence Defensive player should concentrate on playing shuttle to all four corners of the court with emphasis on keeping it in play	Effective in slowing a very attacking player, causing them to fatigue more quickly	Game is not played on your terms. You may be under more pressure as you are constantly trying to retrieve attacking shots	Edwin Chew (WA)
Singles – general Play shots generally straight, looking to play the off cross-court shot occasionally	Cuts off the angles that can be used against you Results in a faster shot with less reaction time	Opponent may look for the straight shot if played too often	Eva Ratenasena (NSW) Ben Walklate (Vic.)
Doubles – offence Half-court smash in front and back position: back player hits smash and moves forward while front player moves to the side and replaces back person	Maintain a strong attack in a position that is always attacking Pre-empt any defensive shot	Leaves back right corner of the court vulnerable if attack is not strong	Travis Denney and Stuart Brehaut (Australia)
Doubles – defence Being smashed at in side-by-side position. Use half-court soft chip up the line played in between attacking players. This is softer than a drive.	Chip will cause confusion if played between players Draws them out of a structured position	Chip needs to be played low and accurately up the line to be effective	Ross Smith and Glen Warfe (Vic.)

Courtesy of Ben Finch.

3 Basketball

Tactic	Advantage	Disadvantage	Real life example
Defensive – zone defence	Has all players in the key-way for rebounding. Limits space for players to attack. Good position to start a fast break from.	Difficult to stop the outside shot	So effective that it is illegal in the NBA!
Defensive – player-on-player defence	Every player is responsible for one opposition player. Pressure is always on. Makes the outside shot a pressure one	Vulnerable to screens One dominant player can score by just beating one player.	The only defence permitted in the NBA as it opens up the key way.
Offensive – fast break	Easy scoring lay-up	Needs players who move quickly and who are quick to read the play	Los Angeles Lakers with Kobe Bryant
Offensive – screen and role	Two options to score Frees up a good shooter Player who roles is close to the basket	If not executed correctly, it is easy to commit a foul. Defence can switch, if communicating well, which can lead to a turn-over.	Most teams at all levels use this tactic.

4 Cricket

Tactic	Advantage	Disadvantage	Real life example
Defensive – fielding All players on the boundary	When boundaries are needed in closing overs, forces batsman to take risks	Skilled batsmen may drop the ball short and get two runs per delivery with no risk.	Australia in the famous underarm bowling incident.
Defensive – batting Only playing at balls that are on the stumps	When survival is important, batsman can force the bowlers to bowl to them. Valuable late in the day when batting until stumps is the goal	Not offering a shot may increase chances of an lbw. Bowlers can set very aggressive fields, increasing chance of a wicket	Last session of each day during most Test matches
Defensive – bowling Leg spin bowler aiming outside leg stump to right-handed batsman	Forces batsman to hit across the spin Makes setting a field easy	Negates lbw decision as ball pitches outside line of leg stump Batsman can 'kick' away full pitch deliveries.	Shane Warne in 2006 Ashes series bowling to Kevin Pieterson
Offensive – bowling Bowling short-pitched at tail-end batsman	Can set bat pad and leg gully to catch panicked defensive shots	Can expect retaliatory short bowling in return Quick boundaries can be scored if batsman attempts pull or hook shots	Australian Peter Siddle bowling at Dale Steyne of South Africa in 2009 first test
Offensive – batting Dancing down the wicket to get to the pitch of ball and hitting straight	Breaks up the length of the bowler Allows momentum to be gathered in the shot	High risk of stumping Failure to get to pitch of ball will result in lofted shot	Kim Hughes, former Australian captain in any game
Offensive – fielding Placing fielders at silly mid-on and silly mid-off	Creates chances when any driven or defensive block is in the air forward of the wicket Puts mental pressure on batsman	Relies heavily on very sharp reflexes Risks injury to fielders Batsman may simply hit over these fielders	Justin Langer was famous for his sharp fielding in close.

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5 Golf

Tactic	Advantage	Disadvantage	Real life example
Defensive – laying up with an iron rather than hitting long over a hazard	Allows a full club to be used in approaching green Safer shot if used from a poor lie	Conservative play all the time tends to mean solid scores without actually winning tournaments	Nick Faldo versus Greg Norman on last day of US Masters
Defensive – playing ball low when hitting into a strong head wind	Keeps the ball flight shorter, thus allowing less impact of the wind on its flight path	Placing the ball further back in the stance can cause slight mis-hit, or choosing longer iron means more difficult contact	Tiger Woods using Fairway hybrid clubs to keep ball low with topspin
Offensive – attacking the pin over treacherous bunkers with long iron	Can land ball on green for eagle possibility	Ball can run through the green as it is coming in low Poor judgement on length may 'plug' the ball in the bunker	Tiger Woods on any par 5
Offensive – drawing the ball around a dog leg approaching a long par 5	Negates the need for hitting a medium iron on the second shot so the ball doesn't run through the fairway on the bend	If the ball is drawn too much or not enough, it may be well off the fairway and unplayable. Drawing the ball is difficult to control	Kevin Merry, England, shaping the ball well around the dog leg

6 Hockey

Tactic	Advantage	Disadvantage	Real life example
Control possession of the ball in the mid-field and/or defensive half	Limits the opposition's score. If you have the ball, they cannot score! Able to build an attack	Mistakes in the back half can be costly Low scoring – may make it difficult to gain lead from a couple of goals down	Germany (Athens Olympic 2004 gold medallists)
Over-head throw pass	Ball quickly into attacking 25 Breaks open the defence	Hard to control and pinpoint a player	Australia scoring a goal in 2009 Champions Trophy Final
Continuous rotation of players off the interchange. Having 50+ rotations in 70 minutes	Players are able to perform at a higher intensity when on the pitch. Run the opposition off their feet	Best players not always on the pitch – need a large squad of talented players Players lose the rhythm of the game	Australian women's and men's teams under coach Ric Charlesworth
Work to get as many short corners as possible	Many controlled scoring opportunities Successful if the team has a player who can flick the ball at a very high speed	Game loses some flow May miss other opportunities to score when always looking to get a short corner Attack can become one dimensional	Netherlands

7 Netball

Tactic	Advantage	Disadvantage	Real life example
Defensive – zone defence	Slows the opposition movement Opens up the chance of interception/turnover Less chance of defensive penalty Players free to attack if there is a turnover	No pressure on individual players Good moving and passing teams can work their way through such defensive systems	New Zealand

Tactic	Advantage	Disadvantage	Real life example
Defensive – one-on-one – on the body (standing in front)	Defenders channel the forward to certain parts of the court (attempting to direct the attack) Moves forwards to their weaker side Being in front in a good position to get an intercept	Open up space behind Requires exceptional foot-work skills Can lose sight of the attacker	Australia
Offensive – speed attack	Less time for defenders to set up a zone. Can score very quickly	Requires high level of skill Can result in a number of turnovers	Australia
Offensive – hold the defender out and lead back to the goal. Pass over the defender	Have a shot from an easy position under the goal	Need a tall goal shooter Need to be careful not to contact goal keeper Pass needs to be perfect	Irene Van Dyke (NZ)

8 Baseball

Tactic	Advantage	Disadvantage	Real life example
Defensive – pitchout (walk) the opposition's number 1 batter	Damage is limited to one base	A runner is in a scoring position	Used regularly in top flight baseball
Defensive – pitchout (walk) the batter when a runner is on second and no-one on first	Causes a 'forced play' to all bases so makes an out and double play easier	Another runner is in a scoring position	
Defensive – allow a runner to score and take the out at first base.	Closer to closing down the innings	They have scored	
Offensive – aggressively lead off from first base.	Less distance to cover when trying to get to second so more likely to make it Easier to steal second Takes the pitcher's mind off the batter Forces the first baseman to come out of the field and stand on the base	Higher chance of being picked off at first Need to be very quick and good at diving	

9 Softball

Tactics here are very similar to baseball with the exception of leading off. (However, in softball, a base runner must not leave the base before the ball is pitched; i.e. there is no leading off.)

10 Soccer

Tactic	Advantage	Disadvantage	Real life example
Defensive – playing a sweeper behind the defence	Eliminates advantage of playing a through ball to a fast forward player	It plays everyone onside if sweeper drops back too early	England 1990 World Cup played a sweeper system
Defensive – always staying goal side of attacker while in defence	Places a simple barrier between the attacker and the defensive goal area	Always gives the forward the opportunity to receive and shield the ball	All moderate to elite level defenders
Offensive – long ball to forwards	Catch defence off guard and provides a direct, low-risk approach	Very predictable and allows the defence to drop a sweeper back to cover the through ball	Perth Glory using tall striker such as Jamie Harnwell Portsmouth using Peter Crouch, who is 201 cm tall

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Tactic	Advantage	Disadvantage	Real life example
Offensive – using the long throw into penalty area	No offside from a throw in, and difficult to defend as ball is approaching from unusual angle	Can create counter-attack if throw is unsuccessful as many players are put in attacking positions for the set play	Stoke City 2008/09 using Rory De Lap throwing flat and long into the penalty box at key forwards
General – always passing the ball along the ground	Eliminates the need to judge the bouncing ball and control it. The ball can be trapped by simply cushioning it on the instep	Poor pitch surface may make the team vulnerable to a mis-trapped ball, especially in defence	Arsenal, Manchester United, Liverpool, Chelsea in 2008/09 season

11 Squash

Tactic	Advantage	Disadvantage	Real life example
Make your opponent spend most of the game in the back corners of the court, while you occupy a point as near to the centre of the court as possible.	If you are in front of centre and watching the ball from your opponent's racket, then there is no possible winning shot that your opponent can play.	An aggressive opponent will be trying to achieve exactly the same position, causing many lets.	Ramy Ashour (Egypt) is a very attacking player.
Aim your shots to keep the ball as close to the walls as possible. Best shot is straight down the wall.	The world's best do this easily, with barely any air between the ball and the wall as it travels to the back of the court.	If opponent has similar tactic, rallies will be very long, so endurance is a key factor.	Ramy Ashour (Egypt) has great control along the walls, setting up attacking shots.
Use the 'lob' (high soft shot) as an attacking shot. For example, if you are fetching a ball from the front corner and your opponent is moving in behind you, play a high lob (diagonal is safer) into the rear corners. This is a very effective shot and extremely hard for your opponent to get back to if played well enough.	Changes the pace of the next shot Different flight trajectory can cause coincidence timing issues	If poorly played, vulnerable to a winning smash by opponent	Karim Darwish – current 2009 World Number One
If you are in the middle of the court and your opponent is behind you, then aim a drop so that it finishes in the front corner near the wall opposite to your opponent's position.	Don't aim your shot so low that it is likely to hit the tin. Always allow yourself a safety margin of about a soft-drink can height above this line. Your aim is not to lose by playing risky, but to win by forcing your opponent to stretch to their limit so they cannot play the ball very well and thus make mistakes.	If played too often, your opponent will read this and make winners from this position.	Natalie Grinham (Australia), being only 155 cm tall, needs to place shots to make her opponents move.
Take every opportunity to play the ball in the air (volleying) and play these into the opposite corners to your opponent's position.	By volleying, you are not letting the ball go past you and not allowing your opponent to get a lucky shot into a rear wall nick or corner. Also gives your opponent less time to regain their footing after their own shot and increases their chances of missing their next shot	If opponent also volleys a lot, very fast points mean an explosive high-energy game. Susceptible to high lob	James Willstrop (England), due to his great height

12 Swimming

Tactic	Advantage	Disadvantage	Real life example
Set the pace in a 200-metre event.	You are in front and others need to catch you. You are controlling the pace.	May go out too hard and have little in reserve for the finish	2000 Olympics 200-metre freestyle – Ian Thorpe set the pace early but used too much energy to get past Pieter van den Hoogenban and came second.
Maximise turns	Speed off the wall Can move in front of other swimmers	May fatigue the ATP–PC system for the finish (see Chapter 12) Requires enormous muscle power and strength	2000 Olympics 200-metre fly – Misty Hyman beating Suzie O'Neill. Hyman put a body length on O'Neill at each turn and O'Neill after expending energy to catch her in each 50 metres failed to do so in the last 50 metres.
Surf swimming – swim on the feet of others	By swimming right behind other swimmers, you will be dragged along and require less energy for the same distance. Therefore, you should have more in reserve at the end of the race.	You are swimming at the pace of others. They may have a stronger finish than you, so you are not giving yourself a chance to win. You are swimming in the pack and risk getting kicked etc.	Most surf lifesaving carnivals
Triathlon swimming – swim on the edge away from the pack	Removes the chance of being kicked Easy to see the course Can swim your own pace	Requires more energy than being in the pack Need to look up to ensure you are on course	Various athletes during triathlons

13 Tennis

Tactic	Advantage	Disadvantage	Real life example
Singles – offence Attacking drop shot played to the front of the court, in response to opponent standing behind the baseline	'Surprise attack' to a player that has been forced back behind the baseline	Drop shot needs to be played deceptively to be effective. If reached early enough, the attacking player will then be vulnerable to angles	Martina Hingis (Switzerland) Roger Federer (Switzerland) James Blake (USA)
Singles – defence High defensive lob played to back of court	Used to buy some time, and force an attacking player back, thus making their next shot harder because it is from deeper in the court	Lob needs to be high enough and deep enough so that it cannot be cut off	Serena Williams (USA) Rafael Nadal (Spain)
General strategy – keep playing the ball straight down the line	Opponent cannot use an angle against you. Opponent's reaction time will be minimised.	Opponent will begin to read your game if played too often	Venus Williams (USA) Anna Ivanovich (Serbia) Casey Delaqua (Australia)
Doubles – offence Serving player serves and then moves immediately in for volley	Puts pressure on opponents as they must come up with a good shot to beat you. It will shorten a point if you are fatigued.	If a good shot is performed by the opponent, the attacking player will be left vulnerable.	Mark Woodford and Todd Woodbridge (Australia) Bob and Mike Bryan (USA)
Doubles – defence Players side by side slightly behind the baseline. Should return ball down the line	Used as a good way to make attacking opposition hit lots of returns with reduced reaction time	Game is not played on your terms. Points are out of control of defending team	Daniel Nestor (Serbia–Canada) and Nenad Zimonjić (Serbia)

Courtesy of Ben Finch.

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14 Touch football

Tactic	Advantage	Disadvantage	Real life example
Defensive – use the first three rucks to make field position. (pass and run and try and get them off side)	Less chance of error/turnover Quickly moves the team into better field position May get the opposition off side and therefore open up gaps or result in a penalty	Can become predictable Vulnerable to a 'shooter' tactic May miss other opportunities to break the line	Prevalent at all levels of the game
Defensive – shooter (one defender charges out of the line to touch the ball carrier)	Limits field position of attacking team Allows time for all defenders to get on side	Can create holes in the defensive line and therefore vulnerable to an attack on angles	Prevalent in higher levels of the game
Offensive – running dummy half	Draws defenders as they are keen to try and force a turnover by touching the dummy half. This creates gaps around the dummy half	Dummy half touched is a turnover Dummy half needs great agility and timing	Teams with a quality dummy half, such as Chris Miles from West Subiaco
Offensive – spread the ball wide	Helps to spread the defenders, which may leave gaps in the middle A chance to work outside your opponent An inside pass may wrong-foot the defenders May help to make dummy passes more successful at later stages in the game	Numerous possessions so more chances of a mistake Gives the defenders time to set up their defensive structure Gains little field position Vulnerable to causing an intercept	Prevalent at all levels of the game

15 Volleyball

Tactic	Advantage	Disadvantage	Real life example
Defensive – individual Pull away from blocking if opposition sets deep to back court spiker	Allows help to back court players Effectiveness of block against back court spike is low	May cause confusion of roles in back court Gives momentum to opposition	Beach volleyball
Defensive – team 6 up	Allows cover behind the blockers to a team that uses dinks over the block to expose gaps, rather than power hitting	Leaves more back court to cover for players 1 and 5 if the spiker then decides to spike deep	
Offensive – individual Power spiking diagonally	Longest line to hit the ball hard and still get it in	Most common attack, so is easy to plan against	Leonel Marshall (Cuba)
Offensive – team Second layer spikers	As front court spikers start jump, back court hitters begin offering themselves as hitters to confuse blockers	Timing is difficult Requires excellent setter to read the spikers on offer	Dusty Dvorak (USA), 2004 Olympics

16 Cycling

Cycling has been a part of elite sporting culture for many years. Although there are many different disciplines, here is a snapshot of some thoughts from a local expert.

Cycling tactics

KEEP IT REAL!

Wayne Evans has been competing in the sport of cycling for 17 years. In that time he has been in numerous state teams, been a member of the Australian Olympic squad (tandems), raced internationally, coached athletes into the Australian team and been a member of the various committees associated with Cycling WA.

Currently Wayne is working out of Cyclemania, coaching athletes under the national program, assistant to the head WAIS coach, and a director of Team Plan B WA.

There are many tactics involved in elite level cycling and a successful rider *must* have a successful and strong team to back him or her up. Often tactics will be the deciding factor in whether or not a rider is successful in winning.

Here are a few.

1 Leaving a breakaway to fry

Often sprinters teams like Robbie McEwen's will leave the breakaway dangling just a few minutes in front of the peloton so as to avoid the counterattacking that usually follows a capture of the breakaway.

This way, they can ride under a steady tempo at a fairly high speed and prevent any other riders from surging ahead and messing up the chance for a bunch sprint. Opportunistic riders will often be lurking in the hope that the teams bring back the breakaway, but by leaving the break dangling they discourage any opportunistic riders from having a go.

2 Lead-out men

Top-level sprinters like Robbie McEwen will also have a lead-out man to assist them in getting to the point in which they launch their final sprint for the line. By having someone ride in front, they prevent wasting energy until it is necessary. The speeds in today's professional and top amateur sprints will reach in excess of 60–70 km/h so having a teammate to shelter you and put you into good position is very worthwhile. Top lead-out sprinters who can't quite cut it at the very top will often be paid in excess of 150 000 euros to assist the team's top sprinter, so it is worth doing their job well even if they never win themselves.

3 Counterattacking

Launching a counterattack just after a breakaway has been caught, as mentioned above, can be a very successful tactic if timed right. Often the sprinter teams will be very tired from chasing and riding tempo so to hit them just as the break is caught will mean that the teams may will look for someone else to take the responsibility of chasing. This hesitation can get a rider the required gap to form a winning move.

4 False tempo

If a rider is struggling or can't climb as well as his main competitors, they will often ride on the front of the bunch at a slower pace than another stronger rider might. This bluffing tactic could mean the difference between getting dropped and staying in touch with the front group.

This tactic is also used when a team-mate is away in a breakaway and a member of the same team wants to appear that they are assisting with the chase. If other competitors are not alert, then the teammate can actually slow things down just enough for the break to seek more advantage.

5 Drifting back

If a rider knows that they cannot ride up the next hill as fast as their competitors, then they can actually adopt this tactic to stay in touch over the top of the climb.

The idea is to start the climb at the front of the group and ride their own tempo and slowly drift back through the bunch and hopefully stay in touch over the crest of the climb. In big bunches of 100–200 riders, this can really be advantageous. The line could be strung out over 500 metres or more.

6 Attack on the descent

Most riders will have given their all on the climb and be looking to recover and stay out of trouble on the descent, but an attack on the descent can mean you will not be chased and you can then pick your line through corners and forge a successful break.

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7 Cross-winds
In European races, strong teams will often mass at the front and 'put the hammer down' in cross-winds. In doing this they don't offer any shelter to the following riders and can often rip open a field. Many races have been lost because riders were caught day-dreaming down the back of the peloton and lost a lot of time to the front riders sharing the strain of riding into the cross-wind.

Figure 2.1 *Tactics are important to cycling teams and can mean the diffrence between winning and losing.*

Coursework: Strategy and tactics

In this assignment, your goal is to improve performance of the skills associated with tactical problems in a physical activity. In Task 1, you will be demonstrating the execution of the skills, tactics and strategies in a tournament situation.

In Task 2, you will use video analysis to reflect on your performance and use information collected and experiences to complete a reflective analysis in relation to movement, skill, and strategic and tactical development.

Task 1

First, select and perform the skills and strategies associated with tactical problems in your sport of study. You will be assessed on your ability to perform effectively in an authentic competitive situation. A teacher judgement about your achievement will be completed.

To achieve this:

a participate in a series of development lessons

b participate in a doubles tournament or work with a partner as a mentor, applying a range of movement skills, strategies and tactics

c apply communication and cooperation skills in making decisions and taking actions.

Task 2

On the basis of your experiences in Task 1, complete an analysis reflecting on your performance.

Stage 1:

- Select your *tactical problem*, determine the skills that are required and video your performance.

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- Provide a description of the tactical problem and the core skills you selected, then select one skill and:
  - analyse and reflect on how it was performed and when it was used in a game including both offensive and defensive examples
  - identify why you made the decision to concentrate on this skill
  - identify aspects of technique that require improvement and describe the changes that need to be made to move into the next phase of learning
  - identify any strategies that were taken into consideration; e.g. position on the court, qualities of your opponent.

Stage 2:

- View the video of you executing your chosen skill and describe what you looked like. Include:
  - the major phases of the action in relation to the range of motion
  - how knowledge of this information was used to improve performance.
- Identify how concentration and arousal affected your performance (both positive and negative).
- Identify evidence that shows skill improvement.

Rule modifications and tactics

As sport evolves, athletes and coaches constantly seek ways to push the boundaries of the referees and umpires to the limit. This often results in sports administrators re-evaluating the rules and modifying them to suit the greater good of the game. Over the years, key rule changes have re-shaped the very nature of certain sports.

Hockey abandoned its offside rule in an attempt to open up space on the pitch and potentially increase the scores. This meant a complete change in strategies and tactics. Players and coaches adapted, and the change has reinvigorated the game.

The AFL experiments annually with rule changes through its pre-season competition. This allows practical experimentation with potential rule changes in a less critical environment.

Rules of hockey 2009: Free hit

Hockey free hit rules

The text of the free hit rules that applied in international hockey from 1 May 2009 is provided on the CD in the back of the book.

One of the objectives of the International Hockey Federation (FIH) and therefore of the Hockey Rules Board (HRB) is to decrease the number and duration of interruptions to the flow of play and so increase the length of time the ball is in active play. A 'self-pass' from a free hit has been introduced. It enables the player taking the free hit to play the ball again after taking the free hit, which will encourage free-flowing hockey.

As with other actions on the hockey pitch, this must take place safely, so other aspects of the free-hit rules have been reviewed. The HRB is concerned that the ball is often played hard, indiscriminately and therefore potentially dangerously into the circle from free hits in the attacking 23-metre area. In future, these free hits must not be played directly into the circle.

These rules changes are referred to as Mandatory Experimental Rules. They are mandatory because they must be played throughout hockey. They are experimental because they will be reviewed after experience before deciding if they become permanent rules. When the full set of rules is published, small changes to some wording and various additional notes will also be added to clarify certain current rules.

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Badminton: Official change of scoring

In May 2006, the International Badminton Federation approved a 3 × 21 experimental scoring system, in time for the Spanish Open World Championships in Madrid. Under the new system, points are scored on each rally, whereas previously under the traditional 3 × 15 system, points were only scored by the serving player or pair. This change has led to shorter matches (better for TV), but it is said to be harder for players who fall behind to regain advantage.

Badminton scoring

Implementing solutions

> Invasion games ... are different to, say, a game of cricket, or even tennis, but if you're talking about basketball or football, soccer, hockey, those sorts of games, you get it, you keep it, and you penetrate, and you make scores, and when the other team gets it, you go and get it back.
>
> **Ric Charlesworth, coach Australian men's hockey**

In invasion games, opponents compete directly for space. Teams use various formations to attempt to gain control of the game.

KEEP IT REAL!

Soccer playing formations

Many sports have distinct formations that they use to set up their basic strategy. This is most true of invasion games. Soccer has traditionally used a variety of formations in order to implement a specific strategy for any given situation.

Traditional formations included 4-4-2 and 4-3-3, which were used a great deal in the past. The name of a soccer formation describes the number of defenders, midfielders and then attackers.

A formation such as a 4-4-2 indicates a defensive mindset from a coach. There are effectively eight players behind the ball in the majority of the midfield play. These formations are still favoured by many amateur teams, as they are simple to implement. They have limitations in that the players tend to move up in lines across the pitch, and thus if one player in a line is beaten, most of the others in that line are out of the play briefly. A 4-3-3 formation is still often used by coaches in the final stages of a game, when the team is behind. Pushing extra players forward does increase goal-scoring opportunities, but leaves the defence vulnerable on the fast break.

Modern teams have chosen formations with greater depth along the length of the field. The 4-5-1 is used by many top teams, although the system is normally far more complicated. The four defenders are in a standard formation with two full-backs and two central defenders. They then place a stopper midfielder in front of the defence. England used Owen Hargreaves in this position in the 2006/7 World Cup Finals to great effect. The outside wingers can also operate as wing backs to boost the defence and attack when needed. The five players in the midfield are spread wide and deep, rather than as a line across the field. One of the central midfielders also plays quite high just behind the single attacker. This allows him to play two roles as he hopes to draw an opposition player out of his normal position while following him into and out of midfield.

This system has become the favoured option of most international teams. It allows attacking on the fast break with many players streaming forward, while still allowing a compact, crowded flooding-style defence.

From a spectator's point of view, this style of play tends to dictate fewer goals scored.

Denying space and delaying attacks

Target Hawks

KEEP IT REAL!

In AFL, the Hawks' much-discussed rolling defensive zone, which forces opponents short and wide, needs smart thinking to counter it, even when that opponent is the current rampant force that is the Cats.

Only three sides have beaten Hawthorn this year [2008]— the Western Bulldogs, North Melbourne and, last week, St Kilda. All those defeats have come in the past seven games as the Hawks have gradually come back to the field, the suspicion being that the opposition is beginning to work them out.

Quick movement of the football and plenty of handballs to penetrate the Hawthorn zone have been key elements of those results. And Geelong is a master of both; the speed of its play at times breathtaking, and its handball prolific, the Cats averaging nearly 200 handballs a game, about 30 more than the nearest rival. No one hits the short target quite like Geelong.

But those starting to find chinks in the Hawthorn armour might also have discovered another Achilles heel as well, one that isn't related directly to another talking point: the alleged vulnerability of its defence.

In fact, it has as much to do with what, ironically, has clearly been a strength of the Hawks – the effectiveness of their kicking.

Hawthorn won't tolerate poor kicking, either in its potential recruits or those already on the list who hope to play senior football consistently.

That thinking reflects in a disposal efficiency this season of 78%, the best in the AFL.

The Hawks also average the fewest ineffective kicks and second-fewest clanger kicks in the competition.

But the obsession with hitting targets comes at a cost, one that is becoming more pronounced as the season goes on. When the heat is put on the Hawks, their determination still to dispose of the ball to clear advantage is seeing them caught all too often.

In 16 games this year, Hawthorn has been 'pinged' for holding the ball on 94 occasions, a whopping 25 times more than the next-highest figure, and an average of nearly six a game.

Adapted from Rohan Connolly, *Real Footy*, 25 July 2008

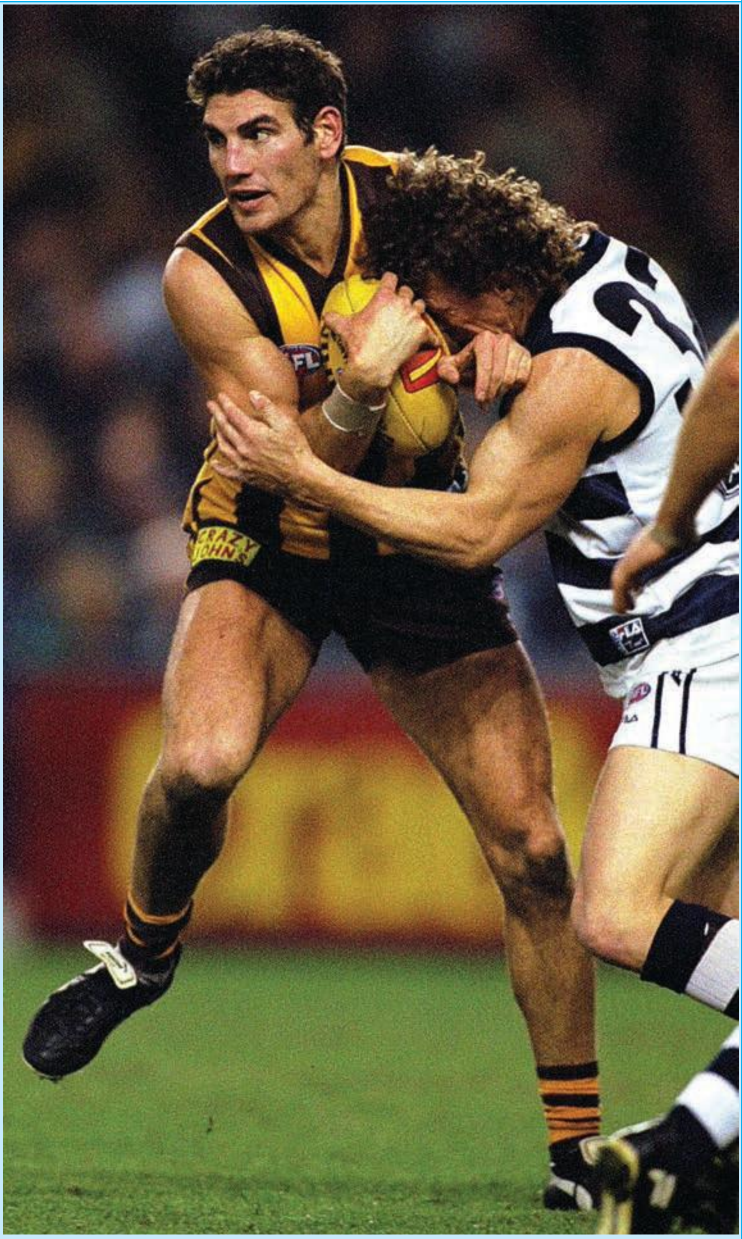

Figure 2.2 Hawthorn has been caught holding the ball more times than any other team. Geelong has more handball receives than any other team. Photo: John Donegan

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Figure 2.3 The Hawks force their opponents to play wide by forming a central grid. The opposition has to take the long route to goal.

KEEP IT REAL!

Hawks in the zone

Opponents have torn their hair out trying to find a way through the Hawks' apparently impregnable midfield this season, their analysts working overtime and their videos on overdrive as they studied the brown-and-gold in action over and over again.

Finally, they found the secret. And it was Richmond coach Terry Wallace who lifted the lid on his coaching rival Alastair Clarkson's audacious strategy of employing a moveable, rolling defensive zone after the Tigers' narrow loss to the Hawks last Sunday.

Geelong cut a swath through season 2007, literally through the middle of the football ground. But it's space that, a year on, Hawthorn has repeatedly taken away from its opposition.

In basic terms, the Hawks force their opponents to play wide, taking the long route to goal. At an opposition kick-in, they'll form a central grid of up to 15 players, leaving the only free space along either defensive flank. There's nowhere else for the kicker to go.

And there the fun begins. If the kicker takes the obvious option, his team will be forced to hug the boundary or run into a wall of Hawthorn jumpers. If he switches direction, the Hawk zone simply slides across the ground in formation to block that space, too. Go back the other way again, and the Hawks go as well. It's intense defensive pressure, non-stop.

'As soon as you go wide, they rush in to hold you up,' explains a rival club coach who has watched the Hawks intently.

Adapted from Rohan Connolly, *Real Footy*, 3 May 2008

How do you beat the rolling zone in AFL?

Run and carry: Most zones are 50 metres in depth and you can run 15 metres without bouncing, which makes the zone run away from you and displaces them.
Long kicks: If you can kick the ball 50+ metres it allows you to break the zone.
Hit targets: It is even better if you can kick the ball 50+ metres and hit targets.
No short kicks: Short kicks just make the zone even more effective as more players get in the 50-metre area.
One on one: You have to man up; you cannot let a player fill in that gap and be unaccountable.

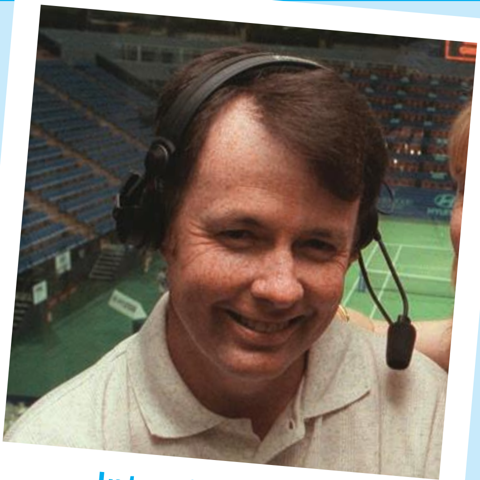
Source: Kick 2 Kick

Responding to the opposition

Glenn Mitchell is senior sports commentator at ABC Perth.

What are the main sporting strategies that you think have changed significantly over the last 10 years? Ones that people maybe can observe, that people like yourself in the media can observe and point out to us?

In a sport like hockey, for example, I know that Ric Charlesworth's team the Hockeyroos used to use this type of device during half time. They could isolate, for example, the way a team set up on a penalty corner. And in the break between first half and second half, they could go down there and have a look at the way players are running off the line when a penalty corner is taken. So I think the computerisation and the use of computer technology and DVD and the real time turnaround you can get rather than the old VHS it would take you forever at half time to spool back and try and find something, nowadays it can be tagged and put into the menu form instantly.



Interview with Glenn Mitchell

Responding to the strategies employed by the opposition is the essence of successful coaching performance. Technology has made that process more instantaneous than ever. However, an astute coach needs to know which strings to pull in response to the opposition. This is the real difference between the good, the bad and the ugly, in terms of coaching.

Ric Charlesworth is the current Australian men's hockey coach and former captain of the Australian men's hockey team.

Who is the hardest team to play against?

The most skilful teams are always hard, but sometimes the most dour teams who like to defend and spoil and just make it difficult, and that is horrible. But in my time, teams with the most skill were difficult. High skill, discipline and organisation make it very hard.

Interview with Ric Charlesworth

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Do you have a philosophy for coaching that helps define what you are about?
Coaching is about high-level skill; if you don't have that you won't be successful. My task is to develop that skill, and something which fits right alongside that is vigilance. Paying attention to the details, and then being able to apply it is critical.

Attending to every detail of your preparation?
Not only in training, but also in the game. It is the thoroughness with which you do it. Most players think they are being thorough, but they are not. So the coach's role is to underpin and reinforce that.

How do you focus at training to make your players better decision-makers? How do you structure training to improve their decision-making?
I have two rules for training. The first is to get a physiological benefit, so you have to increase the load because you know what is required in the game situation. In terms of our decision-making, you have to make training decision-making more complex than the match. Having less space and time than you have in the match, or making the other team overloaded with players, to create situations which are more difficult than those in the game.

We want players to be able to solve those problems under pressure. If they can do that and we can put them under more pressure than a game, then in the game it becomes easier because they feel like they have the time and the space to do things. So what is the key to this decision-making skill? Some of it is intuitive, some of it can be directed by the coach, but most of it comes from the formative years.

In terms of you versus other coaches, do you do much to try and analyse the Dutch, or the Germans?
Yes. You better understand what the other team is likely to do, you better understand the players. People are creatures of habit. Even the best players in the world do the same things, they just do them better than anybody else. They have their own tricks, their own way of playing; in a given situation this is what they are going to do, and the past gives you the best indication of what they are likely to do in the future. I think inductive reasoning tells us that, so I think that is where you are coming from. So you had better know as much as you can about them.

And how they might behave in any given situation, you get some clues from the past.

On the other side of that, you have to have that knowledge, but you have to see what happens on the field each day. It isn't like the coach is the chess master moving the pieces around, because in the end, all the important decisions are made by the players. People ask how did you coach on the day – it's all about preparation. Most of what happens on the day is beyond your control. Even in a game like basketball, you call a time out, and the game stops, and the coach has everybody listening, and says we are going to do this from the sideline pass, and then a player slips, he drops the ball and the other team who was previously playing a zone now goes man on man. What are you going to do? You can't stop it again. The players have got to ad lib. So even in a game like that, the coach's effect is so incidental.

TEST YOUR KNOWLEDGE

>> multiple choice

1 In a basketball game where the opposition has two very tall forwards who it is not possible to man-up against, the best defence would probably be:

A player-on-player defence
B full court press
C half court press
D zone defence.

2 How do you beat a rolling zone in Australian Rules football?

A Kick short and wide
B Play a zone-style attack
C Kick long
D Hit targets, preferably long

>> short answer

3 In an invasion sport of your choice, outline the difference between a zone defence, a player-on-player defence and a press defence.

4 If you were a hockey coach, name and describe strategies from two other sports that would transfer across.

5 Based on your new-found knowledge of soccer formations, what would be the most effective types to use in the home and then away leg of a champions league game, where the aggregate is crucial, as are the away goals. (Champions league matches are played in two separate games with the overall scores linked. If you score a 2-1 win at home and they score a 1-0 win away, then the aggregate is 2-2. However, away goals count for double if the scores on aggregate are tied, so the other team would win on away goals.)

6 Choose an invasion/evasion sport.

a Comment on depth in defence, motion offence, delay defence and creating space.
b Focus, in simple terms, on how you would implement each.

>> essay style

7 Discuss the tactical changes that a coach would need to consider in order to control tempo in game play against:

a very weak opposition
b opposition with a fast forward line
c opposition of identical abilities and strengths
d opposition that is much fitter across the field.

8 In a junior sport of your choice (assume 12-year-olds) outline the strategies and tactics that you would use, based on the age and ability of the participants. Include in this any commonly accepted team plans (e.g. stay goalside of your player when marking). Include suggestions of the focus of drills and training sessions.

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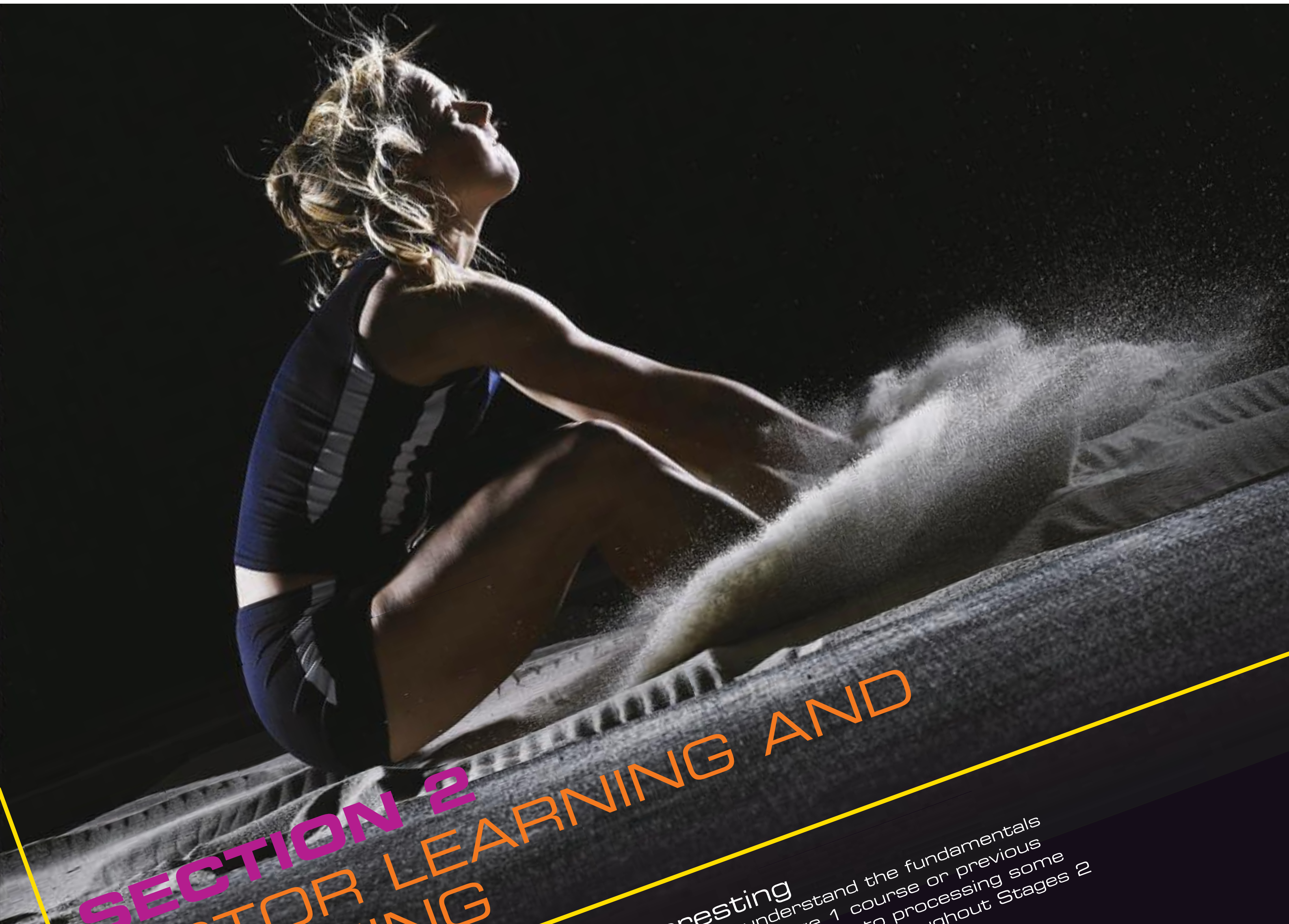

SECTION 2
MOTOR LEARNING AND COACHING

Chapter 3 Making coaching interesting

Chapter 3 is included to help students understand the fundamentals of coaching that are assumed from the Stage 1 course or previous knowledge. This information is considered critical to processing some of the more complex material that will be covered throughout Stages 2 and 3.

Chapter 4 Motor skills

2A.4 Describe the classification of motor skills and the phases of motor learning, i.e. gross, fine, open, closed, discrete, serial and continuous.

2A.5 Describe the phases of motor learning (Fitts and Posner model) and how they can be used to develop/improve specific physical skills.

Chapter 5 Information processing and skill performance

2A.6 Identify the types of cues used to help improve performance, i.e. visual, verbal, proprioceptive.

2A.7 Know the phases of information processing during skill performance, i.e. identification of stimuli/input, response identification/decision-making, response/output, feedback.

Chapter 6 Feedback and factors affecting skill learning

2B.4 Define the types of feedback: extrinsic (inherent), extrinsic (augmented) – terminal, concurrent, verbal and non-verbal.

2B.5 Identify the features and purpose of feedback, i.e. reinforcement and motivation.

2B.6 Identify the relationship between skill-learning processes and individual differences related to age, skill and fitness level, injured athlete, level of competition, type of activity.

3 Making coaching interesting

Coaching is teaching. Some coaches try to make what they do sound mysterious and complicated when it's not … to be a good coach, you have to be a good teacher.

John Madden, champion professional American football coach, writer and broadcaster

It's a lot tougher to be a football coach than a president. You've got four years as a president, and they guard you. A coach doesn't have anyone to protect him when things go wrong.

Harry Truman, President of the United States 1945–53

coach
an individual involved in the direction, instruction and training of the operations of a sports team or of individual sportspeople

To understand how to make coaching interesting, we first need to look at how a coach proceeds in a methodical way. We will look at the:

- skills of coaching
- structure of a training session.

Skills of coaching

K Knowledge

O Organisation

O Observation

T Teaching

Knowledge

The best coaches are not necessarily people who have been successful athletes.

Consider John Buchannan, former Australian cricket coach. He was not an international cricketer of note, but he had excellent knowledge of how to help coach and mould the Australian cricket team between 1999 and 2007.

Knowledge of the sport, and the ability to effectively relay that information to athletes, is at the top of the coaching skills hierarchy.

Organisation

Different types of coaches will have various methods of organising their players. However, as coaching has developed a scientific approach over the last two decades, there are similarities between what coaches need to do in terms of their organisation.

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A routine at each training session can provide much comfort for players, and help reduce the stress that athletes constantly face. However, in order to maintain interest and motivation among the players, many coaches prefer to regularly surprise athletes.

Coaches need an overall strategy for the week, the month and the entire season. This planning for periods of hard training (peaking), followed by periods of reduced training (tapering), and periods of little or no training is termed 'periodisation'.

Table 3.1 is an example of a simple periodisation schedule. Figure 3.1 shows an annual training plan.

Table 3.1 Conventional divisions of the training year

Training phase	Subphase	Purpose
Preparation	General preparation	Foundations established in all components of performance (and the relationships between components)
	Specific preparation	More sport-specific preparation of the components of performance and of the relationship between them
Competition	Pre-competition	Stabilisation of the components of performance and the relationship between them; basic competition simulation in training/competition (or early season competition)
	Competition	Maintenance and refinement of the components of performance and the relationships between them; specific competition simulations; i.e. preparing athletes for the actual stress of competition, pre-competition unloading, competition, post-competition recovery
Transition (recovery)		Active recovery/participation in alternative sport or activities that maintain existing capacities and stimulate underdeveloped capacities

Source: F.S. Pyke 2001

Cross-training can be beneficial – coaches choose alternative sporting pursuits to tax similar energy systems, or that have related skills and strategies. A simple example is an AFL team completing a yoga session once a week in order to supplement strength and flexibility training. This would have obvious benefits for these two components of fitness, and may also help reduce mental fatigue through the relief from physical, high-intensity training.

In their organisation, coaches must also consider helping athletes to set and achieve goals throughout the season. Goal-setting will be looked at in more detail in Chapter 16.

Some general principles

Every goal can be expressed as a C-SMARTER goal:

C Challenging (testing and stretching)

S Specific (closely defined)

M Measurable (changes that are recordable)

A Achievable (within capability)

R Realistic (relevant)

T Time framed (achievement time/date)

E Evaluated (against personal or external standards)

R Reviewed (debriefed)

Source: Brianmac

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<tr><td>Phases</td><td colspan="20">Preparation</td><td colspan="27">Competition</td><td colspan="5" rowspan="2">Transition</td></tr>
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Figure 3.1 Annual training plan

Annual training plan

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Summary

- Provide a routine for individual training sessions.
- Consider cross-training.
- Create a healthy training environment.
- Have an overall plan for the entire season (periodisation schedule).

Observation

Coaches need to be able to analyse the athletes in their care. This is an important tool to help map out future direction. Coaches must be skilled at observing performance and translating this into meaningful information that the athlete can use.

'Feedback' is the term used to define this process of returning externally viewed information back to the athlete.

In simple terms, a coach will need to look at knowledge of results and performance. Knowledge of results is objective – we look at what actually happened. Can a numerical or statistical value be attributed to the activity? For example, how many successful kicks did a player get in an AFL match? However, statistics should not be considered in isolation. Knowledge of performance is subjective – it relies more heavily on the opinion of the observer, perhaps when using a checklist to dissect technique.

These are discussed in detail in Chapter 5.

Summary

- Feedback   KR (knowledge of results)   KP (knowledge of performance)
- Valid observation and informed analysis are the keys to future direction.
- The coach needs to be aware of the varying needs of athletes as to how this information is relayed.

  This will be covered in detail in Chapter 6.

Teaching

Coaches must be able to get the message across to their athletes effectively through the process of teaching.

This teaching revolves around:

- sequencing skills in the correct order from simple to complex
- using varied instructional methods to suit different learning styles
- motivating athletes during training
- providing constructive feedback
- identifying different requirements of players regarding skills and fitness.

The three main teaching styles are:

1 coach-directed
  a command style
  b reciprocal style
2 athlete-directed (sport education model)
3 game sense (self-directed).

Checkpoints

1 List and explain briefly the components required by a coach.

2 **Extended test/exam question.** Discuss the components required by a skilled coach in a sport of your choice, with special reference to methods used during pre-season, in season and post-season.

3 Think of a coach you have had and rate them from 1 to 5 on the four main skills of coaching.

  a Which skill were they best at and why?

  b Which skill were they worst at and why?

KEEP IT REAL!

Ric Charlesworth is former Australian women's hockey coach, former Australian Men's hockey captain, high performance coach with Fremantle Dockers (AFL), former West Australian Sheffield Shield cricketer, and current Australian men's hockey coach.

Interview with Ric Charlesworth

Do you lay any blame on your player (risk-taker) for trying to take a player on and then turning the ball over and costing you a score at the other end?

My view is that that goal will only be scored if five other people make an error, the cascade effect. So you had better organise an enquiry into each one of those incidents, not just one in isolation. If he does something at the front that starts the cascade that was unwise, then that is the same in the first minute as the last minute.

Rule number one in sport psychology is that you have to focus on process rather than outcome. That is the central most important thing. With your group of players, you have to focus on the process of the next task, the next job, whether you are up or down.

So in relation to the English Premier League, Alex Ferguson is better at focusing on the process whereas Chelsea are focused too much on the outcome?

I think that is a mistake that some people make, but in the end, the money buys the best players, and the best players should win. So that is severely wrong for coaches, when they pay ridiculous overinflated prices for players. Two years ago Chelsea won the premiership and recorded losses of some £250 million. That is a bad business, by any measure, but they did win the premiership. What those coaches do know, is that if we get the best players and we add skill, then we are going to win most of the games. It is not any more sophisticated than that.

Guus Hiddink makes a living out of coaching teams for a couple of months in order to get a result. He does well because the other teams don't prepare very well. In the 2002 World Cup in Japan and Korea, the best team in the world was France. France went in to the World Cup with the leading goal scorer in the French League, the Italian League and the English League. They were a bunch of superstars. They were the World Cup holders, they were European champions. Now, they didn't win a game, they didn't score a goal, and they went out in the first round. They went out

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in three matches. Who got to the semi-finals? Korea. Who had ever heard of them? No-one could even name one of the Korean players. The whole Korean team earned in a year what Beckham earns in a month, so it's nothing to do with how much they were paid. Guus Hiddink prepared a team; he got them together six months before and prepared a team. He got them all the way to the semifinals against all those superstars. That can't happen, won't happen in another sport, or at least won't happen in our sport (hockey).

Is that because the top teams are so well prepared?

Yes. Everyone is well prepared. In days gone by it might have happened, but it may still happen in sports that have low scoring. That may allow it to happen in that event but the point I am making is that for the best team to so spectacularly fail, I mean you can always get to the semis, lose in the semis or something. But they didn't even get there, get past the first round. That has to do with how they prepare their team. So for that event, they prepare for a month at most. They play every now and again together. The reason Australia is starting to do better in soccer is that they now play in Asia. They have a program to prepare over a four-year period. In the past they simply had to play the fourth-ranked South American team and they just had to throw a team together. They have to play a team from South America who have come through that intense cauldron of competition.

How detailed is the recovery after a game? Is it about recording weight pre- and post-game and taking on board the lost fluids, as in AFL?

The most important aspect of recovery is getting enough fluid and food. We also have ice baths and stretching. I think the players now are pretty understanding of that stuff, and show diligence in that area.

When you came back from playing, as a doctor, and a member of parliament, before coaching the women's team, what made you decide you were going to be a coach?

It wasn't part of the plan. If you asked me 20 years ago would I be doing this, I would have laughed. When I played hockey it wasn't to make a living out of it, I did it because I loved playing hockey. In your life there are lots of things that are stressful and tedious, but this was a release for me. So I loved to play, and I didn't expect to be able to make a living out of it. I fell into coaching, as some of the players approached me and asked if I would be interested, so I started thinking about it. I liked it because I got to wear a pair of shorts to work every day rather than a suit and tie, and I worked in an environment where there were a lot of people who wanted to do well, and they were talented. I was able to help make them succeed, so I felt like I was making a difference. So that was where great satisfaction came from in coaching. Although after Sydney [Olympics, 2000], I was exhausted, and needed a break.

When I was in charge of the women's team I was away about 12–14 days a month.

Do you think your medical background helps in your role?

I think if you want to be an effective coach these days, you need to have a good understanding of physiology, psychology and sports science. My medical training equipped me for a lot of that stuff, so I suppose that I can then ask the difficult questions of the medical staff when a player is injured, and second guess the medical staff. This is helpful but not essential. I mean I am a former player, but you don't have to be a former player to be a coach. But what it does do is give me more authority than what I may have had otherwise, so that can be useful, because the players believe that I may know what I am talking about. In the AFL, some of those guys don't have the playing reputation, but they can still be an effective coach.

What is the hardest thing about being a full-time coach?

The hours, and the time it takes you away from your family. I am away 12–14 days a month, interstate and overseas. Our game doesn't have a season as such, and when we are playing a competition, we are playing 7–8 matches in a fortnight. There are really intense periods like that which are very demanding

Do you see this as similar to the Australian cricket team?

No, that is much worse – about 250 days a year away from home. And sitting watching cricket all day is damned hard, even when I am not batting.

Structure of a training session

training
the process of bringing a person to an agreed standard of proficiency by practice and instruction

Each training session should follow approximately the same basic format, regardless of the activity. The order of the session may vary, as may the duration, intensity and focus; however, the following general principles apply.

Warm-up

Preparation for the impending physical activity is the main focus of the warm-up. This includes both physical and mental aspects.

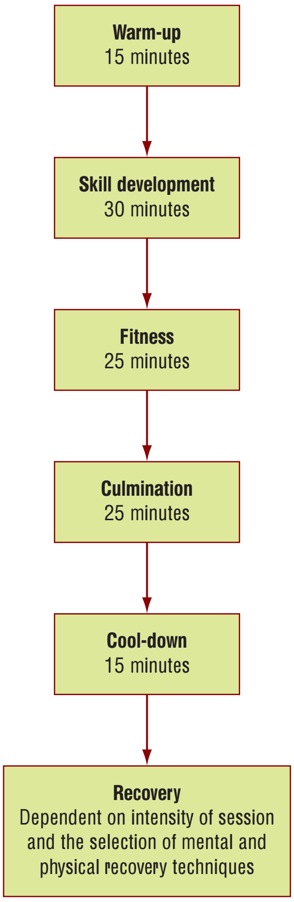

Figure 3.2 Breakdown of a training session

Figure 3.3 Players warming up as a group

It is often stated by sports commentators that at the elite level, 90% of the game is mental. If this is even remotely true, it would be wise to devote a large portion of *both* preparation and training to improving mental skills.

In simple sports science terms, the purpose of a warm-up is to:

- redistribute blood flow to the working muscles
- elevate muscle temperature to improve flexibility and muscular contraction
- prepare specific muscles for activity
- prepare the mind for the greater arousal level that will be required to focus on the task
- increase enzyme activity in the muscles, allowing improved efficiency in the release of energy
- increase heart rate and respiration, which will allow more efficient delivery of oxygen to the muscles, especially in the early stages of exercise.

Skill development

Once the body and mind have been adequately prepared for activity, it is important that the athlete focuses on the core skills, advanced skills and the strategies and tactics of the sport.

There is much debate about whether skill development should be left until after the fitness (conditioning) phase, when the players are semi-fatigued. This has the benefit of making the athletes practise difficult skills under the game-like conditions of exhaustion and mental fatigue.

However, most coaches agree that there is a place for sequencing the skill development after the conditioning phase, but it should not be a common practice.

The main benefit of athletes performing skills while alert and non-fatigued is that the quality of movement is likely to be higher. An athlete who has just completed their warm-up is perfectly prepared to absorb new information and consolidate old skills.

In simple sports science terms, the purpose of skill development is to:

- consolidate / revise core skills
- introduce new, potentially complex skills
- develop and practise game plans, strategies and tactics.

See Chapter 1 for further information.

Fitness (conditioning)

The key concern in this section of training is to adequately extend the physiological systems of the athlete in order to develop or maintain current fitness levels.

This is once again where the term 'specificity' takes on major significance. The coach must direct this physiological conditioning in such a way as to clearly focus on the energy systems that are relevant for the selected activity.

specificity
an athlete is attempting to make changes that are specific to the requirements of their sport

Consider track versus field in athletics. A sport such as javelin demands that its athletes have tremendous strength, explosive power and speed over short distances. As such, it would be pointless including huge aerobic running programs in the training that will provide no real benefit to the athlete.

In contrast, the middle-to-long distance runner is primarily going to focus on developing a lightweight body that can sustain long distances over long time periods. There will obviously be the need for bursts of speed within the race, but the underlying energy system is the aerobic one.

Many sports even differentiate conditioning from player to player, depending on playing positions. For example, a sport such as Australian Rules football has requirements across all energy systems. Depending on the position that an individual is playing in, he may require a specialised training program aimed at developing one system more than the others. A full back will require less aerobic capacity than a ruck rover, but perhaps a little more strength. It would be natural to expect that the coach may have a common general running program for aerobic endurance, a common sprint program, and perhaps even a common middle distance program. He would then separate players into groups to focus on energy systems specific to each position.

Catchy fact
The 'huddle' originated when a deaf American football player used sign language to communicate and his team didn't want the opposition to see the signals he used.

In simple sports science terms, the purpose of physical conditioning is to:

- develop and maintain existing energy systems that are specific to the chosen sport
- identify deficiencies in athletic performance
- ascertain whether an athlete has sufficiently recovered from an injury or illness.

Culmination

Culmination is designed to allow modified or full game play at the end of a session in order to reinforce the key focus.

For example, if the skill development in a soccer training session was mainly concerned with passing the ball to feet, and working in triangles, then this could be the main focus of a culmination game. The coach could remove the goals, and play a full-pitch game with midfielders, attackers and defenders making up three distinct teams. The aim would be to string ten passes together in order to score a point. The culmination activity ties together the main points of the session to reinforce a key skill under game-like conditions.

In simple sports science terms, the purpose of culmination is to:

- draw together the key focus of the session in a game situation
- allow coaches to view athletes in game play after the fatigue of physical conditioning.

Cool-down

During cool-down blood flow is redistributed from the periphery back to the internal organs. The working muscles no longer require the blood to deliver oxygen and energy, and so it is very important to steadily reduce the heart rate to allow venous return to occur; otherwise blood will pool in the periphery.

In simple sports science terms, the purpose of a cool-down is to:

- redistribute blood flow from muscles to core organs
- steadily reduce heart rate to help return venous blood to the heart with mild muscle contractions
- reduce the possible effect of DOMS (delayed onset muscle soreness)
- maintain flexibility after exercise by stretching warm muscles.

Recovery

The recovery is an integral part of any training session, and is designed to help reduce the effects of fatigue in preparation for the next performance. Fatigue may be both physical and mental. Both physical and mental strategies improve recovery.

Fluid replacement plans

Physical recovery strategies

Stretching

Stretching immediately after training or competition has been shown to assist in the prevention and/or severity of delayed onset muscle soreness. Stretching types can range from static, ballistic (a stretch that involves bouncing) to proprioceptive neuromuscular facilitation (PNF), depending on what the demands were of the actual sport. Ballistic stretching is not popular with all coaches, but martial arts and gymnastics have been using these stretches for many years as they mimic the demands of the activity. Obviously, these stretches should be done as soon as possible after finishing the activity. For more information on stretching, see Chapter 13.

Figure 3.4 Stretching helps prevent muscle soreness.

Hydration and diet

Rehydrating after exercise involves replacing lost fluids as soon as possible. The old coach's adage, 'Lots of little drinks, rather than one big drink', has merit here. Placing a large quantity of fluid directly into the stomach immediately after exercise may cause the athlete to vomit, thus reversing the effect of rehydrating. Having many smaller drinks gives the digestive system longer to successfully absorb the fluid.

Food consumed immediately after exercise should have some simple sugars and some complex carbohydrates. Competitors at the Australian Open tennis tournament can be seen eating bananas and high-fibre bread after their matches.

Hydrotherapy

Using water in an active weight-supported recovery has become one of the most popular recovery strategies of AFL clubs. Media footage of players in the water at City Beach in Perth, or St Kilda Beach in Melbourne, is common after the weekend fixtures.

In general, any weight-supported active recovery can help ease fatigue.

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Figure 3.5 AFL players using hydrotherapy to recover after a game

Massage

Massage will help increase blood flow (and, in turn, oxygen) to an area in an attempt to speed up removal of wastes and decrease tension from muscles. The increased blood flow will also help deliver nutrients to the muscles.

Compression garments

Sports skins and similar compression products designed to assist blood flow (see Chapter 1, page 13) have become very important in the recovery process. These provide many of the same benefits as massage, and are especially helpful with teams travelling interstate.

Mental recovery strategies

Progressive muscle relaxation (PMR)

This recovery strategy involves making the mind and body aware of the difference between tension and relaxation by progressively moving through the body and tensing up various parts, before systematically relaxing.

Meditation

Meditation involves relaxing by reducing the number of cues and disturbances to the brain. Athletes are able to slow down and focus body processes in order to lower blood pressure and heart rate, slow breathing rate and relax muscles.

Autogenic training

This is similar to PMR except the focus is more on focusing mental energy on warmth and recovery processes. Joe Hyams (author of *Zen in the Martial Arts*) refers to a similar mental process with regards to healing from serious injury.

Breathing techniques

Controlling breathing has been a part of health culture since ancient times. The Chinese martial art of kung fu refers to this as 'chi', and has used it for thousands of years to help control and release tension.

Figure 3.6 Meditating helps relaxation.

Athletes involved in shooting events must learn to control breathing in order to reduce muscle tension prior to squeezing the trigger (see Chapter 1, page 6).

Mental imagery

As in pre-game preparation, mental imagery is the process of thinking through and focusing on key aspects of past or future performances. This may involve sight, smell, sound and touch in order to make the process more stimulating.

KEEP IT REAL!

Socceroos' recovery process

Here is a sample post-game recovery process used by the Socceroos.

- On arrival, players weigh in.
- After the game, players weigh out, and then start consuming snacks and taking in fluids.
- Players then shower and put on their sports skins. They wear them for 24 hours, including during sleep.
- They then complete a 30-minute run, swim and stretch session.
- The post-match meal should be eaten within 1 hour of leaving the stadium. Snacking is encouraged between the three main meals – muffins and fruit are provided.
- The next morning players weigh in, eat breakfast and then have a compulsory 30-minute massage.
- During the first afternoon post-match a light, 45-minute training session comprising run-throughs and a stretch is a standard part of the regime.

Checkpoints

1 Assess whether the Socceroos' recovery strategy would be effective for:
   a boxing
   b Australian Rules football
   c tennis
   d a sport of your choice.

2 Is recovery specific to all sports?

3 Explain the principle of recovery.

4 Explain the role of stretching, hydrating and eating suitable foods in recovery.

5 Describe the format required for a training session of 8-year-old soccer players, as opposed to a semi-professional team in a local men's league.

   Hint: Consider the differences between the requirements of a children's team and an adults' team. Although the basic structure of training sessions would be very similar, the duration of each section is critical. The adult team would need to focus a great deal of their session on fitness work, especially in the pre-season.

   In contrast, children's sport is designed around developing skills, as these will remain far more permanent than any fitness gains achieved through intensive training sessions. The old adage, 'If you don't use it, you lose it', has great significance to this issue.

   A coach in junior sport must be responsible for achieving a suitable balance between skill and fitness, as one will have greater impact on the junior athlete than the other.

Coaching pathways

Australia

In Australia, the Australian Sports Commission is the key body for overseeing the coaching structure and institutionalisation of sport.

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For many years the system involved coaches in all sports progressing from Level 0 through to Level 3, where Level 0 was a general coaching principles course, with Level 1 taking on sport-specific elements.

Level 2 was for coaches hoping to progress to a higher level of competition, and required experience to be gained at Level 1 first. In Western Australian sport, this would equate to WAFL football coaches and A grade netball coaches. Level 3 was at an elite level, usually national or even international.

This system has now been modified so that the Australian Sports Commission has encouraged each individual sport to develop its own pathway, relevant to the type of activity. This process is still ongoing, and as sports complete their structure, they are slowly being recognised by the Commission.

The current position is described below.

Coaching and officiating

The Australian Sports Commission's coaching and officiating unit provides national leadership in the development of coaching and officiating. Working closely with national sporting organisations and state departments of sport and recreation, the unit seeks to develop more and better coaches and officials at every level of Australian sport, from high participation to high performance.

Focus areas include:

- National Coaching Accreditation Scheme
- National Officiating Accreditation Scheme
- community coaching and officiating
- high-performance coaching and officiating.

National Coaching Accreditation Scheme and National Officiating Accreditation Scheme

The National Coaching Accreditation Scheme (NCAS) and National Officiating Accreditation Scheme (NOAS) offer education, training and nationally recognised accreditation to coaches and officials working at all levels of sport. The NCAS and NOAS provide the industry standard qualification for coaches and officials. Accreditation programs developed in conjunction with national sporting organisations are designed to improve and recognise the competence of coaches and officials.

The Coaching and Officiating unit services more than 70 recognised NSOs and their coaches and officials, through the management and coordination of the NCAS and NOAS and all supporting programs, resources and initiatives. Each year, the Coaching and Officiating unit accredits approximately 25 000 coaches and officials.

Flexible accreditation framework

Prior to the introduction of the flexible accreditation framework, all sports were required to follow a set accreditation structure – Levels 1, 2 and 3.

Under the flexible accreditation framework, each sport now determines the number, name and levels of their NCAS and NOAS accreditation programs to best meet the needs of their coaching and officiating education pathways.

Figure 3.7 shows examples of flexible accreditation frameworks adopted by some sports.

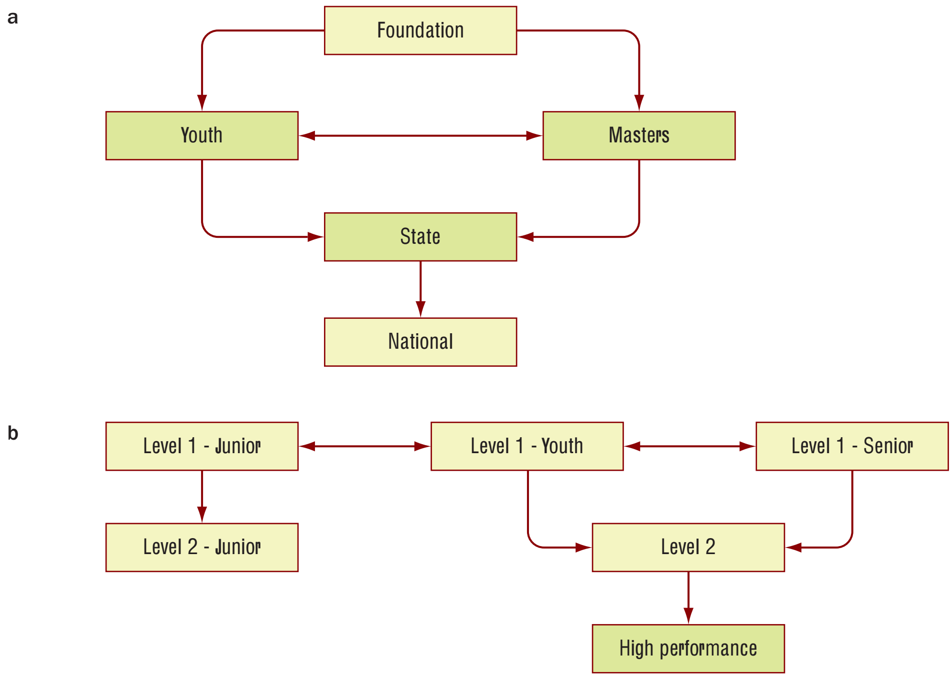
General principles

Whichever framework is adopted, the general principles for coaching and officiating are common to each sport within the NCAS and NOAS.

The general principles cover areas such as planning, development, communication and risk management. There are general principles for:

- coaching – beginner, intermediate and advanced levels
- officiating – introductory and advanced levels.

Figure 3.7 NCAS and NOAS accreditation frameworks for coaches: (a) one entry point; (b) multiple entry points



Entry into the NCAS requires sports to include the Beginning Coaching General principles into their accreditation program.

Presenter, assessor and mentor training

Presenter, assessor and mentor training

Presenter, assessor and mentor training is also a part of the framework.

Coaching and officiating

High-performance coaching

The Australian Sports Commission provides a number of development programs for emerging and existing high-performance coaches. The Coaching and Officiating unit manages the following components as part of the national high-performance coaching framework:

- The **Elite Coach Development** Program focuses on the development of the 'next generation' of national coaches (or, in some cases, existing national coaches) whose development will be fast-tracked within targeted sports over a three-year period. The program supports five to seven new coaches annually.
- The **National Coaching Scholarship Program** enhances the development of identified high-performance coaches in a structured program that combines the Australian Sports Commission, the national sporting organisation and an established high-performance coach. The scholarship coach undertakes a comprehensive program combining education, professional development and practical coaching experience at a high performance level.
- High-performance coach workshops target the top 500 high-performance coaches across Australia annually and provide professional development opportunities for these coaches.

The peak sporting bodies as recognised by the Australian Sports Commission are in the Australian Sport Directory. Information on any individual sport must be pursued through each peak body.

Coaching Association of Canada

Canada

In Canada, the system is a little simpler. It is heavily monitored by the Coaching Association of Canada.

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United Kingdom

Details of the UK coaching framework can be found on the sportscoach UK website.

Summary of coaching systems in Australia, Canada and UK

Sportscoach UK

From analysing the three coaching systems, you can see that many of the coaching blueprints are changing and de-centralising.

Individual sports are designing pathways that suit the specific needs of their own organisations.

Coursework: Extension activity

Research a coaching pathway in a sport of your choice in Australia. Compare and contrast this with the systems in the UK and Canada.

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TEST YOUR KNOWLEDGE

>> multiple choice

1 What are the four main skills of coaching?

- **A** Knowledge, observation, management, coaching
- **B** Organisation, observation, teaching, knowledge
- **C** Organisation, motivation, management, coaching
- **D** Organisation, deliberation, feedback, teaching

2 Which of the following is least likely to cause a bad case of delayed onset muscle soreness (DOMS)?

- **A** Ballistic stretching
- **B** First game of the season
- **C** Water aerobics
- **D** Plyometrics

>> short answer

3 Outline a four-week program for 12-year-olds in a sport of your choice, with reference to the structure and content of each training session.

4 Briefly discuss the need to focus on skills for junior athletes rather than fitness.

>> essay style

5 Discuss and debate the need for accreditation of junior coaches, with special reference to injury prevention and the development of skills.

6 Comment on the concept 'All coaching sessions must be structured', as described in Brian Mac Coaching (see below). Explain the relevance of each point as it relates to a sport of your choice.

All coaching sessions must be structured. This is not referring to content structure (e.g. warm-up, exercises, cool-down) but to process structure. Sir John Whitmore's proven GROW model:

- **G** Goal(s) – what the athlete wants to achieve overall and particularly this session
- **R** Reality – acknowledging the athlete's current skill/performance and, against the objective, the consequent coaching gap
- **O** Options – considering the different learning/development methodology choices
- **W** Will – determining the athlete's real conviction/readiness

Source: www.brianmac.co.uk

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4 Motor skills

Classification of skills

Skills can be classified in a number of ways. This can be based on the length of the action, the number of body parts moved or even whether any body parts move. Here are the main systems of classification.

Classification system 1: Motor/cognitive

This system of classification is based on whether the movement is observable.

A motor skill is an observable movement involving the muscles that is aimed at achieving a desired outcome. This is distinct from a cognitive skill, in which the ability to think and decide is the desired outcome.

Obviously these two skills are heavily intertwined. A player with a perfect technique in a given activity will fail miserably if the decision-making process selects the wrong motor program to run.

This is in fact the key argument for training/practice and coaching. Exposure to repeated similar sporting situations forces the performer to face the same set of stimuli and make appropriate decisions.

Figure 4.1 *Running long distance requires both motor and cognitive skills.*

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Consider the example of cricket. If a batsman faces a ball from a fast bowler that is pitched short, causing it to bounce up towards his ribs, he can make several choices.

- He can duck under the ball.
- He can step back and execute a pull shot.
- He can step away to leg and cut the ball away over slips.
- He can play back and fend the ball down into the pitch.

These are just some of the options available.

If the batsman chooses to step back and pull the ball away, and he is caught on the boundary, then the outcome is poor. However, there were many other options which may have resulted in a better outcome.

Experience at being put in the same situation over and over again through practice and game play will be critical in guiding future efforts.

This is an ideal point of intervention for a good coach.

Relevance to a coach

Motor skills dominate training sessions, despite the fact that most experts agree that a large percentage of any elite performance occurs in the mind. Therefore, as a coach, you must dedicate a significant amount of time to mental preparation within training sessions.

Motor skills must be sequenced and introduced to novices in the correct order for maximum uptake.

Elite performers will probably require a greater percentage of training time on mental aspects than beginners.

Classification system 2: Open and closed skills

This system of classification is based on the stability of the environment.

An open skill requires the performer to take into account the environmental factors, and respond to them in order to successfully perform the technique. An outdoor tennis player needs to consider wind, sun and heat in order to execute a skill.

Figure 4.2 Surfing is an open skill – the performer must take many environment factors into account.

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The environment also includes other competitors and their relevant positions.

In contrast, a closed skill allows the performer to negate environmental factors when preparing for skill execution. The same tennis player in an indoor environment need not fear interference from the sun, wind and heat.

This has obvious implications for devising strategies and tactics, as well as simple skill training in the lead-up to a tournament. If sun and wind will be factors when a player is serving, the serve should have been practised prior to the competition in order to learn to adjust ball tosses.

Catchy fact
At the Beijing Olympics in 2008, special air conditioning was used during the badminton tournaments, so that there was minimal air flow in the badminton court.

Relevance to a coach

Open skills require consideration of environmental factors in the lead-up to training to an event.

Closed skills allow a more narrow focus of training by coaches, as the environment remains relatively constant. Closed skills can become victims of 'massed practice', leading to boredom for performers.

Table 4.1 Qualities of open and closed skills

Open skills	Closed skills
Occur in an unstable, unpredictable environment where conditions are continually changing (e.g. windsurfing)	Occur in a stable, predictable environment where conditions stay the same (e.g. ten-pin bowling)
The performer is often in a dynamic position (moving) when these skills are performed (e.g. kicking a soccer goal after running down the field).	The performer is often in a static state or position (not moving) when these skills are performed (e.g. billiards).
The performer is forced to initiate action in response to the demands of the task (externally paced).	The performer decides when and how to initiate the action (self-paced).
The demands of the skill vary depending on the requirements of the game.	The person can plan what to do and when to do it because the demands and requirements of the activity are known and can be practised (e.g. archery).
The person has to adjust the motor program or movement pattern to perform the skill (e.g. handballing over an opponent and reaching a team member while baulking [dodging] another opposition player).	They allow the person to repeat the same executive program or movement pattern to perform the skill (e.g. discrete skill)

Classification system 3: Gross motor and fine motor skills

This system is based on the amount of muscular involvement required to perform the action.

A fine motor skill is one that requires delicate muscle movements to perform a refined action; for example, threading a needle.

A gross motor skill is concerned with the movement of large muscle groups in order to complete a major movement action; for example, running. The term generally refers to the whole body or multi-limb movements.



Figure 4.3 *Examples of gross and fine motor skills*

Relevance to a coach

Gross skills relate to most sporting movements. Delicate motor skills can lead to repetitive injuries if massed practice is overused.

Table 4.2 Requirements of motor skill types

Fine motor skill requirements	Gross motor skill requirements
A small amount of force to be exerted by the muscles	A great amount of force to be exerted by the muscles
A delicate and precise movement	Use of the large muscle groups
Hand–eye coordination (e.g. threading a needle)	Smooth coordination of the movement (e.g. kicking a football)

Figure 4.4 *(a) By using his fingers to hold and spin the ball, the bowler is using fine motor skills. (b) The entire bowling action is a gross motor skill.*

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Classification system 4: Discrete motor, continuous motor and serial skills

This system is based on the ease with which one can determine the beginning and end of the skill.

A discrete skill is one that has a clearly defined beginning and end point. A golf swing is a discrete skill as it begins with the address of the ball and set-up, followed by the backswing, downswing, impact and follow-through.

The very controlled movement means that a golfer will only have a few external factors to account for when executing each stroke. Wind, rain, extreme heat and loud noises may be environmental factors that need to be considered.

The success of the swing could be affected by the stage in the game that the stroke needs to be made. As the game draws to an end, and perhaps an opponent's score is known, the pressure to relax on each stroke and allow the swing to move freely grows steadily.

Figure 4.5 *Examples of discrete, serial and continuous skills. (a) Swimming is a continuous skill; (b) a soccer kick is a discrete skill; (c) marking, running and baulking in AFL are serial skills.*

A continuous skill is one that sits at the opposite end of the spectrum – it is almost impossible to see exactly where the skill begins or ends. In soccer, a goalkeeper coming to meet a crossed ball in a crowded penalty area is responding to a highly dynamic situation. As he approaches the ball, he will have to avoid other moving players, judge the flight of the ball, time his jump perfectly, and execute the catch. It is not entirely clear where the skill begins or ends. A simpler example would be the action of running. It is not totally clear where the movement begins or ends, often requiring constant repetition of the same movement. The opportunities for intervention by a coach are a little more restricted.

Serial skills require a sequence of steps or motor movements to complete a task. An example of this would be bowling in cricket, which involves a run-up, delivery action and follow-through. As a coach, this skill has several components that must be considered if performance is to be improved.

Relevance to a coach

Discrete skills provide the opportunity for coaches to intervene constantly and correct errors. This allows efficient use of time in a training session.

Continuous skills have many variables occurring at once, which rely heavily on many changing factors. This makes them harder to coach in order to efficiently use time.

Serial skills do not always provide a good opportunity for coaches to intervene constantly and correct errors. The coach must consider all factors of the skill in order to improve performance.

It may be necessary to break the skill down into component parts before reassembling later (chaining).

Skill acquisition

Before we can look at the different phases of learning a new skill, we must understand a little more about skill acquisition.

What is skill acquisition?

skill acquisition
the study of how a person acquires or develops skills

learning
when there has been a relatively permanent change in performance as a result of training or skill practice

performance
the externally measurable effort that we can easily observe

When we are attempting to learn a new skill, we are in fact attempting to 'acquire' the skill. This is referred to as acquisition of skill, or skill acquisition.

In technical terms, skill acquisition is the study of how a person acquires or develops skills. Understanding the process of skill acquisition is crucial for any coach or teacher in order to sequence the learning process, and optimise the use of time in trying to develop an athlete.

What is skill learning?

Learning is when there has been a relatively permanent change in performance as a result of training or skill practice. Learning is not easy to measure, as it is often more internal than external.

We can measure performance over an extended period of time in order to see if there is a relatively permanent improvement. If performance steadily improves over time, we can assume that learning has occurred.

What is skill performance?

Performance is the externally measurable effort that we can easily observe. Therefore, the relationship between learning and performance is evident.

How, then, can we ascertain if learning has occurred in a practical sense?

Learning curves

How do we actually know if someone is learning, or has learnt, a skill, or is simply just performing it once in isolation? The actual observed performance may be a 'fluke', never to be repeated. In this case, the skill has definitely not been learned.

Learning is said to have occurred only if the observed behaviour can be repeated consistently over a long period of time. Therefore, we must have a process to ascertain if learning has occurred by observation over a significant time period.

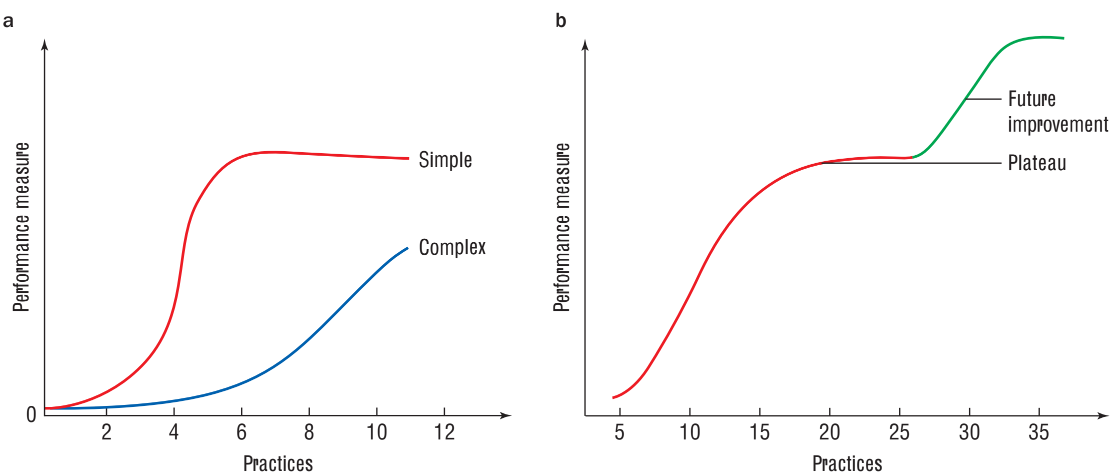

Figure 4.6 Learning curves: (a) simple vs complex skills; (b) a positive curve with plateau. This means that complex skills take longer to master, but once a skill is mastered, the athlete plateaus before improving further.

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Learning curves (Figure 4.6) can help ascertain if an athlete is making significant permanent improvements over time.

Modern coaches are heavily concerned with statistics and the conclusions that can be drawn from them. This has become one of the most powerful tools available to help guide coaching staff as to which direction to go for either an individual or the team as a whole.

Table 4.3 Three methods to measure performance

Method	Description
Practice observations	A coach records a learner's performance, usually over time.
Retention tests	A coach tests a student's performance after practice and then re-tests it a few days later.
Transfer tests	A coach determines how well a skill has been learnt by seeing how the learner can perform it in a different situation (such as moving from practice to a game situation).

Coursework: Laboratory activity

Learning versus performance: One-handed juggling

Materials

Two tennis balls per student

Methods

Work in pairs. Score each time a ball is tossed. Record the results for your partner.

Trial 1: Each student has 20 attempts at juggling.

Trial 2: Each student will have 30 minutes' practice time (concurrently) and then 20 more attempts at juggling with three balls.

Discussion

1 Draw up a table to show the results of you and your partner.

2 Which trial was more successful, Trial 1 or Trial 2? Describe the difference between learning and performance using your results.

3 Do you think the practice time improved your performance?

4 Do the results indicate that learning occurred? Discuss your results.

5 How could you improve your learning of juggling?

6 What variables could have affected your results?

Note: To best demonstrate the difference between learning and performance, it is necessary to select a new or novel skill.

Phases of motor skill learning

Fitts and Posner (1967) proposed that the learning process is sequential and that we pass through different phases as we learn. They proposed that there were three stages to learning a new skill: cognitive, associative and autonomous phases.

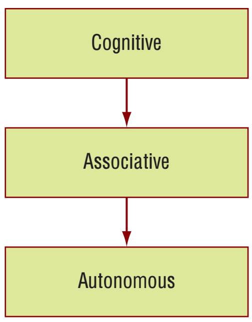

Figure 4.7 Phases of motor skill learning (Fitts and Posner)

Cognitive phase

Cognitive refers to 'thinking', and therefore this phase relates to the formation of a mental picture of what to do, and the basic movement patterns. It is most beneficial at this stage to give a visual demonstration to the performer, as this visual blueprint will help them formulate what the movement should look like. Unfortunately, an unskilled performer will not have a great kinaesthetic feel for what needs to occur.

The performer at this stage has very little ability to detect what went right or wrong, and what cues were present.

Feedback at this stage must be immediate and uncomplicated.

Example

A tennis player being shown how to serve practises several times and eventually hits a ball into the correct service court. The performer has no idea how this occurred, and has no real feel for what just happened. It is certainly not easily repeatable at this stage.

Associative phase

This is the trial and error stage. The performer attempts to link all of the parts of the skill into one smooth movement. Intervention from a coach here is critical in making this process of stimulus, decision-making, response and feedback. The coach observes the success of the performance and attempts to intervene in order to guide improvement. Timing and sequencing of the movement is the main focus of an athlete in this phase of learning.

This is the phase where internal feedback from the body becomes important.

The athlete in this phase can begin to feel what the movement is like, and so gains extra valuable information in order to guide improvement.

Example

A tennis player serving the ball has learnt about the height of the ball toss, what a swing pattern feels like, and when coincidence timing allows a clean strike of the ball. They are using temporal patterning to phase in correct body segments in order to maximise impact speed. They have also learnt to vary the direction of the serve, although with only minimal accuracy or control.

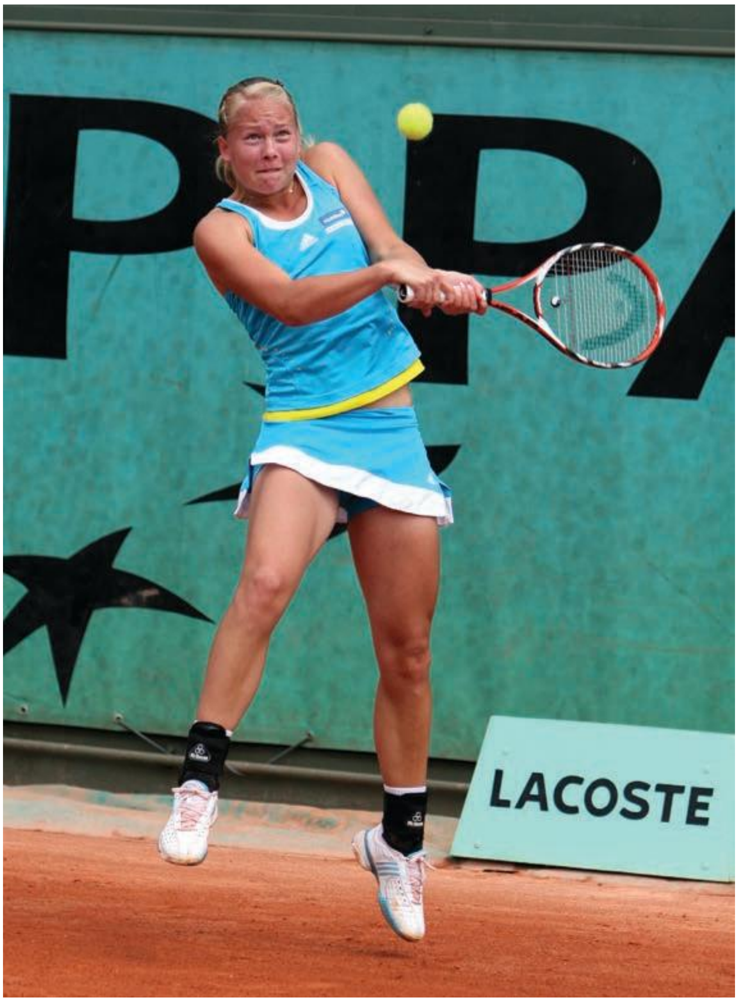

Figure 4.8 *Sweden's Johanna Larsson is an autonomous player and has a high degree of consistency and accuracy.*

Autonomous phase

The performer has refined the skill so that the established motor program is automatic and requires no conscious thought. This means that the athlete is clear to focus on some of the other cues that are present, because they do not need to concentrate on the actual muscular movements. This stage is often beyond most performers. Most people in your class would be in the associative stage, as they still need to pay great attention to the intricacies of the actual skill.

The performer at this stage generally has a high degree of consistency and accuracy, with the ability to repeat the performance time and again.

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Example

The autonomous tennis player is actually able to focus on the position of her opponent, the wind, the sun, and even her opponent's strengths and weaknesses. She is well aware of how to run the motor program for serving, with little conscious thought, so is able to focus on other cues. This performer may even see her opponent move to the left as she tosses the ball up for service, and then actually modifies the direction of the serve at the last millisecond.

Table 4.4 Summary of the main characteristics of the stages of learning

	Cognitive	**Associative**	**Autonomous**
Standard of learner	Beginner	Beginner/intermediate	Advanced
Characteristics of learning	Needs to know what to do Makes frequent errors	Understands how to do skill, needs practice Selects relevant cues from the environment Applies feedback to performance	Skills automatic Few errors Accurate, consistent performance
Appropriate instruction	Simple instructions/ demonstration	Task-specific (demonstration and feedback)	Expert coaching (feedback essential) Specific and concentrated
Time in this stage	Short	Varies, usually many years	For as long as the learner continues the sport, if performing the same skill regularly
Ready to progress	Once the learner has a rough idea what to do and how to do it	Once skills are almost automatic	

Figure 4.9 Basketball players

Checkpoints

1 Look at the basketball players in Figure 4.9.
   a Outline the characteristics of each performer with regard to stages of learning.
   b List the key skills that you believe a coach should focus on at each of these stages.
2 For a sport of your choice, outline the main aspects to be covered at each stage of learning; i.e. cognitive, associative and autonomous.
3 Read the following Keep it real, and explain why the black belt, in theory, returns to being a white belt after many years of training.

KEEP IT REAL!

Martial arts

The yin yang symbol is a recognised icon worldwide, and means many things to many people.

Many martial arts practitioners use the symbol to represent the phases of learning of a beginner as they progress.

A beginner receives a white belt, indicating that their mind is open and uncluttered with motor programs. Anyone at this stage would react to an opponent's attack with instinctive movements with no preconceived ideas. The movement would be fast and uncomplicated, but probably not very effective.

After a short period of training, they may receive a coloured belt, indicating that they have learnt new methods of dealing with the same attack. But they may be confused as to which block or deflection to use in order to effectively stop the attack. Their mind is 'cluttered' with many options.

Once they have trained for many years (becoming a black belt), and have well-refined and automated movements, they will be able to respond to the same attack with speed and good technique. They may even be able to attend to many other cues offered by their opponent, and so make their defence even more effective.

Figure 4.10 *The yin yang symbol*

The yin yang symbol reflects the transition from white belt to novice to black belt – expert – in the form of a circle. In between these two stages is the 'trial and error' stage. The black circle then becomes the white again as the circle continues, indicating that the mind is once more uncluttered, and the performer has completed the journey.

Coursework

Using a sport of your choice, outline the phases of learning and the main focus that you would expect a beginner to work on in progressing to an elite level, using Worksheet 4.1 available on the CD.

Stage of skill learning	Major focus
Cognitive	
Associative	e.g. volleyball overhead serve
Autonomous	e.g. spike serve to weakest opponent

Worksheet 4.1

How skill classification helps a coach design training programs

Now that we have this information, how do we put it into practice? In simple terms, the type of activity will determine the most effective method of practice.

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Practice and learning: How do we improve an athlete?

Without practice, we cannot be expected to improve at any task. Therefore, the quality of the practice is what will determine, amongst other things, how quickly we will progress.

We can assume that a skilled coach who uses a variety of suitable training methods will accelerate the learning of a performer. So we must understand the various forms of practice available to us in order to achieve effective results.

Whole practice

This involves practising the entire movement in one effort, and is the least confusing method provided that the skill is not too complicated. There are certain movements that cannot easily be introduced through this method, because the movement patterns require the entire technique to be completed; e.g. archery.

Part practice

Part practice is when only a small section of the skill is worked on at any one time. If a boxer was to work on his stance and foot movement, this would be part practice. He may do this in isolation for an extended time period in order to reduce distractions.

Progressive part practice

This involves shaping and chaining.

If a skill is overly complex, it should be broken down into parts. The parts will need to be reassembled at a later stage, to create the overall skill.

The old adage 'A picture paints a thousand words' applies here as the athlete should be given a demonstration of the entire skill prior to breaking it up. This visual picture will put the task in perspective, and allow focus towards the final goal.

Imagine a 10-metre platform diver trying a double somersault with a pike. She would need this complicated skill to be broken into several components before attempting the whole skill. Part instruction can be used to address the limitations in the performance and then the diver can repeat the whole skill with the coach monitoring for any further corrections that are required.

Mental or physical practice

The last decision to be made is to determine how much time to devote to the above physical practice types, and how much time to devote to mental practice. Unfortunately, many junior coaches sacrifice this time to work on hard skills. This is where we have to get a balance between playing hard and playing smart!

Here are some simple general principles.

Variable practice

The skill is practised in the range of situations that could be experienced. Open skills are best practised in this way.

Fixed practice

A specific movement is practised repeatedly, known as a drill. Closed skills are best practised in this way.

Massed practice

In massed practice, a skill is practised without a break until the skill is developed. This practice is suitable when the skill is simple and motivation is high.

massed practice
repetitive, continuous practice with little rest between successive efforts

distributed practice planned periods of work and rest in order to limit the effects of fatigue and boredom

Distributed practice

In distributed practice, breaks are taken while developing the skill. This practice is suitable for a new or complex skill, where fatigue could result in injury, motivation is low and environmental conditions are poor.

Summary

- Simple skills (different athletes regard different skills as simple) are best learnt through whole practice.
- Skills of intermediate difficulty are best learnt through part practice.
- Closed skills are often taught with part practice.
- Difficult skills are best taught by switching between part and whole practice.

There are many opinions on the best way to teach various skills. There is often no right or wrong way, as each individual will respond differently depending on factors such as their preferred learning style, the coach's teaching style, age and gender.

Massed versus distributed practice

A golfer practising hitting a long iron shot would be well suited to massed practice; i.e. play shot, get feedback, complete practice swing with no ball, then hit the next shot.

This is a very effective way of getting in many repetitions quickly. Obviously fatigue and boredom can be significant factors here.

Another example of massed practice would be basketballers shooting field throws in basketball. They shoot five shots from each of six markers set up around the key. This is designed to ensure high-quality efforts and is most suitable for large muscle movements and/or complex skills.

An example of distributed practice is the soccer coach who tells the wingers to carry the ball from the halfway line down to the touch line, and then send it across into the penalty area before sprinting back to the start. They commence each run at 90-second intervals.

Table 4.5 Massed and distributed practice

Massed practice is better when the task is:	Distributed practice is better when the task is:
• Discrete – brief in nature; e.g. hitting a golf ball, shooting baskets • Simple	• Continuous – requiring repetition of gross skills; e.g. swimming, cycling, running • Complex – precision-orientated • Dangerous

Source: Wesson *et al.* 1998

Coursework: Laboratory activity

Massed or distributed practice?

Materials

Netball and basketball equipment

Method

1 Divide the class into four groups. Groups 1 and 3 will be trying to shoot basketball goals, and groups 2 and 4 will be trying to shoot netball goals.

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2 All groups will perform pre-test shots (ten trials) and record their results.

3 Groups are then to practise goal-shooting under the following conditions (remaining in the same position on the court):
   - Group 1 practises the basketball shot under massed practice conditions, with 50 trials continuously.
   - Group 2 practises the netball shot under massed practice conditions, with 50 trials continuously.
   - Group 3 practises the basketball shot under distributed practice conditions, with 10 5 trials with two minutes' break between each trial.
   - Group 4 practises the netball shot under distributed practice conditions, with 10 5 trials with two minutes' break between each trial.

Results

1 Record the results.

2 What conclusions can be drawn as to the best method of skill coaching for these two sports skills?

3 Was fatigue or boredom a factor during the practice session? If so, which method do you favour to make practice more interesting?

4 Would the results be any different if the skills being tested were continuous rather than discrete? How?

5 What factors affected motivation and performance in the trials?

Putting theory into practice

The list of practice activities available to a coach is limitless, as are the names for them. Below is a sample list of practice types that can be used in invasion games. This list is not exhaustive.

Full game

The whole group is involved in a full-pitch scratch match.

Coached practice game

The game is played normally except that the coach intervenes at appropriate times to draw attention to key points.

Small team game

Player numbers are reduced, as is the size of the playing area.

Set play practice

Players are set up for a stoppage in play so as to formulate a strategy to use in game play.

Modified position-specific practice

Players from one area of the field work together to formulate a group strategy for game play.

Minor game

A miniature version of the actual game is designed to allow many opportunities for a skill to be practised in a short space of time due to reduced competitor numbers.

Dynamic drills

This involves simple drills where the focus is on repeating a skill in a simple component part of the whole game.

Static drills

These are traditional physical education drills of a simple skill worked between a pair of players for repetitive, simple massed practice.

Checkpoints

1. In a sport of your choice, select five key skills and determine which of the practice types would best suit the performance. Choose both simple and advanced skills.
2. Explain why junior coaches are less likely to devote large quantities of time to mental and cognitive skill training.

Which is better – whole, part or progressive part practice?

If the skill is complex and its components are specific or separate, part practice is recommended; for example, a complex skill such as a tennis serve, where the parts of the skill are independent of each other. In this case, the grip, foot position and swing would be taught separately from each other. Some parts would be combined together, such as the action of the swing.

When using the part method, it is critical to allow the competitor continual exposure to the whole skill. Otherwise, the isolated components may not smoothly transition from one part to the next. This will be vital when we consider segmental interaction in biomechanics.

The part method allows the coach to concentrate on areas of the task that are more difficult to learn. However, when teaching skills using part practice it is important to ensure that the learner is able to practise combining the subroutines so that they can get a 'feel' for the whole action. Part practice is often used with combinations of whole practice and therefore becomes more like progressive part practice.

Progressive part practice works best for serial or sequential tasks that are long in duration or where the parts are performed relatively separately. For example, in a gymnastics routine, each part of a routine (such as a handstand, cartwheel, somersault and handspring) is separate and can be practised independently. The skills are then later linked together to form the basis of a whole routine.

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TEST YOUR KNOWLEDGE

>> multiple choice

1 A putt in golf would best be described as:

A an open skill
B a continuous skill
C a discrete skill
D a cognitive skill.

2 Which of the following is least likely to affect response time?

A Reaction time
B Movement time
C Age
D Short-term memory

3 Which of the following sports would most likely use distributed practice?

A Golf
B Billiards
C Basketball
D 10-metre platform diving

4 Which of the following practice types would best suit a highly complex skill such as a jump, spike or topspin in volleyball?

A Mental practice
B Whole practice
C Demonstration/imitation
D Progressive part practice

>> short answer

5 Explain why beginners are suited to distributed practice.

6 **a** What effects would the length of training have on practice types?

b In a sport of your choice, explain which types of practice you would use. Justify why you selected these.

c If most sport is played during the day on a weekend, explain how a junior coach can modify training to try and replicate some of the conditions that athletes will face.

7 What are the advantages to a coach of understanding the differences between:

a an open and closed skill?
b a discrete and continuous skill?
Briefly discuss why?

>> essay style

8 Using the information from this chapter on coaching and classifying skills, choose a sport, classify the main skills and describe how they would be taught and improved.

.5 Information processing and skill performance

Cues to help improve performance

In order to give any sporting performance at the highest possible level, it is necessary to successfully and effectively interpret the relevant cues from oneself and the environment. Cues are any information that one receives from within the body or from the actual environment itself.

External information

external information information provided by the environment

External information is information provided by the environment. This could be the spin on a ball, the speed of approaching players, or even the direction of a ball toss by a serving player. This information can also be referred to as exteroceptive.

In essence, this information is gathered from our senses, and will be looked at in more detail on page 73.

A skilled performer can gain valuable information from these cues, which will help refine the decision-making process.

KEEP IT REAL!

Case study

Andre Agassi was one of the most successful returners of serve in modern tennis, and attributed much of his success to being able to watch the placement of the ball toss of his opponent. He could gauge the direction of the serve by watching for cues from his opponent, thus knowing which way to move. He later revealed that the reason he only had limited success reading the serve of his major rival Pete Sampras was that Sampras could use exactly the same ball toss for all serves. This negated Agassi's ability to read the direction of the serve and gain any advantage.

Source: *Peak Performance* newsletter, issue 199

Internal information

Internal information (kinaesthetic or movement sense) is the information given to the performer by the body about a motor skill before and during the performance – information about the body's relative position in space, how much force should be put into the

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movement, and the relationship of the limbs to each other. In simple terms, how does the movement feel?

This information is received from proprioceptors in the body. These proprioceptors provide the brain with information about the relative position of joints and limbs at any given time. This information will help determine the starting position of the body prior to the performance. A more skilled performer may in fact immediately increase their chances of success in the pending movement simply by placing their body in a more advantageous starting position.

internal information (kinaesthetic or movement sense) before and during the performance of a motor skill, the body itself gives the performer information about their relative position in space, and how much force to put into the movement, as well as the relationship of the limbs to each other

Information-processing model

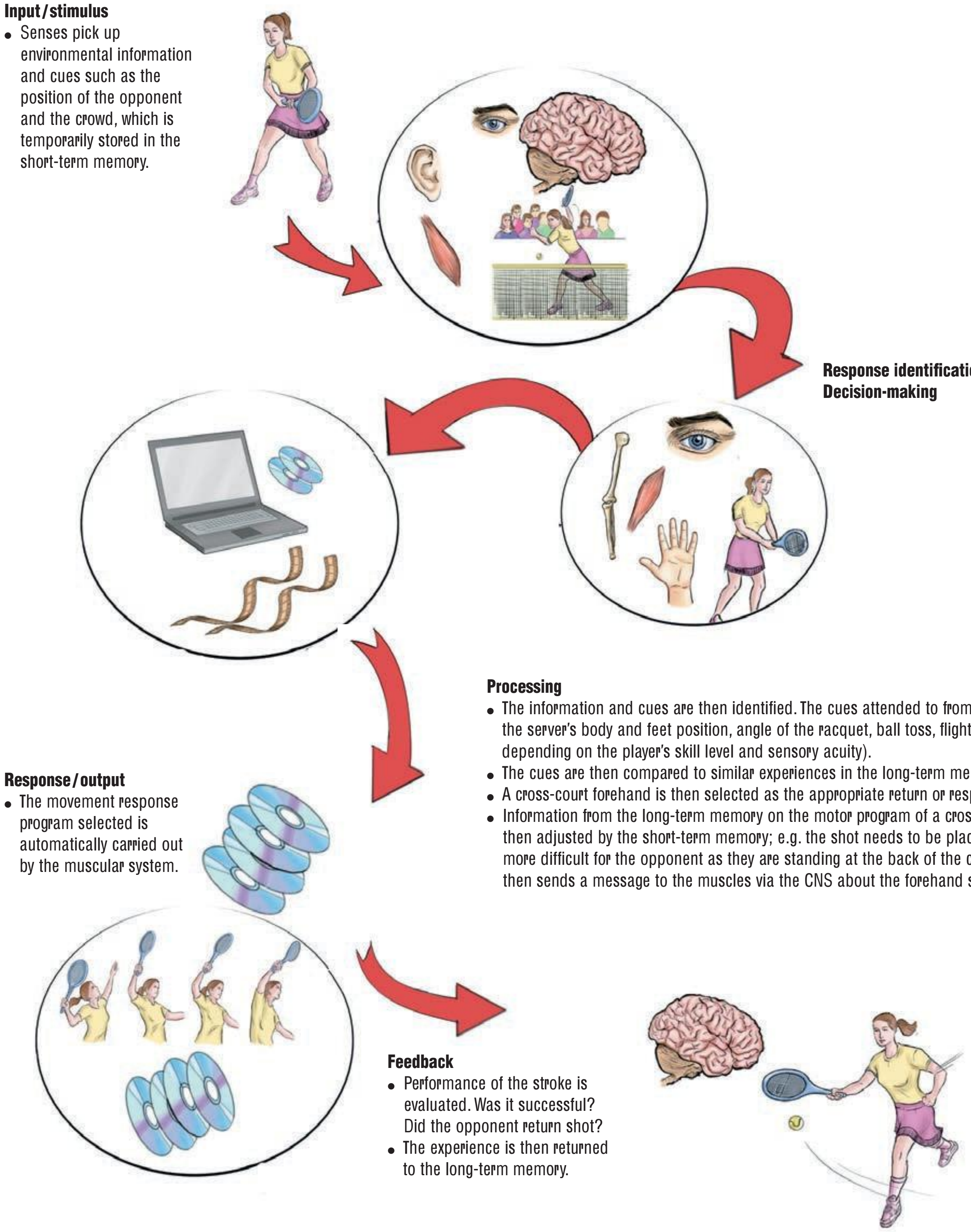

Figure 5.1 The information-processing model as demonstrated in tennis

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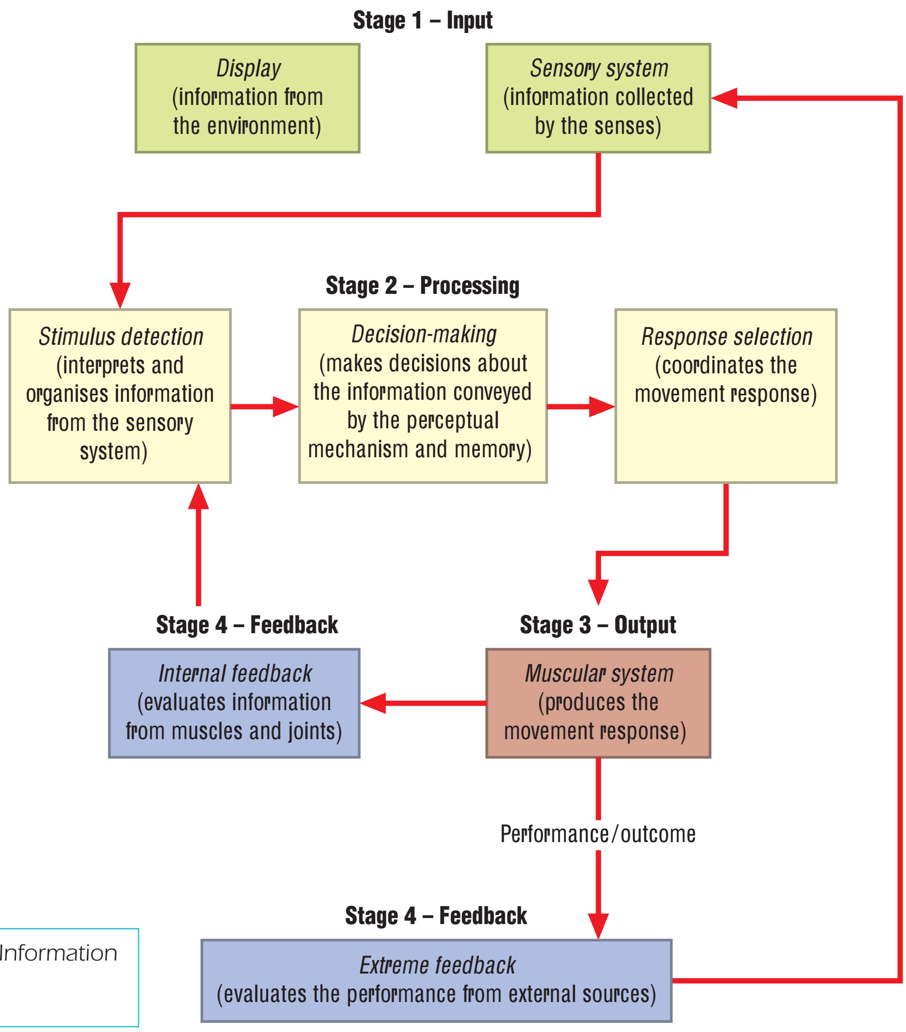

Figure 5.2 Information processing

Stage 1 Input/stimulus

During the input stage, information is gathered from the external environment by the body's sensory system and from the internal environment (within the body) through the proprioceptors, or internal sensors – the muscles, tendons, joints and nerves.

Inputs or stimuli will occur in a number of ways:

- internal or kinaesthetic information (information received from within one's own body)
- external information.

selective attention the ability to only attend to relevant cues

External information

Beginners tend to take in all of the cues offered from the external environment instead of simply focusing on relevant cues. We need to understand that selective attention is important.

KEEP IT REAL!

Case study

Learner drivers are faced with a massive amount of information as they first drive onto the road.

They will be bombarded visually with images – the road, other cars, street signs, the dashboard dials, a dog walking past and countless others. Learners do not yet know what cues to attend to and which to ignore. As beginners, they have not had enough experience to filter out irrelevant information.

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They will also be receiving information such as noises from the environment, the car and passengers, and internal information from their own body, including nervous tension.

A skilled driver would have well-defined motor pathways for their own movements, and would be able to selectively filter out 'noise', or irrelevant information. They may in fact only focus on steering the car, and watching the distance to the car in front, while performing the basic motor skills of accelerating and changing gears.

The task of gathering inputs is much less confusing for the skilled performer, even at this early stage. Advanced filtering makes the task appear easier as the brain has less incoming information to process.

This is the reason many people believe that a P-plate driver should only be able to carry a limited number of passengers.

Figure 5.3 *Learner drivers and skilled drivers differ in their abilities to filter out irrelevant information.*

Coursework: Laboratory activity

Materials

Tennis racquets, balls, markers

Method

Working in pairs, attempt to teach your partner how to serve a tennis ball left-handed, assuming you are right-handed.

Player A will be allowed to receive verbal instructions only.

Player B will be allowed physical instructions as well as verbal instructions and feedback.

Analysis

1. Why was the skill so difficult to learn?
2. Who had the most success and why?
3. Outline the most important aspects for coaches guiding athletes' improvement.

Stage 2 Response identification/ stimulus detection/decision-making

In simple terms, this is where the body looks at all the options available to respond to the stimulus. These options will be limited by past experiences, level of skill, kinaesthetic awareness and, especially, the time given to respond.

The processing stage is made up of three components:

- *Stimulus detection* – Information from the environment is identified, interpreted and organised.
- *Decision-making* – The most appropriate response is decided on.
- *Response selection* – Movement response is initiated and coordinated.

Stimulus detection

In order to process information, we must first identify the signals that have been made available to us. This is where selective attention is critical, and background noise is filtered out wherever possible.

A more experienced performer may notice cues that go unnoticed by a novice. For example, in cricket if a fast bowler is clearly holding the ball for an away swinger, an experienced batsman may notice this prior to the delivery. A novice is simply focused on watching the bowler's whole body run towards them, instead of watching the hand for important cues.

This stage of processing determines how the information gathered by the senses and proprioceptors is identified, interpreted and organised by the performer. The process of identifying the information is called signal detection and the process of selecting the most relevant information is called selective attention.

Signal detection is the ability to recognise a relevant cue. Not only is the strength of the cue important, but so is the performer's ability to be ready to receive it.

The factors that affect our signal detection ability are cue intensity, the length of time the cue is present, the amount of noise, and the capability of our senses.

Cue intensity

How strong is the cue? Is it obvious to everyone or only to a skilled performer?

Length of time the cue is present

If a cue is available for a long time, there is less time pressure to respond. A golfer who is noting the wind gusts is able to plan steadily after recognising the cue.

However, a cricket batsman facing Brett Lee is only going to have about 0.25 seconds to respond to the cue of the ball approaching after it leaves the bowler's hand.

Noise

Noise can be described as irrelevant cues that will distract the performer from the task.

Noise is different in literal terms between one sport and another. A golfer will receive absolute quiet before performing a stroke. A cricket batsman facing a 156-gram thunderbolt from Brett Lee at 150 km/h will have opposition fans chanting wildly at the point of delivery. However, noise does not refer only to sound. Noise is *any* irrelevant cue from the environment.

Our senses

It is likely that the more skilled we are, and the more similar experiences to a stimuli we have had, the better tuned our senses will be to recognising the correct information.

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Information overload

If you attempt to attend to too many cues at once, you suffer from information overload.

This necessitates selectively attending to only the relevant cues. Unfortunately, this skill is usually in the realm of the experienced or naturally gifted athlete.

Our ability to selectively attend to the most relevant cues is influenced by three areas:

- Arousal level
- Experience and anticipation
- Quality of instruction

Catchy fact

Tiger Woods' father used to bang steel rubbish bin lids together as he was swinging his golf club, in order to teach Tiger to filter out irrelevant cues.

Decision-making

The performer must decide on an appropriate response after gathering the information.

As mentioned in Chapter 3, exposure to repeated similar sporting situations forces the performer to face the same set of stimuli and make an appropriate decision.

Let us use a volleyball example. If a player receives a serve from the opposition, she has several choices.

- She can move to the path of the ball and forearm pass it to the setter.
- She can respond to the call from a teammate to leave the ball.
- She can walk under the ball and set it directly to an outside spiker.
- These are just some of the options available.

If the player tries to set the ball to the outside spiker, and the power of the serve forces it through their hands so that it is unplayable, then this is a poor result. However, there were many other options that may have resulted in a better outcome.

It is at this stage, decision-making, that all previous similar experiences will become possible options for the performer.

Experience at being put in the same situation over and over again through practice and game play will be critical in guiding future efforts.

EVERY SINGLE TIME YOU ARE EXPOSED TO THE SAME SPORTING STIMULI, YOU ARE TRAVELLING AROUND THIS MODEL:

INFORMATION PROCESSING OUTPUT

THE SUCCESS OF THE CHOICE THAT YOU MAKE, AS WELL AS THE EXECUTION, WILL HELP GUIDE WHAT YOU DO NEXT TIME COMBINED WITH THE INTERVENTION OF A GOOD COACH (FEEDBACK).

The number of possible responses for each situation also affects the response selection. The greater the number of possible responses available to a person, the longer it will take to decide on an appropriate response.

Refer to the yin yang example in Chapter 4 in order to understand the clutter that can inhabit the minds of some in this process, at certain stages of learning.

KEEP IT REAL!

Ric Charlesworth is coach of the Australian men's hockey team.

How do you focus at training to make your players better decision-makers? How do you structure training to improve their decision-making?

You have to make training decision-making more complex than the match. Having less space and time than you hav in the match, or overloading the other team with players, to create situations which are more difficult than those in the game.

We want players to be able to solve those problems under pressure. If they can do that and

Interview with Ric Charlesworth

we can put them under more pressure than a game, then in the game it becomes easier because they feel like they have the time and the space to do things in the game. So what is the key to this decision-making skill? Some of it is intuitive, some of it can be directed by the coach, but most of it comes from the formative years.

Response selection

Once a decision has been made, the central nervous system (CNS) will then initiate the motor program response.

The motor program that will run has been stored in the long-term memory, and is retrieved in order to sequence the movement. We do not have to cognitively assemble all of the intricate muscle movements at this point. Experience from previous learning allows us to select the key thought for the motor program, and simply set it in motion.

The skill level of the performer and the technical execution of the motor program will always be dependent on the relative skill of the performer.

Schmidt (1991) found that for rapid movements, the movement response is organised through the motor program, which has been previously established. The motor program is the plan of action that orders the movement pattern of a skill. These movement patterns are stored in the long-term memory and are retrieved automatically once the performer has decided which program is most appropriate.

Memory

Memory will be critical in the ability of the performer to quickly retrieve the necessary information to respond appropriately to the stimulus.

There are three types of memory:

- Short-term sensory store
- Short-term memory
- Long-term memory

short-term sensory store
a snapshot of what you last looked at and observed, which is not highly detailed and is constantly being updated; it relies on selective attention to remember as much immediately relevant information as possible

short-term memory
'working memory', which has a limited time of around a minute for retrieval. Psychologist George Miller proposed in 1956 that the human mind could only retain seven items plus or minus two depending on individual differences; this was called Miller's magic number

long-term memory
an infinite memory store that can be accessed at a later date

Coursework: Laboratory activity

Test your reaction time

Materials

Ruler, pencils

Method

1. Work with a partner. The tester holds the ruler at the top while the subject gets ready to catch the ruler by placing their open thumb and forefinger just below the ruler. On the count of three, the tester drops the ruler and the subject tries to catch it as quickly as possible. Make three attempts and mark them on the ruler.
2. Make three more attempts, this time without the count of three.
3. Make three more attempts, without the count and this time using the other hand.
4. Make three more attempts with eyes closed and the tester saying 'Go!' when dropping the ruler.
5. Record the attempts in a table and draw a line graph to show the results.

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6 Discuss the different reaction times you and your partner recorded for the four different tests. Consider whether anticipation affected your results in step 1.

7 List some activities and sports where quick reaction times are important.

Report

How does memory affect information processing?

movement time
the time taken from initiating a movement to completing a movement

reaction time
the time taken to respond to a cue prior to actually initiating a response

response time
reaction time movement time; i.e. time taken from onset of cue to finished execution of movement

Stage 3 Response, output or action

This is the observable movement or 'what actually happened?' This will be dictated by the time taken to react added to the time taken to move.

In simple terms:

movement time reaction time response time

KEEP IT REAL! Some thoughts from Jack Nicklans

Legendary golfer Jack Nicklaus described the need to have very few thoughts during his execution of a golf swing. The 'output' that we are viewing is at the third stage of the model after the decision has been made as to what to do. Jack Nicklaus said 'Every good golfer possesses a carefully developed set of key swing thoughts that he uses to keep his game in balance. Generally one thought will be especially helpful in combating pressure. The one that has been the most beneficial over the years to me is, interestingly enough, also the simplest. The thought is: "Complete the backswing." Like most other golfers, I have a tendency to start coming down before I've finished going up any time tension begins to shorten and stiffen my muscles. By thinking "Complete the backswing," I remind myself to wait for the feeling that I've completed my turn and maximised my arm extension. The thought also has a good effect on my overall tempo, because I know I can't achieve that feeling if I don't swing smoothly and deliberately.'

He often preached the idea to beginners to have a single word or two during the backswing to help unclutter the mind and allow the motor program to run. His suggestion was 'back,' 'hit,' at an even tempo.

J. Nicklaus, *Jack Nicklaus Playing Lessons*, Treasure Press, London, 1988

During the output or action stage, the muscular system automatically carries out the movement as determined by the selection from the central nervous system; i.e. the previous stage, the decision-making stage, has already selected the appropriate choice.

The long-term memory has huge significance in terms of improving sporting performance. It allows us to store complex motor programs that can then be simply transferred into similar movements on another occasion.

The old adage 'You never forget how to ride a bike' helps explain why skill programs exist in the long-term memory for a great length of time. This appears to be truer of certain skill types, and will also relate to the skill of the individual.

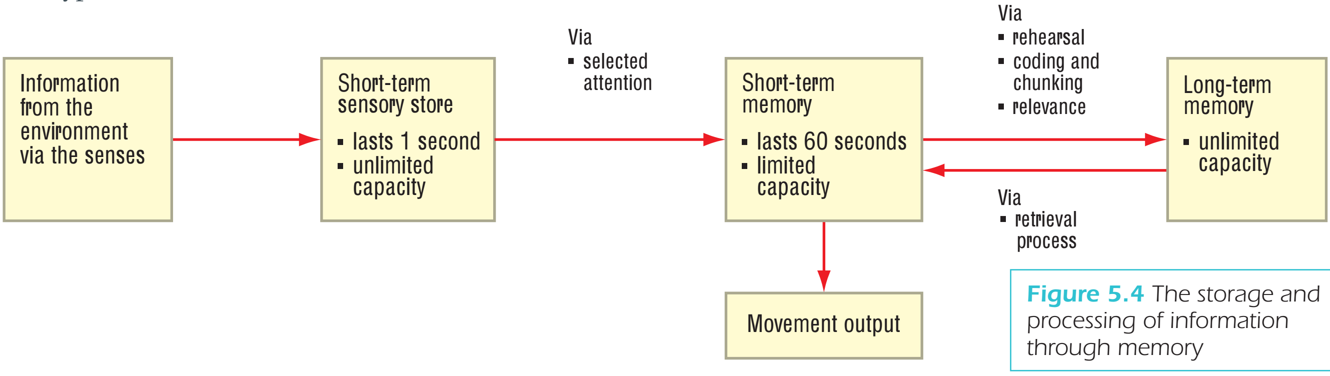

Figure 5.4 The storage and processing of information through memory

feedback
any information the performer receives (internal or external) on how the movement was completed

Stage 4 Feedback

Feedback is received by the performer regarding the performance. It can come from within (kinaesthetic/proprioceptive) or from external sources such as a coach or a video. Feedback can be given before, during and after a performance.

Feedback will be looked at in more detail in Chapter 6, but in general terms, the potential to improve performance will relate directly to the quality of the feedback.

In the case of elite athletes, the performer will give more internal feedback as their kinaesthetic feel is well developed, and provides them with accurate information. On the other hand, a beginner will need much prompting from an external source with the expertise to guide improvement and help refine the motor program.

The main roles of feedback are to:

- motivate
- reinforce positives
- modify behaviour or technique.

A coach should reinforce the good aspects of your performance as well as point out areas to be improved, rather than always only mentioning the things you did incorrectly.

A general principle is to always sandwich a corrective (or negative) comment between two positives. Consider the following example.

'Well done with the serve.'	General feedback	Positive
'Next time try extending up further at impact.'	Specific feedback	Corrective
'But I did like the way you completed the follow-through with your weight transfer into court.'	Specific feedback	Positive

Positive feedback is generally acknowledged to motivate learners to improve their skill level, and as such is a powerful tool.

Figure 5.5 Learners are motivated by positive feedback.

Different forms of feedback

This is covered in great detail in Chapter 6; however, here are the basic principles.

In general, we categorise the two types of feedback as internal or external. As a guide, coaches will be most concerned with knowledge of results and knowledge of performance.

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Knowledge of results (objective)

What actually happened? Can a numerical/statistical value be attributed to the activity?

Example

How many successful kicks did a player make in an AFL match? In simple terms we could compare two midfielders in the AFL, and make decisions on who is a better player based on total possessions accumulated.

Other examples:

- Did the soccer goalkeeper keep a clean sheet?
- How many aces did the tennis player hit?
- How many holes in golf were played below par?

Unfortunately, this simple analysis does not take into account how the action looked, and more importantly, whether the technique that led to the result was repeatable, or was a fluke.

Coaches would be ill advised to look at statistics in isolation.

Knowledge of performance (subjective)

What did we witness in terms of the technique? This relies more heavily on the opinion of the observer, perhaps when using a checklist to dissect technique. It also relies on the internal feedback as indicated by the performer. How did it feel?

Example

When Lance Franklin (Hawthorn AFL forward) shoots at goal, his leg swings in an arc that is not reinforced by classic coaching manuals. The technique looks as though it could be improved, yet he has still made it to the elite level of the AFL. Intervention by coaches has failed to significantly change his technique.

Summary

Feedback KR (knowledge of results) KP (knowledge of performance)

Valid observation and informed analysis are the key to future direction.

This will be covered in detail in Chapter 6.

TEST YOUR KNOWLEDGE

>> multiple choice

1 There are three types of memory:

A Short-term sensory store, short-term memory, long-term memory
B Short-term memory, long-term memory, kinaesthetic memory
C Short-term memory, short-term kinaesthetic memory, long-term kinaesthetic memory
D Short-term sensory store, long-term memory, long-term sensory store

2 Stimulus detection refers to:

A information in the environment being identified, interpreted and organised
B irrelevant information that is ignored
C kinaesthetic information being received from the limbs
D direct perception from the normal senses.

3 Andre Agassi was famous for his return of serve. His success is attributed to:

A improved reaction time
B improved stimulus detection
C improved kinaesthetic awareness
D improved response time.

4 The best place for a coach to intervene in a performance in the information-processing model is:

A input
B response
C stimulus
D output.

>> short answer

5 List and explain the main roles of feedback.

6 Explain how decision-making can be improved at a beginner level using examples from a sport of your choice.

>> essay style

7 It is likely that the more skilled we are, and the more similar experiences to this stimuli we have had, the better tuned our senses will be to recognising the correct information.

Explain what is meant by this statement. Use examples to clarify how this occurs at an elite level.

8 Explain how your PE teacher uses the input–processing–output–feedback model to improve the skills of a student in their class.

9 Using the input, processing, output model, explain in a game of volleyball the key stages that a beginner would move through in receiving a serve from a spike server.

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.6 Feedback and factors affecting skill learning

Types of feedback

In any coaching or teaching situation, feedback is the critical factor in shaping future direction. Feedback is the process of giving information back to the performer in order to direct future improvement. This can be both internal (intrinsic) and external (extrinsic). Augmented feedback is any additional information gained about the movement or success of the movement.

A blind player who shoots 100 free throws in basketball in order to improve will only make adjustments to his technique if he receives some form of feedback. This may be in the form of the sound off the backboard or ring, or helpful words from a coach. Internally he would receive feedback from his muscles on force production, so he can attempt to remember the amount of effort used when his free throw was successful. Without this feedback, he would struggle to make any worthwhile gains in performance.

The old saying 'Practice makes perfect' is only a half truth. In reality, only perfect practice makes perfect.

Let us now take a look at the various forms of feedback that are available.

intrinsic feedback
the feedback athletes receive internally as a natural consequence of their performance; e.g. the kinaesthetic feedback arising from sensory receptors in muscles, tendons and joints, which provides performers with information about their movements

extrinsic feedback
the feedback athletes receive from outside the performer, usually as sound or sight stimuli received from coaches, fellow performers or spectators through exteroceptors

augmented feedback
any additional information gained about a movement or success of a movement

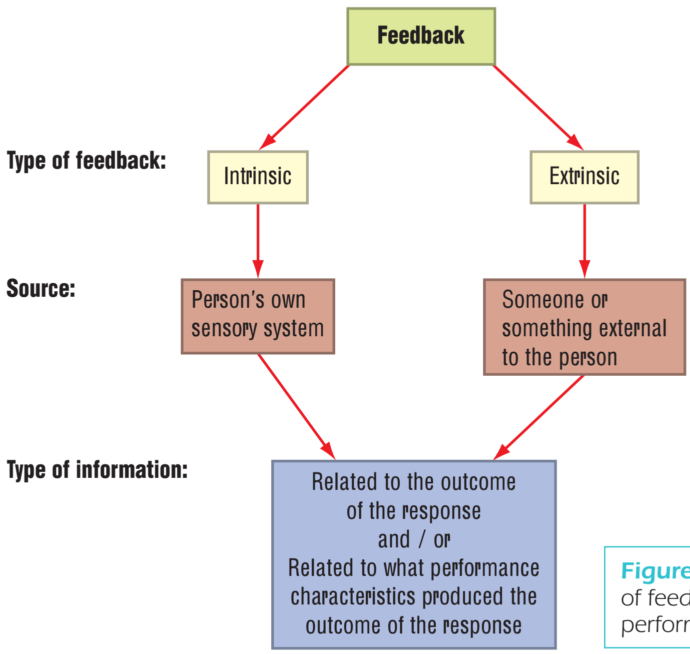

Figure 6.1 The two types of feedback related to performing a motor skill

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Feedback can come in many forms. These include:

- video
- specific verbal
- general verbal
- public acknowledgement
- feelings of mastery, self-confidence
- financial reward
- kinaesthetic.

Two common forms are:

- knowledge of results (objective) – where we measure what happened
- knowledge of performance (subjective) – which relies more on the opinion of the observer.

Effective feedback should combine the two. These are explained more fully in Chapter 5. A skill is not truly learned until it is consistent, repeatable and not simply a unique one-off occurrence (fluke).

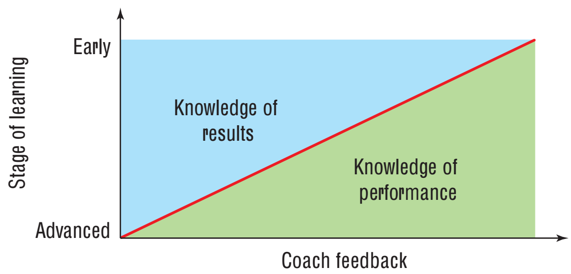

Figure 6.2 Coach feedback – in the learning stages, knowledge of results feedback about the overall skill predominates. Knowledge of performance feedback is offered when the performer is more skilled.

KEEP IT REAL!

At the local school fete there was a Hole in One golf competition with first prize being a brand new car. The hole was set 80 metres from the tee area, which did not allow a full swing with a club, therefore making it a real 'feel' shot.

A golfer struck a ball that flew a short distance, dribbling along the ground, then struck another ball which went into the hole, registering a winning shot.

In terms of knowledge of results, the outcome could not have been better.

In terms of knowledge of performance, the swing itself and contact with the ball were heavily flawed, and would be unlikely to register any future success or consistency.

Table 6.1 summarises how feedback guides future performances.

Table 6.1 The relationship between knowledge of performance and knowledge of results as a guide for directing future attempts at a skill

	Knowledge of performance			
	Type of evaluation	Was the movement executed as planned?		
Knowledge of results	Was the goal accomplished?	Outcome	Yes	No
		Yes	Got the idea of the movement	Surprise!
		No	Something's wrong	Everything's wrong

Source: Pyke, 1991

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Below is an example of a checklist for providing feedback to an athlete about skill performance in terms of 'knowledge of performance'.

Cricket self-assessment checklist	Name ______________________
I feel confident striking a ball off a marker and making it go where I want it to.	1 2 3 4 5 6 7 8 9 10
I feel I can pick the gaps to avoid fielders when batting.	1 2 3 4 5 6 7 8 9 10
I am able to hit the wickets in a game to cause a run out.	1 2 3 4 5 6 7 8 9 10
I can field a ball below my feet and attack the wickets during a game.	1 2 3 4 5 6 7 8 9 10
I know where all the fielding positions are and what they are called in cricket.	1 2 3 4 5 6 7 8 9 10
I know what the scoring system is in cricket and most of the rules.	1 2 3 4 5 6 7 8 9 10
I can hit fast balls bowled at me with ease.	1 2 3 4 5 6 7 8 9 10
I would be able to apply a field strategy to prevent runs being scored.	1 2 3 4 5 6 7 8 9 10
I can hit spin/swing bowling with ease.	1 2 3 4 5 6 7 8 9 10

The above self-assessment checklist could be used to assign a numerical value to an individual's performance at a given time. Because the scoring system relies heavily on opinion, it is in fact a qualitative measure.

Table 6.2 is an example of a quantitative measure that could be used in athletics.

Table 6.2 An example of a quantitative measure that could be used in athletics

Time to complete 100 m	Assigned score out of 100
Less than 10.0 seconds	100
10.01–10.5 seconds	90
10.51–11.0 seconds	80
11.01–11.5 seconds	70
11.51–12.0 seconds	60
12.01–12.5 seconds	50
12.51–13.0 seconds	40
Greater than 13.0 seconds	30

The coach can simply time an athlete over their best of three trials, after completing an identical warm-up, to gain a measure of current performance. This feedback (knowledge of results) will provide a number that maps out a profile of athletic progress if completed at regular intervals.

Checkpoints

1 List and explain the common types of feedback.

2 Give examples of each the following types of feedback that should be used in your school:

  a Public acknowledgement

  b Video

  c General verbal

d Specific verbal

e Reward

f Proprioceptive/kinaesthetic

3 Consider an elite-level coach. Rank the types of feedback in question 2 in the order you think this coach would favour. Justify your reasons.

4 How would the ranking from question 3 change if the coach were involved in an under-9's junior team in the same sport?

5 In a sport of your choice, design a checklist for coaches to use that will give them both qualitative and quantitative information about the athlete.

Coursework: Activity

Investigate how knowledge of results feedback affects performance

Materials

Rulers and paper

Method

Divide the class into four groups.

- Each subject tries to draw a straight line 15 cm long.
- Each subject then has 15 more trials, with each group receiving different feedback:

  Group 1 receives no feedback; completes the trials.
  Group 2 is told 'yes' or 'no' (yes is exactly 15 cm; no is any other length).
  Group 3 is told 'too short' or 'too long'.
  Group 4 is given precise information, such as '1 cm too long' or '5 cm short'.

Results

1 Record how long each line was for each trial.

2 Draw a graph showing the results of the four groups on each task. On the vertical axis, put the error margin (expressed in cm); on the horizontal axis, put the number of trials.

3 Discuss the results of each group and how the feedback affected their performance.

4 How does knowledge of results improve performance in motor skills? (Use a specific example from a sport of your choice.)

frontloading pointing out the key elements or teaching points prior to performing an activity

terminal feedback feedback that is given at the completion of movement

Features of feedback

The best time to give feedback will depend on the type of activity.

Frontloading a performance will allow the athlete time to prepare to retrieve the suitable motor program from long-term memory in order to select the correct movement pattern. Frontloading is, in effect, feedback before the event.

In the case of a high-diver on the 10-metre platform, once the movement has been initiated, the only possible time for feedback is directly after the event; i.e. terminal feedback.

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In the case of a cyclist riding a long road-training session, the coach can give constant feedback from a vehicle as the cyclist progresses, i.e. concurrent feedback.

concurrent feedback
feedback given while a performance is occurring

In Chapter 4 we classified movement skills. You can assume that different skills are more suited to different feedback formats:

- Open and closed
- Fine and gross
- Discrete, continuous and serial

A skill with a definite beginning and end point that occurs without possible interruption will not lend itself to all types of feedback.

Table 6.3 Elements of effective feedback

Feedback should be…	Description
Specific	Information provided by the coach about the performance should only relate to the parts of the task that the athlete was asked to work on before performance.
Constructive	The feedback should give reasons for the identified error and provide possible solutions.
Immediate	Performers briefly retain information in their memory about their performance. For this reason it is important to provide feedback as soon as possible after a performance for it to be meaningful to the athlete.
Clear	Depending on the type of movement being executed, it is sometimes hard for athletes to relate to specific errors in performance, particularly in very complex actions. The use of slow-motion video replay can be effective in such cases. The athlete must understand exactly what must be improved.
Positive	The general aim of feedback is to improve performance. Positive, encouraging and constructive feedback should be used in preference to negative, discouraging and unhelpful feedback.

Feedback: Some guidelines

1. Most performers are able to internally critique their own performance, and can usually describe how the movement felt. This process of self-analysis will be crucial for athletes who aspire to reach the elite level. External information can only guide performance up to a point. Internal feedback is the essence of making a movement pattern repeatable, especially once external pressures are added.
2. Feedback should be given at frequent intervals, not as a constant background noise. With beginners, feedback should be given at every trial until the basic movement pattern is established.
3. Feedback should be given as soon after the event as possible, while the muscle memory of the movement is fresh. This is to ensure that any possible corrections to the movement can be committed to memory before the key points are lost.
4. Feedback must be accurate.
5. General principle: always sandwich a corrective (or negative) comment between two positives.
6. Feedback can be either specific or general. Specific is designed for constructive error correction, while general is aimed at motivating and confirming continued observation of the performance.
7. Positive feedback is generally acknowledged to motivate learners to improve their skill level, and as such is a powerful tool.
8. Refrain from giving corrective feedback to a single player in front of a whole team.
9. Give only one or two pieces of information at any one time.

Catchy fact
In a study by Hodges and Franks (2001), it was found that the provision of feedback is more important than instructions when learning a motor skill.

Verbal and non-verbal feedback

Verbal feedback may come in the form of:

- specific technique corrections
- questioning
- general encouragement.

Non-verbal feedback may come in the form of:

- heart rate monitors
- joint position sensors
- video analysis
- swing frames
- extrinsic rewards (including financial, trophies, public acknowledgement, sponsorship etc.). This relates closely to goal-setting.

Checkpoints

1 Explain which of the possible types of feedback (terminal, concurrent, frontloading) would be best suited to:
  - **a** open skills
  - **b** closed skills
  - **c** fine skills
  - **d** gross skills
  - **e** discrete skills
  - **f** continuous skills
  - **g** serial skills.

2 How would you explain the importance of feedback to a group of junior football coaches?

Factors that affect feedback

Some factors that affect feedback are the:

- stage of learning
- precision of feedback
- timing and frequency of feedback.

Stage of learning

During the early stages of learning, beginners rely on knowledge of results to evaluate their performance. It gives a simple reference point to judge performance against. Knowledge of results tells them, for example, how well or how poorly they did in achieving the goal. Beginners should be allowed uninterrupted practice time so that they can use their own internal and external feedback. Giving beginners too much augmented feedback can overload their ability to remember and process information.

Information about knowledge of performance is more relevant for intermediate and advanced performers because it provides more detailed and technical information about the timing and sequencing of their performance. Knowledge of results becomes less important as the learner progresses from the associative to the autonomous stage of learning.

The use of augmented feedback, such as videotapes and demonstrations, can provide valuable information about performance. The skill level of the performer is critical in determining the type and extent of feedback, especially for beginners.

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As seen in Table 6.1, achieving both positive knowledge of results and knowledge of peformance will motivate the learner to attempt to reproduce and reinforce the movement produced in practice. However, other combinations provide the learner with information about movement corrections. For example, achieving positive knowledge of performance but negative knowledge of results would mean that the learner should attempt a different movement pattern the next time he or she tries that skill.

The coach must ensure that the learner is given continuous, clear feedback about movement outcomes and patterns. Feedback not only provides information about the skill but also reinforces the skill and motivates the athlete to achieve improved performances.

Precision and type of feedback

Feedback needs to be precise, accurate and meaningful to the performer. Comments such as 'You need to keep working on that' do not reinforce or specify what the learner is doing correctly or what they need to work on. It would be much better to say, 'Your swing has definitely improved. You are now keeping your head down, but you need to spread your feet further apart.' This type of feedback could be followed up by a demonstration from the coach and physical guidance of the learner through the skill. It is important for beginners to receive specific information that isolates the most important error or cue.

It is also important that feedback is given to competent performers as well as beginners. What the athlete is doing correctly should be highlighted first and then feedback content should be provided relating to errors.

Feedback can also be given in a positive or negative way. Positive feedback is generally a better approach than negative. The coach saying 'That's pathetic' and reinforcing the negative aspects of a performance will only demoralise the performer and fail to encourage a greater effort to succeed. A better verbal response might be 'That was a great try, well done! Next time try to...'

The method of providing feedback will vary according to what resources are available to the coach and the type of skill being attempted. Feedback is effectively given by using verbal information, physical cues, written reports, video playback and peer comments.

Effective feedback

Feedback provides information that helps in the learning and development of skills and attitudes. The influence of feedback on performers should not be underestimated. It affects the level and speed of maturation, learning, attention and self-image. Table 6.3 (page 87) outlines the key elements of effective feedback.

Coursework: Video analysis as a form of feedback

1 Have a partner video you performing a skill you have not seen yourself perform previously (e.g. running, a golf shot, basketball throw, a hockey drive).

2 View the video and comment on the difference between what you felt during the performance of the skill and what you saw on the video.

3 Describe why you think video analysis of performance is being used more frequently in the analysis of a range of elite sporting performers.

Training methods to focus on to improve skill execution

KEEP IT REAL!

Ric Charlesworth is former Australian women's hockey coach, former Australian Men's hockey team captain, high-performance coach with Fremantle Dockers AFL team, former West Australian Sheffield Shield cricketer and the current Australian men's hockey coach.

'The role of coaching is assessing what the talent is and then actually improving that talent. That is real coaching, and not just bringing out the cheque book and buying someone who fits the bill. That is managing and, if you like, that is a different skill.

'And as I see it, what we have to do is get the talent together and then add value to it.

'As a coach, your role is to expand the boundaries of your athletes, and I don't think most of the players in the team believe, or know, how good they could really be. I've got an idea, and that is where I hope to take them. So if you don't have that high ambition, then that is where you are going to run into trouble.'

Interview with Ric Charlesworth

Purpose of feedback

We have already defined feedback in the previous section as any information the performer receives – internally or externally – on how the movement was completed.

How does feedback impact on reinforcing good behaviour, motivating athletes and even punishing poor behaviour?

More importantly, what are the key features of good feedback?

Reinforcing the good; eliminating the bad

Feedback provides the opportunity to modify behaviour if it is accurate, constructive and understood by the athlete. We have already considered the many types of feedback available to the coach.

The skill of coaching relies heavily on the ability of the coach to select the feedback appropriate to the athlete. An elite performer will require very technical corrections, while a beginner may only be able to cope with a very simple adjustment.

Consider this example. A batsman in cricket is constantly getting caught clipping a ball off his pads in the air to square leg. He receives specific error correction from his coach, attempting to have him open out his front leg to meet the ball, and driving it towards mid on. His coach has identified the technical error, which is falling away to the offside and moving his head, which forces the ball to be hit in the air. The adjustment he has made will need to be repeated in several training sessions to become permanent.

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The coach has gone through the process outlined in Figure 6.3.

This model of qualitative analysis was proposed by Knudsen and Morrison to help explain one method of understanding the cycle for improvement in an athlete.

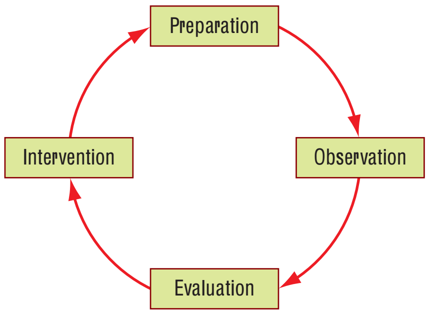

Figure 6.3 Knudsen and Morrison's model of qualitative analysis

In the preparation phase, it is necessary for the coach to recognise the requirements for a correct performance. This is the knowledge component. Observation requires a structured checklist for key points to be observed in the technique. Evaluation is when the coach provides a profile of the strengths and weaknesses of the athletic performance. Intervention is the point at which the appropriate feedback is given.

This process should look very familiar, as it is what coaches should do every session in order to guide improvement.

Feedback as a motivator

How does feedback motivate an athlete? If coaches are skilled at their trade, and understand the needs of individual performers, they can frame feedback to be a highly powerful tool to motivate.

Imagine the situation where a cricketer has been constantly getting caught out on the boundary by hooking the balls of fast bowlers. Over several training sessions with the bowling machine, and suitable corrective feedback, the coach has been able to modify the player's technique so that she rolls her wrists and keeps the ball on the ground. At the player's next match, the coach videos the innings and the player successfully negotiates all short-pitch bowling and plays the ball regularly along the ground.

Watching the video after the performance will provide excellent feedback, and will definitely motivate the player through positive reinforcement. Once this behaviour becomes permanent, we can assume that learning has actually occurred, and that the fault has been eliminated.

Coaches may use many forms of feedback to achieve a similar result. If they have access to joint sensor and analysis software (or programs such as Swinger, Dartfish and Silicon Coach), they can provide outstanding visual feedback to help complement the proprioceptive feedback received from within the athlete.

As a motivator to reinforce good technique, feedback remains the primary weapon in the coach's arsenal.

It is impossible to consider feedback in isolation as a motivator. Feedback has a close relationship with goal-setting as a tool to motivate athletic performance.

Goal-setting

Goal-setting will be considered in more detail in Chapter 16, but it is necessary to mention some basics here, in order to tie these two concepts together.

Goal-setting is usually looked at in terms of:

- performance goals
- outcome goals.

Coaches should be most concerned with tying performance goals to feedback in order to recognise the athlete's direction.

Assume a tennis player has set a specific performance goal of achieving a first service percentage of 65%. After each tournament, the coach can then draw on the statistics to provide feedback to ascertain the success or failure at achieving this goal. The relationship between goals and feedback is clear.

Outcome goals are a lot less controllable, as they rely on factors external to the athlete. Despite achieving a first serve percentage of 65%, assume the tennis player loses in the first round of the tournament after meeting the top seed. Even though one of their outcome goals may have been to reach the third round of all tournaments, they failed to achieve this goal due to external influences.

This is why coaches should spend a great deal of time on directing goals towards behaviours that the athlete can control.

As a coach, learn to teach the athlete to 'Control the controllables, and execute the plan.'

KEEP IT REAL!

Control the controllables

At a team talk with a school swimming squad, Adam Lucas (Olympic swimmer) revealed his philosophy regarding racing great swimmers such as Ian Thorpe and Peter Vanden Hoogenband. He felt that despite the skills of his opponents in the adjacent lanes, there was only one thing that he could control in the race. His focus was on the water between his lane ropes. He could entirely control that space, and had practised in training many times how to set up his race tactically. He was, in effect, trying to block out the irrelevant information being supplied by his environment.

Feedback as punishment

In the draconian days of coaching, this section would be noticeably larger. The modern coach has recognised that feedback is most effective as a tool when it is used positively. Even at elite levels, though, coaches will sometimes resort to punishment as a form of feedback to players to make a valid point. The real skill comes in knowing how much is enough. Will the punishment embarrass the athletes so that a wedge is driven into the relationship?

Many a football coach, even at senior AFL level, has been suitably disgusted by player efforts in the first half. In response, they have been sent out during the half-time break to complete circle work and training drills in a show of public humiliation. Some would argue that this type of feedback is misplaced, but others would argue that they are professional athletes accepting a pay cheque for a public display, so when the effort is sub-standard, the public should have the right to know what is being done to modify the behaviour.

An opposite method of dealing with a sub-standard performance was publicised in *The Age* in June 2004 in the article 'Out of sorts Saints give training the flick'. The coach at the time Grant Thomas, sent the players out for a movie night instead of training after some heavy AFL matches. He described the wellness ratings of the players as being lower than usual, and as such a suitable reward was aimed at injecting some energy back into the group, rather than punishing them with a torturous training session.

Communication and intervention

Communicating feedback to the performer is one of the most important steps in the analysis process. Instructions must be very clear, accurate and at a level the athlete can understand. First, errors should be described and shown on video (or demonstrated). Second, the correct technique should be described and demonstrated so the performer can 'picture' the correct movement. Coaches, in particular, will often question the athlete at this point to determine if they have fully understood the changes necessary to improve technique.

It is important for analysts, especially coaches, to offer constructive, positive comments. While feedback such as 'good shot' and 'well done' is positive, it does little to help the athlete understand their performance. 'Good shot' may be better said as, 'You kept your head down over the ball that time. Well done.' Instead of making a negative criticism such as 'That was a shocking pass!', it could be replaced with, 'Next time try stepping forward with your opposite leg as you release the ball.'

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Individual differences

Why some people learn a skill faster than others

There are many factors that will determine the speed with which an individual will master a skill.

In terms of the coach's impact on this process of guiding the development of an athlete, we could ask where the coach learnt to be a coach. Traditionally, coaches based their coaching methods on those of their own coaches in their previous sporting careers. Modern coaching education has now added a more professional and structured dimension to this traditional influence.

If we were to visit the same AFL club week after week to observe training sessions, we would see a vast array of coaching methods. Some would be the old army style of shouting out instructions, while others would be a more modern self-discovery style.

From Table 6.4, it is apparent that we must consider four key areas when explaining exactly why there are differences in how fast people move through the phases of learning.

Wesson *et al.* (1998) identified the following factors affecting motor learning:

- Individual differences
- The task itself
- The learning environment

Table 6.4 Factors that affect motor learning

Information processing	Individual differences	Task requirements	Learning environment
• Observe and interpret information (cues)	• Ability • Age and maturity	• Task complexity	• Teaching style • Method of presentation
• Make decisions on what has to be done	• Gender	• Task organisation	• Forms of guidance
• Decide on a plan of action and generate the movement	• Physiological characteristics	• Task classification	• Type of instruction and practice
• Evaluate performance (including using feedback)	• Psychological characteristics • Experience • Sociological characteristics		

Adapted from Wesson *et al.* 1998, p. 361

Individual differences affecting skill learning

John Lawther (1977) suggests that 'the human needs a great quantity of experience in order to acquire primary learnings'. He goes on to say:

> Early motor skill training seems to be related to higher peaks of skill achievement in later life. Skill, ability to succeed, more opportunity for the more skilled to participate, growth of interest with increase in skill, all may contribute to superiority in skills as an adult for the child who starts younger.
>
> John Lawther (1977)

It was Lawther who suggested that the motor skill experiences that we develop as children are vital building blocks for the base of skills that we can draw on as adults. Adults do not have the time to experience the wide range of skills necessary to develop fundamental movement patterns. Similarly, adults do not have the desire to look like a novice regularly in order to master basic skills, so may avoid this due to self-esteem and confidence issues.

The pyramid of development of fundamental movement patterns helps us to understand that the broader the base that we build, the larger and taller the pyramid can become.

If we consider a sport such as soccer, the base of the pyramid is made up of simple skills. Exposure to as many different variations of the basic skills of passing, trapping and dribbling as possible, will ensure that, later on in the hierarchy, we will be far better equipped to cope with complex tasks.

Figure 6.4 shows an example involving mixed martial arts.

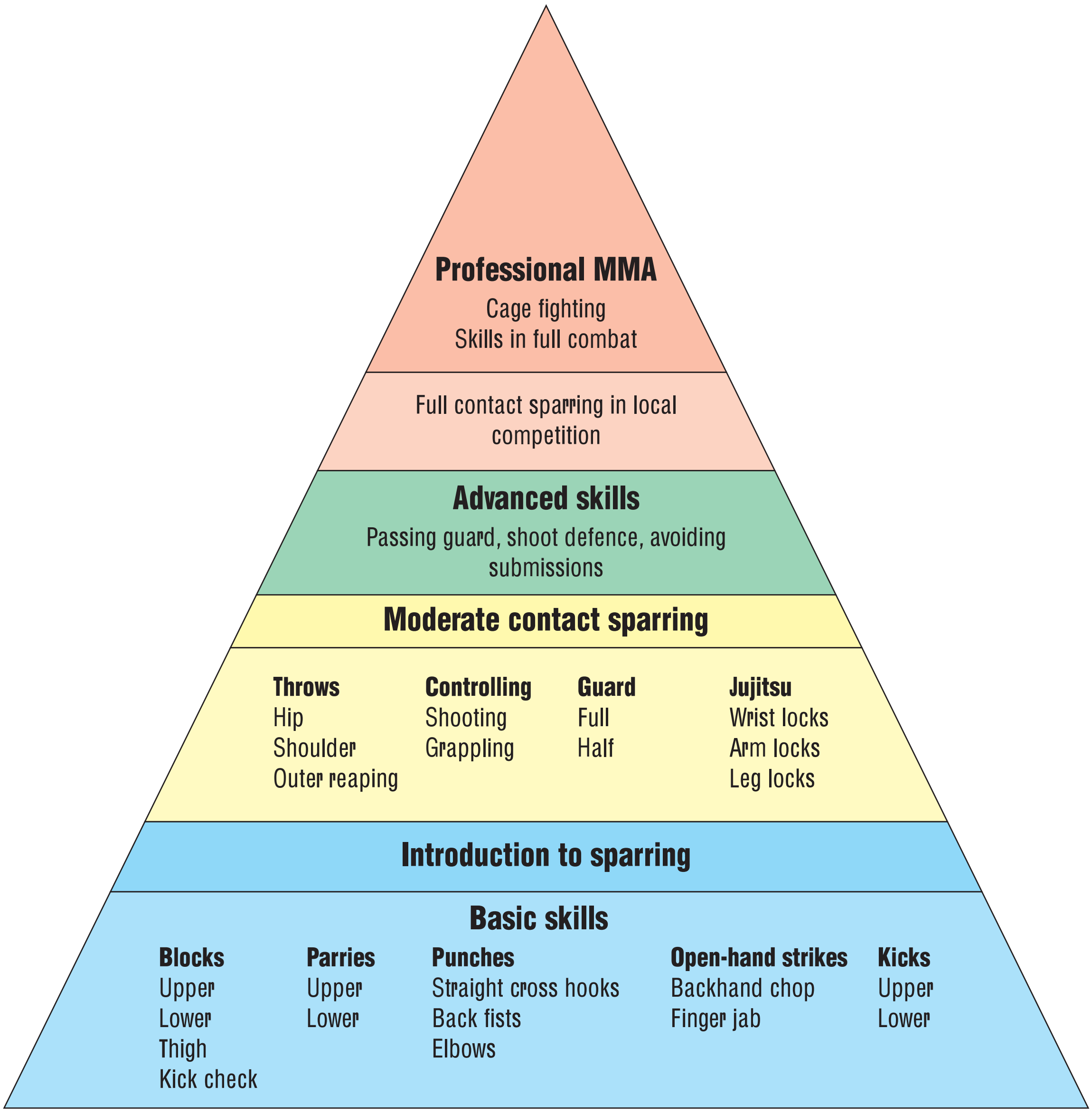

Figure 6.4 Hierarchy of development of skills in mixed martial arts

Factors affecting skill level

There are many factors that can help or hinder the development of motor skills and a person's level of skill. These include:

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- age
- energy expenditure (fatigue)
- practice time
- motivation
- focus
- goals
- vision
- knowledge.

fatigue
mental and/or physical exhaustion that limits the body's ability to perform maximally

motivation
encouragement of an individual in order to improve performance

Age

The age of a person will determine, to a large extent, the speed with which they can acquire motor skills. Leisure time plays a key role in how quickly motor skills are learnt. More time, fewer responsibilities, and less stress mean greater potential time to develop.

Adults will still be able to acquire motor skills at a healthy rate, although once over 50 years old, the natural decline of the body will slow down movements.

KEEP IT REAL! Loss of neural pathways

Between 10 years of age and puberty, the weakest connections in the brain are destroyed; only those that are useful (as shown by experience) are kept. At this time, functions that carry the most messages strengthen, and the weaker ones are cut out.

This process is most predominant in the area critical to planning, working memory, organisation, anticipating consequences, impulse control and mood modulation.

This process of only keeping the most used neural pathways helps support the need for students at primary school having as much exposure as possible to a wide variety of sporting skills.

Catchy fact
Under the age of 12, myelination of nerve fibres may also play a key role in the need to have fundamental movement skills well established.

Figure 6.5 Primary school students engaged in PE classes

Coaching young people

Energy expenditure

Beginners will become fatigued more quickly as they often waste energy attending to the wrong cues and making excessive movements. The quality of instruction and coaching will be critical in eliminating excessive movements and wasted energy.

KEEP IT REAL!

Case study

Natalie is a young PE teacher who has taken up snowboarding. She is well coordinated at most sports and learns them quickly as she has a good base of fundamental movement patterns. She learns most new sports fairly easily, with good kinaesthetic awareness. While learning to snowboard, Natalie struggles with unfamiliar movement patterns. She is forced to expend large amounts of energy trying to master basic balance and coordination in an unfamiliar setting. Being 25 years of age, she is receptive to learning new skills, but is limited in the time that she can practise due to the exhaustion of constantly falling over and having to get up again. In this case, the amount of energy expended due to lack of development has restricted progress significantly. If you add to this the idea that snowboarding is a sport that is done in a concentrated block of time, energy expenditure, fatigue and recovery are key factors in skill development.

Checkpoints

1 Why would early motor skill training benefit a person's skill level in the later stages of their life?
2 What are the consequences for a child lacking motor skill foundations when they become an adult?
3 How do stages of life impact on acquiring motor skills? Use a timeline to demonstrate your answer.
4 Why do beginners fatigue more readily than a skilled performer?

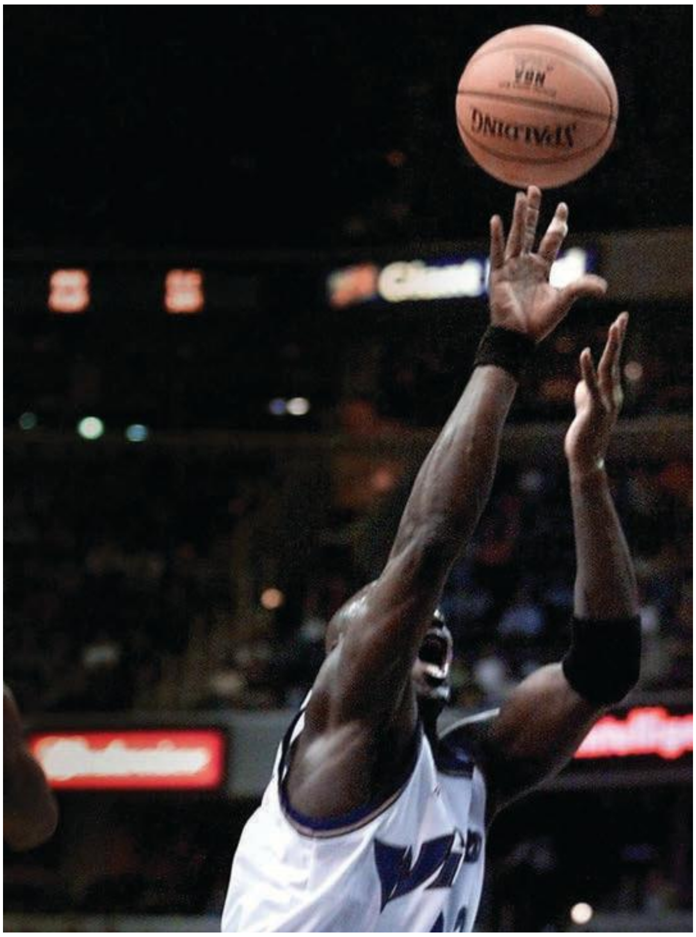

Figure 6.6 *Michael Jordan practised shooting off balance to gain experience in the most difficult situation*

Practice time

More time practising will help eliminate errors, expose the performer to more varied stimulus and, provided they receive good feedback, help them develop faster.

> By practising for longer, they can decrease the amount of errors they make and eliminate inconsistencies in their performance, as well as maintaining their skill level.
>
> John Lawther (1977)

'If you don't use it, you lose it'

Coaches must ensure that they plan interesting, well-sequenced, challenging and not excessively long training sessions. It is unrealistic for a coach to simply extend the length of all training sessions in order to improve skills. There is a finite amount of time for which a performer can practise, focus and deliver a quality performance that will lead to progress.

'More is less'

This often refers to not overdoing the training in response to poor performance.

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Coaches must assess the mental and physical state of their players after a poor match before deciding that a punishment session will be successful. Athletes need adequate recovery from physical activity; otherwise their performance may decline or they may suffer a chronic injury.

Coaches have been known to act even more quickly by having players perform a training session at half-time in response to an extremely poor first-half effort.

Motivation

Elite athletes are more likely to be motivated to develop. That is the reason why they have pursued this pathway, so motivation can be linked to degree of skill.

Psychologist Mihaly Csikszentmihalyi proposed that mastery of skill is one of the 'flow experiences' that we receive in our life. We all like to be good at something, and get a good feeling of self-esteem when we do.

KEEP IT REAL!

Michael Jordan's extra training

Michael Jordan of the Chicago Bulls was perhaps the greatest basketballer of all time. Many thought that his skills were natural and not the result of hard work. His movement prowess was fluid, efficient and even surreal at times. Most did not know the tale of his extreme attitude to training. After each training session with the main playing group, Michael Jordan would then set up his own unique drills in order to surpass his opponents. He was often entrusted to take the winning shot on or near the buzzer. As such, his extra training revolved around taking extreme shots over tall objects while being off balance. He felt that this would create the most difficult possible situation in which to shoot. He felt that this was necessary as his opponents often double- and triple-teamed him near the end of a match to negate his impact. He found it difficult to shoot over two or three opponents, so began practising to do just that. When everyone else had gone home, Michael Jordan, the best of the best, was looking to further extend himself.

Do you think this would be the case for Lance Armstrong, Donald Bradman or Christiano Ronaldo?

Focus

More-skilled performers will have the ability to filter out irrelevant information, and attend to the key aspects of the skill. 'Social facilitation' is a term used to describe the audience effects on the performer. Some respond well to the pressure exerted by a crowd, while others are more introverted. Coaches need to recognise these differences, and help athletes establish routines to help eliminate this 'background noise'.

KEEP IT REAL!

Focus case study

Callum is a young school cricketer who is batting near the end of an innings, trying to chase down the other team's total. Facing the second-last ball, he strikes it into the deep but straight at a fielder. He calls two, which will force a dangerous second run, but he is desperate to face the last ball, which will require three to win or two to draw. The other batsman is keen to take the second run as he does not want to face the last ball and shoulder the responsibility of the team.

Callum makes the second run, and then successfully dispatches the last ball for four runs to win the game. Callum is the type of performer who could focus on skill execution, and not consider the audience effects of having half of his school watching. He responded well to the effects of the audience, and was able to focus. His fellow batsman was allowing irrelevant cues to influence his skill execution, which would have inevitably detracted from the overall performance.

Figure 6.7 *David Hussey has learnt to focus on the ball and ignore the crowd.*

Goals

Goals are essential in order to streamline the learning process. Goals need to be directly measurable, realistic and achievable. If an athlete sets a goal of achieving a high level of proficiency by a certain date, then it is much more likely to be attained.

Goals direct behaviour in a desired direction, rather than just aimlessly wandering down the motor skill path. An example of a goal set by a cricketer would be to drive the ball seven out of ten times between the cover and mid-off markers.

Performers at the high skill level of learning can benefit from the practices of self-analysis and mental rehearsal in order to take their performance to the next level (Lawther 1977). This is strongly linked to motivation and the desire of that performer to obtain an even higher level of ability. Methods include watching and analysing video footage of their current performance level.

Figure 6.8 *Lane marking in a swimming pool helps video analysis for swimmers trying to improve their times.*

ISBN 9780170227094

Vision

Visual attention needs only to be focused on the cues that are relevant. When driving a car in peak hour traffic, the vision must purely focus on steering the car and the brake lights of the car in front. Apart from emergency situations, those two factors will determine if the driver will crash into a car in front.

In test cricket, the batsman should focus on seeing the ball as it leaves the bowler's hand. This will provide valuable information about what the ball may do in flight, or after it bounces.

How many times have you heard your coach say 'Look up'? Unfortunately, beginners are so focused on the basic skill movement, they feel overloaded with information if they then have to look up and take their eyes off their task. Perhaps you can remember when you were first learning to dance? How often did you look at your feet? What purpose did this really serve?

Imagine a novice soccer player dribbling towards opposition defenders. The player will be focused on his feet gently kicking the ball along. In contrast, Manchester United star Christiano Ronaldo is able to run full speed at opponents with little attention to the ball at his feet. This is because his peripheral vision and skills are so well developed that he has more time to focus his vision on the oncoming players. Experts also see more when they look up. It is thought that this use of vision develops with experience, due to the many years of exposure to the skill in the input–processing–output model.

Figure 6.9 Christiano Ronaldo

KEEP IT REAL!

Using visual information

Bruce Abernethy is one of the world's leading researchers on the issue of visual expertise in the performance of motor skills. His research in 1999 compared the use of vision in performance situations where there was a limited time for the performer to detect and use visual information, such as hitting a pitched baseball. He found that:

- experts are faster and more accurate at recognising coordination patterns related to an action and patterns involving several people
- experts detect and use important action-directing cues faster – resulting in better anticipation and faster implementation of an action.

Source: Magill, 2001

Knowledge

Increased knowledge of an activity will give experts more alternatives to respond to a given stimuli.

Imagine a novice who only ever faces a bowling machine that pitches the ball at a length to which a front foot drive can be played. If the novice has no knowledge of cricket, they will have limited resources to deal with a ball in their first match that is pitched short and comes up towards their chest. Lack of knowledge has reduced the opportunity to respond effectively to the stimulus.

Elite athletes have more experiences stored in their long-term memory, and so will have more solutions available to the same problem. Experts adapt to new environments more readily, and are able to use a combination of learned solutions to solve a totally new problem.

From the phases of learning model in Chapter 4, we should recall that a performer in the autonomous phase does not need to consciously think about the motor skill technicalities. They can instead focus on information from both the environment and past experiences.

KEEP IT REAL!

An expert's knowledge structure

Ninety thousand fans sing and chant to the pulsating beat of the drums; the stadium is a cauldron of energy and noise. The atmosphere is electric. This is the soccer World Cup stage. Ronaldinho brings the ball down the field for Brazil. As he looks up, he is confronted by three defenders. Quickly summing up the situation, he makes his first decision and skilfully dribbles around the nearest defender. With two defenders between himself and the goalkeeper, a quick glance from 30 metres tells him that the goalkeeper is off his line. In a flash, Ronaldinho makes his next decision to lob the goalkeeper. With the most delicate of touches, the ball seems to float through the air ... GOAL!! The noise becomes even more deafening. In a matter of seconds, he has gone from gaining possession to an artistic finish.

Question

Using the above explanations of a skilled or expert performer, outline and explain the characteristics that enabled Ronaldinho to score his goal.

KEEP IT REAL!

Science to move 'in the groove'

Figure 6.10 One of CSIRO's body mapping garments

CSIRO is developing interactive clothing to help improve athletes' performance. The garments are being trialled at the Australian Institute of Sport (AIS).

In 2006, CSIRO scientists built a virtual air guitar, known as the wearable instrument shirt. The air guitar consisted of wearable sensors embedded in a conventional shirt, with custom software to map gestures with audio samples. It recognises and interprets arm movements, relaying the information to computers for sound generation.

This technology is being adapted to help train elite athletes at the AIS to attain natural free-flowing movements through a combination of action, disco rhythms, sound and repetition. By mapping the movements and providing feedback in real time, the athletes learn automatic movement responses faster.

The Australian netball team is trying out such a garment to train their goalshooters to perform automatically so that their natural action is not affected by conscious thought.

The goal is to help the netballers find their ideal rhythm and motion. Researchers hope that success with netballers could lead to trialling the wearable body mapping garments in other sports before the 2012 Olympic Games.

Moving in the groove (video)

ISBN 9780170227094

Coursework: Feedback

1 Organise a simple activity, such as throwing balls over your head into a basket set at an unknown distance.

2 Count the number of successful attempts out of ten shots when you are provided with:
- no feedback
- limited feedback – only using words (in, out, left, right)
- full feedback from a partner.

3 How did feedback affect the learning process?

4 What advice would you give to a junior netball coach about the role feedback should play in their coaching?

Coaching advice

Interesting and challenging practice sessions

When a person achieves success in an activity, they tend to enjoy it and are likely to continue doing it. For this reason, a coach teaching beginners should make the task achievable by all participants so that everyone enjoys success. Then the coach needs to find and set increasingly difficult tasks that are both achievable and challenging. Without the challenge, there is no enjoyment. There is a zone that is too easy and which leads to boredom and disinterest, and a zone that is too difficult or (at least for the time being) which the learner does not understand and which is likely to cause anxiety or worry.

Coaches should aim to keep the difficulty of the tasks they set at a level where the athlete is constantly and systematically challenged and experiences steady improvement.

Arousal levels

Arousal levels will dictate the effectiveness of training sessions. This refers to the level of alertness and mental readiness for the upcoming activity. These will be covered in more detail in Chapter 16.

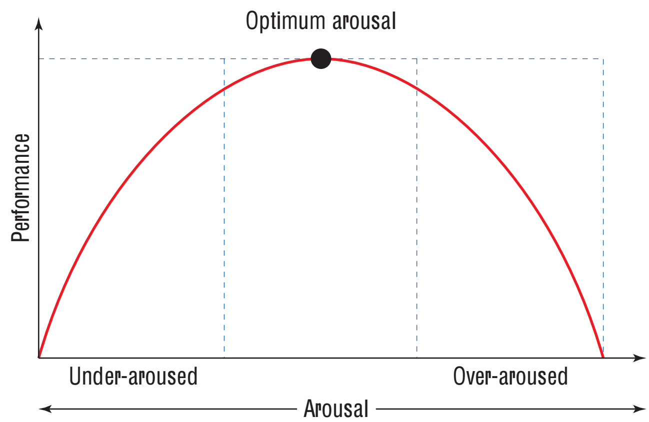

Figure 6.11 The relationship between arousal and performance

Providing suitable demonstrations

Demonstrations are an important part of the process of acquiring new skills. Generally, coaches provide a model of the required performance, either by demonstrating a skill themselves or by asking another skilled performer to demonstrate the skill or technique. Alternatively, you might watch video footage of a skilled athlete performing the skill.

This gives the viewer first-hand knowledge of exactly what the skill looks like, and how it should be performed. Examining photographs is another method.

If the skill is being demonstrated by the coach or an expert performer, the demonstration should be:

- suitable for the skill level and stage of development of the performer
- demonstrated at an appropriate speed that the learner can follow
- demonstrated an adequate number of times
- demonstrated by a person who is able to perform the skill correctly.

The beginner who is just starting to develop a mental plan of how a game is played will not be able to comprehend an overly complex demonstration or explanation, so the coach should not introduce too many concepts and techniques at once. Equally, the coach should continue to demonstrate the skill during practice time while the learner is practising the skill. This will reinforce for the performer how to do the skills properly.

A performer at the intermediate stage could deal with greater complexity, while the elite performer, who has automated many of the skills already, could attend to very specific complexities and subtleties of the skill, and could also work on 'part skill'.

The skill should be demonstrated at a similar speed to that required in the actual game. While there may be some advantage in slowing down the action to highlight a particular aspect, the player must get a feel for the real time in which the skill is performed.

The skill should be demonstrated a number of times consecutively so that the player has an opportunity to see the action from a number of angles, and can form a good mental picture of the performance before trying it for themselves. Research studies in the area of frequency of skill demonstration show that beginners who observed a skilled demonstration more frequently were better at learning the skill.

Attention capacity is another factor the coach must keep in mind when demonstrating a skill. The learner only has a limited capacity to take in new information. Therefore it is easy to overwhelm a beginner with too many instructions. They will have difficulty remembering all the instructions and performing the task. Imagine a 6-year-old being shown and taught the skill of a basketball lay-up for the first time without breaking the skill down into parts.

Coaching children

The following are good general principles:

1. In the first instance, children are motivated to participate in sport to have fun.
2. The family is the primary influence over whether or not a child is introduced to a sport.
3. Children are not small adults. A child's ability to learn skills is limited by their capacity to process information and the maturity of their nervous system.
4. An over-emphasis on winning can be counter-productive to teaching the junior player the skills and strategies of the game, causing many to drop out.
5. Unless the coach's needs (perhaps for achievement, recognition, development of young talent or pride) are met, they are unlikely to remain involved in a coaching or support role for long. However, the needs of the child take priority.

Figure 6.12 Children are motivated to play sport to have fun.

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Coaching the beginner

How the coach approaches the task of coaching beginners will depend upon whether the beginners are children or adults.

Coaching the child beginner

The following are good general principles:

1 The focus in junior training should be on the development of individual rather than team skills.
2 Peers have a major influence on children's behaviour.
3 Children rarely see themselves as being responsible for their own learning.
4 Practice sessions should be short to cater for concentration and fitness levels.
5 Modify rules to reinforce basic skills.
6 Modify sporting equipment to suit smaller bodies.

Coaching the adult beginner

The following are good general principles:

1 Adults bring a vast array of life experiences – which may or not be helpful – to the learning situation.
2 Entrenched values may inhibit their behaviour.
3 Adults will reject the content of the instruction if it is poorly taught. They will have a higher level of expectation of success than children and may also have a higher level of anxiety because of their higher expectations.
4 Adults may also lack the physical flexibility to move freely through the full range of motions.
5 The commitment to learn may therefore be stronger in the adult as they are doing it for intrinsic reasons.
6 Feelings of apprehension, nervousness or being 'rusty' are some of the obstacles an adult may experience.
7 It is as important to the adult beginner, as it is to the child beginner, that they are able to enjoy success and achieve a feeling of self-worth.

Figure 6.13 Parents provide transport, equipment and moral support.

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Coursework

Design a modified game for a sport of your choice. Teach it to the class and have the class play it.

How would you change the sport for:

a 6-year-olds?

b the elderly?

How the coach can improve the athlete's skill development

discovery method
learning through self-exploration and collaboration as opposed to through teacher direction

Various alternatives are available to the coach in order to maximise resources:

- Individual work – Each performer works alone on a simple skill, with regular and constant feedback.
- Group work – Athletes are placed in small groups working on a common modified game skill.
- Partner work – The coach can assign a highly skilled athlete to a less skilled player and use them as an extra means of instruction/coaching.

The discovery method involves giving the beginner minimal instruction, providing the equipment and some safety instructions, and then letting them experiment to come up with the best method of performing an action or skill.

The progressive part method is generally used with complex skills and involves breaking the skill down into simpler parts that are learnt in sequence. The skill is then progressively put together.

The whole method is often used when the skills are simpler. The coach simply demonstrates the whole skill (a few times) then the players are asked to try it out for themselves.

In junior training, the focus should be on developing individual skills. As an individual's skill levels increase, a greater emphasis can be placed on the role they play within the team and how they work as a team.

Coaching the intermediate or middle-level performer

personal best
a performer's best recorded result or performance at a particular skill or activity

consolidating
to maintain and strengthen an established skill

1. Most athletes fall into this category.
2. Focus upon personal bests (PBs) rather than solely upon winning.
3. Setting smaller, achievable goals they can aim for in their training, and in the game, is one way of helping the athlete who decides to pursue a higher level of performance.
4. Variety can also serve as a powerful motivational tool.
5. Provide access to better equipment and regular and individualised coaching.
6. Coaching should focus on consolidating skills.
7. The athlete may have many other goals that are competing for focus on improving in the sport.
8. Be aware of plateaus in learning and how to help the athlete through them.

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Coaching elite athletes

Figure 6.14 *Elite athletes are usually very focused on achieving success.*

1 In the case of individual sports, the athlete is likely to have become fairly autonomous in terms of the training and skill practice.
2 Ensure that mental preparation is adequate since the physical preparation has become routine.
3 In the case of team games, the physical preparation sessions are often of longer duration and higher intensity (due to the superior level of fitness), and there is likely to be a greater variety of specialised sessions.
4 Cross-training may be a valuable tool to relieve boredom.
5 Continual practice of game skills is necessary to ensure that team strategies are implemented, game plans are rehearsed, and team cohesiveness is developed.
6 Active and passive recovery sessions will be factored in to give the body time to regenerate.
7 A coach at the elite level is more likely to have a range of resources available to assist them in the athlete's overall preparation (e.g. biomechanist, fitness and conditioning coaches, positional and skill coaches, a sports medicine team, sports psychologists, dieticians)

The elite athlete is typically very focused upon achieving success in their sport. Winning and being the best are very important. At this level, personal bests are also very important since the opportunities to pit themselves against the best in the world are infrequent. Personal bests also provide feedback, serve as a motivational tool and relate to goals that the athlete will have set.

Elite athletes will generally require less direct instruction and feedback from coaches. They will rely more heavily on internal feedback on how the movement felt, and what they perceive as needing to change. The modifications to movement are usually small.

KEEP IT REAL!

After Ian Baker-Finch won the British Golf Open, he decided that he needed to rebuild his swing in order to hit the ball further off the tee. This proved to be a costly mistake as he never really recovered and was forced to quit golf. Even the very best can lose it mentally.

www

Ian Baker Finch

TEST YOUR KNOWLEDGE

>> multiple choice

1 Extrinsic feedback refers to:

A coaches yelling instructions on how to improve
B use of joint analysis software
C GPS tracking of distance
D all of the above.

2 Children before the age of 12 should practise sporting activities as much as possible because:

A they have more time than adults
B they are more likely to improve fitness that remains long term
C the brain will shut down unused motor connections after this age
D two of the above
E all of the above.

>> short answer

3 Explain the difference between using feedback for juniors and elite athletes.

4 Choose two coaches who have opposing styles. Outline the different forms of feedback that you think would be used by each coach. Do they differ greatly?

>> essay style

5 After viewing your class for several practical lessons, write a report for your teacher summarising the feedback you would give to:

a each individual
b the group as a whole.

6 Explain the main reasons why different people learn skills at different rates.

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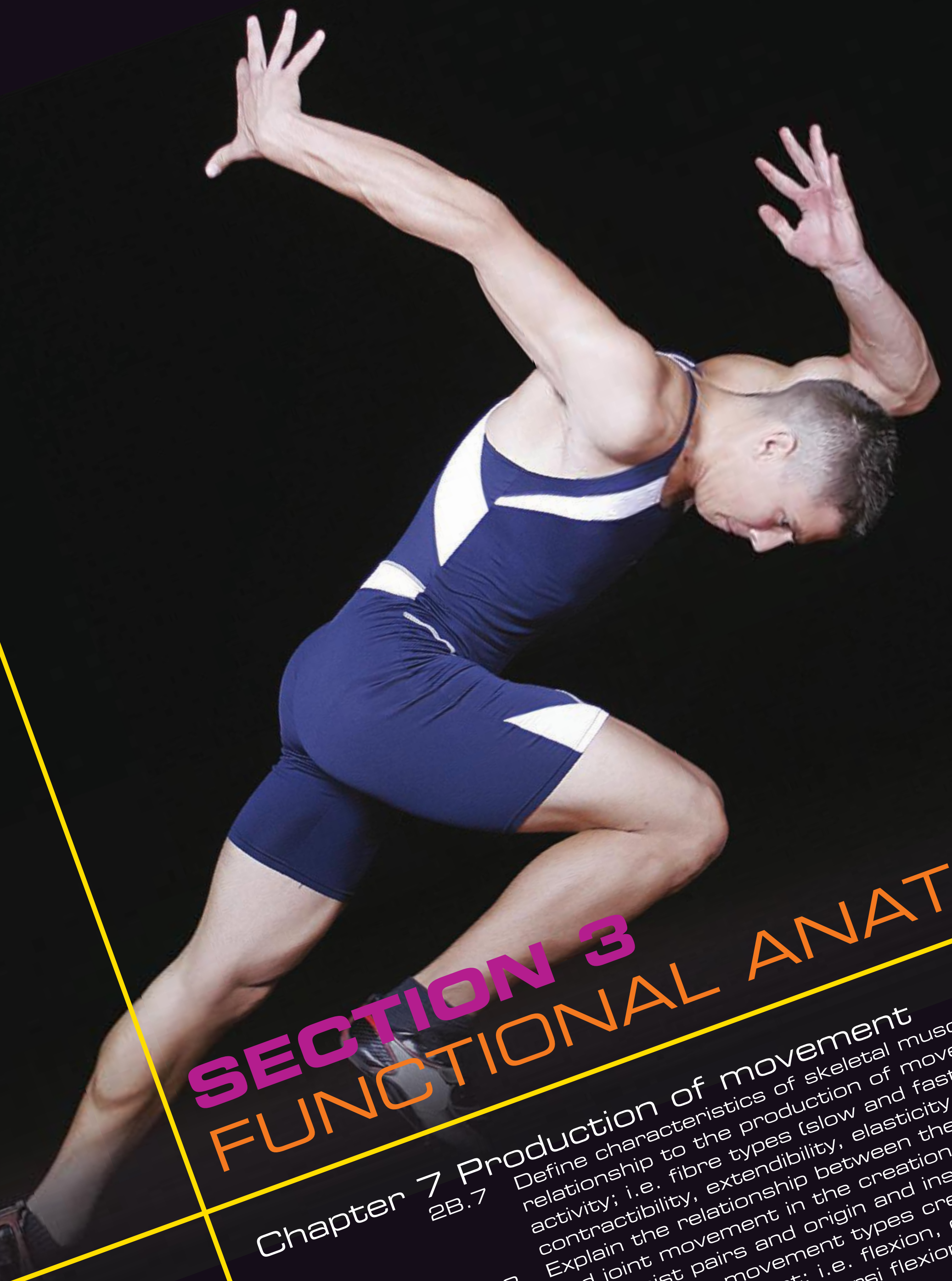

SECTION 3
FUNCTIONAL ANATOMY

Chapter 7 Production of movement

2B.7 Define characteristics of skeletal muscle tissue and their relationship to the production of movement for physical activity; i.e. fibre types (slow and fast twitch), excitability, contractibility, extendibility, elasticity.

2B.8 Explain the relationship between the musculoskeletal system and joint movement in the creation of movement; i.e. antagonist pairs and origin and insertion points of muscles.

2B.9 Describe the movement types created by muscle action and joint movement; i.e. flexion, circumduction, extension, supination, rotation, dorsi flexion, pronation, abduction, plantar flexion, adduction.

Chapter 8 Functional anatomy

Musculoskeletal system

2A.8 Understand the use of musculoskeletal structures in the production of movement and apply the correct anatomical terminology. Bones: humerus, radius, ulna, femur, patella, carpals, metacarpals, phalanges, tibia, fibula, pelvis, sternum, ribs, tarsals, metatarsals. Muscles: biceps, triceps, gastrocnemius, trapezius, deltoid, quadriceps, hamstrings, tibialis anterior, adductor group, latissimus dorsi, soleus, abdominals, gluteus maximus, pectorals.

Circulatory system

2A.9 Describe the structure and function of the circulatory system; i.e. heart, arteries, veins, capillaries, blood.

Chapter 9 Respiratory system

2A.11 Describe the structure and function of the respiratory system; i.e. lungs, diaphragm, alveoli and mechanics of breathing.

7 Production of movement

Characteristics of skeletal muscles

Types of muscle

Muscles within the human body are generally divided into categories that are determined by their function. There are three categories: skeletal, smooth and cardiac muscles.

Skeletal muscles

voluntary muscles
muscles that we can control to create movement

involuntary muscles
muscles that work without our conscious control

Skeletal muscles move the body. They attach to the skeleton and contract under the control of voluntary nerve impulses. Skeletal muscles are extremely powerful, and can contract with great force in a short time period.

In the case of highly skilled athletes, some of these movements are so automatic that they appear to happen without conscious thought.

We will consider skeletal muscles in Chapter 8.

Smooth muscles

Smooth muscles control many of the automatic movements that occur within our bodies. Control is involuntary, as they do not require conscious thought to enact movement. The digestive, respiratory and vascular systems all require smooth muscle contractions to complete their life-giving functions. Smooth muscles are far less powerful than their skeletal muscle counterparts, but they can contract almost indefinitely without noticeable fatigue.

Catchy fact
Muscles cannot push; they can only pull. That is why they occur as antagonistic pairs.

Cardiac muscle

Cardiac muscle is unique; it occurs at only one location – the heart. The structure of cardiac fibres means that they have characteristics that are common to both skeletal and smooth muscles. Cardiac muscle, like skeletal muscle, can contract very quickly, and is set up as a network rather than bundles structured to pull in a straight line. Cardiac muscle has the ability to contract without exhaustion for the entire length of a human life.

Characteristics of muscle fibre

Arrangement of muscle fibres, the way fibres are recruited, gender, age, level of fitness, heredity and whether or not they are fast or slow twitch, will determine the force of a contraction. The arrangement of muscle fibres will determine a great deal about the strength of muscle contraction.

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Arrangement of muscle fibres

Fusiform muscle fibres

Fusiform muscle fibres run parallel to the direction of the tendon. They generally occur on large limbs and allow larger, slightly weaker movements (lower force of contraction). Examples are the biceps brachii and gracilis.

tendon
cord of thick strong fibres that connects muscle to bone

Penniform muscle fibres

Penniform muscle fibres run at an angle to the tendon, creating much greater force over a short distance. The majority of skeletal muscles (75%) are made up of penniform fibres. The main benefit of having these muscle fibres aligned at an angle to the tendon is that tendons connect muscle to bone and usually cross a joint so that the associated muscle can cause movement at the joint.

Penniform fibres are of the following types:

- Unipennate muscle fibres only branch out on one side of the tendon.
- Bipennate muscle fibres branch out on both sides of the tendon.
- Multipennate muscle fibres branch out in many directions from a number of tendons.

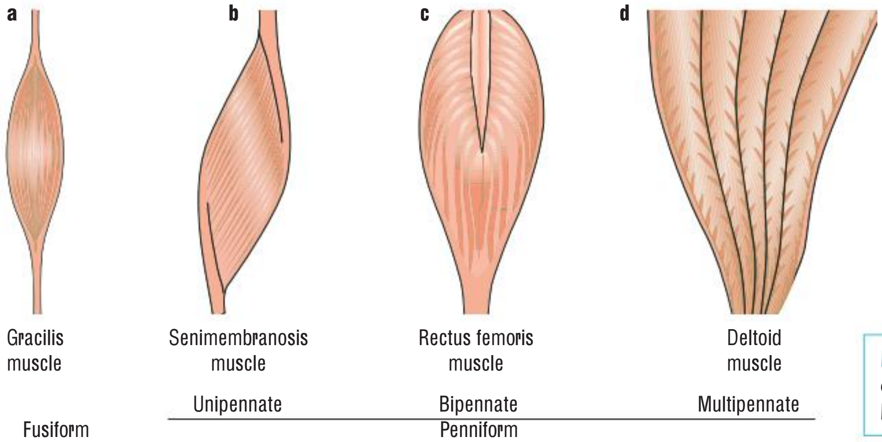

Figure 7.1 Arrangement of muscle fibres in four human muscle types

Table 7.1 outlines some characteristics of penniform and fusiform muscle fibres.

Table 7.1 The four types of muscle fibre/tendon alignments

Muscle fibre/tendon alignment	Key characteristics	Examples
Fusiform	Longer, weaker contractions Fibres run parallel to the tendon	Biceps brachii
Penniform unipennate	Fibres are arranged on one side of tendon at an angle to tendon	Semimembranosis
Penniform bipennate	Fibres branch out to both sides of the tendon	Rectus femoris
Penniform multipennate	Muscle fibres branch out in a network, forming a broader muscle	Deltoid

Muscle fibre types: slow or fast twitch?

Muscle fibre types relate to the speed with which they can contract. If we were to randomly remove muscle fibres from a single muscle in the body, we would find fundamental differences in both their colour and ability to generate repeated force (see Tables 7.1 and 7.2).

Muscle fibres can be classified into three main types. These are determined in part by genetics and in part by the type of training that an athlete does.

The three types are:

- Type 1 – slow twitch, oxidative, red
- Type 2A – fast twitch, oxidative, white
- Type 2B – fast twitch, glycolytic, white.

Slow-twitch and fast-twitch fibres are explained in Table 7.2. Type 2B fast-twitch fibres can be manipulated with long-term endurance training. This will help increase the aerobic capacity of the athlete by improving a muscle's capacity to perform repeated contractions. This may be advantageous to athletes in certain sports, where endurance is a key component (see Figure 7.2).

Once the benefit of the biochemical and functional characteristics is understood, it becomes easier to explain how they change in response to training. For example, oxidative enzymes increase the rate at which ATP is produced aerobically. It makes sense that these would increase in response to aerobic training to allow slow-twitch fibres to perform more effectively under these conditions. Conversely, phosphocreatine stores would increase as a result of ongoing anaerobic training and provide fast-twitch fibres with greater amounts of this fuel to perform high-intensity actions for longer before switching to other fuels.

Table 7.2 Characteristics of slow- and fast-twitch muscle fibres

Characteristic	Fast-twitch type 2B	Fast-twitch type 2A	Slow-twitch type 1
Performance conditions	Purely anaerobic	Partially aerobic	Aerobic
Colour	White	White	Red
Oxidative enzymes	Low	Medium	High
Myoglobin content	Low	Medium	High
Glycolytic capacity	High	High	Low
Mitochondria density	Low	Medium	High
Capillary density	Low	Medium	High
Calcium capacity	High	Medium/low	Low
Myosin ATPase	High	High	Low
Phosphocreatine stores	High	Medium/low	Low
Triglyceride stores	Low	Medium/low	High
Fibre diameter	Large	Intermediate	Small
Contraction speed	High	Moderate	Slow
Force capacity	High	Intermediate	Low
Fatigue resistance	Low	Medium/Low	High
Activities most suited to	Anaerobic and high-intensity activities		Aerobic and endurance activities
Force exerted	Exert great force in bursts of power and speed		Exert less force and can contract repeatedly

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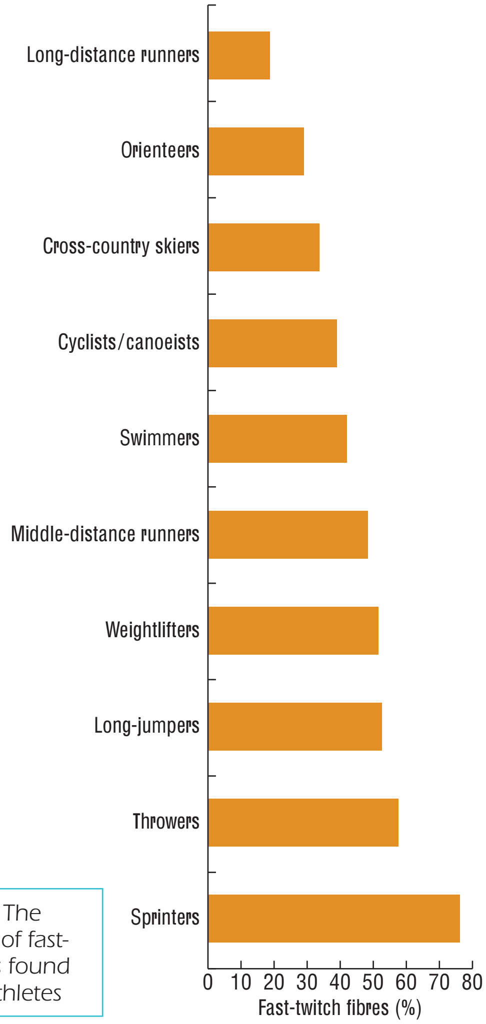

Figure 7.2 The percentage of fast-twitch fibres found in various athletes

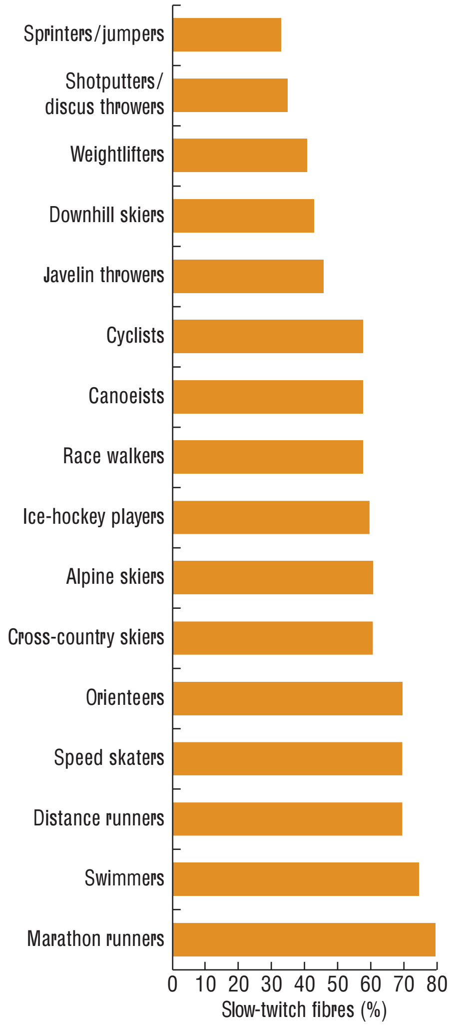

Figure 7.3 The percentage of slow-twitch fibres found in various athletes

Muscle power

Gender and age differences

In addition to the types of muscle fibre within our bodies, gender and age will also determine the strength and power of muscular contraction.

In general terms:

- Males have greater cross-sectional size of any given muscle, so females have about two-thirds (66%) of the strength.
- This lack of muscle bulk in females has the advantage of improving flexibility at a joint.
- Muscle strength normally peaks just before 30 years of age and then slowly declines.
- Young males have higher levels of testosterone, which results in larger muscle mass after puberty.
- Weight-bearing and fitness training can help minimise the effects of strength deterioration with age.

Excitability (irritability)

The mechanical muscular action of shortening or thickening (also called ‘contraction’) is activated by a stimulus sent through a motor nerve. All muscles are linked to nerve fibres that carry messages from the central nervous system.

Muscle excitability is the ability of a muscle to respond rapidly to a stimulus. The minerals magnesium and potassium both aid in this process. Magnesium helps maintain potassium levels in the cell. Potassium and magnesium help regulate the excitability of

excitability
the ability of a muscle fibre to respond rapidly to a stimulating agent

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muscle tissue, and the conduction of nerve impulses. This is especially important in cardiac muscles. As fatigue is the most common symptom in potassium and magnesium deficiency, ergogenic aids that contain these minerals can help improve performance. So where do we find good sources of potassium?

KEEP IT REAL!

From an Internet chatroom

My friend is in tennis and she says her coach told them they had to eat a lot of bananas. Why? Is it for potassium? What is potassium good for anyway?

It is for the potassium; it helps keep your muscles from cramping.

To give you a more detailed answer …

Bananas are great in a few ways:

- They contain high levels of fructose, which is a quickly digested and metabolised sugar for energy.
- They are very high in potassium.

Potassium does more than just stop the muscles from cramping. Potassium is responsible for the electrochemical balance in tissues of the heart and all other muscles and is the main healing element in the body.

KEEP IT REAL!

Astronauts

It is not just bone density that changes in space.

Prolonged weightlessness also results in a loss of muscle strength and volume, particularly in the legs. This can reduce spinal cord excitability, which can lead to loss of locomotor function in the legs. NASA scientists are studying spinal cord excitability to look at ways to reverse these effects of weightlessness while the astronauts are still in space.

www

Astronauts

Contractibility

contractibility
muscle cells can react to a stimulus by shortening, or decreasing their overall length

Contractibility (contractility) is where muscle cells react to a stimulus by shortening, or decreasing their overall length.

Whether slow or fast twitch, muscles fibres work the same way. When a muscle fibre receives a command from the brain, that muscle fibre either fires or doesn't fire. This is called the all-or-none principle. Additionally, when a muscle fibre fires, it contracts with all its strength. There is no range of effort for an individual muscle fibre. It either contracts completely or not at all.

We do not perform every activity flat out, with all our strength. Instead, our brain controls the overall strength and speed of movement by controlling the number of fibres it activates. If additional strength or speed is required to perform an exercise, the brain recruits more slow- and/or fast-twitch fibres. Additionally, fibres will contract as quickly as they can unless some external force slows them down. That is why we cannot move heavy weights as quickly as we can move lighter weights. The weights are heavy enough to slow down the speed of contraction.

Muscle fibres are activated by the brain as they are needed, generally slow-twitch fibres first and then more slow-twitch and fast-twitch fibres as needed. The more fibres activated, the faster and stronger the movement will be.

So why is this important?

Muscle contractibility controls performance

We can only improve contractibility with training. The only way to train muscle fibres is by activating them and working them hard. An untrained fibre will not improve. Unfired fibres

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are untrained. The brain will activate only the minimum number of muscle fibres needed to meet the needs of a particular exercise. If your exercise program does not cause a muscle fibre to be activated, that inactive muscle fibre will not improve.

If you want to improve your overall muscle contractibility, it is important to train all the muscle fibres you are capable of activating.

You can only do this by making sure you exercise hard enough so that you fire most or all of your fibres, and training those fibres at close to their maximum capacity. This should be the basis for any effective training program.

KEEP IT REAL!

Leroy Burrell

Training will not improve the speed of muscle contraction. As a high school student, American Leroy Burrell's fastest time in the 100 metres sprint was 10.43 seconds. As an adult, he set the world record in 1994 with a time of 9.85 seconds, an increase of only just over half a second and a less than 6% improvement.

Muscle contraction

Muscle tissue has a highly developed ability to contract.

Contractibility enables a muscle to become shorter or thicker, and this ability, along with interaction with other muscles, produces movement of internal and external body parts. Muscle contraction in a tissue or organ produces motion and provides power and speed for body activity. A contracting muscle is referred to as an agonist (prime mover). A muscle that is relaxing while a prime mover is contracting is called the antagonist.

agonist (prime mover)
the muscle that instigates movement by contracting

antagonist
the muscle that relaxes to allow the agonist to contract

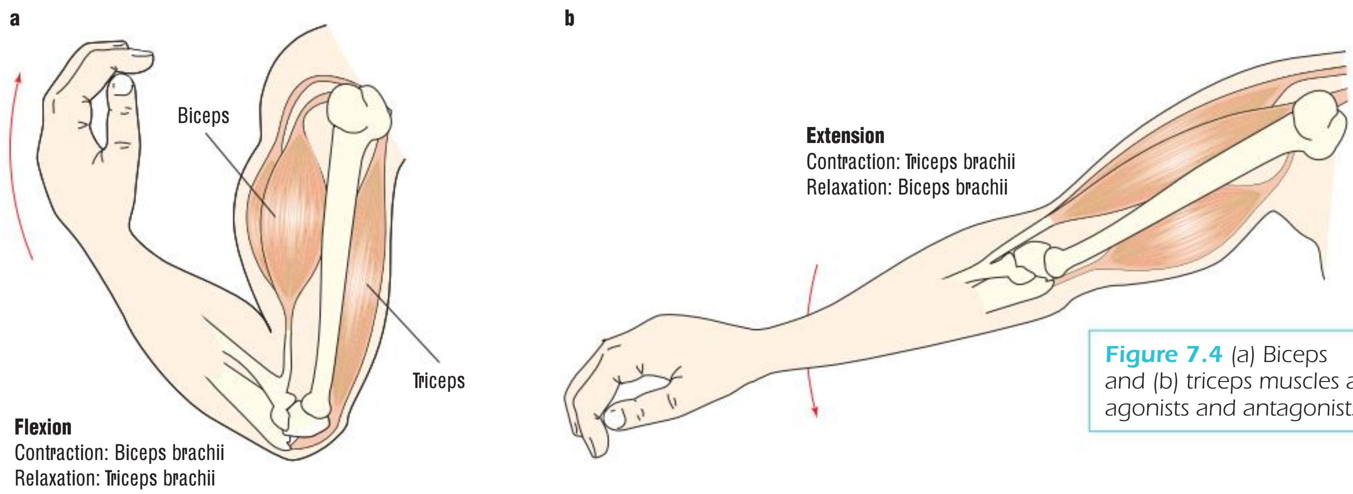

Figure 7.4 (a) Biceps and (b) triceps muscles as agonists and antagonists

Contraction and recovery

The chemical action of muscle fibres consists of two stages – contraction and recovery.

During contraction, two proteins (actin and myosin) react and energy is provided through the breakdown of glycogen into lactic acid. During recovery, oxygen reacts with lactic acid to form carbon dioxide and water. If contraction continues, the muscle cells will not recover. Waste materials such as lactic acid and carbon dioxide build up and the muscle can be permanently damaged (muscle fatigue). Muscles need rest to allow the blood to carry away the waste materials and bring in fresh glucose, oxygen and protein. Toned muscles are firm because they are in a continual state of partial contraction.

muscle fatigue
when a muscle contracts, it produces chemical waste products (carbon dioxide, lactic acid and acid phosphate) which make the muscle more irritable; continued contraction causes the muscle to cramp and refuse to move

Extendibility and elasticity

(extendibility) extensibility
the ability of a muscle to be stretched or extended without damage to the tissue

elasticity
the ability of cells, surfaces and objects to 'give' and then return to their original state or shape

Extendibility (extensibility) and elasticity are closely related. Muscles are capable of stretching when force is applied (extendibility) and regaining their original form when that force is removed (elasticity).

Flexibility is highly specific, and very sensitive to regular maintenance. This means that athletes must maintain strength and flexibility through movements that encompass the full range.

Maintaining muscle tissue

Any movement of the muscle will cause its blood supply to increase. The additional blood brings in fresh nutrients and carries away wastes more rapidly, and the muscles can build up and restore their efficiency and tone. Although exercise is important for normal muscle function, excessive muscle strain is damaging and can lead to tearing. The resultant scar tissue can limit the future performance of that muscle.

Muscle quiz

Muscles and muscle contraction

Coursework: Internet activities

1. Work in pairs, each partner developing a list of 10 questions about the muscular system. Use at least three Internet sites to find your information.

   Your questions could include trivia facts or questions about:

   - voluntary and involuntary muscle movement
   - types of muscles
   - types of contractions
   - muscle fatigue.

   Swap questions with your partner, providing them with a list of links where answers to the questions may be found.

2. Use the Internet to research muscular dystrophy. Write a one-page paper that explains the different forms of this disease, its symptoms, medication used to treat symptoms, age at onset, possible effects on other body symptoms and other relevant facts.

How muscles help us move

origin
the point at which the muscle joins the non-moving bone

insertion
the point at which the muscle is attached to the moving bone

ligament
a tough band of connective tissue that connects various structures such as two bones

The origin and insertion of a muscle are its two attachment points on the skeleton. The origin and insertion combined with the muscle will bridge a joint, and the resultant contraction will alter the angle at that joint, creating movement.

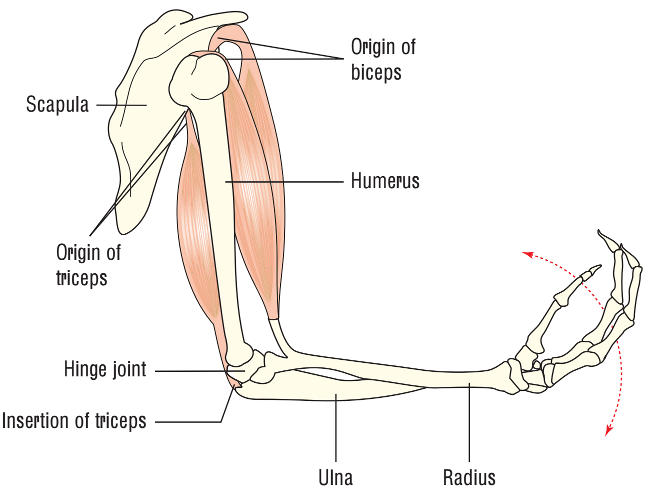

Figure 7.5 Muscle origin and insertion

A muscle crosses a joint in the body, and once it shortens, it changes the position of the joint. The muscle can attach to a bone either directly or via a tendon. A tendon allows the muscle to reduce its overall mass, but still allows it to span a large limb.

Muscle bulk can increase (hypertrophy) through weight-training. However, the skeleton and ligaments underneath remain as they were before the increased muscle bulk. Hanging more muscle on the same frame can create problems.

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Muscles in action

Table 7.3 shows some typical joints and movements involved in a forearm pass in volleyball.

Table 7.3 Volleyball forearm pass (dig)

Phase	Skill description	Joint type	Bones that make the joint	Movement	Muscle involvement
Preparation	Knees bent Arms make platform Eyes on ball Arms extended out in front	Ankle – gliding Knee – hinge Hip – ball and socket Wrist – gliding Elbow – hinge Shoulder – ball and socket	Tarsal, fibula Femur, tibia, fibula, patella Femur, pelvic girdle Carpals, ulna, radius Humerus, radius, ulna Humerus, scapula, clavicle	Dorsi flexion Flexion Flexion Extension Extension Extension	Tibialis anterior Hams group, gastrocnemius Quads group Hand and finger extensors Triceps Deltoid, latissimus dorsi, trapezius
Contact	Ball contacts on both arms Legs bent on contact then push up to extend Contact on arms between elbows and wrist Arms straight and still Point where you want the ball to go	Ankle – gliding Knee – hinge Hip – ball and socket Wrist – gliding Elbow – hinge Shoulder – ball and socket	Tarsals, fibula Femur, tibia, fibula, platella Femur, pelvic griddle Carpals, ulna, radius Humerus, radius, ulna Humerus, scapula, clavicle	Plantar flexion Extension Extension Extension Extension Extension	Gastrocnemius Quads group Gluteal group, hams group Hand and finger extensors Triceps Deltoid, latissimus dorsi, trapezius
Follow through	Arms follow in the direction of the ball Ball has high arc to the person who is going to set	Ankle – gliding Knee – hinge Hip – ball and socket Wrist – gliding Elbow – hinge Shoulder – ball and socket	Tarsals, fibula Femur, tibia, fibula, patella Femur, pelvic griddle Carpals, ulna, radius Humerus, radius, ulna Humerus, scapula, clavicle	Plantar flexion Extension Extension Extension Extension Extension, elevation	Gastrocnemius Quads group Gluteal group, hams group Hand and finger extensors Triceps Deltoid, trapezius, latissimus dorsi

Source: Fiona Wilkinson, Kings Way Christian College, 2009

Checkpoints

1 What problems can you foresee in having greater muscle mass on the same skeletal frame?

2 What are the main reasons for gender differences in muscular strength and power?

3 List the four types of muscle fibre/tendon alignment patterns and suggest reasons for the location of each within the body.

4 Identify two sports that would benefit from long-term endurance training to modify muscle fibre types.

Coursework: Laboratory activity

Temperature, fatigue and muscle contractibility

Materials

Narrow strip of paper that will fit around your upper arm; outdoor thermometer or laboratory thermometer; rubber ball or spring clothes peg; large bowl; clock, watch with second hand or stopwatch; water; ice

PART A: MUSCLE ACTION

1 Place your fingers along the angle of your jaw just in front of your ear. Grit your teeth, and feel what happens to the hardness of the muscles in your cheek.

2 With the thumb and little finger of one hand, span the opposite arm's biceps (front muscle of the upper arm) from the elbow to as close to the shoulder as possible. Bend the arm, and observe the change in the length of the muscle.

3 Wrap a strip of paper around your upper arm, and mark the circumference of your arm on the paper. Clench your fist tightly, and bend your arm to contract the muscle. Mark the new circumference on the paper. Observe what happens to the circumference of the muscle when it is contracted.

PART B: EFFECT OF TEMPERATURE ON MUSCLE ACTION

1 Measure the air temperature in the room with the thermometer. Record this in Data table 1.

Count the number of times you can make a fist in 20 seconds. Start with your hand completely outstretched, and make a tight fist each time. Do it as rapidly as you can. Record the count in Data table 1.

2 Partly fill the bowl with cold water. Place the thermometer in the water. Add ice to the water until the temperature is near freezing (0°C). Record the water temperature in Data table 1. Now submerge your hand in the water, and leave it there for a full minute.

3 Remove your hand, and immediately count how many forceful fists you can make in 20 seconds. Record the result.

Data table 1. Effect of temperature on muscle action

	Temperature (°C)	Number of fists in 20 s
Air		
Ice water		

PART C: EFFECT OF FATIGUE ON MUSCLE ACTION

1 Count how many times you can tightly squeeze a rubber ball in your hand in 20 seconds. (Alternatively, count how many times you can open and close a spring clothes peg with the thumb and index finger while the other fingers are held out straight.) Record this result in Data table 2 for trial 1.

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2 Repeat the squeezing test for nine more 20-second trials, and record your results in Data table 2. Do not rest between trials.

Data table 2. Effect of fatigue on muscle action

Trial number	Number of contractions in 20 s
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	

Questions

1 In Part A, what are the three changes you observed in a muscle while it is working (contracted)?

2 What effect did the cold temperature have on the action of your hand muscles in Part B? Explain.

3 Make a line graph of your results of the fatigue experiment in Part C. Plot trials 1–10 on the horizontal axis, and number of contractions performed on the vertical axis. Choose a scale that will allow you to graph all your results in Data table 2. Plot a point for each trial's result, and draw a line connecting the points.

4 What does the graph show about the results of the experiment?

5 What effect did fatigue have on the action of your hand muscles? Explain.

What's going on?

A contracting muscle can be observed to get harder, shorter and thicker (the circumference increases). When it is cold, the muscles become stiff and slow. The graph should show a decline in muscle activity, represented by a line that slopes downward from left to right. The line is not usually steady or straight, and occasionally it will show a slight rise after a decline. Fatigue slows the action of hand muscles for two reasons. The muscles are using up oxygen faster than it is being supplied to them, and there is a toxic effect from a build-up of waste products (carbon dioxide and lactic acid) in the muscle tissue.

Muscles move in pairs

An agonist (prime mover) muscle is the instigator of movement. It contracts to change the angle at a joint. This can only occur when the antagonist partner relaxes sufficiently to allow the prime mover to work (see Figure 7.4). The antagonist can resist the prime mover, and stop the movement entirely. Sufferers of cerebral palsy often have major problems with coordinating movements because of the opposing forces of these pairs of muscles. The rigid

fixation muscle steadies one body part to allow another to initiate its movement from a stable base

synergistic muscle controls intermediate joints, allowing the distal prime mover and antagonist to generate maximum force

movements of some extreme sufferers illustrate the mixed neural messages that are causing muscle pairs to oppose each other. In a milder form, these awkward movements appear as tremors where the limbs move with a 'shaky' appearance.

A fixation muscle steadies one body part to allow another to initiate its movement from a stable base. Imagine trying to do a push-up aimed at working out biceps and pectoralis, without first tightening the abdominals and erector spinae group. Without a rigid torso, this movement would not be possible.

A synergistic muscle controls intermediate joints, allowing the distal prime mover and antagonist to generate maximum force. Think of a fast bowler in cricket. The wrist uncocking is the final link in the movement chain, but it can only occur once synergistic muscles have acted on intermediate joints to allow maximum speed at the wrist.

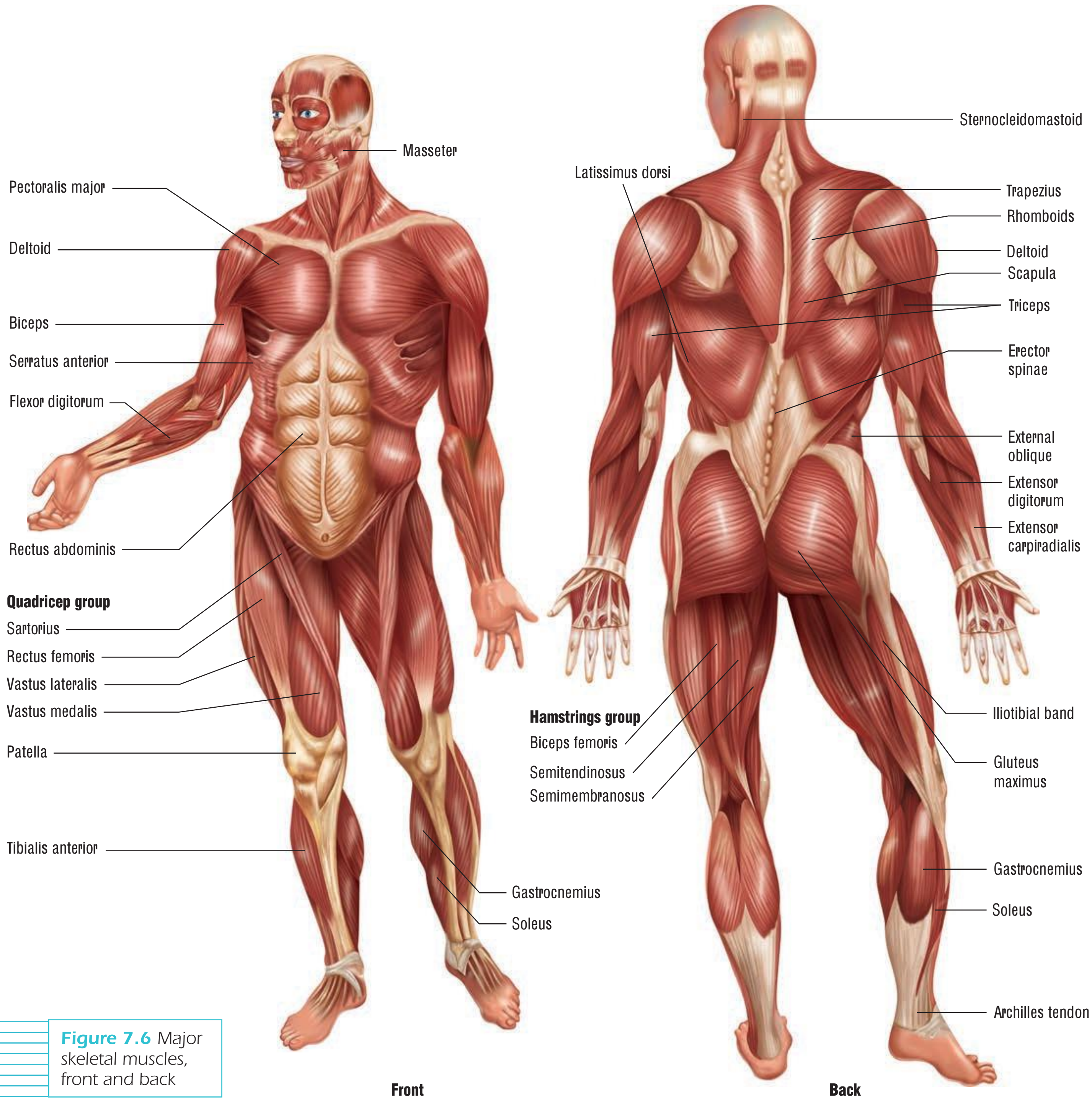

Figure 7.6 Major skeletal muscles, front and back

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Coursework

Using Figures 7.4 and 7.6, attempt to match up agonists and antagonists, and describe the primary movement that you have used to determine which is which.

Draw up a table in your notebook with columns as shown below.

Movement	Agonist	Antagonist

Joints

Types of joints

Any place in the body where two bones meet forms a joint. Joints are classified according to their structure and function: synovial (freely moveable), cartilagenous (partially moveable) and fibrous (immoveable or fixed). Some of these joints are described in Table 7.4.

Table 7.4 Types of joints

Joint	Movement	Position
Synovial	Freely moveable	
Hinge	Has only one axis and allows only flexion and extension	Knee, elbow, fingers, toes, lower jaw to cranium
Pivot	Has only one axis and allows only rotation	Elbow: two lower arm bones Skull on vertebral column
Gliding	Allows sideways, backwards and forwards movements	Wrist, ankle
Ball and socket	Able to move in all directions (forwards, backwards, sideways, rotation)	Shoulder, hip
Saddle	Is bi-axial and allows sideways, backwards and forwards movements	Thumb (carpal and metacarpal), ankle
Ovoid	Has two axes and allows sideways, backwards and forwards movements	Wrist
Cartilaginous	Partially moveable	Vertebrae, ribs to sternum and vertebrae
Fibrous	Immoveable	Skull, vertebrae in sacrum and coccyx, sacrum

Adapted from Getchell *et al.* 1994

Fixed joints

These are the minority of joints within the body. The bones of the skull form a fixed joint.

Moveable joints

Moveable joints can be synovial, cartilagenous, condylar or cushioned (e.g. spine). Synovial joints are further classified as:

- hinge
- pivot
- gliding
- ball and socket
- saddle
- ovoid.

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Synovial joints

Most of the commonly found joints are made up of cartilage covering the ends of the bones, combined with a lubricating fluid known as synovial fluid.

synovial fluid
a transparent, protein-rich, sticky fluid that lubricates joints and nourishes the cartilage in a joint; also found in tendons, sheaths and bursae

Damage to many joints is caused by tearing of cartilages, causing swelling and bleeding in the joint. Modern surgical techniques use lasers to disintegrate mild tears. The recovery period may only be a matter of days, and return to competition can occur within a week.

The pressure inside a synovial joint is lower than that of the surrounding air. So air pressure pushes the bones together tightly into the capsule, while the fluid keeps them from actually touching. This ensures a tight joint but still gives a slight separation of the surfaces due to the fluid lubricant.

Synovial fluid has another important quality. Most bodily tissues are nourished by blood vessels, but the cartilage on bone-ends in joints does not have blood vessels. Synovial fluid provides the nutrition for the cartilage that keeps it strong and healthy.

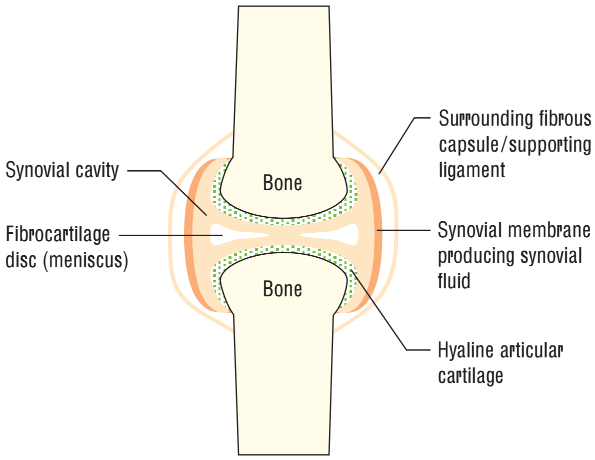

Figure 7.7 Generalised structure of a typical synovial joint

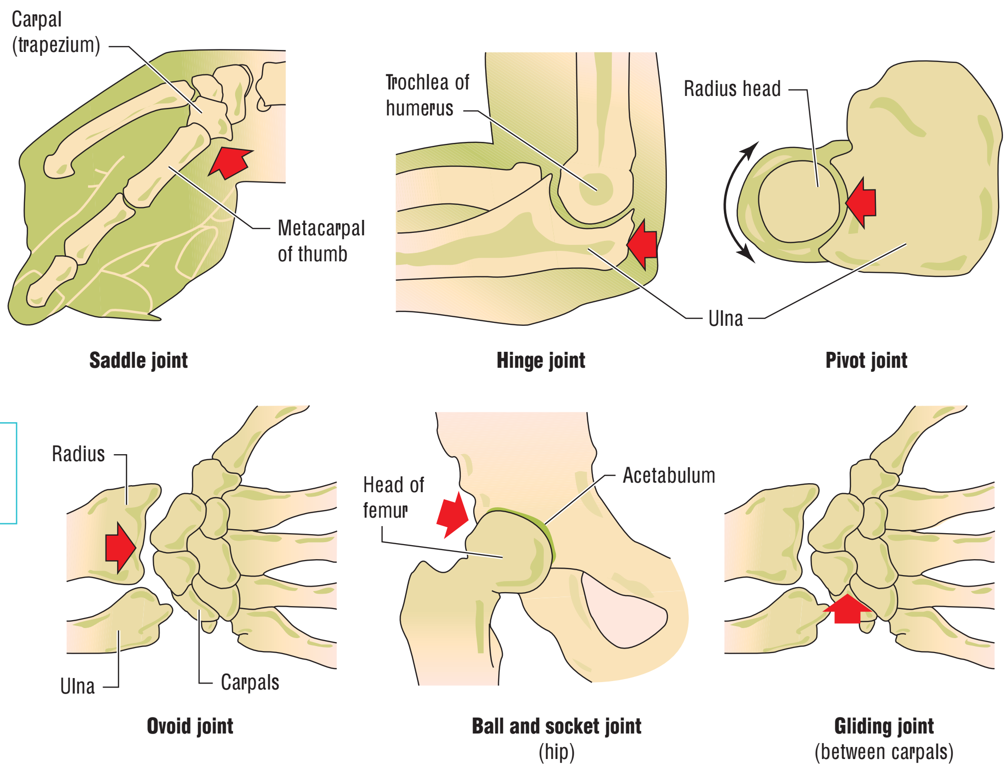

Figure 7.8 Classification of synovial joints

Gliding joints

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Hinge joints

These joints only have the ability to open and close in a single direction. The most commonly recognised hinge joint is the knee. The femur sits on top of the tibia and is cushioned by cartilage, and strengthened by ligaments and muscles crossing the joint.

cartilage
fibrous but flexible connective tissue, usually with no blood or nerve supply

Figure 7.9
Hinge joint

Pivot joints

These joints allow one bone to pivot on another. This means that there is a twisting movement allowed about an axis of rotation. The radius and humerus at the elbow joint form a pivot joint.

Gliding (sliding) joint

A gliding joint allows movement at two flat bony surfaces.

Ball and socket joint

This joint allows for great range of movement, such as the hip or shoulder.

Figure 7.10
Gliding (sliding) joint

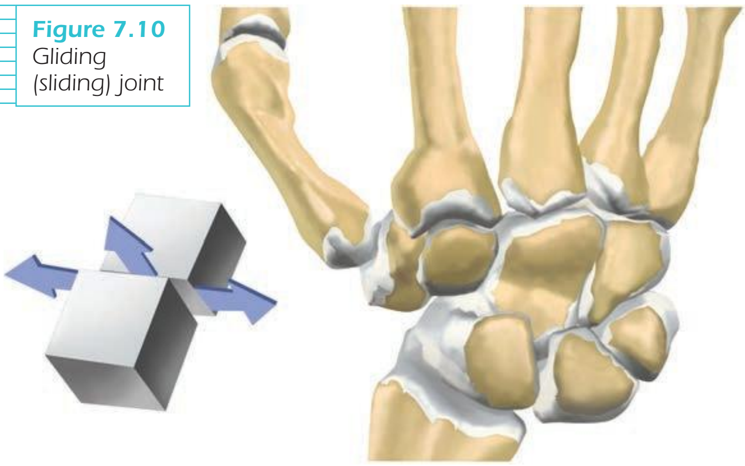
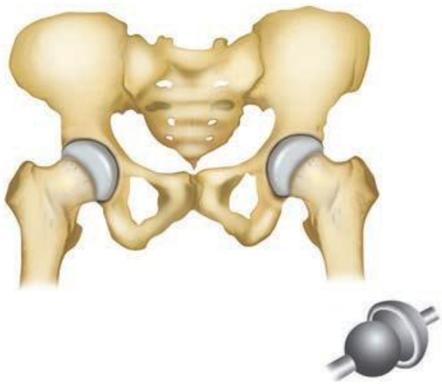


Figure 7.11
Ball and socket joint



Saddle joint

This joint allows for back and forth movement and up and down movement.

Ovoid joints

In this joint, the articular surface is egg-shaped.

Cartilaginous joints

These are partially moveable joints that are held together firmly by cartilage. Ribs are attached to the sternum via cartilage. The cracking and creaking noise made when a rescuer is performing external cardiac compressions on a victim is caused by this cartilaginous joint being compromised.

Fibrous joints

Fibrous joints are connected by thick connective tissue, consisting mainly of collagen. Fibrous joints have no cavity as in a synovial joint. The bones are joined by fibrocartilage (e.g. pubic symphysis, intervertebral discs).

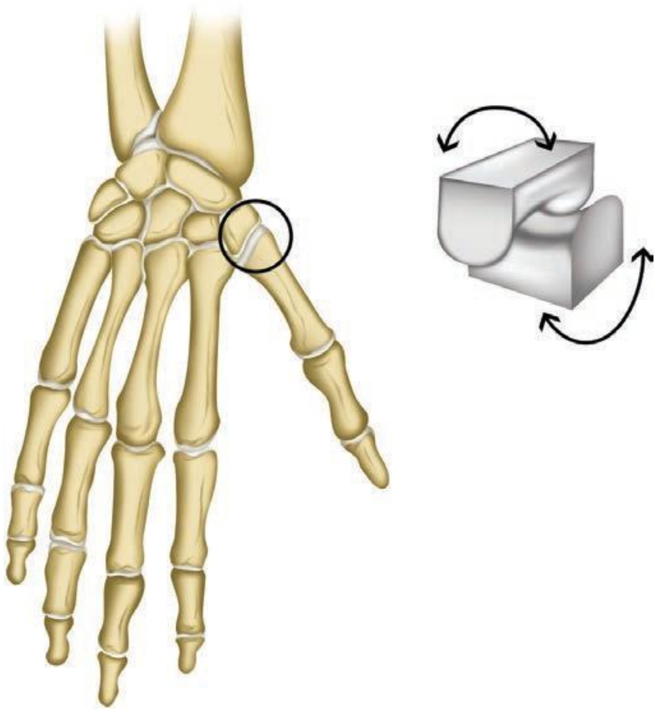


Figure 7.12 Saddle joint

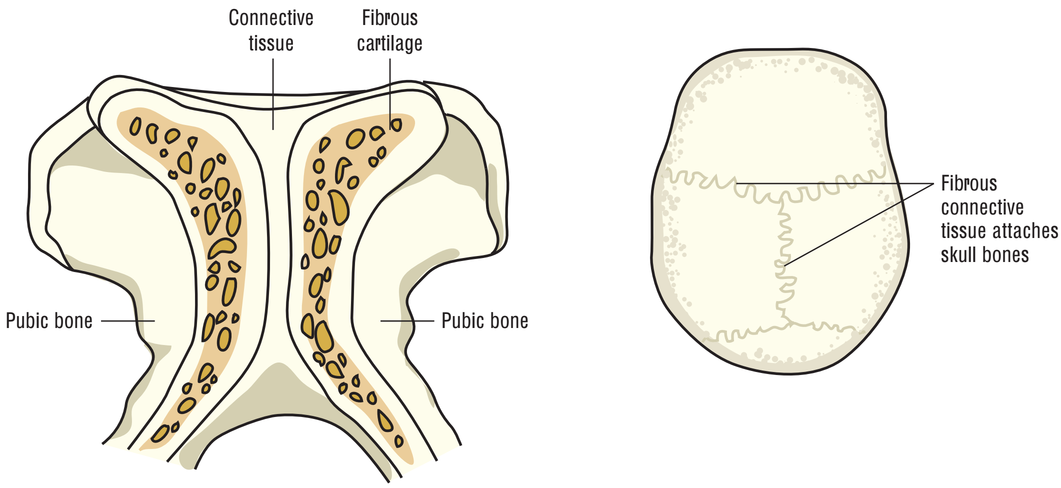


Figure 7.13 (a) Fibrous joint in pubic bone; (b) fibrous connective tissue attaching skull bones

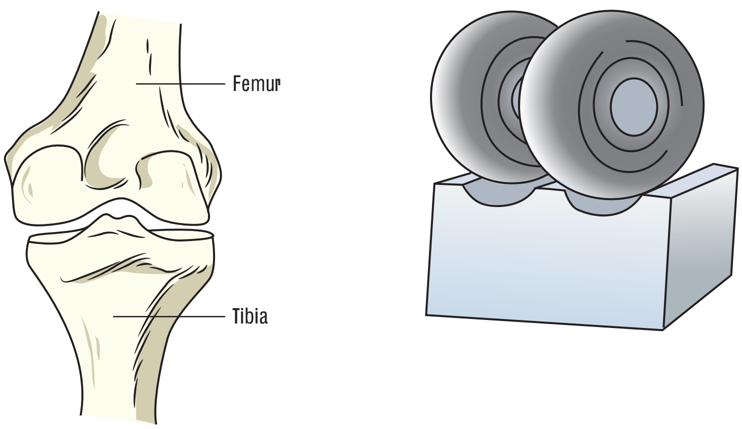


Figure 7.14 Condylar joint

Condylar joint

In a condylar joint (ellipsoidal joint), an ovoid (oval or egg-shaped) articular surface (a condyle) moves in an elliptical cavity of another bone. This allows movement in many planes, with the exception of rotation and circumduction.

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Coursework

Looking at Table 7.4 (pp. 119), and working with a partner, answer the following.

1 Choose five joints that are used in your sport. 'Guesstimate' the range of movement of your partner at the specified joint. Was your partner's movement greater than, less than or equal to each guess?

What physiological characteristics do you think would be advantageous in the sport you have chosen regarding joint movement?

2 Why do you think there are differences that mean women are consistently more 'flexible' than men?

3 See if you and your partner can list one type of exercise and one type of stretch that may help improve the movable joints in the body.

Types of movement

Table 7.5 lists and describes muscle movements. They are also illustrated in Figures 7.15–7.20.

Table 7.5 Description of movements

Movement	Description
Flexion	Joint angle is decreased (i.e. bending)
Extension	Joint angle is increased (i.e. straightening)
Rotation	Moving a body part inwards or outwards, pivoting around its long axis
Circumduction	Cone-shaped rotation around a pivot point
Adduction	Returns a body part to the midline
Abduction	Takes a body part away from the midline
Pronation	Moving hands into a palm-down position
Supination	Moving hands into a palm-up position
Eversion	Tilting the sole of the foot outwards
Inversion	Tilting the sole of the foot inwards

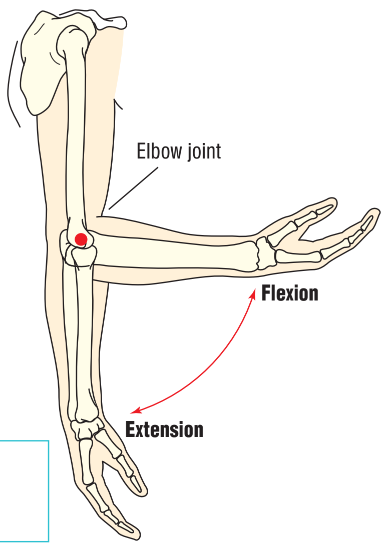

Figure 7.15 Flexion and extension

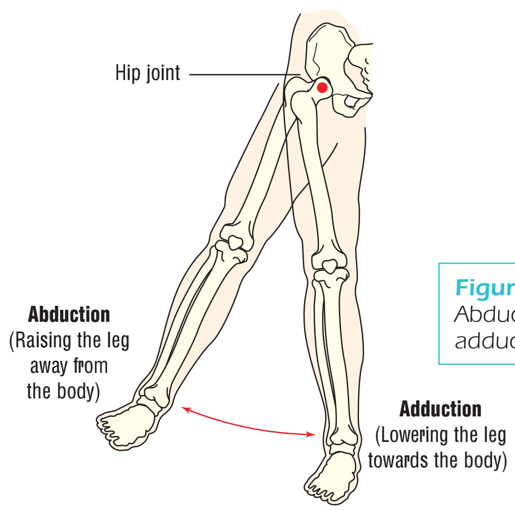

Figure 7.16 Abduction and adduction

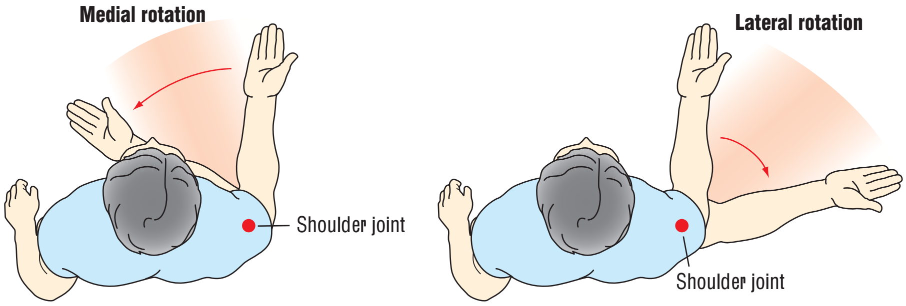

Figure 7.17 Lateral and medial rotation

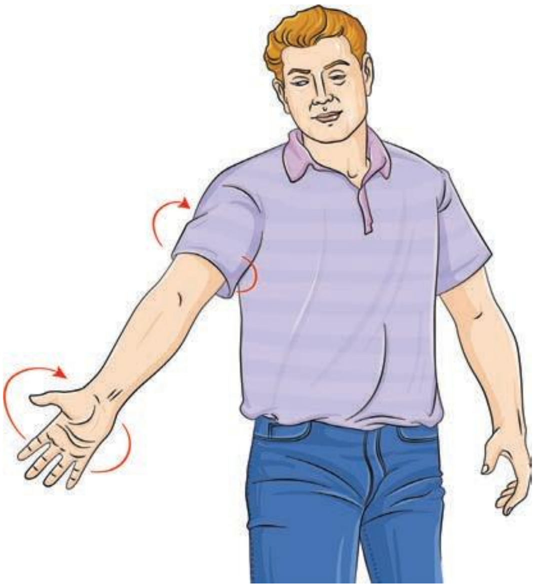

Figure 7.18 Circumduction of the upper limb at the shoulder joint results in the arm moving in a circular motion.

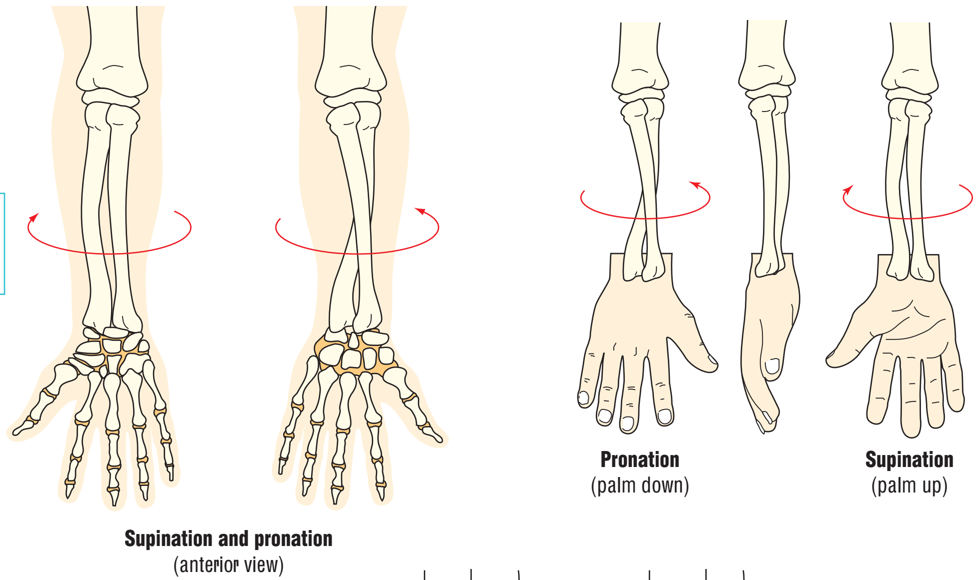

Figure 7.19 Supination and pronation of the forearm

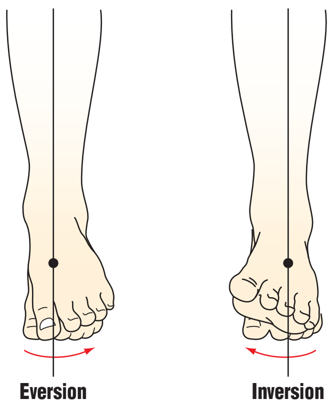

Figure 7.20 Eversion and inversion of the feet

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TEST YOUR KNOWLEDGE

>> multiple choice

1 _________ and _____________ are the two properties of muscles.

- **A** Lactic acid, contractibility
- **B** Fatigue, irritability
- **C** Irritability, contractibility
- **D** Isometric, isotonic

2 The backswing of kicking a soccer ball can be described as:

- **A** extension at the thigh, flexion of the lower leg
- **B** flexion at the thigh, extension of the lower leg
- **C** eversion at the thigh, extension of the lower leg
- **D** inversion at the thigh, flexion at the lower leg.

3 Which of the following is a ball and socket joint?

- **A** Elbow joint
- **B** Shoulder joint
- **C** Radio-ulnar joint
- **D** Wrist joint

4 The all-or-none principle refers to:

- **A** when a muscle fibre receives a command from the brain, and that muscle fibre either fires or it doesn't fire
- **B** the recruitment of muscle fibres being based on proximal elongation in a sagittal plane
- **C** when a muscle fibre receives too much potassium, causing it to cramp
- **D** when a muscle is overloaded to the point that it will either cope with the demands or it won't.

5 If the agonist was the quadriceps group, the antagonist would be the:

- **A** rotator cuff group
- **B** extensor group
- **C** hamstring group
- **D** gluteal group.

6 Which of the following is not one of the recognised types of muscle?

- **A** Agonist
- **B** Cardiac
- **C** Smooth
- **D** Skeletal

>> short answer

7 Identify and describe the different arrangements of muscle fibres.

8 Explain the relationship between training types and fast-twitch and slow-twitch muscle fibres.

9 How does exercise help you? When can it be dangerous?

10 Select the limbs of the upper or lower body, and classify and discuss three types of joints present.

>> essay style

11 Explain what is meant by contractibility, excitability, elasticity and extendibility.

12 If you were asked to prepare an exercise program for an overweight neighbour who used to play tennis, what considerations would you need to make regarding care of the relevant joints and muscles in order to avoid chronic injuries and poor motivation?

8 Functional anatomy

Functional anatomy involves the nomenclature (naming) of body parts and the way in which body systems operate for our everyday, healthy existence. The names of bones, muscles, joints, organs and nerves have evolved from their individual shape, structure and function. In many cases, the study of anatomy revolves around rote learning of key simple and complex terms.

In the case of the microstructure and mechanics of muscle action, the concepts can be more difficult to grasp. The sheer quantity of muscles, attachments and bones can make even the naming of anatomical parts seem a massive task.

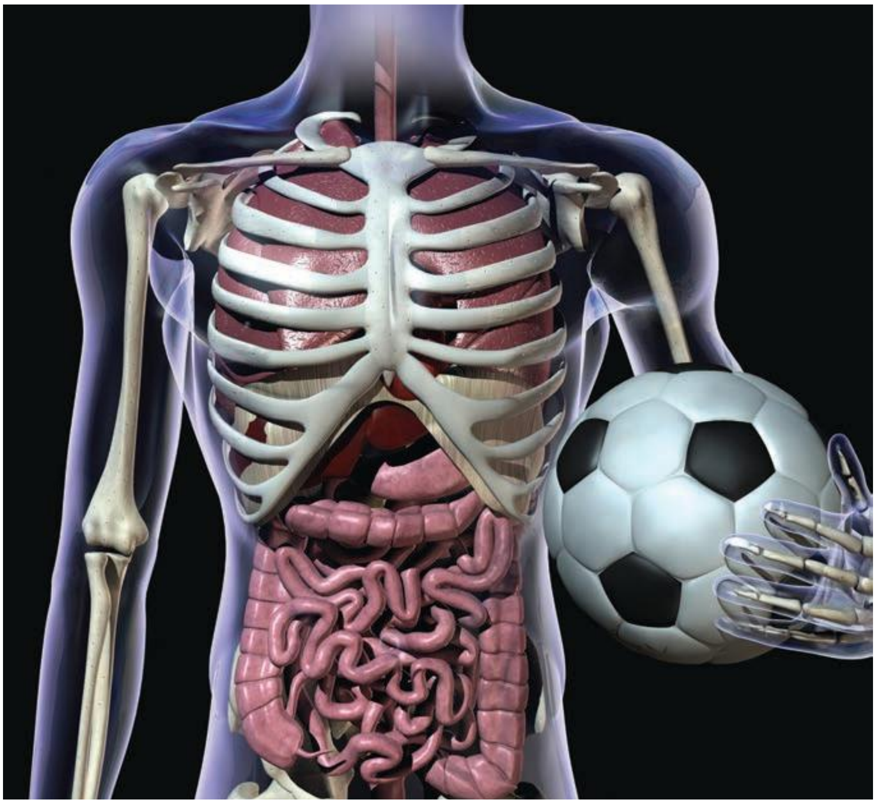

Figure 8.1 Part of the musculoskeletal system

The human skeleton

Anatomical terminology

We need to be able to accurately describe movements and positions of limbs in order to relay information on sports performance. Standard terminology is used to avoid confusion.

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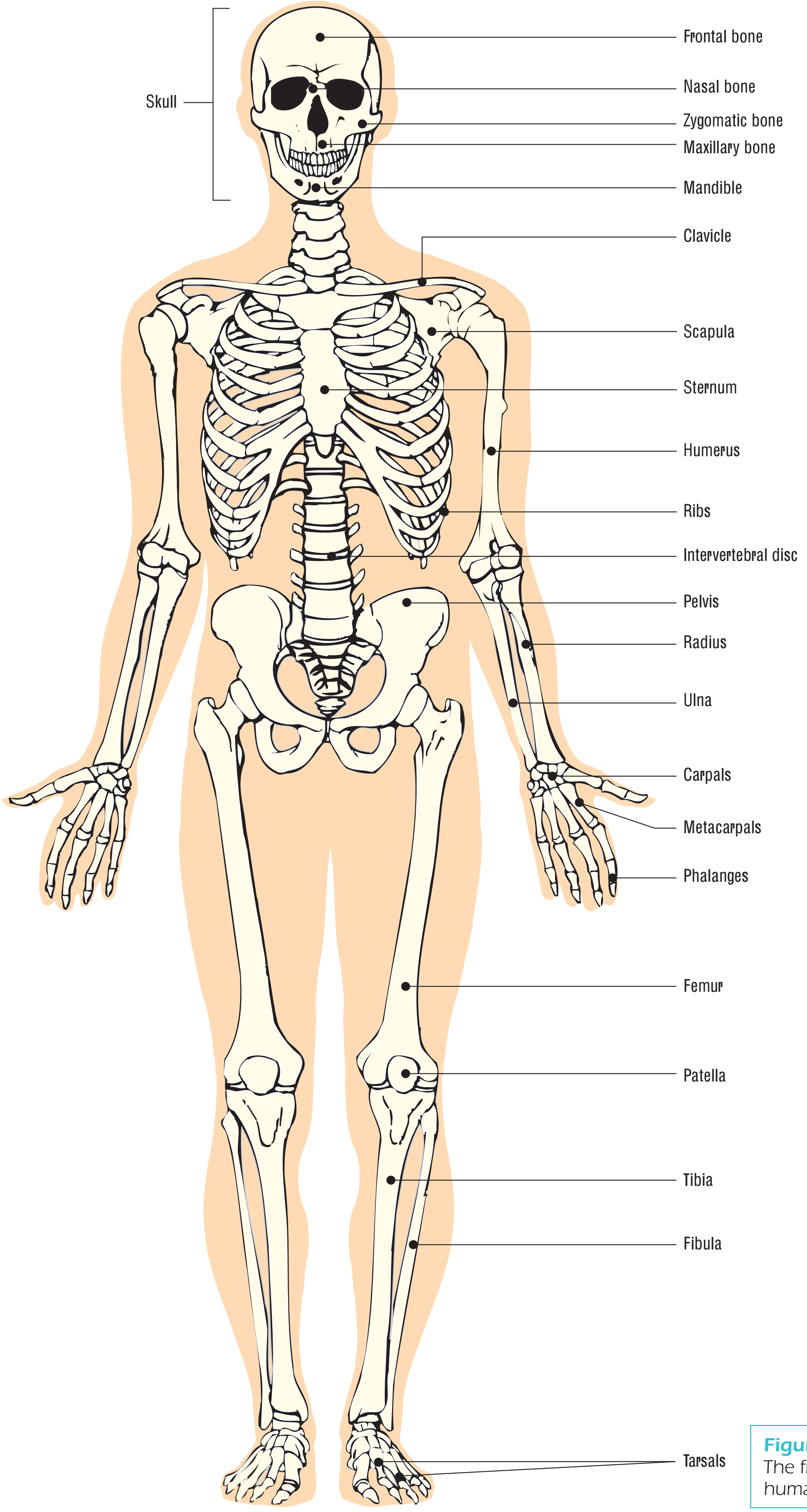

Figure 8.2
The front of the human skeleton

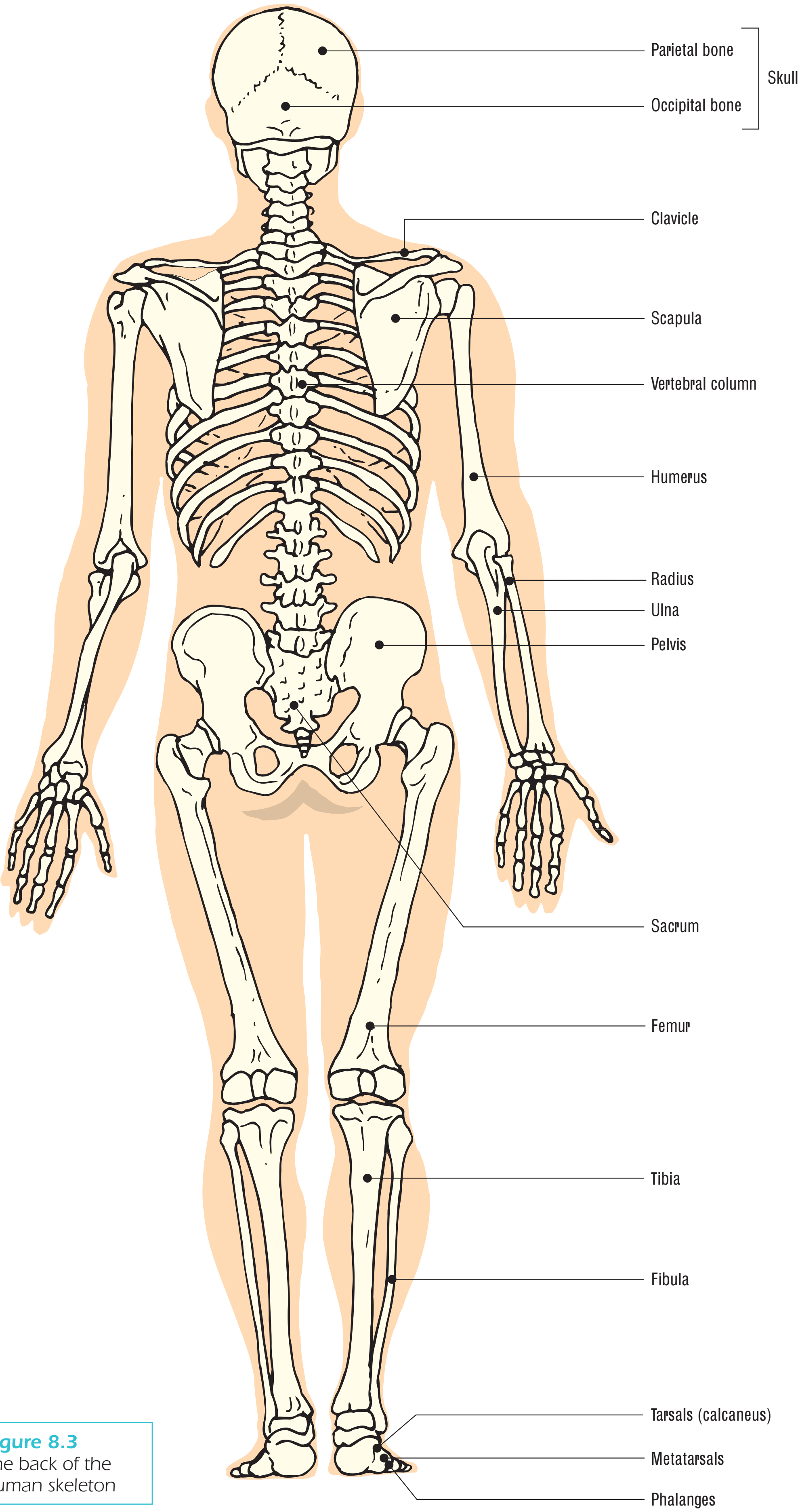

Figure 8.3
The back of the human skeleton

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In general, a standard beginning reference position is used. This is known as the anatomical position and refers to standing upright, palms facing forwards with thumbs out. All anatomical terms are then described with the body in this assumed position.

General terms used	
Medial–lateral	Near the midline – away from midline of body
Anterior–posterior	Forward–backward
Superior–inferior	Upward–downward
Superficial–deep	Nearer to the surface – further away from the surface of the body
Distal–proximal	Further away from the attachment point of a limb – closer to the attachment point of a limb
Plantar–dorsal	Sole of foot – top of foot
Palmar–dorsal	Palm of hand – back of hand

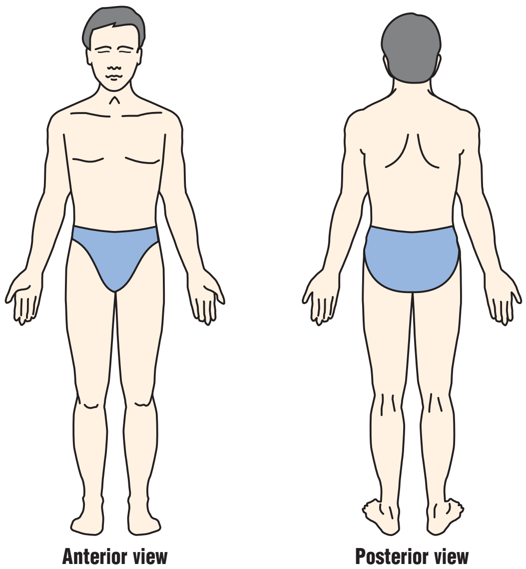

Figure 8.4 The anatomical position. Anterior view and posterior view

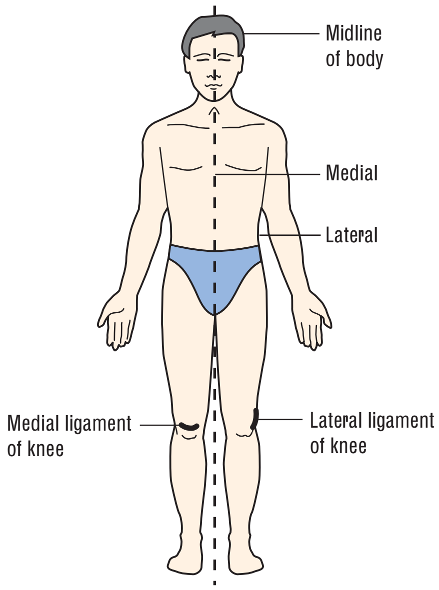

Figure 8.5 Medial (front) and lateral (behind) directions

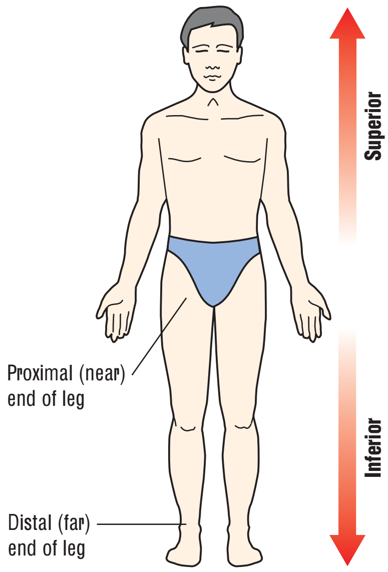

Figure 8.6 Superior, inferior, distal and proximal anatomical positions

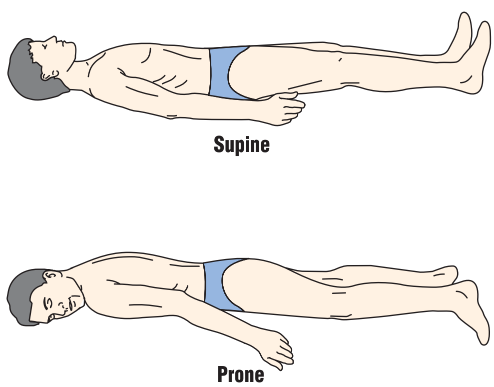

Figure 8.7 Supine (on back) and prone (on front) positions

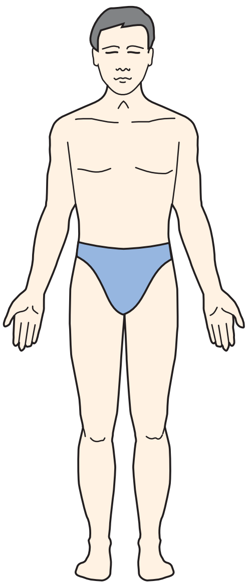

Figure 8.8 Frontal plane

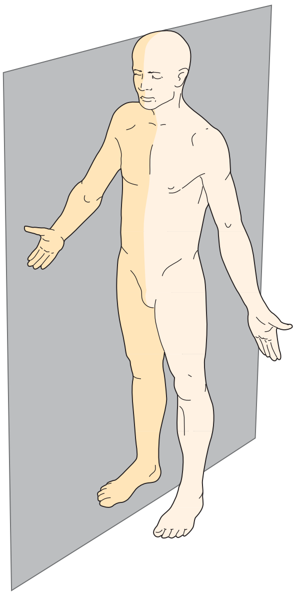

Figure 8.9 Sagittal plane

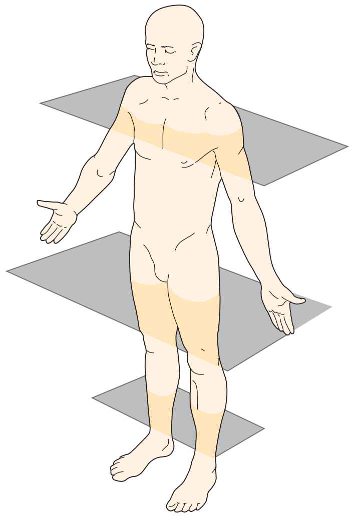

Figure 8.10 Transverse plane

Worksheet 8.1

Coursework

1 Using Worksheet 8.1 from the CD in the back of the book, fill in the bones of the body.

2 Find the following table on the CD and fill in the columns, giving a sporting example that primarily relies on that specific bone.

Bone	Location (using anatomical descriptions)	Sporting movement that uses this bone
Humerus		
Scapula		
Clavicle		
Cranium		
Tibia		
Metatarsals		
Phalanges		

Catchy fact
Astronauts returning from space have problems with changes in bone composition because the lack of gravity, which would normally cause compression forces, means that the structural make-up of the bone alters. Astronauts need to let their bones readjust to the physical demands of Earth's atmosphere.

Physiology of bones

Bone is made up of 35% protein (mainly collagen) and 65% mineral salts (mainly calcium and phosphate). Despite its rigid texture, bone is actually partly made of living tissue that performs many essential functions including:

- storage of minerals
- manufacture of red blood cells
- manufacture of white blood cells
- providing support
- protection of our organs
- allows movement.

Importantly, bones are structurally capable of resisting tensile forces (those that pull outwards) and compression forces (forces pushing inwards). This will affect the internal

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composition of the bone, depending on how large these forces are. The long bones require great strength to resist huge impact forces during jumping events.

Bone composition changes throughout our life. Older people often lose calcium from their bones, meaning their bones become more brittle and easily broken. Younger bones are far more pliable.

One great concern for young athletes is potential damage to epiphyseal (growth) plates. It is these epiphyseal plates that allow bones to extend as a child grows. Perhaps the most important bones here are the long bones of the appendicular skeleton. These are the main bones used to create movement. If the growth plates are damaged, often the growth of that limb will be compromised. In the case of the femur or tibia, this can have massive implications.

Many believe that for this reason alone, younger athletes should not take part in high-impact (e.g. gymnastics) or heavy weights training. The constant compaction of growth plates will affect growth and development.

However, peak bone mass is achieved in late childhood and early adolescence. Research indicates that high-impact and weight-bearing activities at this time will help promote good bone densities. This will help in later life to avoid the effects of osteoporosis. So, high-impact activity is regarded as promoting bone density, but damage to growth plates is a serious problem for developing athletes.

Low-impact training is also essential for older athletes, as it allows their bodies to adapt and the internal bone structure to change to cope with the new workloads. This will also help retard the effects of ageing, and loss of vital calcium from bones.

epiphyseal plates
growth plates located at the end of long bones

appendicular skeleton
the bones of the limbs and those connecting to the limbs giving humans most movements; e.g. arms, legs, pelvic and shoulder girdles

osteoporosis
a medical condition where bone mass and strength is reduced, making the bones more susceptible to fracture

Catchy fact
Sharks do not possess any bones at all. Their skeletal structure is made up entirely of cartilage. Have you ever seen a shark's skeleton?

Types of bones

There are four main types of bones: long, short, flat and irregular.

Long bones

These refer to the bones of the limbs and the clavicle.

Short bones

These refer to the wrists and ankles.

Flat bones

These refer to the sternum, ribs, shoulder blades and cranial bones.

Irregular bones

These are unusual-shaped bones that do not fit into other groups, for example the vertebrae, pelvis, ribs and skull.

Catchy fact
A human baby has about 305 bones, whereas an adult has 206!

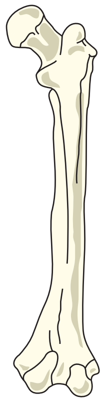

Figure 8.11 A long bone (femur)

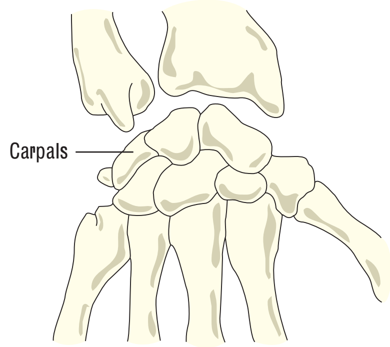

Figure 8.12 Short bones (carpals)

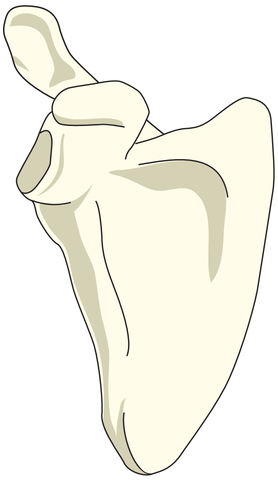

Figure 8.13 A flat bone (shoulder blade/scapula)

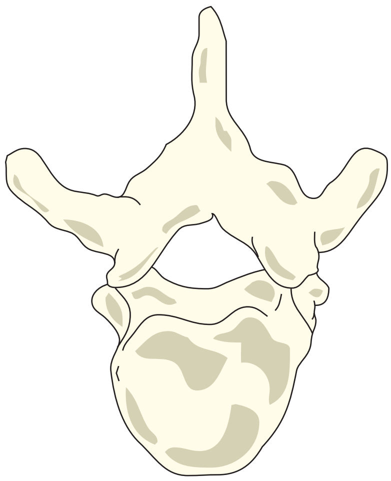

Figure 8.14 An irregular bone (vertebra)

Structure of a bone

red bone marrow
tissue found within the bones that creates red blood cells as well as small numbers of white blood cells

Bones need to be both extremely strong and lightweight. The hollow centre of long bones is critical in storing vital minerals (especially calcium) and marrow for the creation of red and white blood cells. Red bone marrow creates blood cells while yellow marrow is used to store fat.

Bones contain blood vessels. Even compact bone has a network of tiny blood vessels. Nerve cells and living bone cells known as osteocytes are also found within the bones. Non-living material includes calcium and phosphorus. Periosteum – a thin membrane – covers the bone surface.

There are two main compositions of bone. Spongy bone is a more open network of bone that has some shock-absorbing capabilities. Spongy bone is very lightweight. Compact bone is far more dense, and makes up the shaft of long bones. Compact bone, with the periosteum on the outside, covers the surface of all bones.

Bone shape and structure

Different-shaped bones have different structures:

- Long bones are mostly made of compact bone with some spongy bone near the ends.
- Short bones (see Figure 8.12) are mainly made of spongy bone.
- Flat bones are made of a layer of spongy bone sandwiched between two thin layers of compact bone (Figure 8.13).

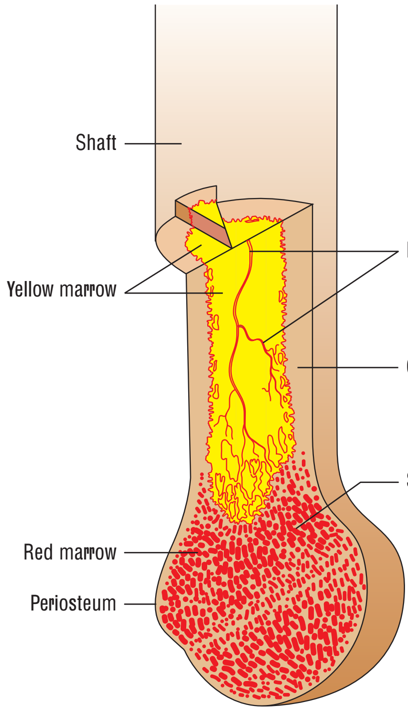

Figure 8.15 Long bone structure

How bones grow

A long bone grows from either end in the epiphyseal plates where cartilage cells divide and increase in number. The new cartilage cells push older, larger cartilage cells towards the middle of the bone, where they eventually die and the space they occupied is replaced with bone. When a bone has reached its full size, its growth plates are converted into bone.

Long bones stop growing around the end of puberty, at which stage you stop getting taller.

Catchy fact
The appendicular skeleton consists of 126 bones. The axial skeleton consists of 80 bones.

Two types of skeleton: axial and appendicular

axial skeleton
all the bones grouped together in the midline – the skull, vertebrae, ribs and sternum

The skeleton is divided into two parts: axial and appendicular (Figure 8.16). Axial refers to all the bones that are grouped along the midline (middle) of the body – the skull, vertebrae (see Figure 8.17), ribs and sternum. The appendicular skeleton refers to appendages that are attached to the axial skeleton – the pelvic girdle, shoulder girdles and the arms and legs.

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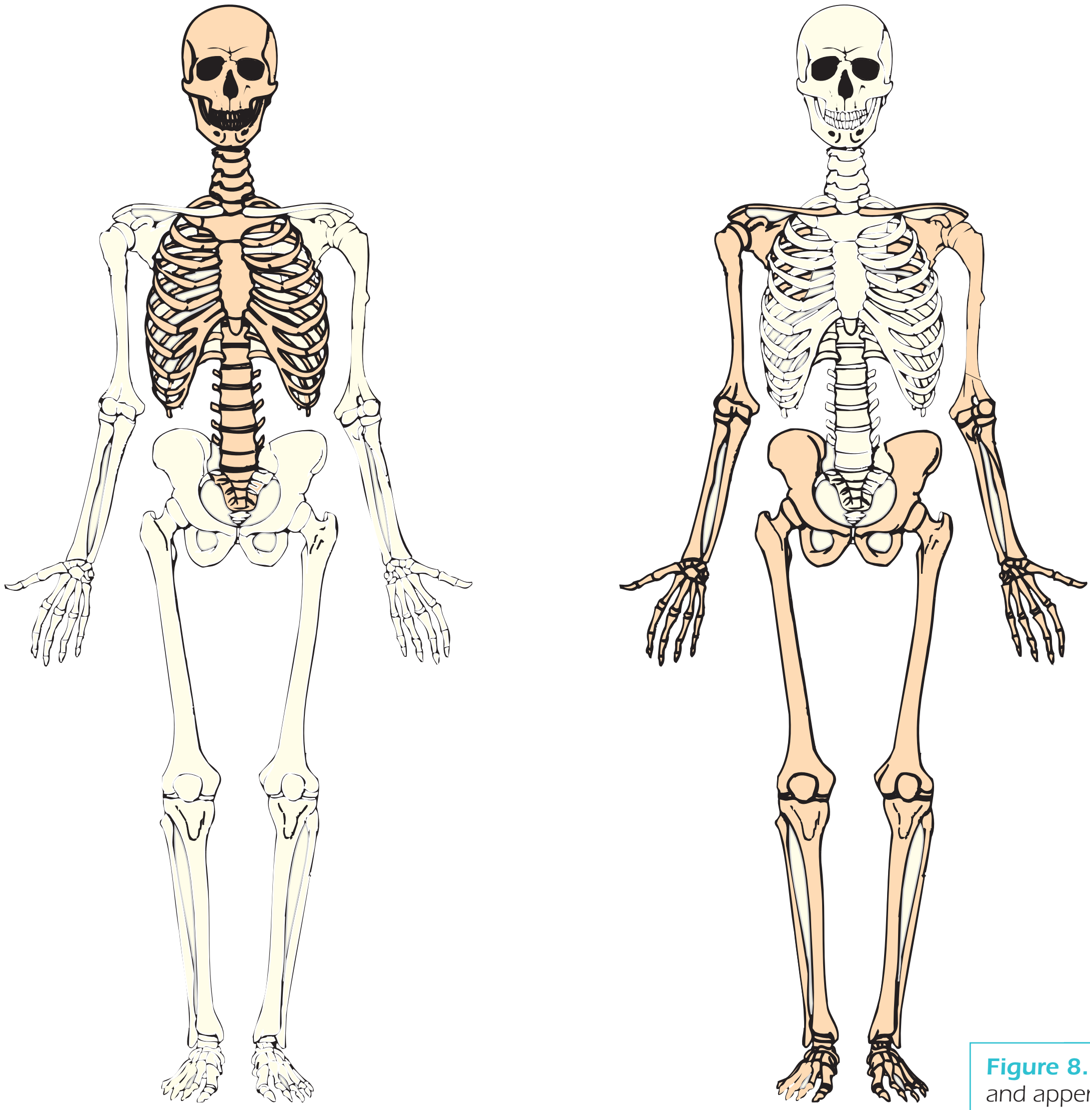

Figure 8.16 The axial and appendicular skeleton

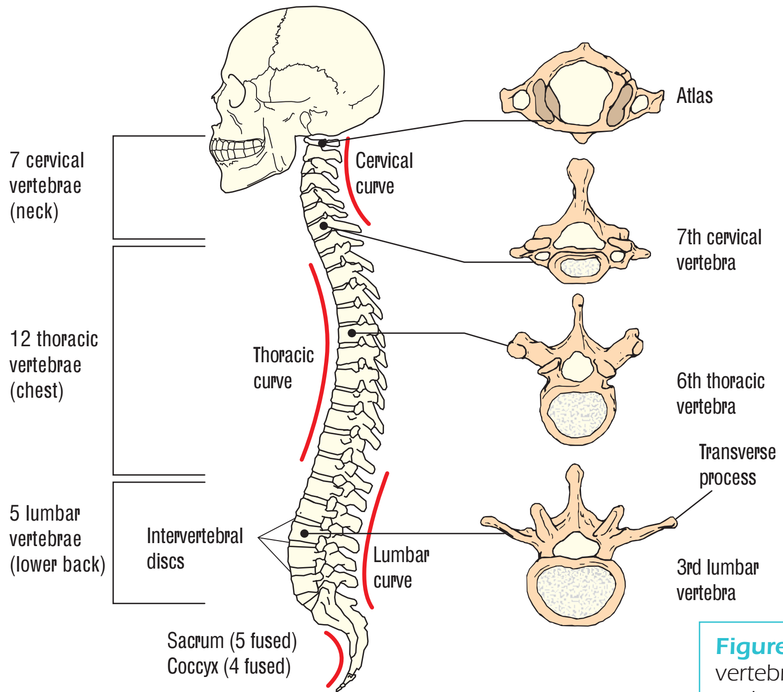

Figure 8.17 The vertebral column and vertebrae

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Broken bones (fractures)

Fractures can be classified according to how the break occurred – whether it damaged anything else, whether it was caused through overuse, or if it was age related. In some cases, more than one term can be used to describe a fracture.

Figure 8.18 X-rays are used to detect broken bones; here a broken ulna.

Simple fracture

A simple fracture is a single crack across the shaft of a bone (also called a simple transverse fracture). An oblique fracture, when a bone breaks at an angle, is uncommon.

Complex fracture

This is when a bone is broken in an irregular way, such as a spiral fracture. This is most common in long bones, and often means a long healing time and lengthy immobilisation. Surgeons are likely to use an external halo cage surrounding the limb, with wires passing through the limb holding the bones in place.

Stress fracture

A stress fracture occurs when repeated stresses are placed on a bone, causing a partial crack in the bone. If left untreated, stress fractures can become simple transverse fractures. Stress fractures require the usual six weeks to heal, but in many cases athletes work through the pain with steroid injections. Stress fractures are most common in the lower back and tibia.

Keep your skis on!

A skier was forced to take off her skis after attempting a run that was too steep with sparse cover. She tried to walk down the slope in ski boots, but she slipped and slid down the slope in the seated position with her legs out in front. When she attempted to stop by digging her heels in to the snow, she accidentally hit a rock just beneath the surface. The impact caused a severe spiral fracture of her lower leg, which was serious enough to require several months in hospital.

Figure 8.19 A skier 'wiping out'

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Avulsion fracture

Where muscles or ligaments attach to a bone, they can generate enough force during activity to break the bone, or in some cases tear an attachment off. Boxers and weight-lifters have been known to tear off the olecranon process at the elbow through a vigorous muscle contraction of triceps. This is known as an avulsion fracture.

Hairline fracture

As the name suggests, hairline fractures are so fine that they often cannot be detected even by X-ray. Hairline fractures are common after an uncontrolled fall, especially in children. They are very similar to stress fractures, although they are acute in nature (occurring instantly, not over a period of time).

Depressed fracture

A depressed fracture occurs when a section of a bone is broken and pushed from its normal alignment. Motor vehicle accidents will often result in a depressed fracture of the skull. The impact of a steering wheel or dashboard causes a section of the skull to be pushed inwards, sometimes damaging underlying tissue.

Pathological fracture

A pathological fracture occurs if a cancerous tumour or a disease that compromises the bone develops, resulting in a fracture. Soccer players are often concerned with growths on their tibia from continual bumps forming from tackles. In some cases, these can become cancerous, and weakening of the structure results.

Complicated fracture

A complicated fracture occurs when the structures adjacent to the bone are damaged by the jagged ends of the injured bone. A heavy tackle in rugby can cause the player's rib to puncture a lung – this is said to be a complicated fracture.

Compound fracture

If a broken bone punctures the skin, which is our major protective barrier, then it is described as a compound fracture. This may be a very serious injury with the bones being exposed to infection, and a high chance of injury to adjoining nerves and arteries.

Closed fracture

When the break is contained within the skin, it is known as a closed fracture. This is the most common form, especially in sports injuries.

Comminuted fracture

When a bone disintegrates into many pieces, this is called a comminuted fracture. The force required to do this is usually only generated in occurrences such as vehicle accidents.

Impacted fracture

If a severe break causes one bone to be driven into another bone, this is called an impacted fracture. Again, these are uncommon in most sporting injuries, with the exception of high-speed pursuits.

Fragility fracture

As bone density decreases with age or degenerative diseases, fractures can occur from relatively minor falls. Aged-care facilities have to deal constantly with broken bones, especially hip and lower leg fractures from falls. This means that hand rails and facility design are crucial in limiting hazards.

Catchy fact
Each day your spine is compressed by the forces applied to it and you shrink in height by about 1.25 cm. At night when you sleep, your vertebral discs expand and you regain lost height.

Broken bones in children: Greenstick fractures

Children have softer, more flexible bones that tend to give on impact. Although this can be of benefit, this softness can create the problem of a greenstick fracture, where a bone bends and breaks partially.

As mentioned previously, children also have the potential to damage growth plates if they injure the long bones of the body. In some cases, one limb can end up significantly shorter than the other.

Catchy fact
A stress fracture is in fact a partial break of a bone. If left untreated, and enough stress is put on it through athletic performance, it will eventually become a complete break.

Treatment of broken bones

Before bones can be allowed to heal, they need to be realigned. Doctors generally need to see an X-ray before they are willing to 'reduce' a broken bone. This is to ensure that underlying structures, such as nerves, blood vessels and organs, are not pinched as the bones are re-set in place.

In severe breaks, the bone can be secured with screws, pins, plates, rods and even wires that protrude out through the skin to a rigid cage. In most cases, broken bones are immobilised in a plaster or fibreglass cast to provide stability during healing.

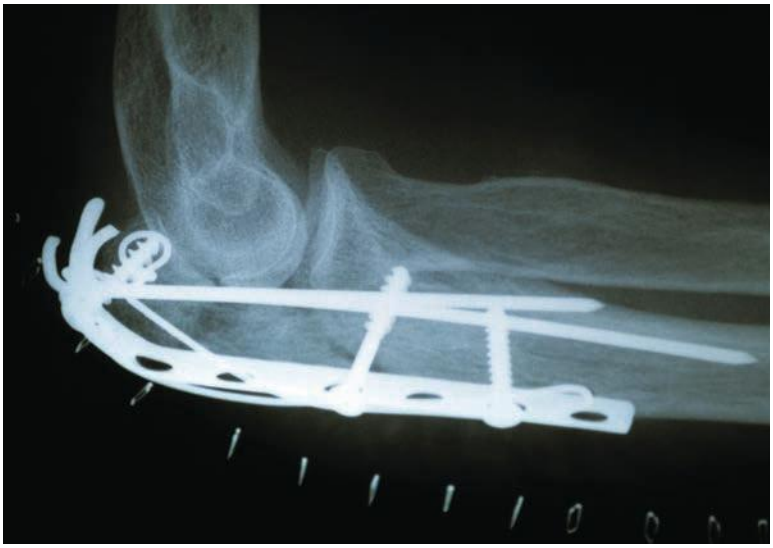

Figure 8.20 Severely broken bones are secured with screws, pins, plates rods and wires.

Healing time

A simple fracture takes approximately 6–8 weeks to heal. Complicated severe breaks can take much longer. Richmond footballer Nathan Brown was out of AFL for a year after a player fell across his leg and caused a severe break. Arsenal striker Eduardo was out of Premier League soccer for a year after a severe tackle left his leg broken in two.

It can take up to two years for the bone to heal and be back to full strength.

There are four main steps to bone repair:

1. A haematoma (swelling due to blood escaping from broken blood vessels) forms at the actual break site.
2. The haematoma is replaced by the body's own version of a splint – cartilage. This cartilage is referred to as a cartilage callus.
3. The cartilage callus is replaced by a bony callus. This structure is effectively made of spongy bone.
4. Once the bony callus has mild stresses placed on it, the structure develops into a permanent repair. Initially the bone appears to thicken at the site, as shown on an X-ray, and then slowly returns to its normal shape. This process takes an average of six weeks.

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Joints

Types of joints

A joint is the area where two bones are attached for the purpose of motion of body parts. A joint is usually formed of fibrous connective tissue and cartilage.

A tendon is a thick, strong cord by which a muscle attaches to bone. It is flexible, but fibrous and tough. The term 'tendon' comes from Latin and Greek words meaning 'to stretch'.

A ligament is a tough band of connective tissue that connects various structures such as two bones. 'Ligament' comes from the Latin *ligare*, meaning to bind or tie.

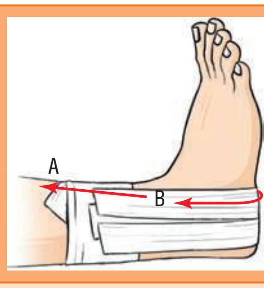
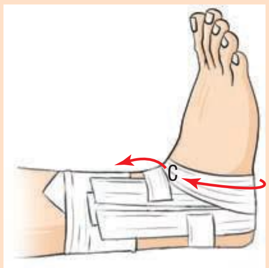
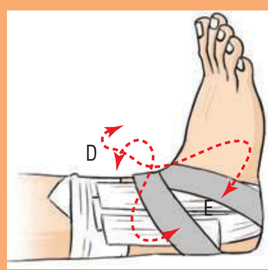
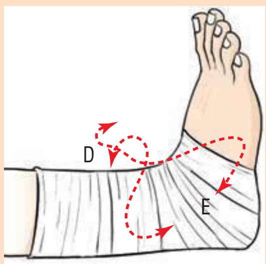
For further discussion of joints, see Chapter 7, pages 119–24.

Catchy fact
When a tendon becomes inflamed, the condition is referred to as tendinitis or tendonitis. Inflamed tendons are at risk of rupture. Despite their tough fibrous nature, tendons and ligaments are both considered to be 'soft tissue'; i.e. soft as compared to cartilage or bone.

How to protect the ankle

Taping (or strapping) can help support damaged ligaments. Table 8.1 lists the steps involved in strapping an ankle for protection.

Table 8.1 How to protect the ankle

Step 1	Attach anchors (A) first and then stirrups (B). (Usually three stirrups are attached from the inside to the outside in a U-shape formation.)	
Step 2	Bind the tape in two figure 6's around the foot, starting from the inside to the outside, returning to the inside after crossing the front of the foot (C). Figure 6's help counteract the inversion movement that can cause injury.	
Step 3	Apply a half-heel lock to provide further support to the rear ankle area. Begin on the inside of the lower leg (D) and move down and across the outside of the ankle towards the front of the heel. Pass the tape under the foot and cross the inside of the heel at a 45° angle (E). Pass the tape back to the outside of the ankle to finish on the inside of the lower leg where you started. (Another half-heel lock may be applied in the opposite direction, using the same technique).	
Step 4	Overwrap the tape with elastic bandage to provide mild compression and to further secure the taped area. Using the figure-8 formation and a spiral, completely cover the rigid tape.	

Adapted from http://www.elastoplastsport.com.au/InteractiveAssistant/Default.aspx#AssistantKnee

Muscles

What do muscles actually do?

Muscles:

- produce movements
- produce body heat
- provide structural stability.

Physiology of muscles

Muscle fibres are some of the largest cells in the human body. The largest can be up to 5 centimetres long.

Although we cannot change the actual number of muscle fibres that we have, through training, we can enhance the strength of muscle fibres.

Muscle micro-structure will be covered in more detail in Stage 3. At a simple level, muscle movement occurs when myosin and actin fibres slide between each other, thus shortening (see Figure 8.21).

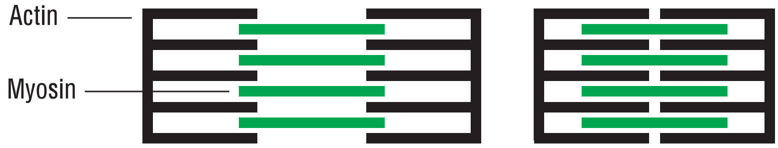


Figure 8.21
Muscle filaments

Origin and insertion of muscles

In order to understand how a muscle moves a body part, we need to know where it originates, which joint it crosses and where it culminates. (This is covered in detail in Chapter 7.)

Origin

The origin of a muscle is the end of the muscle attaching to the relatively fixed bone of its joint. The point of attachment of a muscle remains relatively fixed during contraction.

Insertion

The insertion of a muscle is the end of the muscle attaching to the freely moving bone of its joint. It is the point of attachment of a skeletal muscle to the bone or other body part that it moves.

Muscles of the human body

Muscles of the human body

The main muscles of the human body are shown in Figure 7.6, page 118. The muscles of the legs, back, shoulders, buttocks and abdomen are shown in Figures 8.22–8.26 on page 139–40. Table 8.2 (p. 140) lists some of the muscles and their actions. A more detailed version of this table, which includes extension material, can be found on the accompanying CD.

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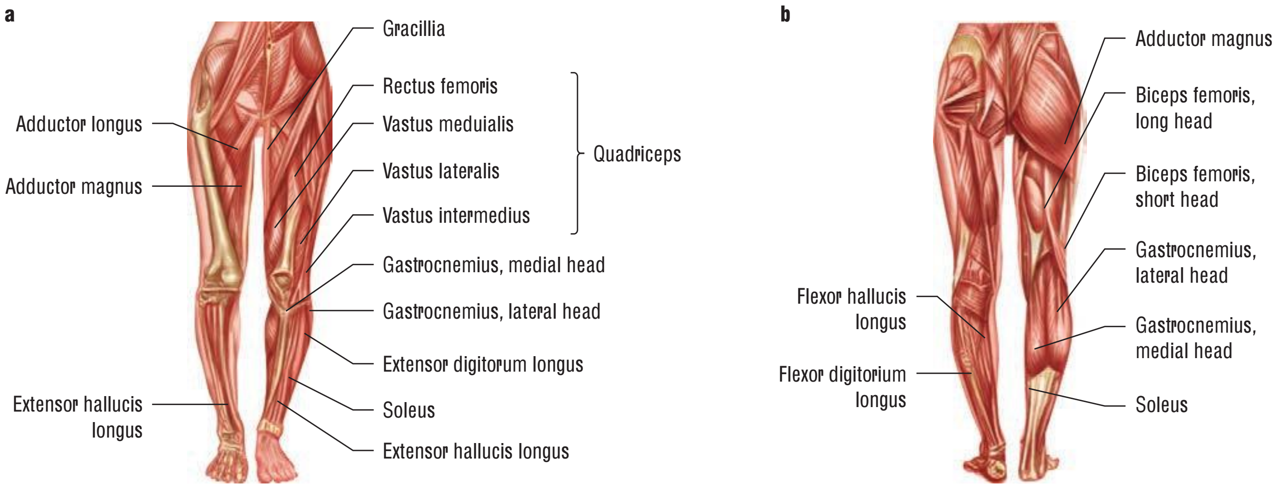

Figure 8.22 Muscles of the legs: (a) from the front, (b) from the back

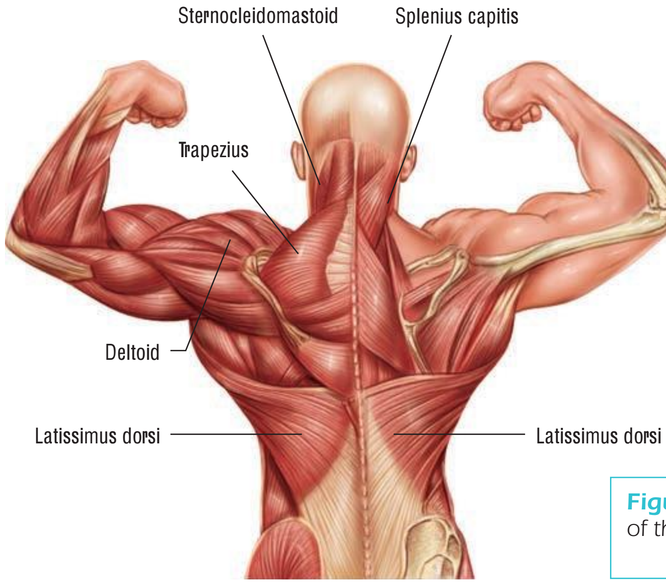

Figure 8.23 Muscles of the back

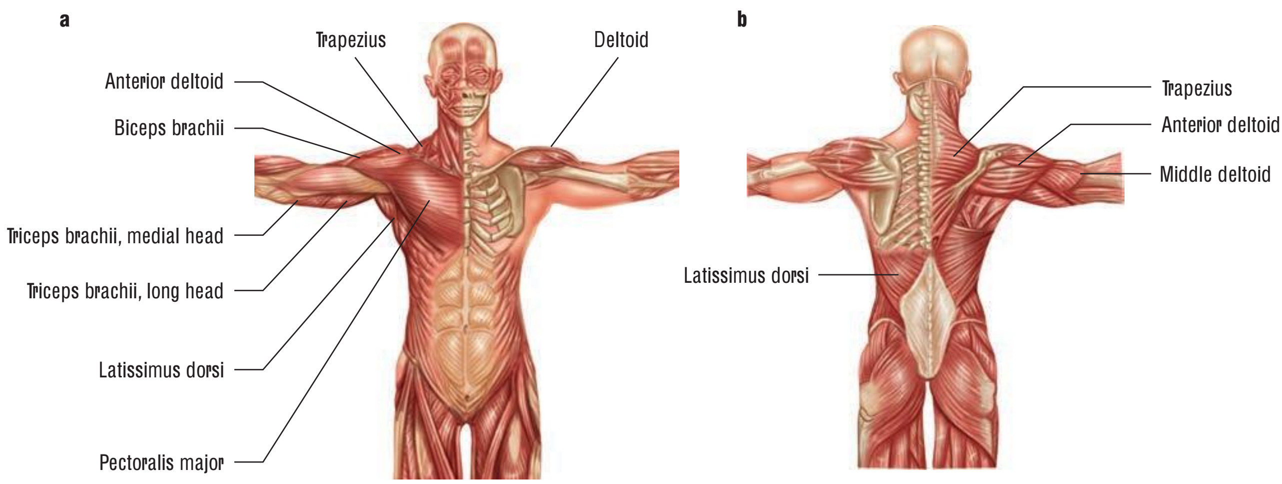

Figure 8.24 Muscles of the shoulder: (a) from the front, (b) from the back

Figure 8.25 Muscles of the buttocks

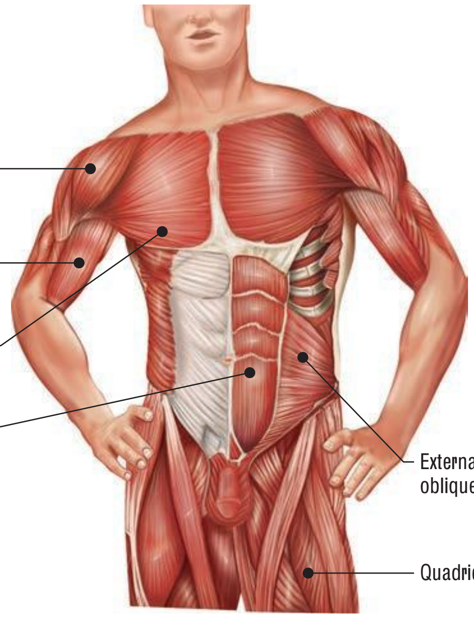

Figure 8.26 Muscles of the trunk, arm, shoulder and leg

Table 8.2 Muscles of the human body

General name	Action
Muscles of the trunk and neck	
Sternomastoid	Flex neck sideways and rotate neck
Pectoralis group	Elevate and adduct scapula
Latissimus dorsi	Extend, internally rotate and adduct shoulder
Abdominals	Flex and rotate trunk
Intercostals	Elevate and depress ribs
Muscles of the arm and shoulder	
Deltoid	Flex, extend, rotate and abduct shoulder
Biceps	Flex elbow Supinate forearm
Triceps	Extend elbow
Hand flexors	Flex wrist and fingers
Hand extensors	Extend wrist and fingers
Muscles of the leg and hip	
Quadriceps	Extend knee, assist flexion of hip
Hamstrings	Flex knee, extend hip, tilt pelvis posteriorly, rotate femur laterally
Adductor group	Adduct leg
Gastrocnemius	Plantarflex foot at ankle, flex knee
Soleus	Plantarflex foot

Table 8.3 shows the main muscle groups and exercises to develop each of the muscles.

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Table 8.3 Exercises to develop the muscle groups

General name	Exercises without weights equipment	Exercises with weights equipment	Action
Muscles of the trunk and neck			
Sternomastoid	Freestyle swimming Isometric pushing against resistance	Side-load roman chair	Flexes neck sideways Rotates neck
Trapezius	Bench tricep dips	'Dumbbells around the world' Dumbbell flies Shoulder shrugs with dumbells	Extends and adducts head, rotates and abducts scapula, fixes scapula
Pectoralis group	Push-ups	Bench press Pec dec machine Dumbbell flies horizontal	Flexes, adducts and medially rotates arm Depresses glenoid cavity, raises ribs 3–5
Latissimus dorsi	Bench tricep dips	Lat pull down Seated row	Extends, adducts, and medially rotates arm, depresses shoulder
Abdominal group	Sit-ups Crunches Core stability exercises	Abdominal machine Roman chair Vertical knee raises	Flexes lumbar vertebrae, compresses abdomen Compresses abdomen, laterally rotates trunk Compresses abdomen, laterally rotates trunk
Intercostals	Yoga Sit-ups	Military press Lateral raises – dumbbells	Elevates ribs (increases thoracic volume) Depresses ribs (decreases thoracic volume)
Muscles of the arm and shoulder			
Deltoid	Push-ups Tricep bench dips	Military press Pec dec Dumbbell flies – horizontal	Abducts arm, flexes, extends medially and laterally rotates arm
Biceps	Push ups	Preacher curl Bench press Dumbbell curls	Extends and adducts arm, extends forearm
Triceps	Tricep bench dips	Close grip bench press Tricep curls	Extends and adducts arm, extends forearm
Forearm flexors	Push-ups	Bicep curls Preacher curls Roll up weight on a rope	Flexes forearm
Hand flexors	Squeezing squash ball	Wrist curls – barbell	Flexes and abducts hand
Hand extensors	Isometric resistance	Wrist extensions – barbell	Extends wrist and fingers
Muscles of the leg and hip			
Gluteal	Stair running	Lunges with dumbbell/barbell	
Quadriceps	Stair running Piggy back running	Leg extensions Squats Leg press	Extends knee, assists flexion of hip

General name	Exercises without weights equipment	Exercises with weights equipment	Action
Hamstrings	Downhill running Cycling	Hamstring curls Squats	Flexes knee, extends hip, tilts pelvis posteriorly, laterally and medially rotates femur and knee
Adductor group	Sidestep running	Multi hip machine Machine adductions	Adducts thigh
Abductor group	Sidestep running	Cable hip abductions	Abducts thigh
Foot flexors		Standing machine calf raises	Inverts foot, dorsiflexes ankle
Foot extensors	Toe raises		
Gastrocnemius	Donkey calf raises Sandhill running	Standing machine calf raises	Plantarflexes foot at ankle, flexes knee
Soleus	Donkey calf raises	Seated barbell calf raises	Plantarflexes foot

Skeleton shape and structure

Coursework: Extension

For this activity, you will need a skeleton and access to the Internet and other reference material such as textbooks. Divide your class into small groups. Assign each group two or three muscles from Table 8.3, taking note of the origin and insertion of each muscle. Each group should research the location on the bone of each origin and insertion, and report this to the class. They should also demonstrate an activity that will work that particular muscle.

As a class, you could put this information on the board to give visual reinforcement. For example, you could use the following headings: Muscle, Origin, Insertion, Action, Exercise.

The circulatory system

homeostasis
the maintenance of core body temperature within the normal healthy range

The circulatory system, also known as the cardiovascular system, is made up of the heart, blood vessels and blood. Its main functions are to deliver nutrients to and remove waste products from the cells throughout the body. The circulatory system also plays a considerable role in helping the body maintain an even core body temperature, known as homeostasis.

The heart

The heart is a hollow muscular structure, made up of cardiac muscle that is essentially a pump that pushes blood around your body. It is approximately the size of your clenched fist and is located to the left of the centre of the chest between the lungs and behind the ribs. The thick walls of the heart contract and relax about 60–80 times each minute when you are resting. This is known as your heart rate. This enables the heart to pump blood to the lungs and around the body.

The entire volume of blood in the body is recirculated in less than one minute, depending on the body's activity. During an average lifetime of 70 years, the heart will pump between 100 and 150 million litres of blood and it will beat more than 2.5 billion times.

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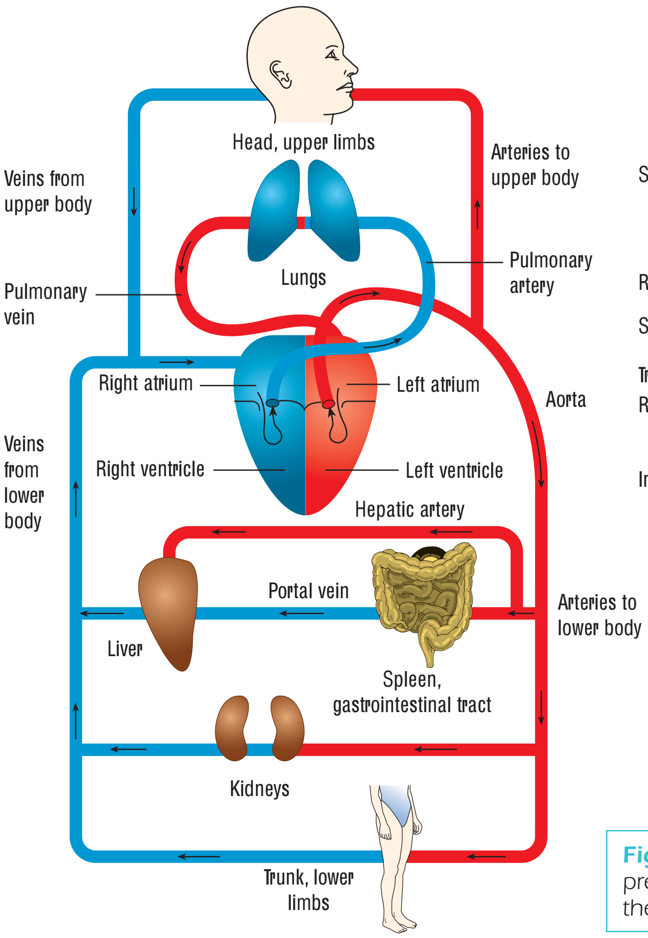

Figure 8.27 A diagrammatical presentation of the pathways of the circulatory system

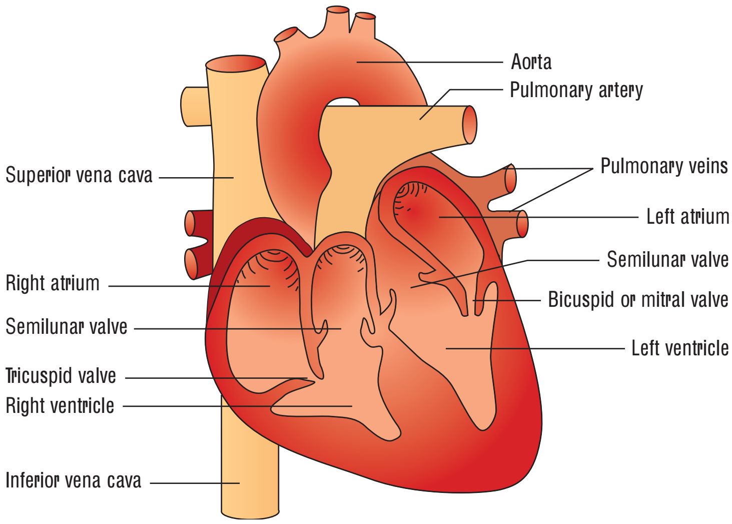

Figure 8.28 Structure of the heart

The heart has four chambers:

- Two atria: the upper chambers – right atrium and left atrium
- Two ventricles: the lower chambers – right ventricle and left ventricle

The contraction phase of the atria and ventricles is called systole. The relaxation phase of the atria and ventricles is called diastole. The atria have systole (contraction), while the ventricles have diastole (relaxation) and vice versa (see Figure 8.27).

atria
the two upper chambers of the heart (right and left atrium)

ventricles
the two lower chambers of the heart (right and left ventricle)

systole
the contraction of the atria and ventricles

diastole
the relaxation of the atria and ventricles

blood pressure
the pressure within the arteries that is caused by the pumping action of the heart

What is a 'pulse'?

When the ventricles of the heart contract, the resulting thrust causes a pressure wave – a pulse. The pulse travels along the arteries at close to 7 m/s. It takes about 20–30 seconds for the same portion of blood to complete a full circulation – from foot to foot. It takes a little less time for blood to travel from the right jugular vein in the neck to the left jugular vein due to its proximity to the heart and lungs.

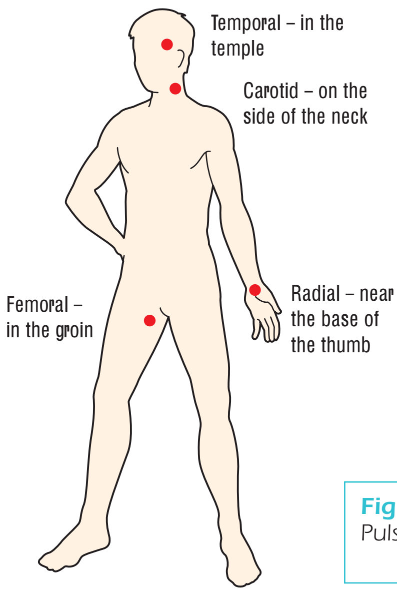

Figure 8.29 Pulse points

What is blood pressure?

As blood is pumped through the body, it creates pressure within the arteries. This pressure is known as blood pressure. Blood pressure measurement is an important diagnostic tool used to assess functioning of the heart, kidneys and blood vessels.

Table 8.4 Blood pressure ranges (mmHg)

	Normal	Low	High
Systolic	100–140	below 80	above 180
Diastolic	60–85	below 60	above 100

Blood pressure measures the pressure exerted by the blood against the walls of the arteries as the heart pumps blood around the body. It changes according to the body's needs. Blood pressure is measured on a sphygmomanometer; a stethoscope is used to listen to the heart beat.

As the heart ventricles contract, the pressure measured is called systolic blood pressure. As the heart ventricles relax, the pressure measured is called diastolic blood pressure. The average systolic blood pressure is 100–140 mmHg (millimetres of mercury). The average diastolic blood pressure is 60–85 mmHg. This is recorded, for example, as 120/80.

The blood pressure is highest in the brachial artery at the time of the contraction of the ventricles, so this artery is most commonly used to determine blood pressure readings.

Some factors that affect blood pressure are:

- the sex of the person – prior to menopause women have slightly lower blood pressure than men, but after menopause it is approximately the same as men
- the time of the day – blood pressure changes throughout the day. It tends to be lower during sleep. Systolic blood pressure rises after meals
- stress – stress can significantly increase blood pressure. If you are nervous or scared, your blood pressure will rise. In the long term, stress can also cause hypertension (or high blood pressure).

Figure 8.30 Using a sphygmomanometer

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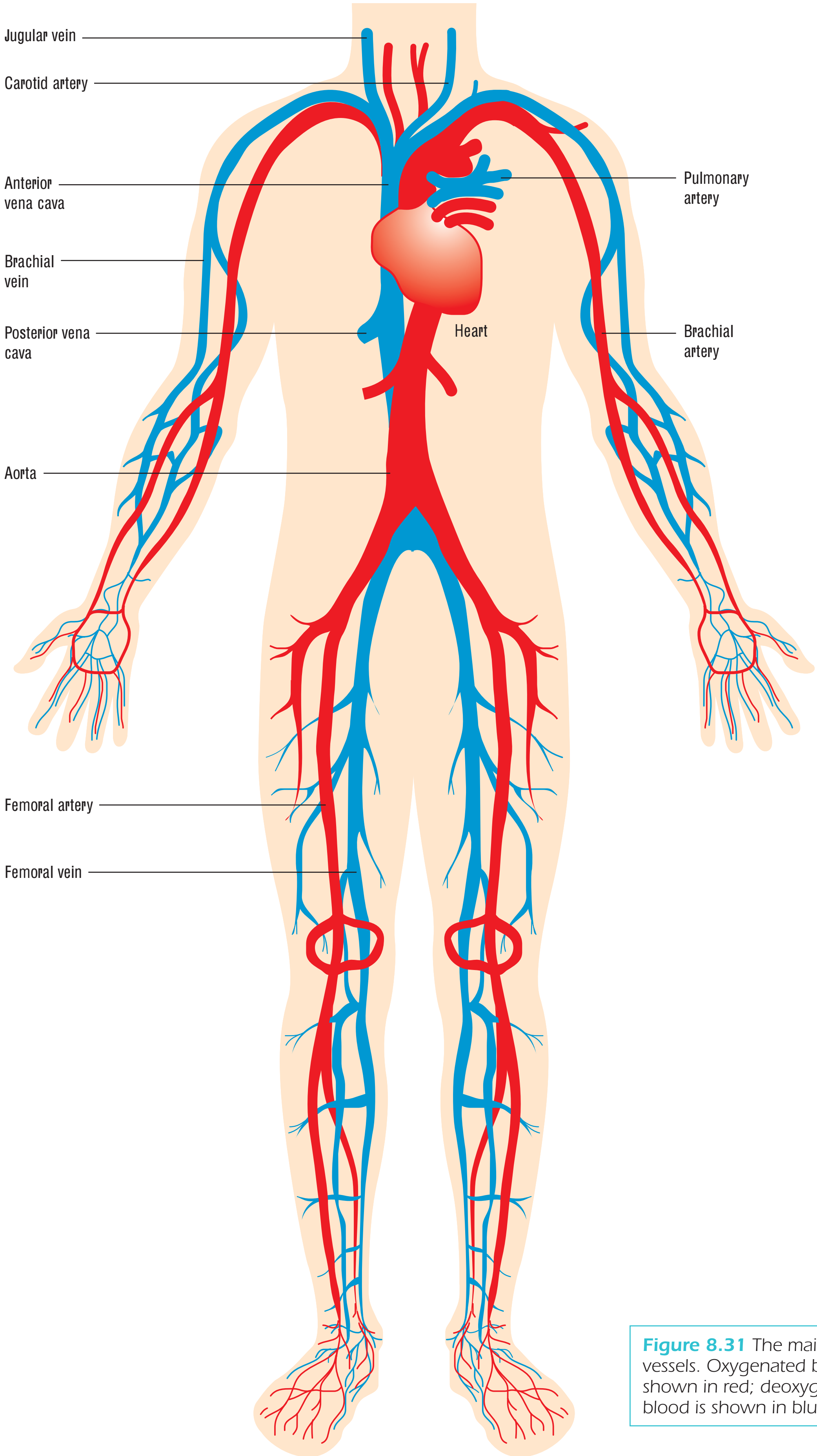

Figure 8.31 The main blood vessels. Oxygenated blood is shown in red; deoxygenated blood is shown in blue.

Coursework: Laboratory activity

Measure your blood pressure

Aim

To compare your blood pressure to that of others in the class

Materials

Sphygmomanometer, stethoscope

Method

1. Sit the subject down with their arm outstretched.
2. Fit the cuff to their arm so that the edge of it is just above the slightly bent elbow.
3. Put the stethoscope just below the cuff (but above the elbow, on the brachial artery).
4. Pump the upper bulb to 160–180 mmHg to inflate the cuff. You will not hear any noise through the stethoscope, as the blood to the artery is cut off.
5. Slowly release the valve. The level of mercury will start to drop. When you hear a beating noise, this is the systolic blood pressure reading. Record it.
6. Keep releasing the valve. You should be able to hear the blood still flowing. When the noise becomes muffled and then stops, this is the diastolic blood pressure reading. Record it.

Results

1. Record your results, and those of the class.
2. How does your blood pressure compare to the class average?
3. What are some of the factors that could have affected your results?

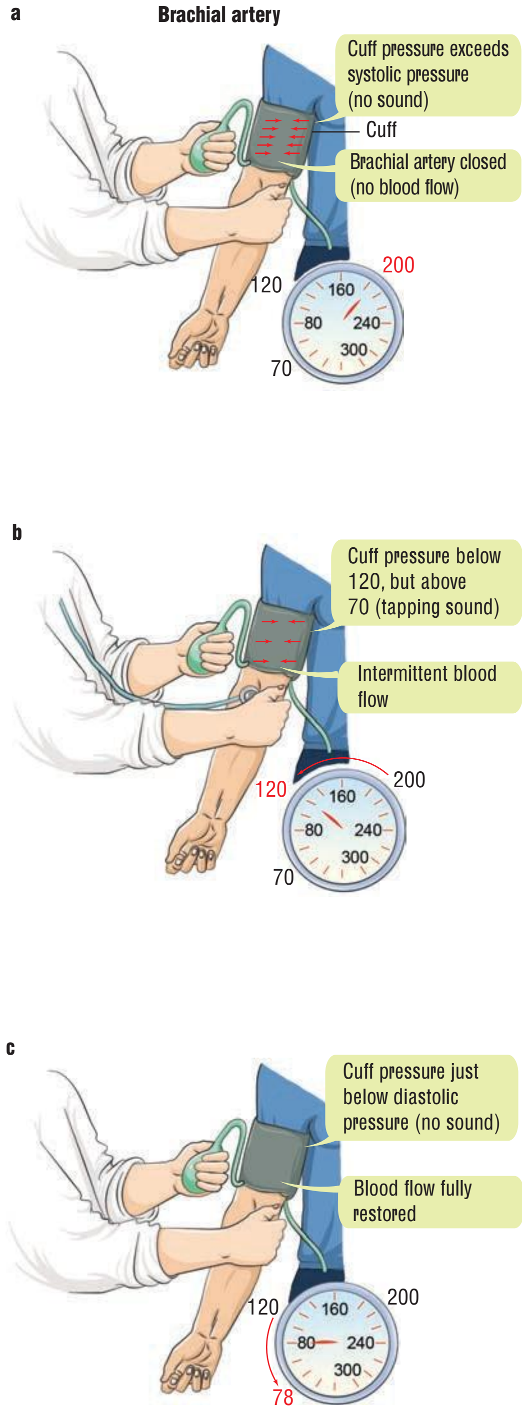

Figure 8.32 Measuring blood pressure

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Blood vessels

Veins and arteries are the network that carries blood around the body. Arteries carry blood away from the heart, and veins carry blood back to the heart. The largest blood vessels are closest to the heart and the smallest are near the outer surfaces of the body. Interestingly, when a blood vessel divides, its branches, although smaller, always have a combined cross-sectional area larger than the vessel they came from. This is so that the same amount of blood can be carried through an increasingly smaller network of tubes.

The blood that returns to the heart via the veins contains higher levels of carbon dioxide and other waste products and its oxygen levels are low. It is referred to as deoxygenated blood. The heart then pumps this blood to the lungs (via the pulmonary artery). Once in the lungs, it eventually travels to the capillaries (smaller than arterioles) where the gaseous exchange takes place. Carbon dioxide and other excretory products are exchanged (breathed out) for oxygen (which is breathed in).

deoxygenated blood
blood that is returned to the heart and carries little oxygen and a lot of the waste product from respiration (carbon dioxide)

capillaries
microscopic blood vessels with extremely thin walls

arteriole
small blood vessel that carries blood to various parts of the body

Arteries have strong, elastic walls which include a component of muscle, as they are under considerable pressure when the heart contracts. The smallest arteries have walls made almost entirely of muscle, so that they can contract and narrow significantly. In this way, these small arteries can influence the volume of blood flowing to their part of the body. Consider how cold your hands can become when they are unprotected on a very cold day. You may notice how your fingers turn red or white as the peripheral circulation (to the skin) is reduced, so that the body's temperature can remain stable. Arteries have a pulse and carry bright red blood, rich with oxygen.

Veins carry blood that tends to be reddish-blue in colour. It is low in oxygen and high in carbon dioxide. The walls of veins are thin and less elastic than the walls of arteries. Veins do not have a pulse and have valves inside them to prevent blood from flowing back, away from the heart. As the muscles that surround the veins contract, they push blood towards the heart, especially in the legs and arms during exercise.

Capillaries link arterioles to venules (the smallest arteries and the smallest veins). There are more than 100 000 kilometres of capillaries in the body, forming a vast network throughout the body tissues. Capillaries are thinner than human hair and most only allow single blood cells to pass through one after the other. They allow the nutrients and oxygen into muscle and tissue and allow carbon dioxide and waste to pass out. By the time blood reaches the capillaries, blood pressure is much less than when it travelled through the coronary (heart) arteries.

venules
the smallest veins adjoining the capillaries

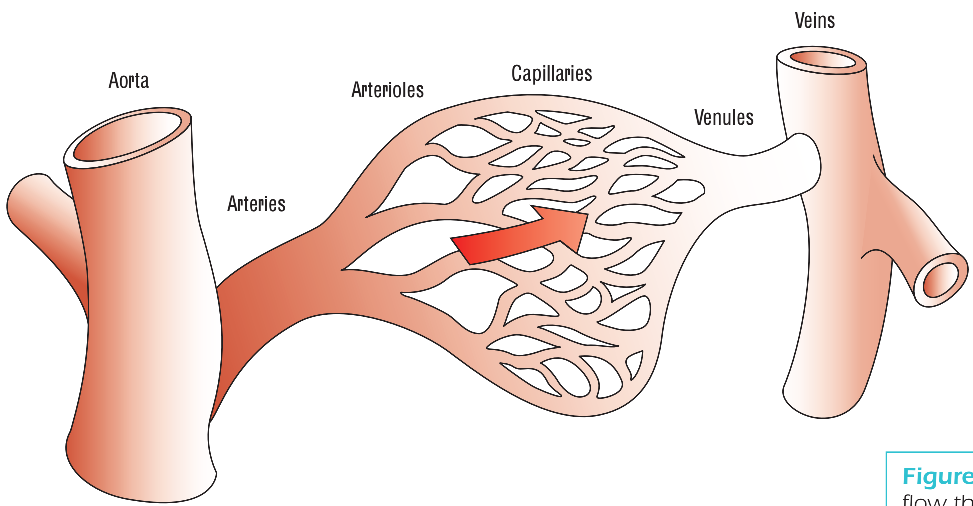

Figure 8.33 Blood flow through the blood vessels

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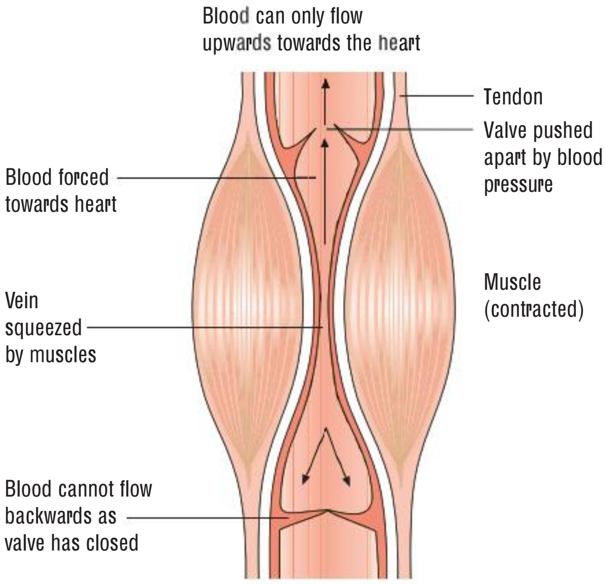

Figure 8.34 The skeletal pump in action

This large vein is situated between muscles. As the muscles contract, the vein is squeezed, forcing blood towards the heart – the muscle pump effect.

Blood

Blood is the fluid that flows through the circulatory system. It contains blood cells, food, minerals and gases that are vital to the correct functioning of the body.

Each person has approximately 4–5 litres of blood, which take about 20 seconds to circulate once around the body at rest. Blood makes up around 8% of your total body weight.

Blood is a suspension made up of:

- blood cells (45%)
- blood plasma (5%).

Blood cells include red blood cells, white blood cells and platelets.

red blood cells
iron-rich cells that carry oxygen around the body

white blood cells
the body's defence system, fighting infection and building up the body's immunity

platelets
cells that help form blood clots to stop bleeding; produced in bone marrow

Functions of the blood

Blood provides and controls the internal fluid surrounding the cells and through circulation distributes food, oxygen and other vital substances to the cells themselves.

Circulation simply refers to the movement of blood around the body. In this role, the blood transports:

- oxygen from the lungs to the tissues
- carbon dioxide from the tissues to the lungs
- waste materials from the tissues to the kidneys
- digested food from the ileum (final section of the small intestine) to the tissues.

Blood distributes hormones and heat and controls the temperature of the body. Blood also forms clots to prevent excess blood loss.

Red blood cells give blood its red colour. They are produced in bone marrow (in bones such as the sternum, ribs and vertebrae).They contain the protein haemoglobin, which carries oxygen to body tissue. Women have slightly lower haemoglobin levels than men.

haemoglobin
oxygen-carrying pigment present in red blood cells

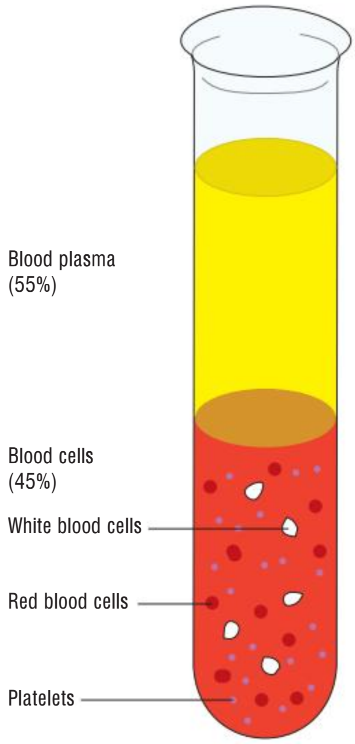

Figure 8.35 The composition of blood

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White blood cells fight infection by absorbing and digesting disease-causing organisms. They are produced in bone marrow, lymph tissue and the spleen.

Platelets are cells that help form blood clots to stop bleeding. They are produced in bone marrow.

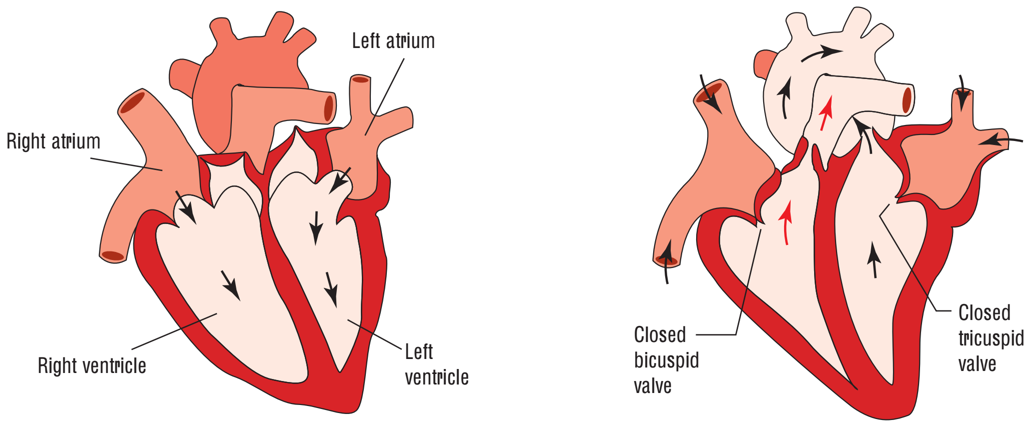
Blood plasma is a clear yellowish fluid that carries nutrients. It also transports waste products and assists their removal from the body. It is 90% water. Plasma contains the protein fibrinogen, which assists platelets in blood clotting.

Blood is also classed according to the presence or absence of a protein known as the rhesus factor. Those people whose blood contains this protein are said to be Rh^{+}; those without it are known as Rh^{-}. If a blood transfusion is required, differences in the Rh factor may lead to rejection of donor blood by the recipient.

Checkpoints

1 What are the main mechanisms of the circulatory system and what role does each part play in ensuring that blood and oxygen are efficiently transported around the body?
2 What role do the following components of the blood play in its composition?
   a Red blood cells
   b White blood cells
   c Platelets
   d Blood plasma
3 Name two types of blood cells and explain the importance of each in the human body.
4 How is a pulse created in the body?
5 What is normal blood pressure? What happens to blood pressure when you exercise?
6 Explain the difference between veins and arteries.
7 What are four conditions that can significantly alter your pulse rate?
8 How can it be that the same volume of blood travels through blood vessels as they divide into narrower branches throughout the body?

Blood flow around the body at rest and during exercise



Atrial systole: Both the left and right atria contract and force blood into the ventricles.

Ventricular: The cardiac muscle around the ventricles relaxes and the ventricle chambers fill with blood.

Ventricular systole: Both the left and right ventricles contract and force blood into the arteries. The bicuspid and tricuspid valves prevent blood from flowing back into the ventricles.

Atrial diastole: At the same time, the cardiac muscle around the atria relaxes and the atria fill with blood.

Figure 8.36 Blood flow through the atria and ventricles

Blood flow through the heart

The right side of the heart receives deoxygenated blood (red-bluish blood with much of the oxygen taken out of it) from the body and pumps it to the lungs. This is called pulmonary circulation.

The right side of the heart receives deoxygenated blood returning from the body through the superior and inferior vena cava (vein) to the right atrium.

↓

As the right atrium contracts, the tricuspid valve opens and the blood is forced into the right ventricle. The tricuspid valve then closes, preventing the blood from moving back into the right atrium.

↓

The blood is then pushed out of the right ventricle, through the pulmonary artery to the lungs. In the lungs the blood unloads the carbon dioxide (which we breathe out) and waste products in the blood, and is re-oxygenated (turned into blood rich with oxygen).

↓

The left side of the heart receives oxygenated blood (redder blood, rich with oxygen) from the lungs and pumps it to the body. This is called systemic circulation.

↓

The pulmonary vein carries the oxygenated blood to the left atrium.

↓

As the left atrium contracts, the bicuspid (mitral) valve opens and blood is forced into the left ventricle. The bicuspid valve then closes, preventing the blood from moving back into the left atrium.

↓

The left ventricle contracts and pumps the blood into the aorta (artery). The blood is then pumped through the arteries to all parts of the body. The two sides of the heart are divided by the septum.

pulmonary circulation
blood pumped to the lungs from the heart

superior and inferior vena cava
where the veins from all of the body above (superior) and below (inferior) the heart empty into

tricuspid valve
valve in the heart with three cusps (points)

Catchy fact

There are four main blood groups:
O – approximately 45% of people
A – approximately 41% of people
B – approximately 10% of people
AB – approximately 4% of people

systemic circulation
movement of blood from and to the heart

pulmonary vein
carries blood to the left atrium (upper left chamber) of the heart

bicuspid (mitral) valve
valve in the heart with two cusps (points)

Catchy fact

Anaemia is a shortage of red cells in the blood, and can occur through a large blood loss, lack of iron in the diet, failure of the red bone marrow to make cells or excessive destruction of the cells. The anaemic person usually feels constantly tired, weak and breathless. It can usually be identified by a simple blood test and remedied by increasing iron intake or in more severe cases (e.g. by accident or injury) through a blood transfusion.

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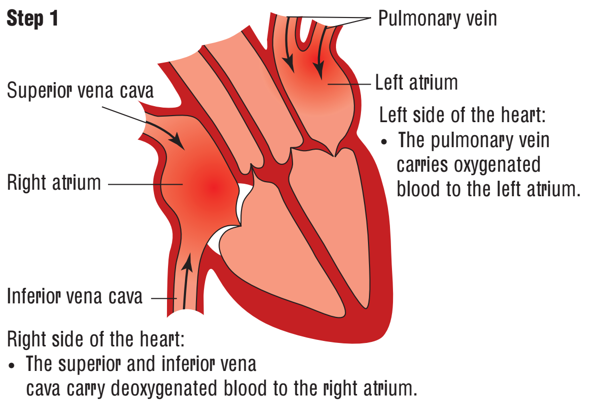

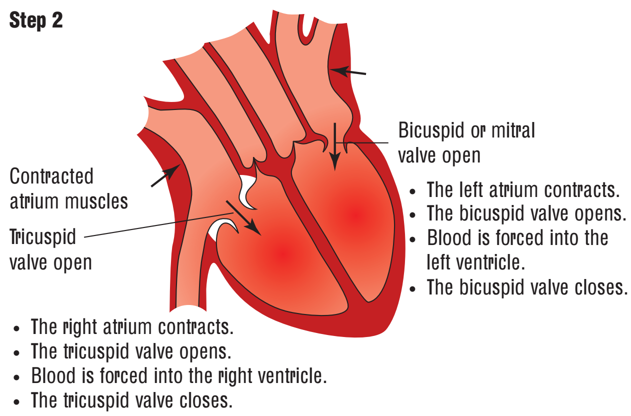

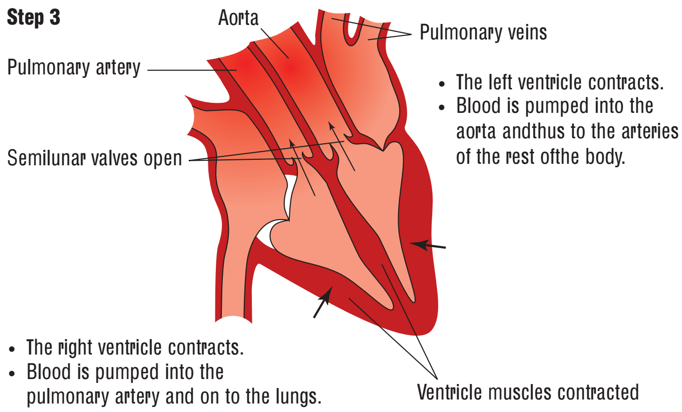

Figure 8.37 Blood flow through the heart

Coursework: Laboratory activity

Observation and dissection of a sheep's heart

Aim

To observe the main structures of a mammalian heart

Materials

Two sheeps' hearts per group, dissecting tray, dissecting instruments, plastic gloves, water

Method

1 Comment on the following aspects of the heart:
- Size
- Colour
- Weight
- Outside features of the heart, such as fat and blood vessels
- Size and number of openings

2 Fill the heart with water and squeeze it. Observe where the water flows from in the heart, and identify these openings.

3 Cut horizontally through one heart as shown in Figure 8.38.

4 Find the following features of the heart:
- Left and right ventricles
- Septum
- The valves inside the ventricles

a Which ventricle is bigger, the left or right? Why?
b Which ventricle wall is thicker and why?
c Which valves could you find? Describe them.

5 Cut the heart vertically, as shown in Figure 8.38. Find the following features of the heart:

- Pulmonary artery
- Atrium and ventricles
- The valve which separates the two chambers

Comment on the difference in size between the atria and ventricles.

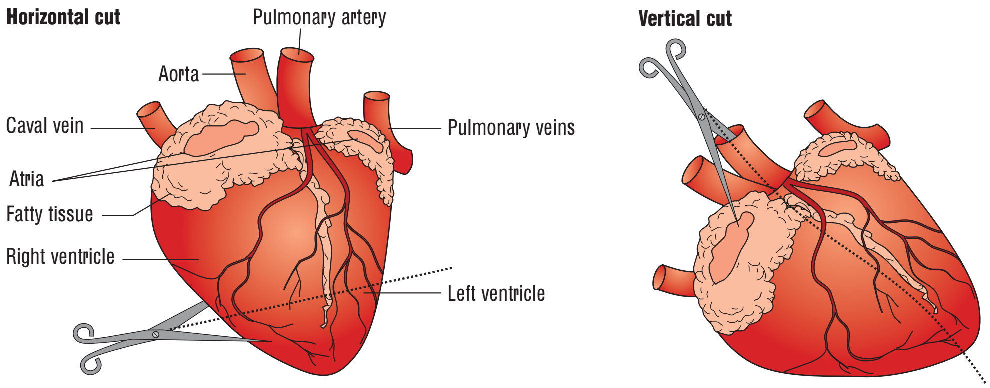

Figure 8.38 Heart dissection

Results

Draw and label a diagram of a heart. Present the findings you were asked to comment on throughout your dissection.

Heart rate

Your heart beats more than 100 000 times a day. Heart rate is the number of beats (of the heart) per minute. The heart rate is measured by counting the pulse rate, which is simply the blood flow pushed through the arteries by the heart. A pulse can be felt most easily at the wrist (radial pulse) and the neck (carotid pulse) (refer to Figure 8.29, p. 143).

A healthy heart beats rhythmically at a pace initiated by the heart itself. In the right atrium, a region called the sinoatrial node, or pacemaker, generates an electric signal that causes the heart to contract and pump blood.

sinoatrial node (pacemaker) generates an electric signal that causes the heart to contract and pump blood

It is very difficult to talk about a 'normal' pulse rate because there are many factors that affect it. It is usually somewhere between 50 and 80 beats per minute (bpm) in adults at rest.

The most common factors affecting heart rate are:

- a person's sex – the resting heart rate of an adult female can be 5–10 beats per minute faster than an adult male's. This is because females have a smaller heart size than males
- age and body size – at birth your heart rate is much higher than in adulthood; e.g. birth 130 bpm, 1 year 120 bpm, 10 years 90 bpm, average adult 50–80 bpm
- fitness level – the fitter you are, the less your heart has to work
- body position – a person lying down may have a heart rate of 5–10 beats less than a person standing
- food digestion – your heart rate increases while you are digesting food. This is one reason why you should not exercise straight after a big meal; your heart is already working to break down food in the stomach.

The pace of the heartbeat is also influenced by electrical signals from the brain, which explains how emotions, excitement or stress can suddenly change the rhythm of the heart. If you are scared or stressed, your heart rate can increase by more than 50 bpm. You will feel it as a pounding in your chest just before you start a race or talk in front of the class.

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Coursework: Laboratory activity

Resting heart rate

Aim

To determine your resting heart rate

Method

1 Count your heart rate (using your carotid pulse – see Figure 8.29):
   a in bed when you first wake up for one minute
   b in class.
2 Count someone else's pulse.

Results

1 Record your results, and those of the class. Graph the results.
2 How does your heart rate compare to the class average?
3 What are some of the factors that could have affected your results?

Medical conditions of the cardiovascular system

Varicose veins

If the valves in the veins fail to maintain the one-way blood flow, this can result in varicose veins. This usually occurs in veins that are close to the surface and in veins in the lower leg. The valves in these veins are under considerable pressure from gravity, which is forcing the blood in the veins towards the ground.

Deeper veins are helped in moving the blood by the surrounding muscle tissue. When the muscles contract, because of movement, the blood is massaged back towards the heart. The best time of movement is regular rhythmic movement to help move the blood.

Venous pooling

Blood can pool (collect) in the lower legs as a result of stopping exercise and not performing a cool-down, not exercising enough or standing on your feet for too long. Moderate exercise will help the blood to be pushed back to the heart and limit the amount of blood that seeps out of the capillaries and into the surrounding tissue. This then causes swelling around the ankle known as oedema. This is a reason why people need to move around on long plane journeys.

KEEP IT REAL!

Exercise ECG test

The exercise ECG test is used to check the efficiency of the heart muscle and assist in making a diagnosis of coronary heart disease. Some people also undergo the test to determine whether they are fit enough to exercise, although this is less common.

www ECG

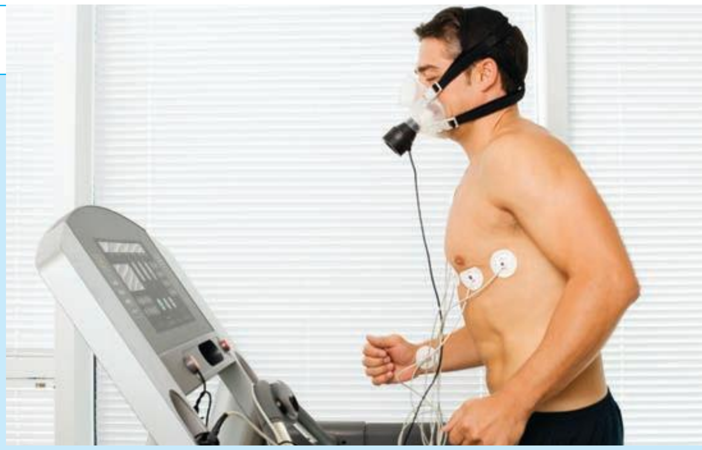

Figure 8.39 Undergoing the exercise ECG test

TEST YOUR KNOWLEDGE

>> multiple choice

1 If a bone has incomplete cracks through it in a transverse plane, these are referred to as:

A comminuted fractures
B colles fractures
C greenstick fractures
D stress fractures.

2 This joins bone to bone.

A Cartilage
B Tendons
C Sheath
D Ligaments

3 Homeostasis is:

A normal blood pressure
B normal body temperature
C the removal of waste products
D the relaxation of the ventricles.

4 The heart has:

A two atria and two ventricles
B two chambers
C four atria
D four ventricles.

5 Arteries can be best described as blood vessels that carry blood:

A towards the heart
B away from the heart
C rich in oxygen
D high in carbon dioxide.

6 Anaemia is a condition where the blood is:

A high in red blood cells
B low in red blood cells
C high in white blood cells
D low in white blood cells.

>> short answer

7 List and explain the main functions of bones.

8 Name and describe the four classifications of bone.

9 Explain the relationship of the muscles to the skeletal system.

10 Draw and label the structures of the heart.

11 What is the role of red blood cells in the body and how can their number be increased?

12 Discuss three factors that influence resting heart rate.

13 Describe three differences between arteries and veins.

>> essay style

14 For a sport of your choice, outline the movements required and the muscles used in each movement. Include in your answer a description of an exercise that would help develop each particular muscle group.

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15 Outline a draft of a speech that you would give to young coaches of junior sport. Your speech should include information on anatomy and physiology. Also discuss simple injuries and their prevention.

16 Describe the path of blood as it leaves the right atrium of the heart and travels around the body and back through the heart. Include the process of diffusion of O_2 and CO_2 at the lungs.

17 Describe the components of blood. How would you expect an elite athlete's blood composition to differ from that of an average person? Include reasons for the differences.

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9 Respiratory system

cellular respiration the different chemical reactions that take place in a cell to form ATP

adenosine triphosphate (ATP) a compound made up of adenosine and three phosphate molecules; energy released by its breakdown enables cellular function and muscular movement

The respiratory system provides oxygen (O_2) to the cells of the body and removes carbon dioxide (CO_2). Like most of the body's systems, it works in conjunction with many other systems, most notably the cardiovascular system.

The respiratory system provides the blood with oxygen, which in turn carries it to all of the cells of the body for the process of cellular respiration. Cellular respiration (using oxygen and nutrients) produces ATP for energy in the mitochondria. In the process of producing ATP, a number of waste products are formed. These include carbon dioxide and water. The blood carries the carbon dioxide back to the lungs, where the respiratory system exchanges it with oxygen and removes it from the body.

Anatomy of the system

The respiratory system primarily comprises the following anatomical structures – mouth, nose, airways and lungs. Most of the system is within the thorax of the body (the thorax is the area defined by the ribs, sternum and vertebrae). The lungs are divided into different sections known as lobes. The right lung has three lobes (upper, middle and lower) and the left lung has two lobes (upper and lower).

The functions are outlined in Table 9.1 and 9.2.

Table 9.1 Anatomy of the respiratory system

Area of the body	Function
Mouth	Used to get high volumes of air into the airways quickly. The mouth is considerably more efficient than the nose.
Nose	Improves breathing as it warms, filters and moistens the air, keeping the airways relaxed and open. This is primarily completed by the cilia.
Pharynx, larynx, cartilage, trachea, bronchi and bronchioles	Airways
Alveoli	The body has more than 600 million air sacs. They have very thin walls to allow for the diffusion of gases. The surface of each alveoli is very vascular to help with gaseous exchange.
Lungs	Volume of the lungs is 4–6 litres.

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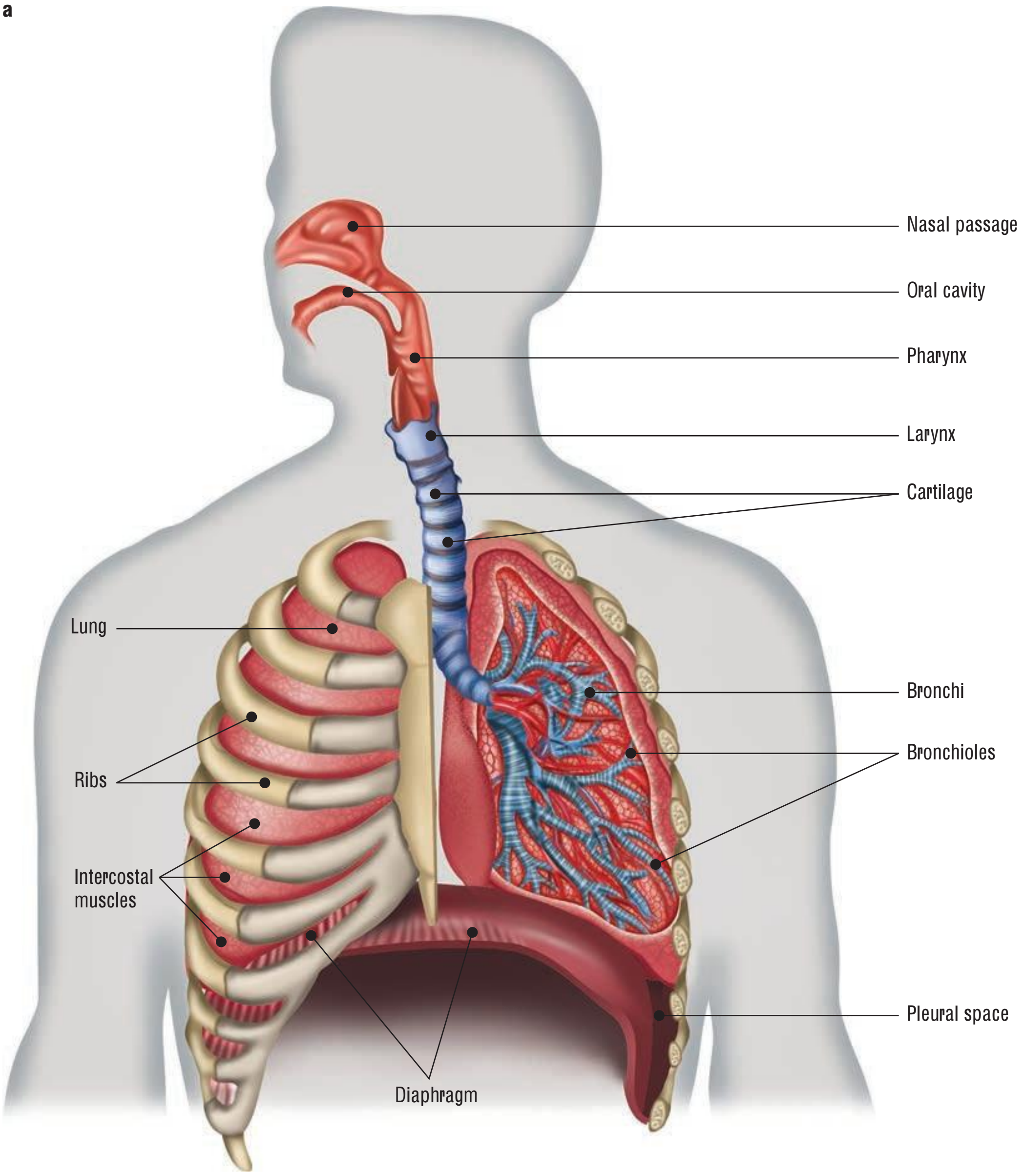
a



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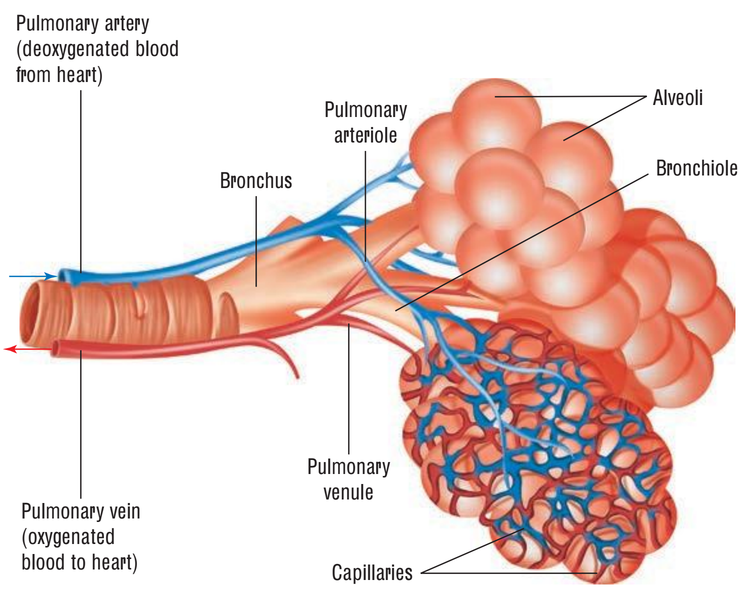

Figure 9.1 Anatomy of the respiratory system: (a) major pulmonary structures within the thoracic cavity; (b) close-up of lung structure

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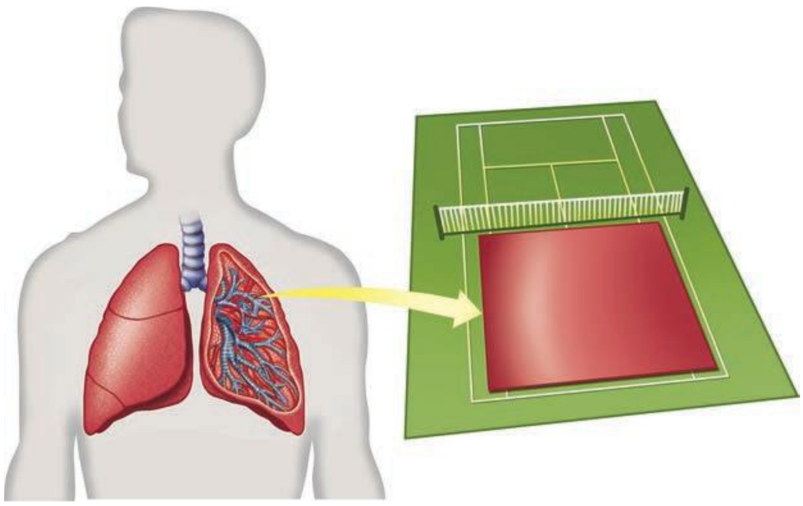

Figure 9.2 Lungs have a massive surface area – about the size of half a tennis court.

Table 9.2 Average lung volumes and capacities for males and females

Lung volume	Description	Average volume (L)	
		Female	Male
Total lung capacity	Total lung volume after a maximal inspiration	4.2	6
Tidal volume	Volume of each breath, inspiration or expiration	0.5	0.6
Residual volume	Volume in lungs after maximum expiration	1	1.2
Forced vital capacity	Maximum volume expired after a maximum inspiration	3.2	4.8

Catchy fact
Normal breathing rate is around 12 breaths a minute.

pulmonary ventilation
the process of moving and exchanging air from the environment with air in the lungs

diffusion
oxygen is transported from the alveoli to the haemoglobin part of the red blood cells, across the alveolar–capillary barrier; carbon dioxide moves in the reverse manner

Pulmonary ventilation

In pulmonary ventilation, air enters the body through the nose and/or mouth; before the air enters the lungs, the body attempts to filter, humidify and adjust it to body temperature.

Air flows down the trachea and into either of the two bronchi, which send it to the two lungs. All the time, the air is being filtered, warmed and moistened. The bronchi divide into many bronchioles and into the air sacs or alveoli.

The alveoli are surrounded by millions of tiny blood vessels. Air moves on one side (within the alveoli) and blood on the other. Air moves by diffusion across through the thin walls of the alveoli and blood vessels.

Mechanics of breathing

The process of breathing uses volume and pressure changes in and around the lungs to create air flow in an out of the lungs. Figure 9.3 illustrates this process. During inspiration (breathing in), the diaphragm descends and the ribs rise, causing the chest cavity size to increase, which causes air to rush into the lungs. Expiration (breathing out) is the opposite – a decrease in the chest cavity size makes the diaphragm rise and the ribs lower, causing air to rush out of the lungs.

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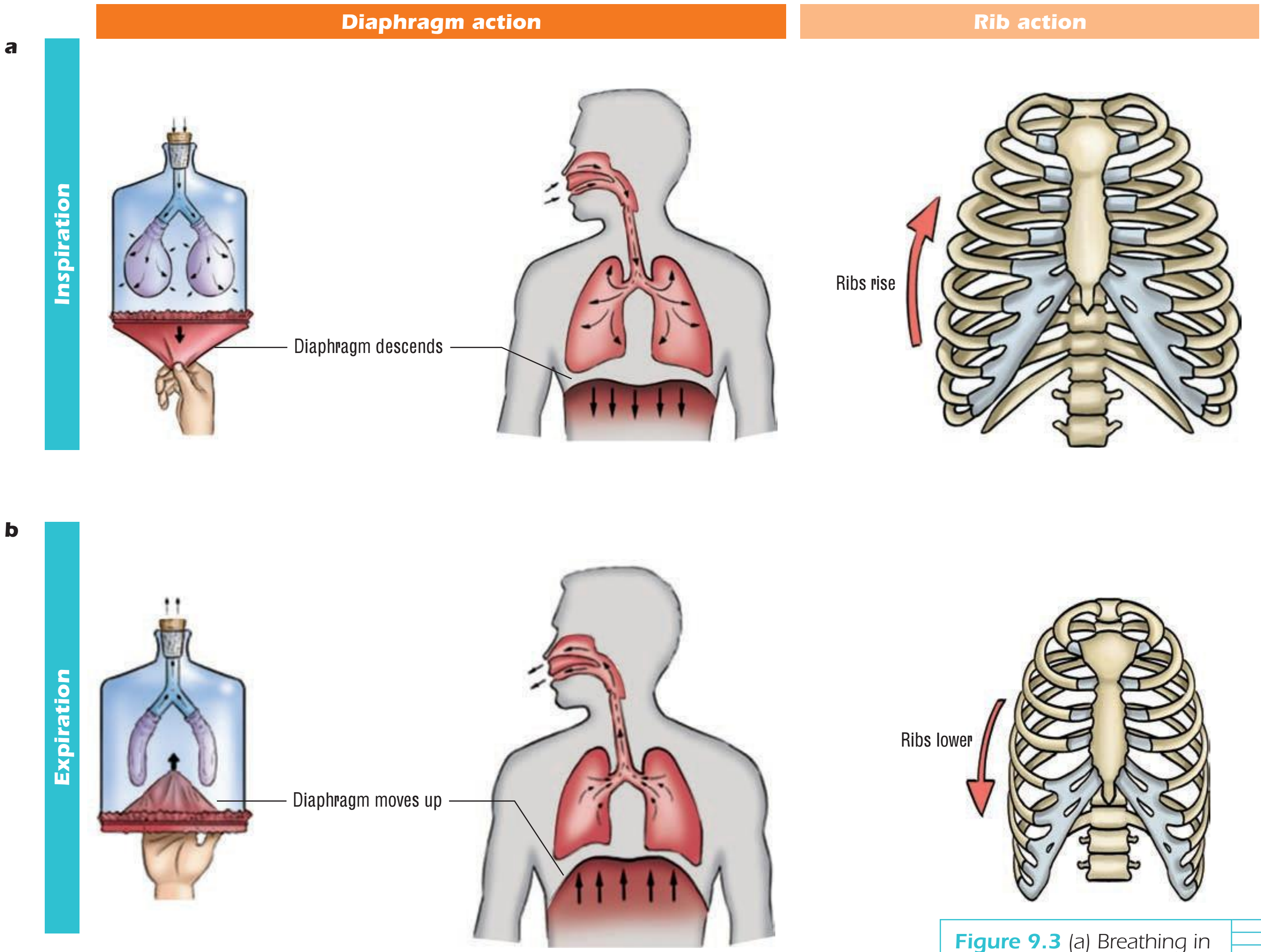

Figure 9.3 (a) Breathing in (inspiration); (b) breathing out (expiration)

The intercostal muscles have a larger role to play than the diaphragm in expanding the lungs.

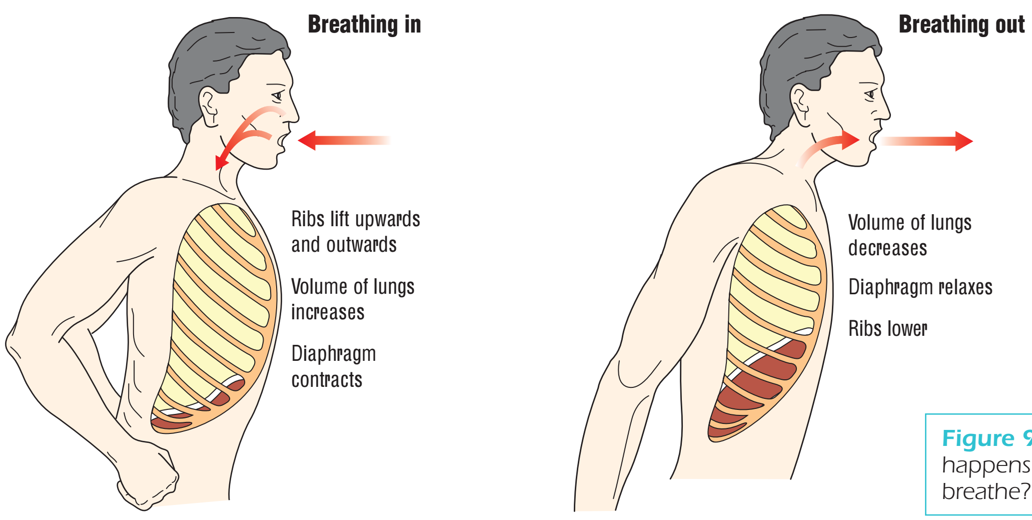

Figure 9.4 What happens when we breathe?

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Coursework: Laboratory activity

The composition of air in an exhaled breath

Aim

To determine the composition of exhaled breath

Materials

Two test tubes, rubber tubing, two rubber stoppers, glass tubing, lime water

Method

1. Prepare two large test tubes, as shown in Figure 9.5, and pour 10 cm^3 of lime water into each tube. Check that the rubber tube is connected to the long glass tube in one test tube and to the short glass tube in the other test tube.
2. Place both pieces of rubber tube in your mouth and breathe in and out through the tubing for approximately 30 seconds. Air breathed out will bubble through the lime water in tube B, whereas air breathed in will pass through tube A.

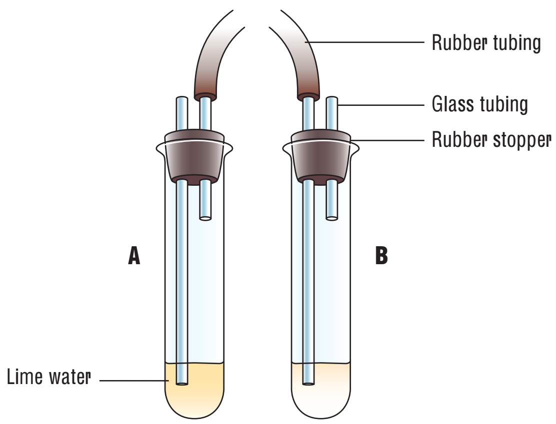

Figure 9.5 Testing exhaled air for CO_2

Result

The lime water in tube B will go milky, while the lime water in tube A will remain clear.

Explanation

Since carbon dioxide turns lime water milky, the results suggest that exhaled air contains more carbon dioxide than inhaled air.

Catchy fact
70% of lung expansion is the result of rib cage movement and 30% is a result of the movement of the diaphragm.

Gas exchange

The exchange of gases in and out of the body require gases, primarily O_2 and CO_2, to move (diffuse) from the alveoli to the blood and vice versa. The movement of gases is determined by the partial pressure of each gas in either the alveoli or the blood.

Pressure generally tries to equalise. If you blow up a balloon and hold the end, you can feel the high-pressure air inside the balloon trying to get out, in order to be at the same pressure as the surrounding air. As soon as you release your grip, the high-pressure air in the balloon rushes out. The diffusion of gases into the blood or alveoli works by the same principle.

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As the blood comes past the lungs after returning from the body, it generally has a higher pressure of CO_2 and lower pressure of O_2 than in the alveoli. This causes CO_2 to diffuse out of the blood and into the lungs, and O_2 to diffuse out of the alveoli and into the blood. The CO_2 is removed from the body in the next breath and the O_2 in the blood is transported around the body.

Oxygen transportation is examined in detail in Chapter 8.

Control of ventilation

The neural control over ventilation is quite complex. There are numerous sensors in the body that feed information to the brain. The medulla in the brain controls the normal ventilatory functioning. The partial pressures of O_2 and CO_2 are fed back to the medulla, which in turn causes the body to breathe to keep these within a normal range.

Hyperventilation

The primary regulators of breathing are blood levels of O_2, CO_2 and pH. During hyperventilation, you are 'blowing off' CO_2 and thus reducing the stimulus to breathe. If you were to then exercise while underwater, you will obviously reduce your O_2 levels, and under normal circumstances this would be a strong stimulus for you to breathe again. However, because you are underwater, the *partial pressure* of O_2 is raised, even though the *concentration* is lowered (perhaps to dangerous levels). Because the partial pressure is a more important 'reading' for the brain, it is tricked into believing that O_2 levels are sufficient when in fact they are not. The stimulus to breathe may not occur until it is too late – indeed the person may still be underwater at that point anyway.

hyperventilation the process of breathing more often and deeper than is necessary (also known as over-breathing)

Coursework

Sit comfortably and get a partner to time how long you can hold your breath for.

1. What is happening the longer you hold your breath?
2. What happens immediately you stop holding your breath?
3. What is the body trying do?
4. Why can you not continue to hold your breath?
5. What do you think would happen if you did not allow the body to breathe?

Respiration during exercise

When you begin to exercise, you use more energy from your body, which comes from the reaction of oxygen and food stored in the cells. For this to occur, you need more oxygen in your blood. By increasing your breathing rate and breathing more deeply, more oxygen enters your lungs and bloodstream.

Respiration rate, tidal volume and ventilation

Respiration rate is the number of times you breathe per minute. An average adult at rest breathes 12–18 times a minute. Tidal volume is the amount of air breathed in and out with each breath. For an average adult, this would be 0.5 litre. Ventilation is the amount of air breathed in a minute.

ventilation   tidal volume   respiratory rate

Therefore, at rest an average person's ventilation could be:

0.5 litre   5 breaths   7.5 litres a minute

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Immediate responses to exercise

When we exercise, our respiration rate will immediately increase to as much as 35 times a minute. The respiration rate is determined by a section in the brain that monitors the level of CO_2 in the blood. Carbon dioxide is one of the waste products of muscle work. As the level of CO_2 rises, the brain stimulates an increase in the respiration rate. Respiration rate can also be increased by nervousness and excitement or decreased through relaxation techniques.

The tidal volume will increase from approximately 500 mL to 5 litres during maximal exercise. Ventilation will also increase. It could increase to as much as 150 litres a minute during maximal exercise.

Training responses to exercise

After a significant exercise period, the body will adapt to the training load placed on it, causing the efficiency of our breathing mechanics to improve. This means that at rest, less breathing work needs to be done to maintain the required oxygen supply. A person of good health and fitness will generally have a lower breathing rate per minute than someone who is not as fit. People who smoke often have a considerably higher breathing rate.

Vital capacity

vital capacity
the maximum amount of air you are able to breathe out after taking in a deep breath

Vital capacity is the maximum amount of air you can breathe out after breathing in.

Responses to exercise

A person's vital capacity does not significantly increase through exercise or training, but it can be decreased by smoking and asthma. Vital capacity is closely related to the size of the chest cavity, and therefore males usually record higher readings.

Respiration rate, tidal volume and ventilation rates do not determine your performance in different sports; the efficiency of your oxygen uptake (VO_2) is a far more important factor.

Maximal oxygen uptake (VO_2 max)

VO_2 maximum (VO_2 max)
the maximal amount of oxygen that can be taken into the body and transported to and used up by the muscles during exercise

arteriovenous oxygen difference (aVO_2 diff.)
difference in oxygen concentration when comparing that in the arterioles to the venules, and an indirect measure of how much oxygen muscles are using

spirometer
measures vital capacity

The VO_2 maximum (VO_2 max) is the maximum amount of oxygen that can be taken into the body and transported to and used up by the muscles during exercise. This is the best indicator of how aerobically 'fit' a person is, or how efficient their circulatory, respiratory and muscular systems are when exercising. Your VO_2 max value is the largest amount of oxygen that you can use per minute and is determined by your maximum heart rate, stroke volume and aVO_2 (arteriovenous oxygen) difference. Your aVO_2 difference is the difference in oxygen concentration between arterioles and venules. It is typically used to provide an indication of how much oxygen muscles and working organs are extracting from the blood.

Several field tests can be used to predict VO_2 max, including the 20-metre shuttle run (beep) test, 12-minute walk/run and the Repco 7-minute cycle ergometer test. It is difficult to accurately test VO_2 max unless you have access to VO_2 apparatus, such as you would find in university physiology testing laboratories.

A more accessible test of the fitness of your respiratory system uses a dry spirometer. This measures your vital capacity.

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Immediate responses to exercise

Immediately on exercise, O_2 uptake increases. The normal resting oxygen uptake is approximately 3–4 mL/kg/min. The average value during exercise is approximately 30–50 mL/kg/min.

Training responses to exercise

VO_2 max increases with training. Elite athletes can have a VO_2 max of 50–75 mL/kg/min (Table 9.3). A summary of cardiorespiratory responses to exercise is shown in Table 9.4.

To work out your own VO_2max score, you need to complete the beep test.

Table 9.3 Maximum values for various activities

Sport	VO_2 max (mL/kg/min)
Track and field	
Running	60–85
Discus	42–55
Soccer	54–64
Canoeing	55–67
Cycling	62–75
Basketball	40–60
Rowing	60–72
Softball	48–56
Nordic skiing	65–94
Swimming	60–85
Weightlifting	38–52

Adapted from Wilmore and Costill 2005

Beep test

Table 9.4 Summary of cardiorespiratory responses to exercise

Immediate responses (during exercise)	Training effects
Blood flow to working muscles increases	Size of the left ventricle increases
Blood plasma volume decreases	Number of blood vessels increases
Heart rate increases	Blood volume increases
Stroke volume increases	Haemoglobin and oxygen-carrying capacity increases
Cardiac output increases	Resting heart rate lowers
aVO_2 difference increases	Recovery rate increases
Systolic blood pressure increases	Stroke volume increases
Respiration rate increases	Cardiac output increases
Tidal volume increases	aVO_2 difference slightly increases
Ventilation increases	Risk of high blood pressure (hypertension) decreases
Oxygen uptake (VO_2) increases	Efficiency of breathing mechanics increases
	VO_2 max increases

Respiratory issues in cold weather sport

The airways have a very high capacity for warming air. In extremely cold conditions, such as those found in alpine winters, the body uses considerably more water to warm the inspired air. This can lead to dehydration, especially during strenuous exercise like skiing.

This loss of water from the respiratory tract can also lead to a dry feeling in the throat. A side effect of this is post-exercise coughing during the recovery period.

Asthma and exercise

KEEP IT REAL!

It is believed that 15% of children and approximately 10% of adults suffer from the respiratory illness known as asthma.

Asthma is a condition where people have hypersensitive airways. Various triggers cause the airways to become swollen and thus narrowed. This makes it more difficult for people with asthma to breathe (see Figure 9.6).

There are two main factors that cause airways to narrow:

- The inside lining of the airways becomes red and swollen (inflamed) and there is mucus hypersecretion.
- The muscle around the airways tightens – bronchoconstriction.

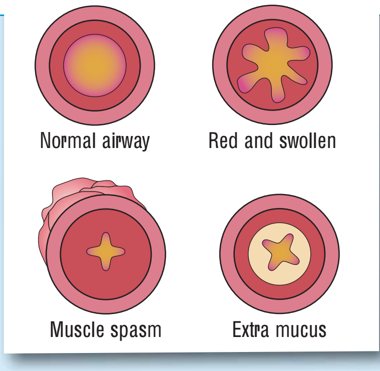

Figure 9.6 Diagram of narrowing airways

The most common symptoms of asthma are coughing, shortness of breath, tightness of chest and wheezing. Symptoms are very individual.

Triggers for asthma

Asthma triggers are very individual too. People with asthma need to recognise their triggers so that they can avoid them and better manage their illness. The more common triggers include:

- viral infections – cold or flu
- inhaled allergens – pollens, mould, animal hair and dust mites
- sudden changes in air temperature
- air pollutants – cigarette smoke, paint and chemical fumes
- some medications
- some food additives – MSG
- some emotions – stress, laughter
- exercise – although this is relatively easy to manage.

Catchy fact

The role of mucus is to stop particles entering the lungs. It also contains antibacterial agents to aid in the body's defence system.

Catchy fact

A large number of Olympic gold medallists suffer from asthma. This is because as children they were attracted to swimming as an important way of managing their asthma.

Exercise-induced asthma

Exercise is important to help asthma sufferers become healthier and thus help control their condition. However, it is also a common trigger for asthma. So it is extremely important to take appropriate simple precautions. Avoiding exercise would probably result in more health problems than the asthma itself.

Why is exercise a trigger for asthma?

At rest, most people breathe primarily through their nose. This helps to warm and moisten air. When you exercise, you tend to breathe faster and through your mouth. The mouth is considerably less effective at warming and moistening the air than the nose is. The colder, drier air from the mouth causes the bronchioles to cool and lose water to the air. It is believed this causes irritation and subsequent tightening.

Preventing exercise-induced asthma

Individuals need to manage their asthma well by using medication, including reliever medication if required, and having regular check-ups with a doctor. When exercising, warming up and cooling down appropriately helps to lessen symptoms.

Asthma Foundation of WA

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Cigarette smoking and exercise

On average, smokers tend to be less active than non-smokers, so the problems that smoking causes in the respiratory system are not seen as much in active people.

Studies have found that cigarette smokers tend to metabolise less fat when exercising and therefore rely more on their glycogen stores. This is one of the reasons cigarette smokers will reach a fatigue state earlier than non-smokers. Smokers' lungs do not work as efficiently as non-smokers' lungs. Smokers' airways are also obstructed because of smoking. Normal exercise heart rate changes in smokers can be inhibited (i.e. the heat rate does not change or increase as it normally would), which gives them a false low at each exercise level. So during testing, they may work with a lower heart rate at a given intensity. This could imply that they have higher fitness levels than they actually do. This can be dangerous; if smokers are pushed too hard, not only are they less fit in general but their respiratory and circulatory systems are compromised because of the smoking.

Coursework: Laboratory activity

Measure your vital capacity

Materials

Dry spirometer

Method

1. Blow into the spirometer and record your reading.
2. Record the class results.

Results

How does your reading compare to the class average and the norms in Table 9.5?

Table 9.5 Vital capacity measures for male adolescence

Age	Vital capacity
12	2000
14	2800
16	3200
18	3800

Size of chest cavity and ethnic origin are better predictors of vital capacity than is age alone. It stands to reason that a tall 14-year-old will have a greater vital capacity than a shorter one as their lungs will be of different size.

Adapted from Baker 1978

TEST YOUR KNOWLEDGE

>> multiple choice

1 For which of the following sports would an athlete be expected to have the highest lung volume?

A Weightlifting
B Cross-country skiing
C 200 m swimming
D Basketball

2 The beep test is a:

A field test to test anaerobic power
B laboratory test to test VO_2 max
C field test to test VO_2 max
D laboratory test to test anaerobic power.

3 Hyperventilation is dangerous before swimming under water as it:

A may cause light-headiness which limits muscle force production
B limits the total amount of O_2 available to the cells
C can cause a loss of consciousness
D may cause the diaphragm to spasm.

4 The part of the brain that controls breathing is the:

A medulla
B pons
C frontal lobe
D ventilation process.

>> short answer

5 Draw and label all of the parts of the airway from mouth to bronchiole.

6 Provide a short description of how the brain controls breathing.

7 Describe the three main reasons why smoking would be detrimental to athletic performance.

8 What is the reason the air is warmed when in the airway?

>> essay style

9 Describe the process of gaseous exchange. What would you expect the differences of a person with a larger VO_2 max to be?

10 Follow the path of a molecule of air through the body into a cell and then follow a molecule of CO_2 out of the body. Ensure that you describe all of the structures that the molecules travel through.

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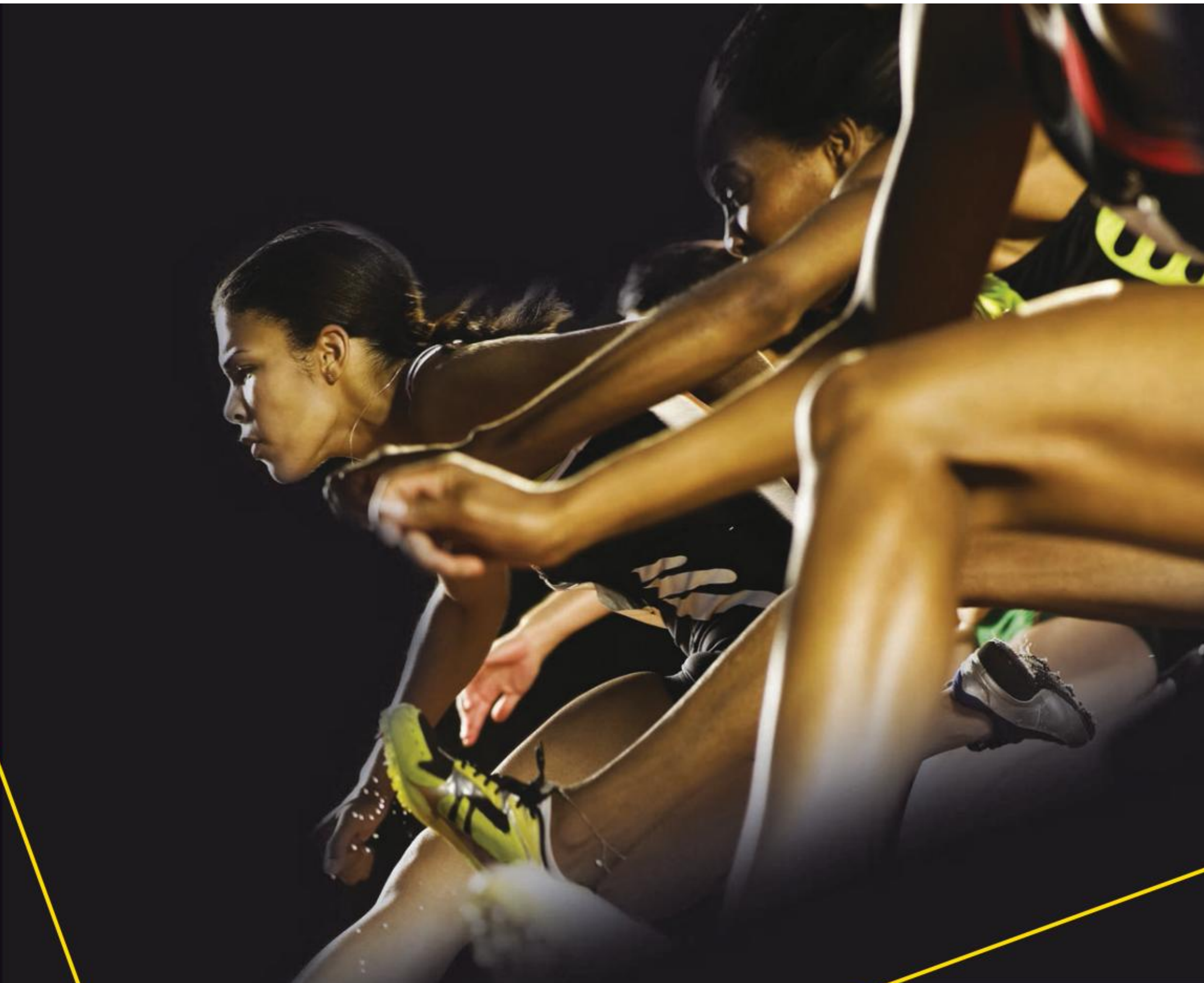

SECTION 4
BIOMECHANICS

Chapter 10 The biomechanics of movement

2A.11 Define and apply linear motion to a selected sport in relation to speed, velocity, acceleration and instantaneous measure/mean measure.

2B.12 Define and apply projectile motion to a selected sport in relation to the principle of optimal projection, parabolic trajectory and release of projectiles (angle, velocity and height).

2A.13 Define and apply angular motion to a selected sport in relation to angular velocity.

2A.14 Define and apply general motion to a selected sport.

2B.10 Define and apply the principle of balance to a selected sport in relation to:

- the centre of gravity; i.e. line of gravity, width of base of support
- height of centre of gravity
- static balance
- dynamic balance.

2B.11 Define and apply Newton's first, second and third laws of motion.

2B.12 The coordination of linear motion; i.e.

- sequential versus simultaneous movement – accuracy and power
- summation of velocity.

10 The biomechanics of movement

Kinematics is the part of biomechanics that is concerned with all facets of motion. We can observe motion all around us – it is the basis for all sporting events. Motion can be described as a change in position – either of people or of sporting objects. The only way objects can change their position is if they move in both time and space. Movements are generally classified as being linear, angular or a combination of both. Various other factors change the way objects move and they will also be considered in this chapter.

Linear, angular and general motion

Most movements in sporting situations combine linear and angular movements to bring about what is commonly known as general motion. Think about a 100-metre sprinter. Her upper body is moving down the track with her whole body moving the same distance and direction over time.

Linear motion

Catchy fact
Linear motion is sometimes referred to as translation.

Linear motion occurs when all body parts move the same distance and direction at the same time. This can also be seen in a shotput event in the side-on technique commonly used by students. Figures 10.1 and 10.2 are some basic examples of linear motion.

Linear motion can further be broken down into rectilinear motion or curvilinear motion, depending on what type of movements are occurring. Both involve all points on a body moving

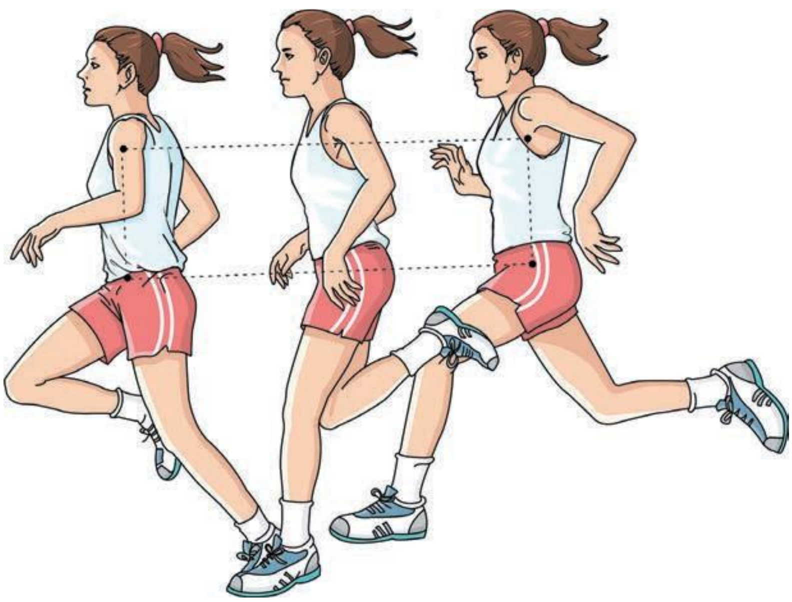

Figure 10.1 Running is an example of general linear motion. Each segment of the leg rotates around the joints at the same time and the body moves in a straight line.

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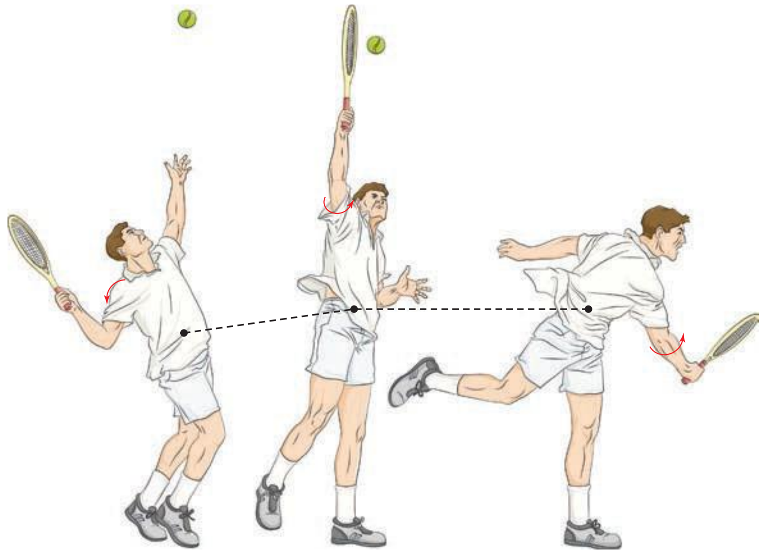

Figure 10.2 The body displays linear motion while the arm displays angular motion as it rotates about the elbow and shoulder joints.

Coursework: Investigation of biomechanics

1 Select a sport that you are interested in.

- **a** Research the types of instruments that may be used to analyse performance in this sport.
- **b** Note what improvements to performance times, distances etc. have been made over the past decade.
- **c** Explain why these improvements have taken place. (Consider clothing, equipment, surfaces and other biomechanical factors that might be responsible for these improvements.)
- **d** Present your findings to the class in a brief oral presentation.

2 Look through some recent issues of sporting magazines or newspapers or carry out an Internet search. Find five statements or diagrams that deal with the biomechanics of a movement or piece of sporting equipment and report this back to the class.

at the same time and covering the same distance. Rectilinear motion involves movements in a straight line without any changes in the direction of motion. Curvilinear motion occurs when the linear movements follow a curved path and hence the direction of travel is constantly changing.

angular motion
movement of an object or body parts around an axis

How can we determine if motion is rectilinear or curvilinear? It is probably easier than you think if you apply the following process. Draw two points separated by a distance on an object. After you have observed any movement, ask yourself the following:

- Do the points keep moving in the same direction?
- Do the points stay the same distance apart during the movement?

If you have answered yes to both of these simple questions, then you are observing rectilinear or linear motion. If the points remain parallel but do not move in straight lines, you are observing curvilinear motion.

Figure 10.3 An example of angular motion is a gymnast swinging over a bar

Angular motion

Angular motion is sometimes referred to as rotary motion, and occurs when body parts rotate in the same direction at the same time around a fixed point. This point is known as the axis of rotation and can be either internal or external. Internal axes of rotation tend to be joints around which rotational movements occur. In the example of a sprinter in Figure 10.1, her arms rotate at the shoulder joint to provide drive, and this similarly occurs as the legs rotate at both the hip and knee joints (axes of rotation). Think about completing a bicep curl at the gym. As you flex/contract the bicep during the upward phase, your arm and wrist are both rotating around a fixed point (the elbow joint). Every point on the moving arm follows the same direction at the same time and over the same distance but moving in an arc or curved manner. The same happens during the downward phase of this exercise.

External axes of rotation tend to occur when body parts rotate around a point that occurs outside the body. Examples include a gymnast swinging on the uneven bars (Figure 10.3) or a male gymnast swinging on the parallel bars. It is worth noting that angular motion is far more common in sport than linear motion.

general motion
a combination of angular motion and linear motion; the most common form of motion in sport

General motion occurs when our bodies move as a result of linear and angular motion. Think of a person walking or running. Their hips, knees and ankles all allow angular movement of the legs and feet to occur, while the upper body is basically moving in a rectilinear or linear fashion. A racing cyclist uses a combination of several angular motions to produce the linear motion of the bicycle.

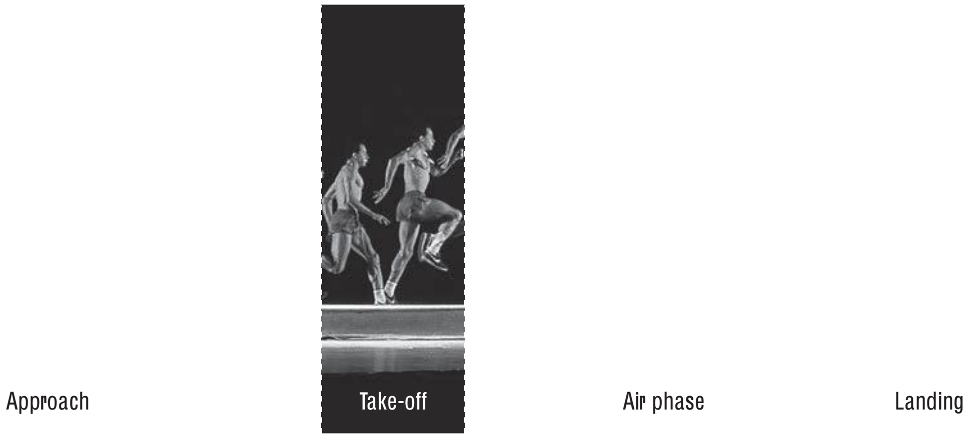

Figure 10.4 *The hang-kick technique in long-jump combines linear and angular motion to bring about general motion.*

When considering linear motion, the concepts of distance, displacement, speed, velocity and acceleration must be clearly understood. Collectively, these allow us to examine linear motion in greater detail. This part of biomechanics is often referred to as linear kinematics.

displacement
the difference between the initial position and the final position of an object

Figure 10.5 *The two skiers have covered different distances but have the same displacement.*

Distance and displacement

Distance and displacement are different parameters used to describe the extent of a body's motion. Distance is the length of the path a body follows. Displacement is the length of a straight line joining the start and finish points. For example, in a 1500-metre race on an Olympic track, the distance (length of the path the athlete follows) equals 1500 metres but the total displacement equates to zero because they finish at the same place they started!

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Consider the example of two skiers standing at the top of a downhill run during the ski season (Figure 10.5). The distance from the top of the ski run to the bottom is 1000 metres. The more experienced skier decides to ski straight down the slope, in the process gaining high speeds. At the end of the run, she has covered 1000 metres. The less experienced skier decides to go down slower and zig-zags across the slope while moving down at the same time. She has the same displacement at the end of the ski run because both skiers started and ended at the same spot. However, she has actually covered a lot more distance by zig-zagging down the slope, so her distance is greater.

Speed and velocity

Speed and velocity describe the rate at which a body, or body parts, move from one point to another. These two terms are often used interchangeably, but they actually measure different variables. The average speed of a body is obtained by dividing the distance travelled by the time taken. Average velocity is obtained by dividing the displacement by the time taken. Consider a runner in an 800-metres race running around an Olympic track measuring 400 metres per lap. If he runs this distance in 1 minute 45 seconds, the distance is 800 metres (two laps) but the displacement is 0 metres (he is back where he started) so speed is 800 metres / 105 seconds = 7.6 m/s and velocity is 0 metre / 105 seconds = 0 m/s.

velocity
the rate of positional change of an object

Consider the skiing example above. We need to know how long it took each skier to ski down the slope before we can start to investigate average speed and average velocity. Assume the more experienced skier took 1 minute to ski down and her less experienced friend took 100 seconds. Table 10.1 shows the speeds and velocities of the two skiers.

Table 10.1 Differences in speed and velocity for two skiers

	Experienced skier	Beginning skier
Total distance covered	1000 m	1500 m
Total displacement	1000 m	1000 m
Time	60 s	100 s
Speed	1000 m ÷ 60 s = 16.6 m/s	1500 m ÷ 100 s = 15 m/s
Velocity	1000 m ÷ 60 s = 16.6 m/s	1000 m ÷ 100 s = 10 m/s

Acceleration

Acceleration is defined as the rate at which velocity changes with respect to time. The average acceleration can be calculated by subtracting initial velocity from final velocity and then dividing this by the time taken to complete the task. If we consider the experienced skier in the previous example again, we can calculate her acceleration in the following way:

average acceleration
(final velocity – initial velocity) ÷ elapsed time

final velocity (16.6 m/s) – initial velocity (0 m/s) ÷ elapsed time (60 s) = 0.27 m/s^2

But simply measuring the distance covered and dividing this by the time taken might not provide us with data such as maximum speed – in a 100-metre race, the person who wins might not be the fastest! A person might reach a higher maximum speed but then slow down towards the end of the race to be beaten. The winner at the end of the 100-metre sprint is the person with the highest *average* speed. In order to work out maximum speeds at various points of the 100-metre race, sport scientists need to take split times throughout the race. Typically, they use high-speed cameras and record speeds at 10-metre intervals to assist them with their investigations.

Catchy fact
When an object starts, stops, slows down, speeds up or changes direction, it is accelerating. This can be positive or negative.

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average (mean) speed
distance travelled ÷ time taken (does not take displacement into consideration)

The maximum speed of a 100-metre sprinter can now be calculated by this method and this coincides with the instantaneous speed; i.e. the speed of the sprinter at a specific point in time during the race. The average (mean) speed is very different from the instantaneous speed at any point because it considers movement over the total distance.

Checkpoints

1 What do linear and angular motion have in common? How are they different?
2 Provide three sporting examples to clearly highlight how general motion is the product of linear and angular motion.
3 What is the difference between distance and displacement?
4 How is instantaneous speed different from mean speed?
5 What is the difference between the speed and velocity of an object?

Table 10.2 compares the average and instantaneous speeds for two Jamaican Olympic sprinters – Asafa Powell and Usain Bolt – in the 100-metre sprint.

Table 10.2 Average speeds and instantaneous speeds for Asafa Powell and Usain Bolt over 100 metres

	Asafa Powell (2007)		Usain Bolt (2008)	
	Instantaneous speed (m/s)	Average speed (m/s)	Instantaneous speed (m/s)	Average speed (m/s)
Reaction time (s)	0.15		0.165	
0–10 m	1.89	5.29	1.85	5.41
10–20 m	1.02	9.8	1.02	9.8
20–30 m	0.92	10.87	0.91	10.99
30–40 m	0.86	11.63	0.87	11.5
40–50 m	0.85	11.76	0.85	11.76
50–60 m	0.85	11.76	0.82	12.19
60–70 m	0.84	11.9	0.82	12.19
70–80 m	0.84	11.9	0.82	12.19
80–90 m	0.85	11.76	0.83	12.05
90–100 m	0.85	11.76	0.9	11.11
Total time	9.77	10.23	9.69	10.32

Catchy fact
If the motion of an object is in a straight line and rectilinear, with no deviation in direction, the average speed and average velocity will be identical.

Note that Bolt displays better speed endurance than Powell during the critical middle stages of the 100-metre sprint. The two men are moving at the same instantaneous speed at the 20-metre mark and Powell is actually moving faster at the 30-metre mark. Bolt speeds up from this point and is able to maintain his speed (speed endurance) from the 50- to the 80-metre mark, where he reaches top speed. Note that both men slow down over the last 20 metres of the race.

Newton's laws of motion

Much of what we understand about motion and forces can be traced back to the work of Sir Isaac Newton. It is important that we understand his three laws of motion and how these can be applied to various sporting situations to better understand how movements can be improved to bring about optimal performances.

ISBN 9780170227094

Newton's first law – the law of inertia

All bodies will continue in a state of rest or uniform motion in a straight line unless acted upon by some external force.

What implications does this have for sporting situations? A sprinter, for example, will not move from the blocks until her legs exert force against them. A high-jumper will not take off from her approach run unless a force is applied to change her direction. A gymnast will continue swinging around the uneven bars until an external force is applied to her movement.

Figure 10.6 The high-jumper must change her movement from horizontal to vertical by applying a greater downward force for the last step before take-off.

Newton's second law – the law of acceleration

The acceleration of a body is proportional to the force acting on it and takes place in the direction the force acts.

How do we calculate forces acting on bodies and hence resulting in movement?

$$\text{Force} = \text{mass} \times \text{acceleration}$$

where force is measured in newtons (N), mass in kilograms (kg) and acceleration in metres per second squared (m/s^2).

This means that that more force will result in more acceleration. A swimmer's acceleration off the starting blocks is proportional to the force exerted against them. The greater the force exerted, the greater will be the acceleration away from the blocks and the further and faster the entry into the water. In shotput or discus events, the larger the force exerted on the shot or discus, the greater will be its acceleration as it leaves the athlete's hand and, consequently, the greater the distance achieved. In swimming, the greater the force exerted against the water, using the various strokes and kicks, the greater the resultant forward acceleration down the pool and hence swimming speed.

In some sports, forces must be applied explosively to achieve maximum acceleration or deceleration. This might be the case for a tennis player serving at 210 km/h or an AFL player pushing off the ground to take a high mark. However, in some instances, it is important that forces be applied for longer periods of time – this is known as impulse. Impulse equals the force applied multiplied by the duration over which it is applied:

impulse
the application of force over a period of time

$$\text{Impulse} = \text{force} \times \text{time}$$

where impulse is measured in newton seconds (N s), force in newtons (N) and time in seconds (s).

KEEP IT REAL!

Ground reaction forces

In some sports, repeated ground reaction forces are a source of concern for coaches and athletes. Fast bowlers in cricket, for example, have to absorb forces five times their own body weight every time their foot impacts the ground. Table 10.3 highlights some ground reaction forces of selected sporting skills. It should not surprise you that gymnasts completing the floor routine find it difficult to 'land' their final tumbling run because they have 12 times their body weight equivalent force to contend with. This could be 12 × 70 kg = 840 kg equivalent force.

Table 10.3 Some ground reaction forces

Skill	Footwear	Force in approximate body weights
Walking	Casual shoes	1
Running	Running shoes	3
Running jump take-off	Spikes	8
Front foot contact of a cricket fast bowl	Cricket boots	5
Vault take-off	Barefoot	4–6
Double backward somersault landing	Barefoot	12

Adapted from Pyke 2001

Once an object such as a cricket ball has been released, there are no forces that can act to accelerate it. The same is true in gymnastic events. The greater the force the gymnast exerts on the floor at take-off, the greater the acceleration and height or distance that can be attained. Once the gymnast has left the floor, nothing she does will accelerate her body. When maximum forces are needed, the muscles contract rapidly and explosively to generate this force and this is why injuries are more likely to occur in the acceleration or deceleration phases of a movement.

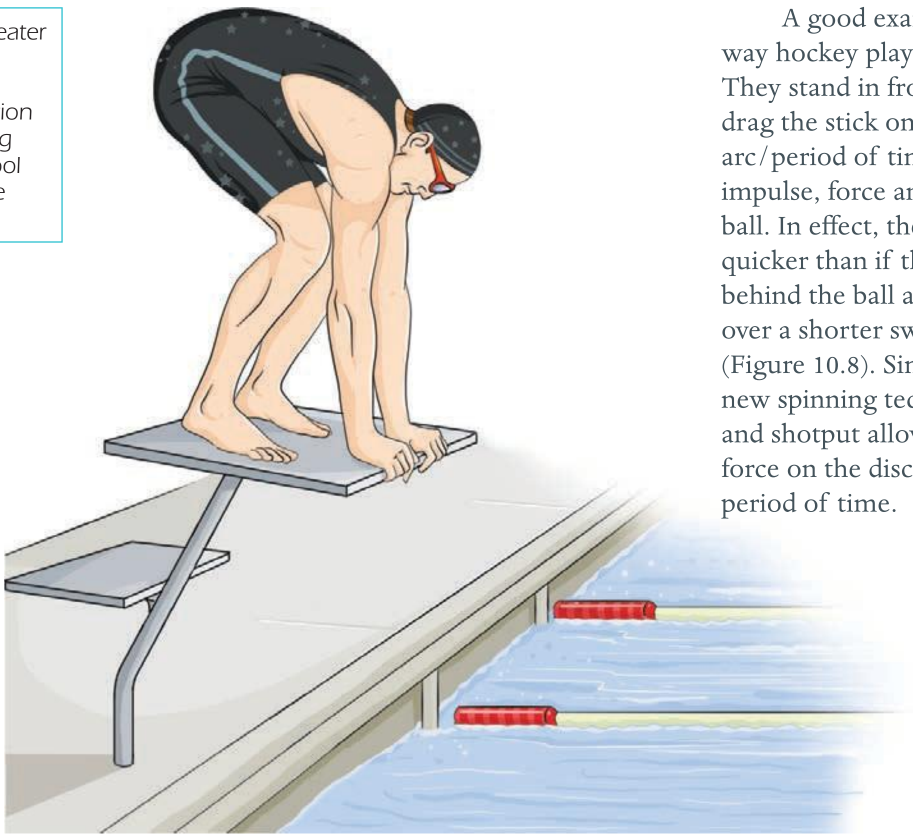

Figure 10.7 Greater force against the blocks ensures greater acceleration from them during entry into the pool at the start of the race.

A good example of impulse is the way hockey players take short corners. They stand in front of the ball and drag the stick on the ball for a longer arc/period of time and this increases impulse, force and speed achieved on the ball. In effect, the ball gets to teammates quicker than if the player simply stood behind the ball and applied the force over a shorter swing/period of time (Figure 10.8). Similarly, the relatively new spinning techniques used in discus and shotput allow performers to apply force on the discus and shot for a longer period of time.

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Figure 10.8 The force is applied to the hockey ball for longer by moving the stick over as great a distance as possible.

Catchy fact
A push shot in hockey relies on impulse instead of a backswing to generate its force. Even without a wind-up, the ball can still be pushed with a velocity of around 160 km/h!

Newton's third law – the law of action–reaction

For every action there is an equal and opposite reaction.

A sprinter exerts a force against the ground every time she pushes off the track. This creates an equal and opposite reaction force that moves her body over the ground – both upwards and forwards. This law also applies to movements that are made in the air. In these situations, the equal and opposite reaction is translated into movements of other parts of the body. A long-jumper, for example, will bring his arms and trunk forward in preparation for landing during the hitch-kick technique. The equal and opposite reaction is movement of the legs into a forward and upward position ready for landing.

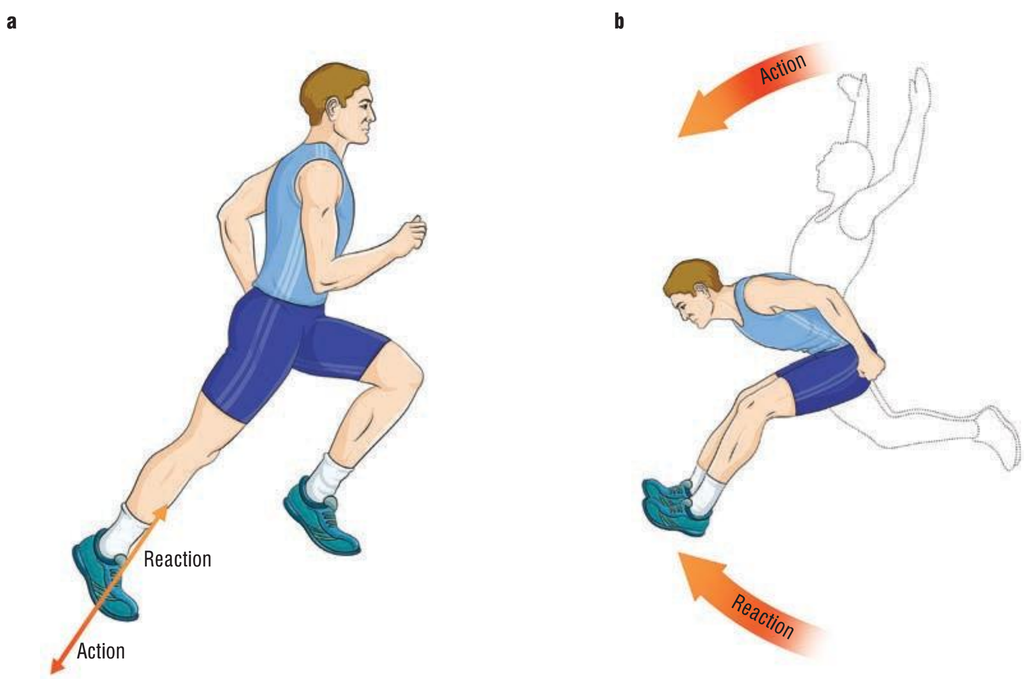

Figure 10.9 (a) A runner creating an equal and opposite reaction. (b) Action and reaction in long-jump landing

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Applying Newton's laws to sports

Now that we understand more about Newton's three laws and factors influencing motion, it is time to consider some other biomechanical principles involved in sports including:

- force production, which deals with the principles of mass, weight, velocity, inertia, acceleration, momentum, impulse, elasticity and accuracy
- balance and stability, which link the base of support to the centre of gravity.

Force production

Force is the 'push' or 'pull' placed upon an object to get it moving, speed it up, slow it down, stop it or change its direction. In short, force is used to change a body's velocity. Internally, force is produced by the contraction of muscles. Externally, the effects of gravity, friction, water and air generate force on an object.

The unit of measurement used for force is the newton (N). One newton is the force needed to move a 1-kilogram mass at an acceleration of 1 metre per second squared. The only time a force does not produce movement is when two forces of equal magnitude act in opposing directions, thus cancelling each other out. In this case, there is no overall change in the object's motion and the forces are said to be balanced A change in velocity will only occur when an unbalanced force acts on the object.

Inertia

inertia
a measure of how difficult it is to move an object

The tendency of an object to maintain its state of motion (velocity), whether it is stationary or moving, is known as its inertia. The greater the inertia, the more difficult it is to change the motion of an object. The inertia of an object is proportional to its mass (it is more difficult to move an object made up of more matter), so we can indirectly measure the inertia of an object by its weight on a set of scales.

To alter an object's motion, we must apply an unbalanced force to overcome its inertia. The force may alter the object's speed and/or direction of movement. In beach volleyball, both aspects of this principle are illustrated when a player spikes the ball after it has been sent to her by her team-mate during a rally. The force exerted by the hand on the ball will alter the ball's speed and direction of travel.

Mass and weight

Mass is the amount of matter that makes up an object, and weight is the force exerted by the Earth's gravity on an object. The weight of an object is directly proportional to its mass. For example, a medicine ball has a greater mass (and consequently weighs more) than a volley ball. We cannot measure the amount of matter in an object directly, but we can measure how heavy an object is (on a set of scales). Therefore, we commonly use weight as an indirect measure of mass. The unit of measurement for mass is the kilogram (kg).

Velocity

Velocity measures the rate (speed) of the positional change of an object. Velocity has two important characteristics – speed (how quickly it is covering ground) and direction.

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Checkpoints

1 What is Newton's second law of motion and what biomechanical principle does it relate to? Provide a sporting example that highlights use of this principle.

2 Explain the difference between mass and weight. Some class discussion may be required.

3 Define velocity and discuss its two most important characteristics. What is the difference between speed and velocity?

4 In your own words, explain why a lighter Australian Rules football player such as a rover is not necessarily at a disadvantage when making contact with a heavier ruckman.

5 Select a sporting example and explain two ways in which we can apply greater impulse.

Direction is indicated by the use of vectors. Both factors must be stated to define an object's velocity. The unit of measurement we use for velocity is metres per second (m/s). A stationary object is said to have a velocity of zero (its position does not change). A ball moving upwards and travelling 5 metres per second has a velocity of 5 metres per second (5 m/s) in an upwards direction.

Momentum

Momentum is a measure of the amount of motion possessed by a moving body (mass multiplied by velocity). The units of measurement we use for momentum are kg and m/s. The momentum of an object is directly related to its mass and velocity. For example:

- If two objects of different mass are moving with the same velocity, it will be harder to stop the object with the greater mass.
- If two objects with identical mass are moving at different velocities, it will be harder to stop the object with the greater velocity.

When two bodies collide, the one that possesses the most momentum will be the least affected (see Figure 10.10). In a collision on a football field, when a smaller, faster-moving player knocks over a bigger player, the smaller player may have had greater momentum due to his speed on the field. In this situation, the smaller player is less affected by the collision than the bigger player.

momentum
a measure of how much motion an object has

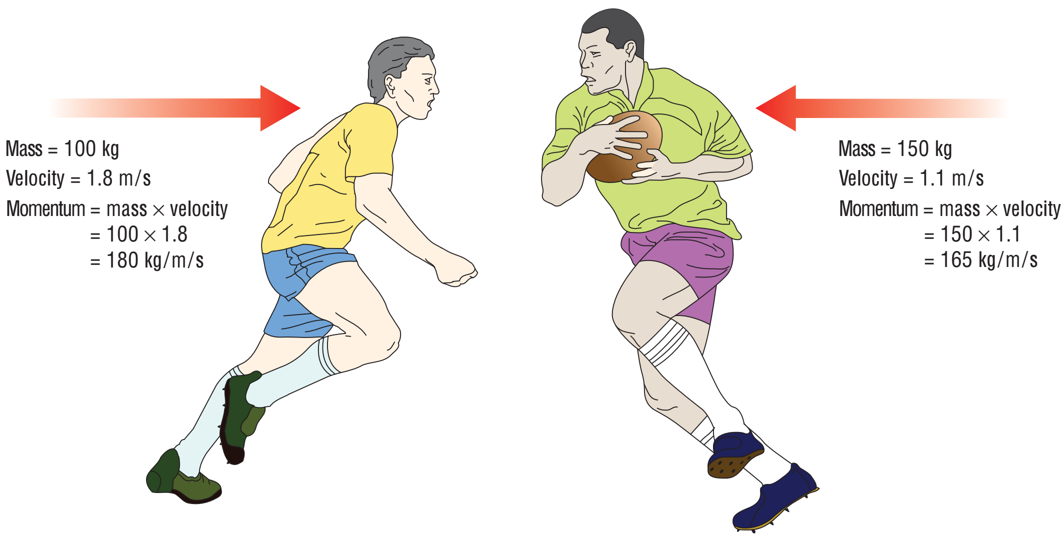

Figure 10.10 The player with the most momentum is least affected in a collision. The player on the left is lighter, but faster so has the most momentum.

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Impulse

The amount of change in the momentum of an object is related to the size of the unbalanced force and the amount of time it acts for. Another name for this change in momentum is impulse. The larger the impulse applied, the greater the change in momentum. The two things that affect impulse are the:

- magnitude of the unbalanced force
- length of time the force is applied.

If the length of time is constant, then impulse can only be increased by increasing the magnitude (size) of the force applied. For example, in rowing, the oar can only physically be in the water for a certain length of time during each stroke; therefore, the rower must exert greater force with her legs and upper body to increase impulse.

If the force applied is constant, the impulse can only be increased by increasing the length of time for which the force is applied. For example, a discus throw in which a spinning action of the body is used prior to release increases the time over which the force is applied, thus imparting greater impulse to the discus. This provides a greater change in momentum and greater speed of release.

Acceleration

Acceleration is how quickly an object can change velocity when an unbalanced force causes movement. Newton's second law of motion explains the principle of acceleration:

The amount of acceleration produced when an unbalanced force acts on a body is proportional to the size of that force.

For example, imagine that two identical shotputs are acted on by an unbalanced force (thrown). One is thrown by an experienced athlete, and one by a beginner. The shotput that is acted on by the greater force (from the experienced athlete) will have a greater acceleration. The unit of acceleration is metres per second squared (m/s^2).

As we have seen, acceleration is affected by force (the greater the force used, the greater the acceleration of the object). However, acceleration is also affected by the mass of the object. If the force applied is the same, an object with smaller mass will have a greater acceleration than an object with a larger mass. For example, if one person used exactly the same force to throw a tennis ball and then a cricket ball, the tennis ball would have greater acceleration due to its smaller mass.

In sport, acceleration is important at the start of events, especially sprints or short distances. Sprint cyclists can accelerate from 0 to 15 km/h in 1 second. Because this type of acceleration requires huge amounts of force, sprint athletes are always more muscular than long-distance runners. It also means that acceleration cannot last for the duration of an event (even a sprint). Runners in the 100-metre sprint, for example, accelerate out of the blocks (positive acceleration) until they reach maximum speed. At maximum speed, there is no change in velocity (zero acceleration) and then they slow down at the end of the race (negative acceleration) (see Table 10.2, p. 172).

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Coursework: Laboratory investigation

The difference between velocity and acceleration

Materials

Tape measure (50 m), markers or cones (at least ten), stopwatches (six)

Method

Accurately measure a 50-metre distance. Place markers at the start and at 10-metre intervals up to 50 metres. A student with a stopwatch stands at each marker and records the time of a sprinter as they pass the marker. Another student signals the start of the sprint and that students with stopwatches need to commence timing.

1 Record the time, velocity and acceleration for each distance, using the following formulas:

velocity = distance covered ÷ time

acceleration = change in velocity ÷ time

= (final velocity – initial velocity) ÷ time

2 Draw a graph of the results, showing the velocity and acceleration over the 50 metres.

Results

1 At which point was the velocity the lowest? Why?

2 Where did the sprinter reach maximum velocity? Can you explain why it may have occurred at this distance?

3 Where did the sprinter reach maximum acceleration? Can you explain why it may have occurred at this distance?

4 Did the sprinter experience zero acceleration at any stage? What does the zero acceleration mean?

5 Did the sprinter experience negative acceleration at any stage? What does this indicate?

Conservation of momentum

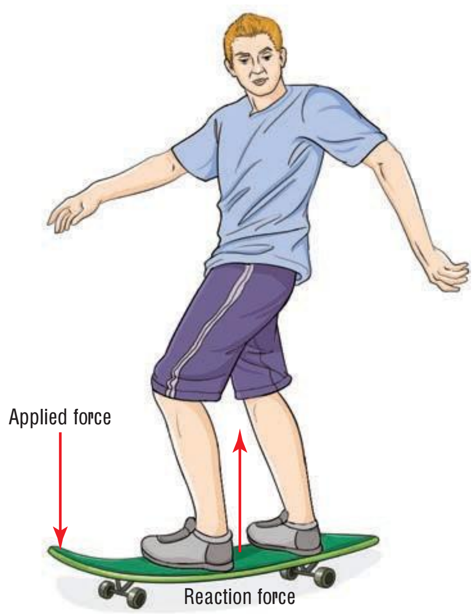
The principle of conservation of momentum applies to any collision between two objects, for example, a foot contacting the ground in running, a stick hitting a ball or two balls colliding. When a collision occurs, the total momentum of two bodies before impact is equal to the total momentum after impact. This is best explained by Newton's third law of motion:

For every action there is an equal and opposite reaction.

For example, in snooker when a straight shot is played, the white ball hits a coloured ball, and stops on impact. The momentum is passed on to the coloured ball. (If the white ball keeps rolling, it is because spin has been applied to the ball when it was struck by the cue stick.) According to Newton's third law, this is because when the white ball applies a force to the coloured ball, during the impact the coloured ball applies the same amount of force in an opposite direction to the white ball ('equal and opposite').

Conservation of momentum is important in sports where impacts occur. In contact sports such as Australian Rules football, it is not uncommon to see a lighter player seriously affect a heavier player in a contact. This is because lighter players are often faster and therefore able to gather more momentum, giving them an advantage at impact (see Figure 10.10).

Figure 10.11 A downward force is applied to the back of the board with an opposite upward reaction force resulting at the front of the board. This is how a kick turn is performed.



The conservation of momentum principle also has implications when choosing equipment. For example, in ten-pin bowling, a heavier ball gives the bowler a better chance of success because it has more momentum at impact (but if too heavy, it becomes more difficult to control). This is particularly important in bowling because energy is being transferred and lost through all ten pins for a strike to take place; therefore, momentum at impact must be very high.

In some sports, Newton's third law of motion is not quite as obvious as a ball hitting a set of pins. For example, in skateboarding (a highly biomechanical sport), the skater accelerates himself upwards into a jump by exerting more force on the tail of the board than the front. This causes the board to pivot around the rear wheel, forcing the tail to hit the ground. When the tail of the board hits, the ground exerts an equal force back onto the tail, resulting in the board rising up into the air.

Elasticity – the coefficient of restitution

The sizes of the forces acting during an impact depend on the speed of each object before collision and the elasticity of the objects involved in the collision. More elastic surfaces result in less energy being lost in the collision because they rebound to their original position more quickly. The coefficient of restitution is a measure of elasticity. For perfectly elastic collisions, the coefficient of restitution equals one and for totally inelastic collisions, it equals zero. The coefficient of restitution has no units.

For example, a tennis ball will bounce higher from a surface such as Rebound Ace than it will from an en tout cas tennis court because the Rebound Ace surface is more elastic. Also, a new tennis ball has greater elasticity than an older one, and therefore will bounce higher and return to its original shape more quickly. This is advantageous for tennis players, because they are able to generate more velocity when the racquet and ball collide, and is why 'new balls' are called for at regular intervals during tennis matches.

The strings of tennis, squash and badminton racquets play an important role in changing the velocity of the ball during impact in each game. The elasticity and tension of the strings affect how quickly the ball will rebound off them. Elasticity in this case refers to the ability of the strings to 'give' and return to their original shape, while string tension is how tightly the racquet has been strung. There is a specific string tension for each racquet that produces the best elasticity.

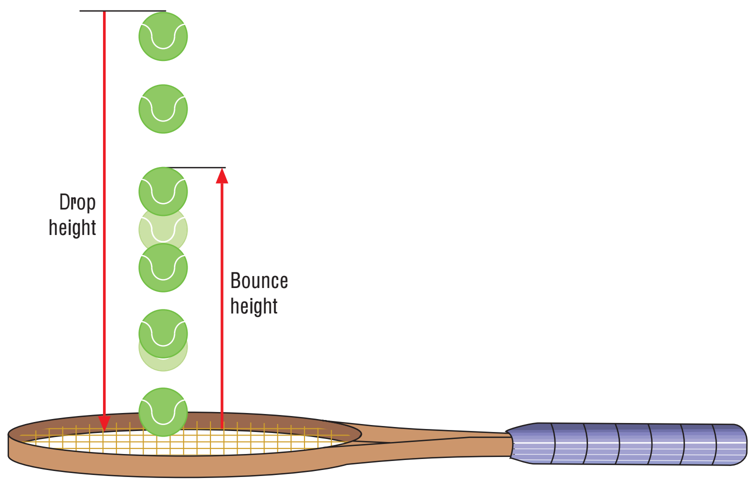


Figure 10.12 The coefficient of restitution (elasticity) of the ball can be computed from the ratio of the drop height and rebound (bounce) height.

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KEEP IT REAL!

Absorption of force

Sport safety gear helps reduce the chances of being injured.

Cricket and hockey players wear pads to absorb the energy of the moving ball. The pads cause the ball to stop over a greater distance, which reduces the force the ball applies to the body as it stops. Pads also spread the force over a bigger area.

The landing mats used in pole-vaulting and high-jumping reduce the force on the jumper's body by increasing the distance in which the athlete comes to rest.

Safety vests and helmets also deform to absorb energy, reducing the size of forces acting on the body and spreading the forces over a larger area of the body.

Summation of momentum

Many sporting activities require an object to be thrown or hit at very high velocities; for example, a golf drive, softball pitch, tennis serve and javelin throw. The athlete must maximise the speed of the hand during a throw, or a bat or racquet during a hit. Summation of momentum is the technique by which an athlete does this.

Effective summation of momentum takes place when the body parts involved in the performance of the skill move in a sequential way, beginning with the largest and slowest segments and finishing with the smallest and fastest segments.

Greater amounts of momentum are transferred from the larger body part to the smaller body part if the timing of the movement is such that the next segment begins to move when the previous segment has reached its maximum speed.

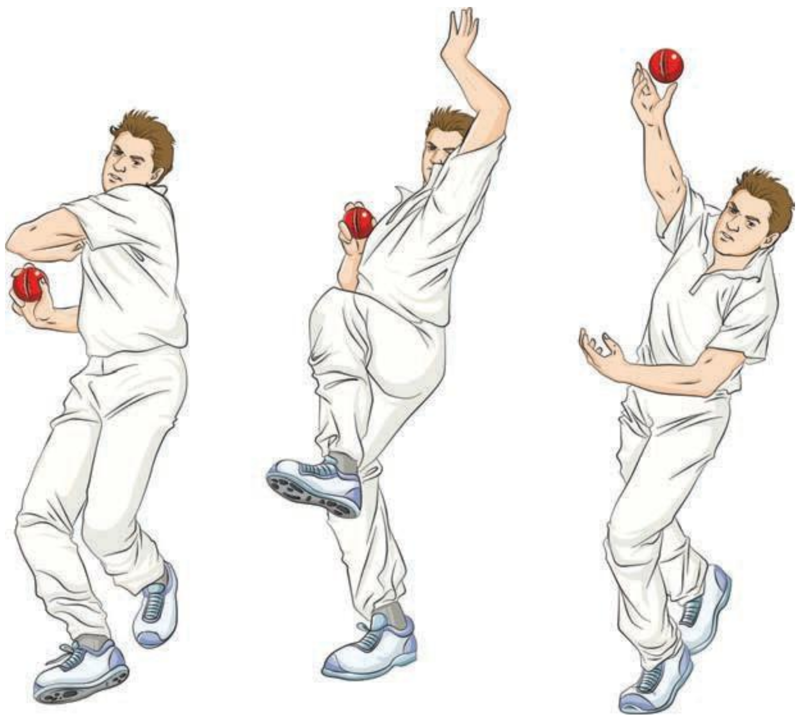

Figure 10.13 Sequential movement of body parts brings about coordinated, accurate and potentially rapid movements.

In some skills, athletes need to achieve accuracy rather than velocity, for example, shooting a free throw in basketball or throwing a dart. In these sporting situations, only the relevant body segments are moved together in a simultaneous manner, rather than in a sequential pattern.

There are two practical principles that apply specifically to running, jumping and throwing where the athlete is concerned with creating optimal force and speed:

- Use all the joints that should be used.
- Use every joint in order.

Use all the joints that should be used

The forces from each joint must be combined to produce the maximum effect. This is best done when all joints that can be used are used. This will help to get the most speed or acceleration out of a movement.

In the shotput, for example, the knee, hip, shoulder, elbow, wrist and finger joints should all be used to exert the greatest force on the shot. Beginners frequently miss out early joint movements such as the knee or hip action, or fail to complete a movement fully by not using the wrist or fingers.

Catchy fact
When performing activities such as bowling a ball or swinging a club, it is important to 'follow through' with the movement to ensure that there is no deceleration of the end body part or piece of equipment.

Use every joint in order

When several joints are used in a skill, their sequence and timing are important. This principle tells us when the joints should be used. Movement should begin with the

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big muscle groups and move out through the progressively smaller muscles, from big to small. This pattern produces optimal forces and correctly sequenced, continuous movement.

The continuous, flowing movement produces a summation of forces – forces adding together. The force generated by one part of the body is built on by the force of subsequent joints. In the well-timed shotput, the hip action commences just as the leg extension decelerates. The shoulder action commences as the hip rotation decelerates and so on.

The release velocity of an implement depends on the speed of the last part of the body at release. The correct sequence and timing allow the athlete to attain maximal release velocity. Thus, sequential movement of muscle groups from largest to smallest and from one as it just peaks in terms of acceleration to the next one in the sequence, ensures most efficient and rapid movements are generated.

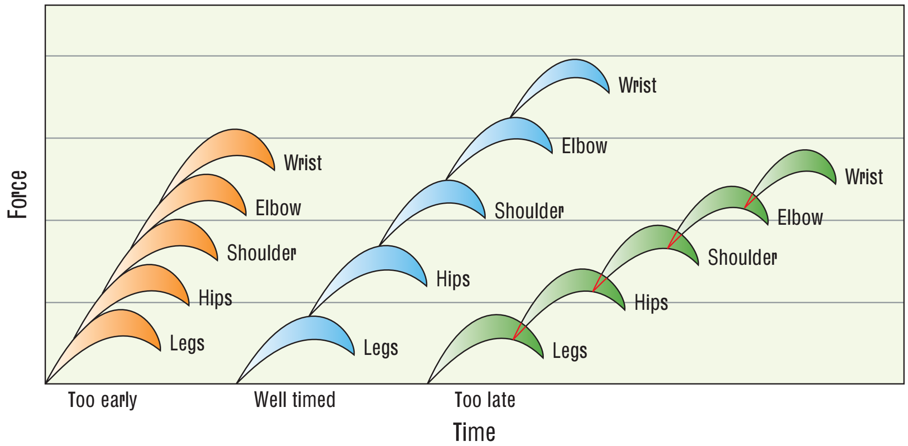

Figure 10.14 Summation of forces in the shotput. Movement of body parts either too early or too late will result in the wrong sequencing of body parts and as a consequence maximum performance will not be attained. Correct sequencing sees maximal force produced and transferred between body parts and better distances result.

Coursework: Laboratory investigation

Sequential movements of body parts

Materials

One softball and pair of catching gloves per student pair

Method

In pairs, sit opposite each other at a safe distance apart and throw the softball from the following positions:

a Sitting with legs crossed, using only your wrist to throw

b Sitting with legs crossed, using wrist and elbow to throw

c Kneeling, using shoulder, elbow and wrist to throw

d Standing with feet together, using trunk, shoulder, elbow and wrist to throw

e Standing, then stepping forward with one leg and using trunk, shoulder, elbow and wrist to throw

Results

1 Make a note of how far you were able to throw in each trial.

2 Which technique produced the best results for you and your partner?

3 How can you explain these results in terms of force production and summation of momentum?

4 Describe another three skills where the correct sequencing of body parts helps to maximise technique.

Catchy fact

Incorrect sequencing of body parts is often associated with learners at the cognitive stage and is sometimes responsible for injuries occurring when body movements are not coordinated and do not 'flow'.

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Accuracy

Shooting a goal in netball, kicking a ball to a team-mate in soccer or putting a golf ball all require accuracy to execute the skill successfully. How accurate you are is determined by the direction in which the force is applied and the amount of force applied.

When accuracy is the key to successful performance, the movement is more dependent on optimising the direction than maximising the amount of force (as is required when maximum distance is the key to success).

How many times have you seen a softball pitch that has fallen short of the plate, landed at the batter's feet or flown over the head of the umpire? If the direction of the force is not accurately applied, the ball will not go where you want it to go.

So how do we develop accuracy when executing a skill in sport? There is a biomechanical principle designed to increase accuracy known as 'flattening the arc'. To flatten the arc, an athlete moves their body parts in such a way that the bat or hand moves in a straight line at the point of contact or release. This increases the likelihood of making contact with the ball or releasing the ball at the correct point, therefore making the ball go in the desired direction. This principle is demonstrated in a softball pitch (see Figure 10.15a) or hockey push, which has been discussed earlier (see Figure 10.15b).

a

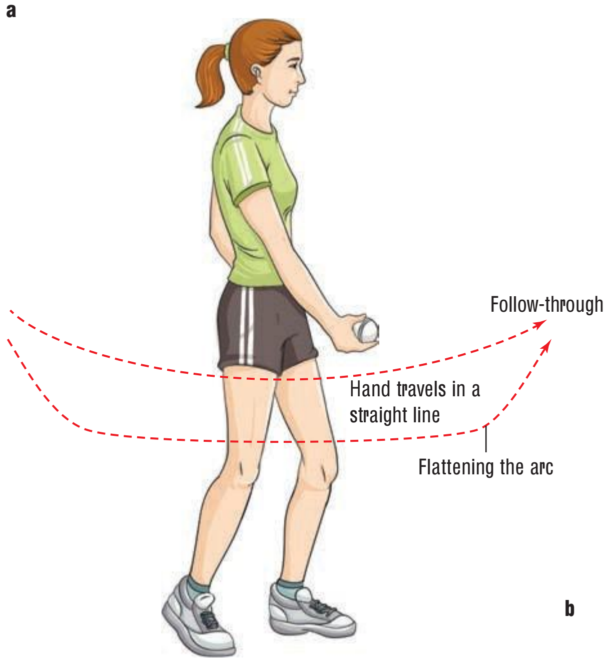

Figure 10.15
(a) 'Flattening the arc' when pitching a softball. (b) Hockey players bend at the hips to lower their bodies and this ensures that the swing at the ball is flattened, with more points on a straight line corresponding to a successful hit.

b

Certain hitting and throwing skills need to combine accuracy and speed for success. There is a trade-off between the two requirements, so the optimum movement pattern may not precisely follow the principles of accuracy or those of summation of momentum.

Coursework: Laboratory investigation

Flattening the arc versus accuracy

Materials

Hockey stick, tennis ball, target (1 m² – may be drawn with chalk on the wall of the gym), traffic cones (1 m apart)

Method

Make five attempts at hitting the target by doing a:

- hockey drive
- throw.

Trial 1: Do not step forward, transfer your weight forward or follow through.

Trial 2: Step forward or transfer your weight forward and follow through.

Trial 3: Step forward or transfer your weight forward, but do not follow through.

Results

1. Draw a table to represent your results.
2. How does stepping forward increase the accuracy of performance?
3. How does the follow-through improve accuracy?
4. How accurate was your performance of each of the tasks? Did your results differ between the three trials? Why?

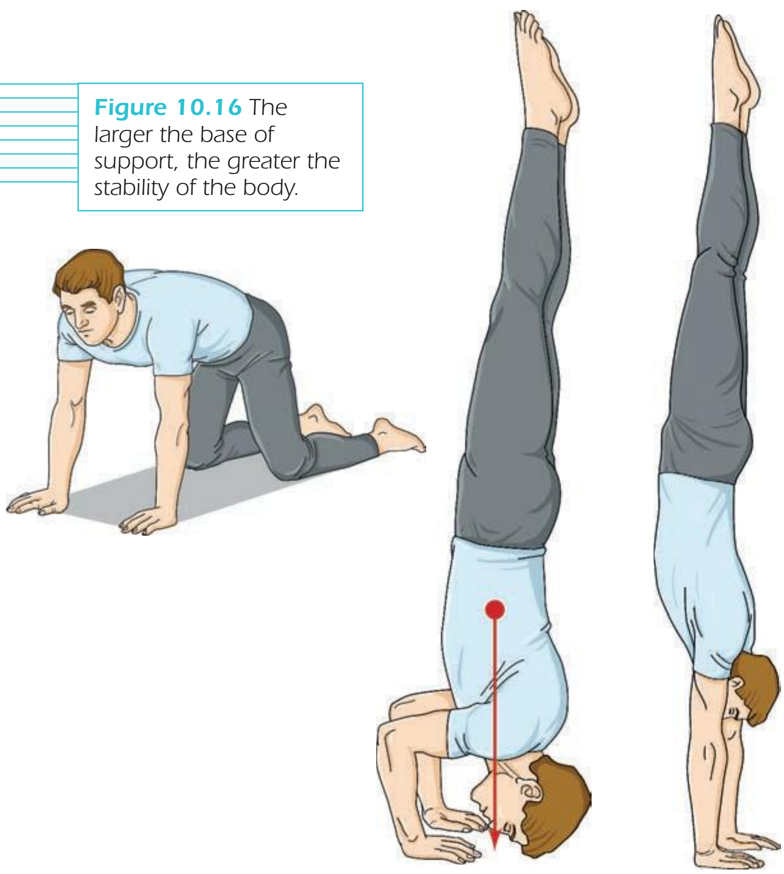

Figure 10.16 The larger the base of support, the greater the stability of the body.

Balance and stability

Balance refers to the ability of a body or an object to maintain stability or equilibrium when stationary or moving. Your balance varies according to the position of your body (gravitational forces), the surface you are standing on (friction) and whether or not you are moving (state of equilibrium). Balance implies coordination and control. For example, an elite gymnast demonstrates great control and balance when she is performing a routine on the balance beam.

Stability refers to the ability of a body to resist being moved; in other words, how difficult it is to disturb your balance. Some activities demand that a set position be maintained for a period of time; for example, shooting, archery or preparing a platform dive. This is known as static balance. Other activities require balance that can be altered easily; for example, dodging around an opponent in a game of netball, soccer or football. Such activities require dynamic balance.

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Factors affecting balance and stability

The body's balance and stability are affected by the:

- size of the base of support
- position of the centre of gravity
- line of gravity
- mass of the body.

Size of the base of support

The base of support is the base or area that is bounded by body parts in contact with a surface. For example, in Figure 10.16 the shaded area defines the base of support in three different positions. The larger the base of support, the greater the stability of the body. It is generally easier to perform a headstand than a handstand because the base of support is larger.

Position of the centre of gravity

The centre of gravity (also known as the centre of mass or centre of balance) is a theoretical point through which all the weight of an object appears to act.

You can find the centre of gravity of a ruler by balancing it on your finger at its centre. If you try to balance it at one end, the ruler will fall. Objects that have regular shapes and distribution of mass, such as a ruler, have their weight through their geometrical centre and therefore their centre of gravity is in the middle of the object. In the human body, it is not quite so simple.

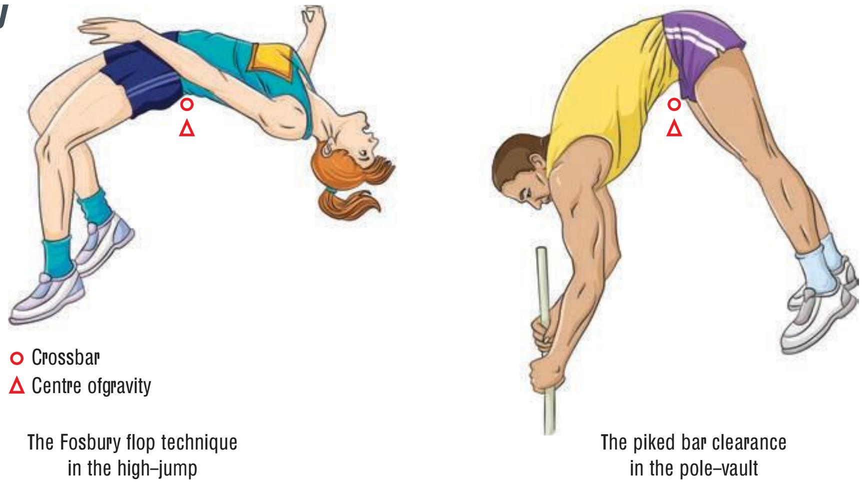


Figure 10.17 The high-jumper and pole-vaulter clear the bar while their centres of gravity pass close to it or even below it.

When a man stands with his arms by his sides, his centre of gravity is located at around half his height. When a woman stands with her arms by her sides, it is located a little lower (because of her different weight distribution). A person's centre of gravity changes as they change body position. Moving your arms above your head raises your centre of gravity. Moving one arm out to the right side moves the centre of gravity to the right.

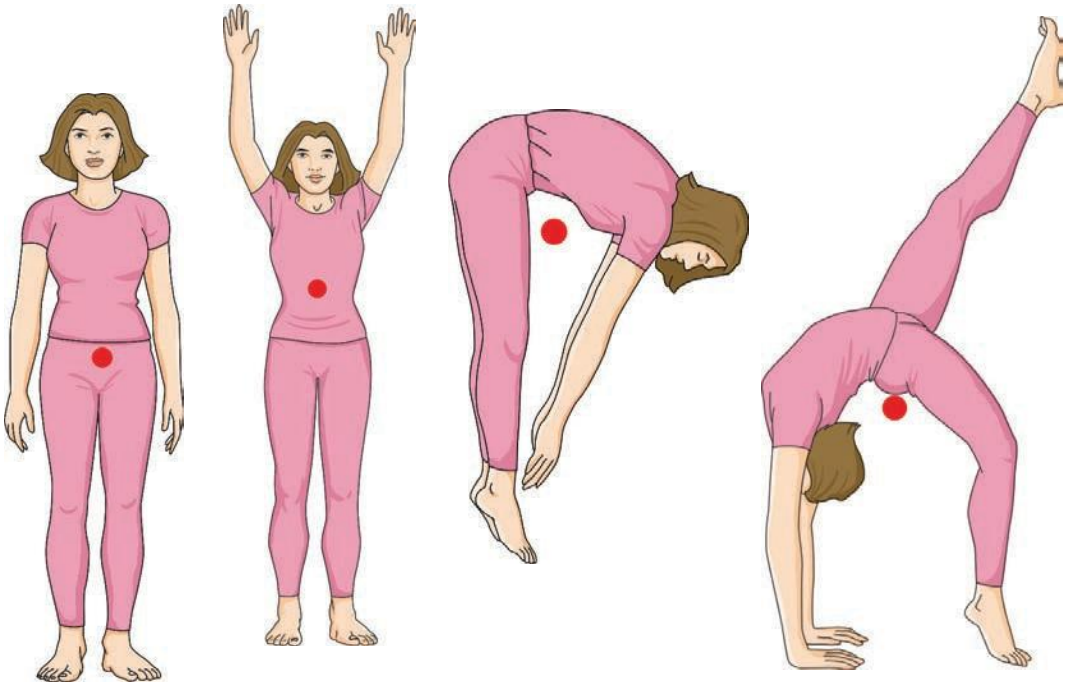
In some cases, the centre of gravity falls outside a person's body, especially when the body takes up an angular pose as in high-jumping or diving (as shown in Figure 10.17). Athletes try to have their centre of gravity outside their body and as close to the clearance bar in the pole vault and Fosbury flop in high-jump clearances. This means they do not need to get their body as high over the bar as they would if their centres of gravity occurred inside their bodies, as was the case for older techniques.

The lower the centre of gravity, the greater the stability of the body. For example, to increase stability, a wrestler (when being tackled) often lowers his centre of gravity (and increases his base of support) by bending at the knees and crouching slightly. Surfers lower their centre of gravity by bending their knees while surfing. To disrupt a wrestling opponent's balance, a force must be applied either above the centre of gravity to topple them over, or below the centre of gravity to remove their base of support, as is the case in most effective rugby tackles.

The line of gravity

The closer the centre of gravity is to directly over the middle of the base of support, the greater the stability of the body. A body is unstable when the centre of gravity is not over (or in line with) the base of support. The theoretical line that can be drawn from the centre of gravity to the base of support is called the line of gravity (see Figure 10.19). For example, if you lean forward (without moving your feet) and your centre of gravity and line of gravity move outside your base of support, you will begin to feel unstable and eventually fall over.

Figure 10.18 A person's centre of gravity changes as body positions change and limbs move. The circles show the positions of the centre of gravity.



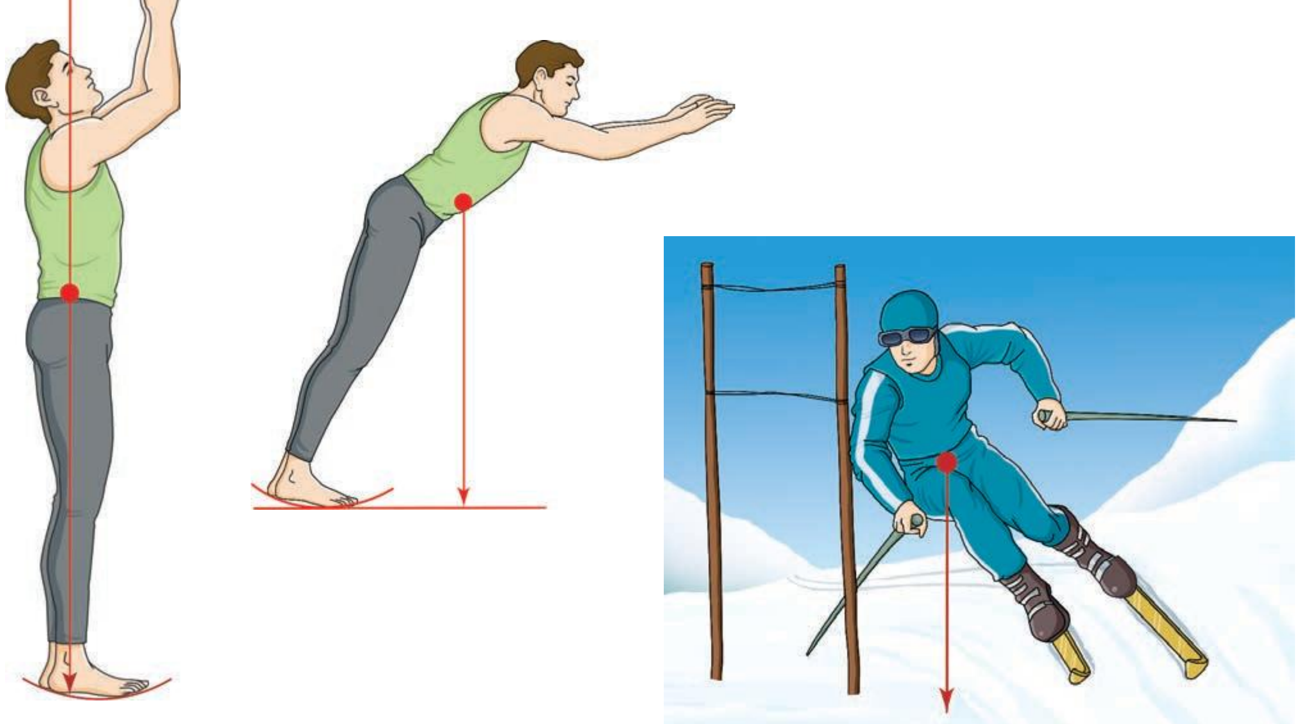


Figure 10.19 Line of gravity in three different body positions

Finding the centre of gravity

There are a number of ways to find the centre of gravity of different shapes. An easy way to roughly determine a body's centre of gravity from a picture is to draw a box around the figure, then diagonal crosses from each corner of the box (see Figure 10.20). The centre of the cross gives an approximate centre of gravity. Remember though, in real life the human body is three-dimensional, and so this method is not always accurate.

Another method of determining the centre of gravity of the human body in a specific position is to photograph the athlete and divide the body into segments (see Figure 10.21). This method is mathematically complicated and relies on population averages to determine the proportion of body mass for each segment and the location of the centre of gravity. Errors occur when a subject does not conform to those averages.

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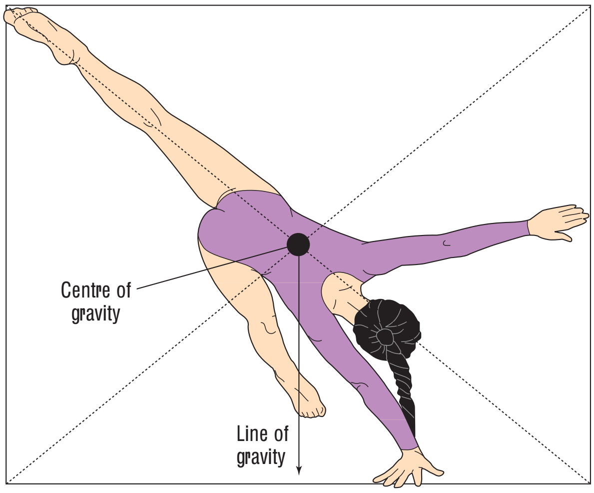

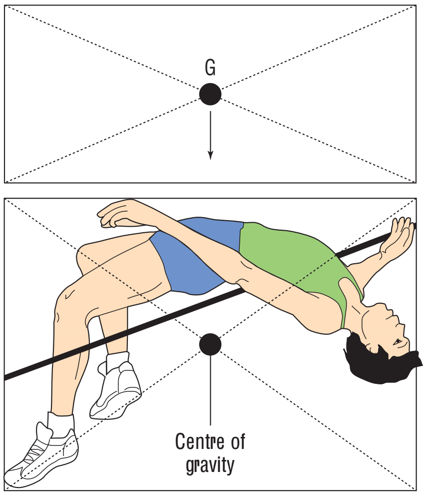

Figure 10.20 An approximate method for determining the centre of gravity

The mass of the body

Increasing the mass of the body or object increases stability. A heavier person is more stable (and difficult to move) than a person with less body mass. In contact sports such as Australian Rules football, ruckmen, who must maintain their position while contesting centre bounces and throw-ins, and stop their opponents, often weigh more than 120 kilograms. The heavier they are, the more it takes to knock them off balance and be out-manoeuvred by opponents.

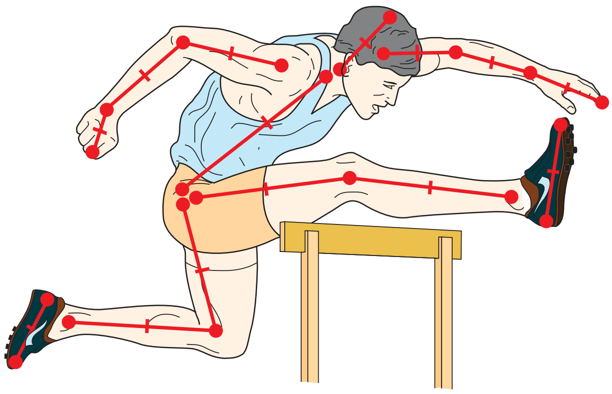

Figure 10.21 Segmentation is an accurate way of determining the centre of gravity.

Coursework: Investigating balance

1. Stand with your back and heels touching a wall. Slowly attempt to bend down and touch your toes, keeping your legs straight. Can you do it? Why or why not?
2. Repeat the activity, this time standing away from the wall. Explain the differences you experience.
3. Now stand with your side against a wall and lift your outside foot to the side. What happens? How can you explain this?
4. Stand facing a partner no more than 1 metre away. Place your palms together and move your feet into various positions to experiment with the base of support. Try applying a gradual force from different directions. What determines maximum stability when trying to push each other off balance? Explain the differences noted.
5. Perform a regular push-up. Why is it easier to perform a push-up by using your knees as a point of support than using your toes as a point of support? What changes in positioning are necessary if you take one hand away and try to do a single-arm push-up? Explain any differences.
6. Think of three sporting situations where it is advantageous to move the line of gravity close to or beyond the edge of the base of support.

Projectile motion

Projectile motion considers factors that affect the movement path of an object or the human body. It is important to understand the motion of a projectile in air because there are many sports in which athletes and objects are propelled into the air. In all cases, the athlete must assess, control and manipulate the flight path of the projectile. For example, a soccer goalkeeper has to assess the velocity and flight of the ball to save a goal. A high-jumper must judge his jump carefully, aiming for maximum height while judging the distance and rotation of the jump to clear the bar successfully.

When sportspeople launch themselves or objects into flight, gravity will act as a force pulling them or the objects towards the ground. The flight path of the centre of gravity of a body is a curve called a parabola. The parabolic flight path depends on three factors:

- Speed of take-off or release
- Angle of take-off or release
- Height of centre of gravity of athlete at take-off, or of implement at release

As we have seen, the speed of an athlete at take-off, or of a piece of sporting equipment at release, is the most important factor. Greater speed generally means greater distance covered. Air resistance can also affect the distance travelled by an athlete or sporting implement.

Catchy fact
The design of the modern javelin has been changed in recent years because of athletes throwing them too far and causing danger to people at the other end of the field. Frequent flat landings and the resulting protests also caused the redesign. The new design has altered the weight distribution of the javelin, making its flight time and distance travelled shorter.

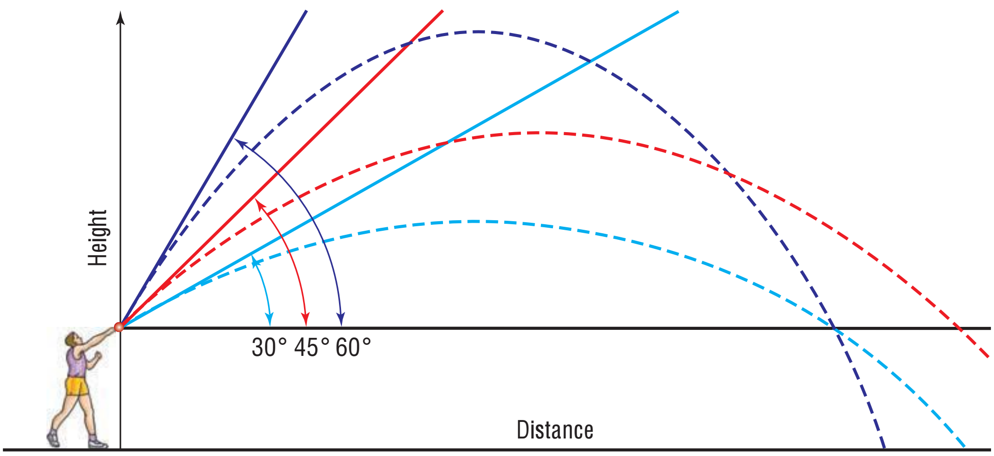

Figure 10.22 The parabolic flight path for various angles of release of a javelin

Factors affecting path of a projectile

A ball that is hit or thrown into the air follows a curved path because it is constantly being acted on by the force of gravity, which naturally accelerates it downwards. As mentioned, the shape of this type of curve is that of a parabola (see Figures 10.23 and 10.24). The exact shape of the parabolic flight path (also known as the flight trajectory), the time in the air, the time it takes for the ball to reach its target, and the total distance the ball travels are all affected by:

- velocity of release
- the angle of projection
- the height of release
- air resistance and spin.

trajectory
the flight path an object takes when released into the air

Velocity of release

Increasing the velocity of the projectile at the time it is released increases the height of the flight path (vertical component), the length of time it is in the air and the distance it travels (horizontal component).

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Angle of projection

The shape of the flight path is dependent on the angle of projection. Without the effects of air resistance, there are really only three alternative flight paths:

- If height of projection is zero (e.g. ground to ground), a release angle of 45° will result in the greatest horizontal distance.
- Angles greater than 45° result in shorter distances, greater heights and longer times of flight.
- Angles less than 45° result in shorter distances, lower heights and shorter flight times.

This concept is shown in the golfing example in Figure 10.24.

In reality, the demands of the sport affect the desirable angle of projection. We would expect the optimal angle of projection to be 45°, but this is rarely the case owing to specific circumstances surrounding each sporting event. For example, to maintain velocity in a long-jump take-off, the optimum angle of take-off must be reduced to around 22°.

In golf, the desired angle of projection varies with each shot. In a sand bunker, the golfer will need to 'lollipop' the ball out; therefore, a very angular club face (like a pitching wedge or sand wedge) will need to be used (see Keep it real, page 190). However, a shot off the fairway or tee that needs to travel a long distance does not require the same high flight path. In this case, the golfer would elect to use a club with very little angle (like a wood or a 3 iron).

Height of release

The height of the release and the height of the surface the projectile lands on also affect the most appropriate flight path.

- For a flat surface (ground to ground), the best angle of projection is 45°.
- If the object is projected from a point above the landing area, the angle to achieve maximum distance will be less than 45°.
- If the object is projected from a point below the landing area, the angle will need to be greater than 45°.

In general, increasing the height of the projection results in greater flight times and greater distances travelled if velocity and angle of projection are constant.

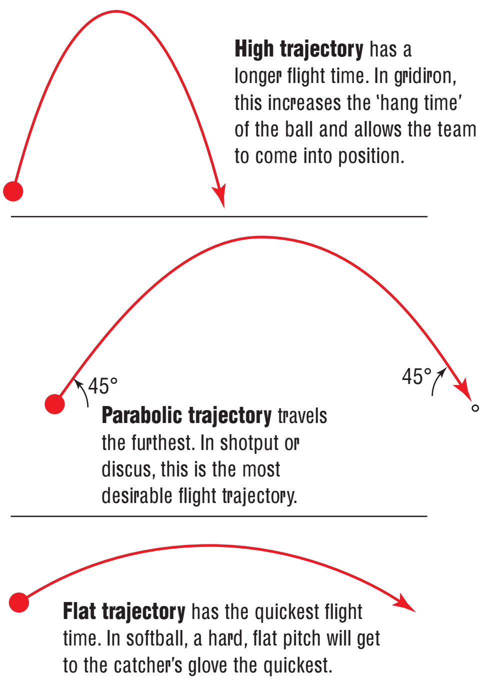

Figure 10.23 Flight trajectories and resultant distance

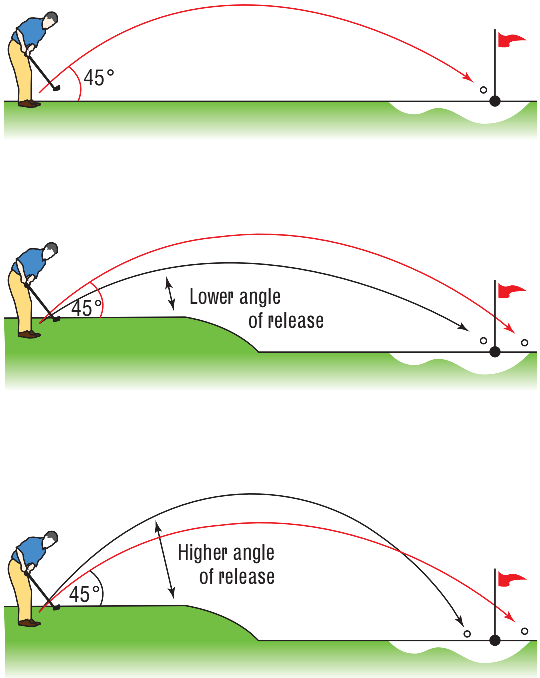

Figure 10.24 Varying the angle of release to account for the point of release

angle of projection
the angle at which an object is released into the air

Catchy fact

The first golf balls were made of a leather pouch stuffed with wet goose feathers, which hardened when dry! These days, golf balls are covered with more than 400 dimples set about 0.25 mm deep. Their job is to capture air, which stays in contact with the ball for longer, creating less drag. The dimples also help to generate lift when backspin is applied to the ball.

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Golf clubs and projectile motion

Golfers use a variety of clubs, each with a different angle between the face and the vertical plane (known as loft). This angle determines how far and how high a particular golf club can hit the ball. Clubs increase in loft through the set from driver to wedges (Table 10.4).

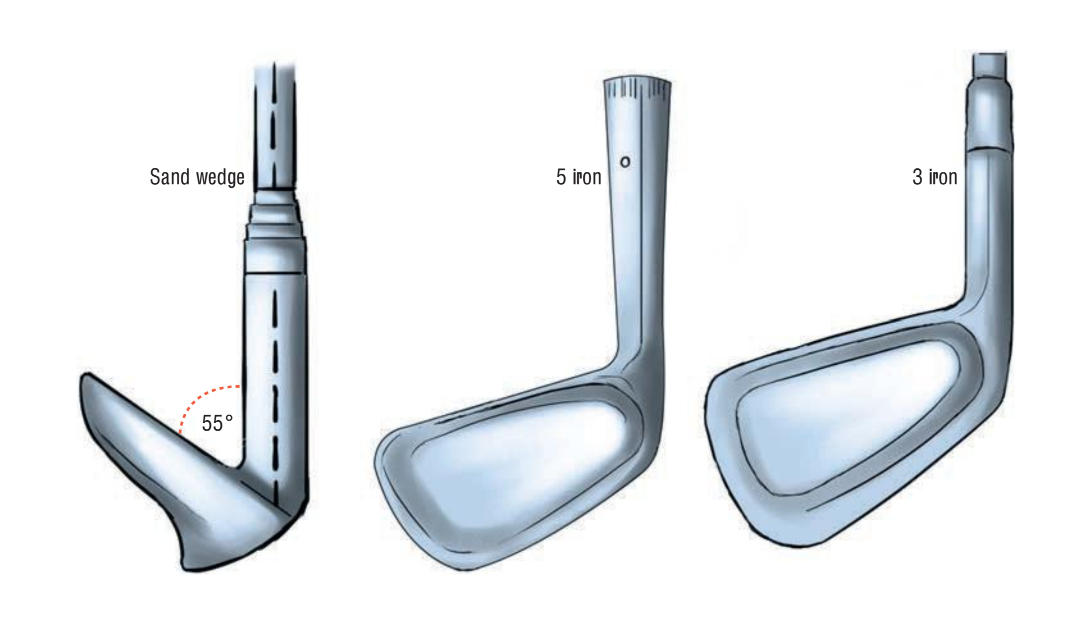

Figure 10.25 Three golf clubs showing the different angles

Table 10.4 Distances achieved with different golf clubs

Club	Angle	Distance (m)	
		Men	Women
Driver	7–9°	200–260	150–200
3 wood	15–17°	180–235	125–180
5 wood	21–24°	170–210	105–170
2 iron	18–20°	170–210	105–170
3 iron	21–24°	160–200	100–160
4 iron	24–27°	150–185	90–150
5 iron	28–31°	140–170	80–140
6 iron	32–35°	130–160	70–130
7 iron	36–39°	120–150	65–120
8 iron	40–43°	110–140	60–110
9 iron	44–47°	95–130	55–95
Pitching wedge	48–51°	80–120	50–80
Sand wedge	54–56°	60–100	40–60

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Checkpoints

1 Why does increasing the base of support improve stability? Give one example to illustrate your answer.

2 What is meant by the 'centre of gravity' and how does it change when you change body position?

3 How does the line of gravity affect stability in relation to base of support? Describe a sporting situation to explain your answer.

4 How does the mass and height of a person affect their stability? Describe a sporting situation to explain your answer.

5 If a golfer is in a bunker, why must they use a sand wedge in an effort to get out of the bunker and onto the putting green?

6 Outline how the Fosbury flop technique in high-jump allows greater heights to be cleared when than the older scissor technique does.

a

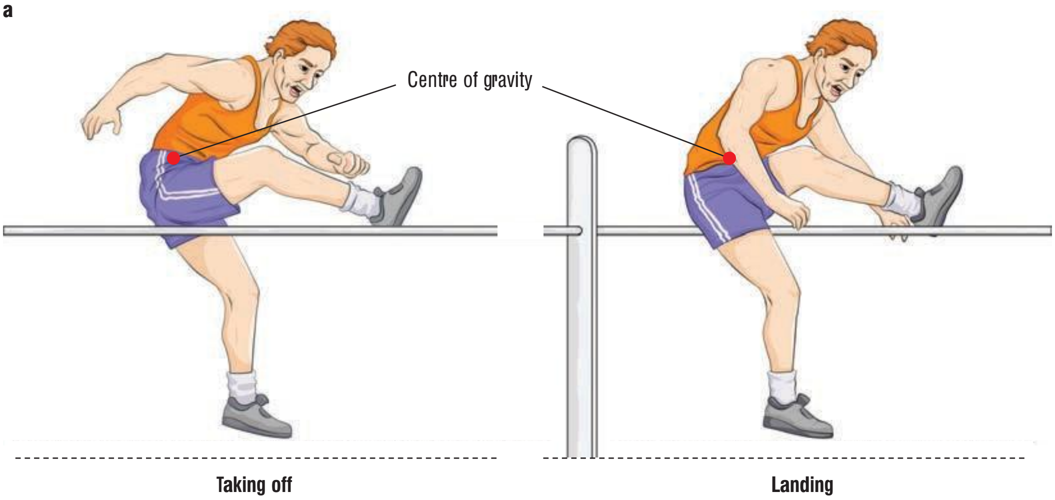

Figure 10.26 Two jumping styles: (a) scissors technique; (b) Fosbury flop technique

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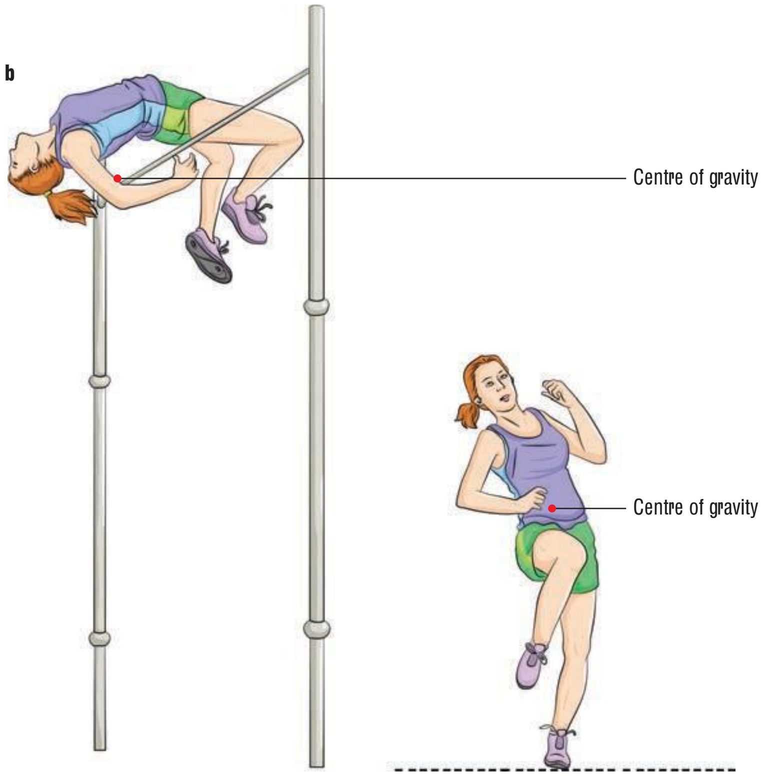

Air resistance and spin

Increased air resistance (for example, throwing into the wind) decreases the time in the air and the distance a ball will travel once it has been hit or thrown. Likewise, decreasing air resistance (throwing or kicking with a tail wind) increases the distance a ball will travel. You will often hear commentators stating that a particular end of a football ground has a certain goal advantage due to wind strength and direction. The greater the surface area of the object being projected and the more speed it has, the greater the effect of air resistance.

The Magnus effect is a lift force that affects the flight path of a ball that has been thrown, hit or kicked. A spinning ball passing through the air causes a disturbance to the air flowing around the ball. It is more difficult for air to pass by the side of a ball that is spinning in the same direction as the ball is travelling. This causes high pressure on one side of the ball. The high pressure exerts a force on the ball, causing a deviation in the flight path in that direction.

Tennis players, golfers, table tennis players, and soccer players all use the Magnus effect to curve the flight path of a ball. The Magnus effect changes the flight path of the ball from what it would have been without spin. There are three types of spin that affect the trajectory of the flight path – top spin, back spin and side spin – and these will be investigated in greater detail in *Nelson Physical Education Studies for WA 3A, 3B*.

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TEST YOUR KNOWLEDGE

>> multiple choice

1 When speed is maximised as a result of sequential force summation, which one of the following is occurring?

A Momentum is transferred from smaller body parts to larger parts, and speed increases up to a maximum point.
B Momentum is transferred from central body parts to distal body parts just as one slows down to ensure the other speeds up.
C Momentum is transferred from a linear plane to an angular plane.
D Momentum is transferred from larger body parts to smaller body parts just as the previous part has reached its maximum speed.

2 Which of the following situations would provide the greatest increase in stability?

A Lowering your centre of gravity by moving from a standing position to a sitting position
B Leaning forwards and moving the centre of gravity outside the base of support
C Moving your arms from the side of your body to above your head and reducing lateral drift
D Moving from a headstand to a handstand, thus increasing the line of gravity

>> short answer

3 Look at Figure 10.4 (p. 170).

a During take-off, why is it important for the long-jumper to hit the take-off board with as much force as possible?
b The technique shown is known as the hang technique. During the air phase, what could you suggest the jumper does in order to maximise flight time?
c At landing, what does the jumper do in order to avoid falling back into the pit and thus decreasing his distance?

4 Figure 10.27 represents an elite cricketer practising a throw at the wickets from 20 metres.

a Why does he take a two-step run-up before releasing the ball?
b Clearly discuss how sequential acceleration of body parts leads to the development of maximum speed at point of release. What must the cricketer do after the ball has been released to ensure maximum speed is still attained?
c In order for the cricketer to bring his body to a rapid stop, what must he do in regard to foot placement and line of gravity?

Figure 10.27 Elite cricketer throwing

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5 Clearly discuss the sequential contribution of key body parts to each of the following sporting skills.

a tennis serve
b penalty kick in soccer

Ensure that your discussion clearly states the major muscles involved in the actions and the correct sequence of their involvement.

6 **a** List the three main factors influencing the trajectory of a projectile which is either thrown, hit or kicked, or is the athlete's body. Provide a different sporting example to highlight each factor.

b In theory, the optimal angle of projection required to achieve maximum distance is 45°. Discuss why in some activities the optimal trajectory angle is not 45°. Provide three different sporting examples to support your discussion. You should aim to discuss situations where the angle is both less than and greater than 45°.

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SECTION 5
EXERCISE PHYSIOLOGY

Chapter 11 Acute and chronic responses to exercise and training

2A.15 Explain the body's immediate responses to physical activity in relation to:

- heart rate (HR)
- stroke volume
- blood pressure (BP)
- cardiac output
- tidal volume
- respiratory rate
- max O_2 uptake (VO_2 max)
- gas exchange
- arteriovenous O_2 difference
- blood redistribution.

2A.16 Explain the body's long-term adaptations to training in relation to:

- cardiac output
- heart rate (HR)
- blood pressure (BP)
- blood volume/haemoglobin
- stroke volume
- capillarisation
- ventilation
- O_2 exchange
- muscle hypertrophy
- increased flexibility
- increased aerobic and anaerobic capacity.

Chapter 12 Foods, fuels and energy systems

2A.17 Explain the utilisation of carbohydrates, fats and proteins as energy sources for physical activity and their role in the onset of fatigue.

2A.18 Describe the response of energy systems to physical activity; i.e.
- anaerobic – ATP-CP (adenosine triphosphate-creatine phosphate)
- lactic acid
- aerobic.

2A.19 Identify the relationship between energy systems and types of physical activity; i.e. energy system continuum.

Chapter 13 Methods of training

2B.13 Define training types; i.e.
- resistance training – isometric, isotonic, isokinetic
- interval training
- continuous training
- circuit training
- fartlek
- flexibility
- plyometrics.

Chapter 14 Principles of training

2B.14 Explain the principles of training:
- specificity in relation to the nature of activity, positions and roles
- intensity
- duration
- frequency
- progressive overload
- reversibility.

Chapter 15 Components of fitness

2B.15 Identify the components of fitness; i.e.
- cardiorespiratory endurance
- muscular strength
- muscular endurance
- flexibility
- body composition
- agility
- balance
- coordination
- reaction time
- speed
- power.

2B.16 Explain the interrelationship between training types, fitness components and the principles of training.

11 Acute and chronic responses to exercise and training

Short-term changes in response to exercise are known as acute responses, with the body returning to pre-exercise levels/conditions once the exercise ceases. Long-term changes or adaptations result in response to continued exercise in the form of training. These changes are there before, during and after the exercise.

Table 11.1 Responses to exercise

Acute responses	Chronic adaptations
Heart rate	Cardiac output
Stroke volume	Heart rate
Blood pressure	Blood pressure
Cardiac output	Blood volume/haemoglobin levels
Tidal volume	Stroke volume
Respiratory rate	Capillarisation
Max O_2 uptake	Ventilation
Gas exchange	O_2 exchange
Arteriovenous oxygen difference	Muscle hypertrophy and increased flexibility
Blood redistribution	Increased aerobic and anaerobic capacity

Acute responses

Acute, or immediate, responses to exercise occur when the body moves from rest to become active; they are determined by the rate, intensity and energy expenditure of the exercise.

Heart rate

When we exercise, there is an increased demand for fuels and oxygen by working muscles and also a resultant increase in the need to remove waste products, which are also being produced at faster rates. These include carbon dioxide, hydrogen ions and lactate. As a result, the heart needs to pump faster and/or harder in order to increase the supply of blood and the elements it carries (oxygen and fuels) to working muscles, as well as increasing waste removal.

There is a direct linear relationship between exercise intensity and heart rate, and as we increase the rate of exercise our muscles and brain send more messages to the heart to increase its rate (beats per minute). The brain signals to the cardiovascular system to increase

Catchy fact
The resting heart rate of an adult female can be 5–10 beats per minute faster than an adult male's heart rate because female heart sizes tend to be smaller. It is worth noting that heart rates may increase even without exercise due to the release of adrenalin in response to increased arousal states (anxiety, nervousness, anticipation, excitement).

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its work and the heart rate increases while blood flow to the lungs, veins and capillaries also increases as vasodilation occurs.

When exercise intensities drop, so too does the heart rate, and when exercise stops the heart rate returns to resting levels. Athletes such as endurance athletes, who have undergone aerobic training, will find that their heart rates return to resting levels quicker than those who have completed less aerobic training.

vasodilation
the veins increase in diameter and hence allow larger volumes of blood to flow to through them, to working muscles

Catchy fact
The maximum heart rate tends to be accurately predicted by using the formula: 220 – your age.

Stroke volume and cardiac output

Stroke volume is a measure of how much blood is squeezed out of the heart into the aorta each time it beats, i.e. per systole (think of systolic blood pressure). The average adult stroke volume at rest is between 70 and 90 mL, with women having approximately 4.5 litres of blood and males having approximately 5.0 litres of blood in their bodies needing to be pumped around. As we start to exercise, the heart pumps more forcefully and more blood is squeezed out per beat and hence the stroke volume increases. In adults this typically increases by 40% when maximum exercise levels are reached (see Table 11.2).

Cardiac output is the amount of blood pumped out of the heart per minute and is easily calculated:

cardiac output (Q)   stroke volume   heart rate

At rest, cardiac output might be 80 mL   60 bpm   4800 mL or 4.8 litres/min.

At maximal exercise, cardiac output might increase to be 130 mL × 200 bpm   26 000 mL or 26 litres/min.

Table 11.2 Stroke volumes and cardiac output for untrained, trained and endurance athletes

	Untrained	Trained	Endurance
Stroke volume (mL)			
Rest	80	110	125
Maximal exercise	115	130	185
Q (L/min)			
Rest	4.8	6.0	6.4
Maximal exercise	20.5	26.0	37.0

Blood pressure

Blood pressure is usually measured by an instrument called a sphygmomanometer. You will recall from Chapter 8 where you measured blood pressure, that it is recorded as two numbers, such as 120/80. The larger number indicates the pressure in the arteries as the heart squeezes out blood during each beat. It is called the systolic blood pressure. The lower number indicates the pressure as the heart relaxes before the next beat. It is called the diastolic blood pressure.

The systolic blood pressure rises sharply in response to exercise because of the increased cardiac output and can reach figures between 180 and 200 mmHg at maximal exercise intensities.

Although blood pressure goes up during any kind of exercise, the changes brought on by exercise vary according to whether the exercise is static or dynamic.

Dynamic activities depend mainly on energy produced by supplying the muscles with oxygen, and hence are associated with an increase in the body's need for oxygen. As mentioned previously, oxygen consumption and heart rate increase in relation to the intensity of the activity. Systolic blood pressure rises progressively, while diastolic blood pressure stays the same or decreases slightly.

static (isometric) exercise
a sustained contraction of a muscle group typically against an immovable resistance/weight – force is developed but no change in muscle length occurs

dynamic exercise
involves large muscle groups engaged in rhythmic, repeated movements; e.g. aerobic activities such as jogging, brisk walking, swimming, bicycling

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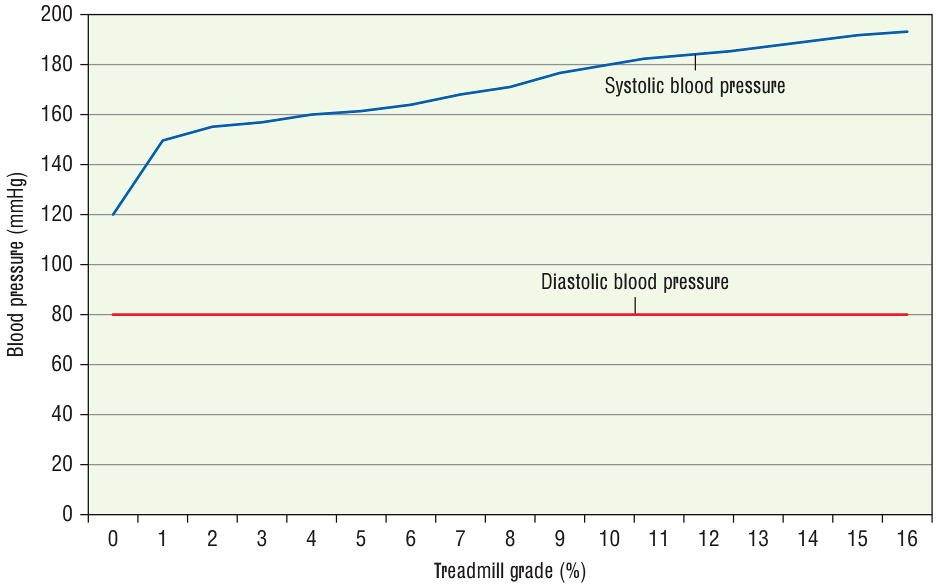

Figure 11.1 Blood pressure responses to exercise of varying intensities

Static activities involve sustained muscle contraction against an immovable load or resistance. This results in a moderate increase in cardiac output, with little change in oxygen delivery to muscles. Despite the increased cardiac output, blood flow to the non-contracting muscles does not significantly increase. This combination of vasoconstriction and increased cardiac output causes a disproportionate rise in systolic and diastolic blood pressures.

vasoconstriction the veins decrease in diameter and hence allow much reduced volumes of blood to flow through them

Blood redistribution

Blood tends to flow to tissues and cells in proportion to their level of activity. Specific increases occur in blood supply to parts of the body that require extra supplies of oxygen and fuels to support increased workloads. Specific decreases occur in blood supply to those parts of the body not requiring extra oxygen and fuel for that period of time. For example, during intense exercise, extra blood flows to the muscles to provide extra oxygen and nutrients, and extra blood flows to the skin to aid in cooling down. During rest approximately 20% of cardiac output is directed to muscles, whereas during maximal exercise this figure increases to 85% of cardiac output.

During exercise, less blood flows to the digestive system.

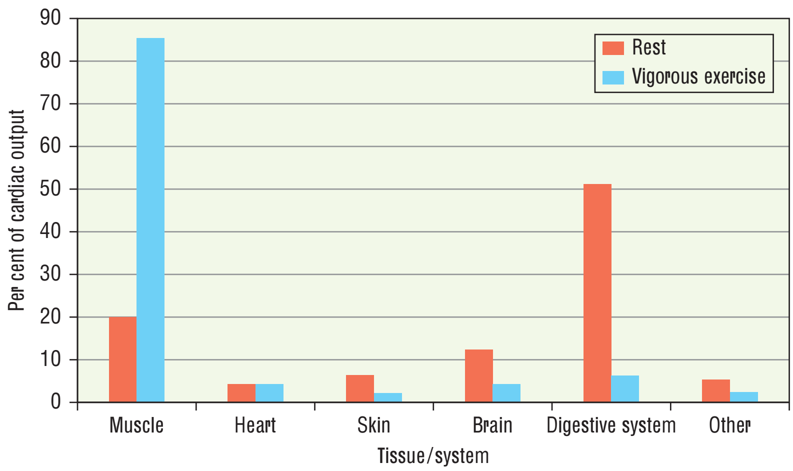

Figure 11.2 Blood flow from the heart during rest and vigorous activity

precapillary sphincters
a band of smooth muscle that adjusts the blood flow into each capillary. It encircles each capillary branch at the point where it branches from the arteriole. Forceful contraction of the precapillary sphincter can close the branches off to blood flow

Blood flow and pressure during exercise requires a balancing act between vessels dilating to allow increased blood flows and vessels constricting to greatly reduce flow rates to these sites. This whole process is controlled by the nervous system rapidly responding to chemical changes occurring at tissues that act directly on the smooth muscle bands of arterioles and precapillary sphincters.

During rest, approximately 1 in every 20–30 capillaries in muscles remains open but this number increases quickly during light exercise to 15–20, and during maximal efforts all are open. With more and more capillaries brought into action during exercise, we find blood flows increase rapidly, as does the surface area for exchange of gases and fuels between the blood and muscle fibres.

Catchy fact
If fully dilated, the body's blood vessels could hold approximately 20 litres of blood, which is four times greater than the average total blood volume of adult males.

Checkpoints

1 Briefly describe the difference between acute and chronic responses to exercise.
2 Calculate your maximal cardiac output – assume that your stroke volume at maximal intensity is equal to 120 mL.
3 Why does the diastolic blood pressure remain relatively unchanged despite changes in exercise intensity?

Respiratory responses

During exercise, there is a linear increase in the number of breaths a person takes per minute (known as the respiratory rate) as exercise intensities increase. The amount of air inhaled and exhaled per breath also increases and this is known as the tidal volume (TV). Because men have a larger lung capacity than women, their resting tidal volumes tend to also be greater – tidal volume for men is 600 mL whereas tidal volume for women is 500 mL. Pulmonary ventilation/minute ventilation refers to the volume of air moved into and out of the respiratory tract each minute and can easily be calculated from:

minute ventilation (V_E)   respiratory rate   tidal volume

At rest, minute ventilation   12   0.5 L

6.0 L/min

Table 11.3 reveals the increases in all three respiratory variables – respiratory rate, tidal volume and minute ventilation – in response to moderate and vigorous exercise.

Table 11.3 Immediate changes to respiration as a result of exercise at different intensities

State	Respiratory rate	Tidal volume (TV) (L/breath)	Minute ventilation (V_E) (L/min)
Rest	12	0.5	6.0
40–50% max HR exercise	25	2.5	62.5
85–95% max HR exercise	50	3.0	150

diffusion gradients
refer to the concentration of gases separated by a membrane; e.g. the concentration of oxygen in the lungs compared to that in surrounding pulmonary capillaries. Gases will move, or diffuse, from areas of high concentration to areas of low concentration and these are known as gradients

Gas exchange

Gas exchange occurs at the lungs as well as the muscles/tissues and, in both cases, happens passively following diffusion gradients. Pulmonary diffusion essentially sees the replenishment of oxygen in the pulmonary capillaries and the removal of carbon dioxide from these same vessels – a two-way exchange of gases! This gaseous exchange occurs

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between the air of the alveoli, through the respiratory membrane to the blood of the pulmonary capillaries.

As we begin to exercise, there is an increase in the diffusion of oxygen into the pulmonary capillaries due to increases in cardiac output, blood pressure, alveolar surface areas, and decreased resistances to gas diffusion across the respiratory membrane. Exercising muscles and cells will produce carbon dioxide in greater quantities than at rest; a small amount is absorbed by blood plasma (7%), three times as much (23%) attaches to haemoglobin and most of it (70%) is converted into bicarbonate ions and carried in red blood cells to the lungs to be exchanged/exhaled. Once again, we see this two-way movement of oxygen into muscles and removal of carbon dioxide from the working sites.

Catchy fact
Carbon dioxide's membrane solubility is 20 times greater than that of oxygen so carbon dioxide can diffuse across the membrane at a quicker rate.

Oxygen uptake

Oxygen consumption rises exponentially during the first few minutes of exercise as the anaerobic energy systems contribute most to energy production. This period is also referred to as oxygen deficit but if the exercise is of moderate intensity this will not last long and steady state is reached. This can be seen as the 'flat' or plateau in the graph in Figure 11.3. During steady state, the oxygen demand is met by the body's ability to supply it in equal amounts. If the exercise intensity increases because the performer is working harder (e.g. running up a hill, surging away from an opponent) there is also a matching increase in oxygen consumption. It is worth noting that oxygen consumption will remain above resting levels during recovery periods, especially during active recoveries. This 'extra' oxygen is very useful in oxidising metabolic by products and assisting recovery.

A person will reach a point where increases in exercise intensity will not result in increases in oxygen consumption and this point is known as their VO_2 maximum (VO_2 max). Athletes are able to work at higher intensities once this point is reached but rely heavily on the lactic acid system (anaerobic glycolysis) and this can only be sustained for a couple of minutes at the most until the accumulation of metabolic by-products causes fatigue. VO_2 max is the maximum amount of oxygen that can be taken up, transported and utilised by working muscles. It is important to understand that this relies upon a person's ability to coordinate and train their respiratory, cardiovascular and muscular systems (slow twitch).

anaerobic glycolysis
the breaking down of glycogen with insufficient oxygen, resulting in the production of lactic acid, lactate and hydrogen ions that all significantly contribute to fatigue

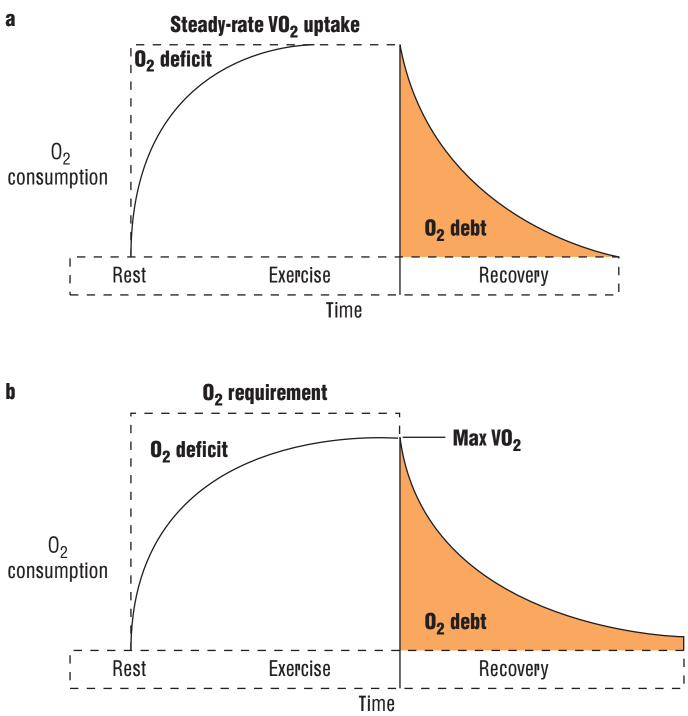

Figure 11.3 Oxygen consumption during and in recovery from (a) light-to-moderate steady-state exercise and (b) heavy exercise

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You will notice that athletes who are involved in extended endurance events have higher VO_2 max capabilities than those who are either trained for more 'short-term/explosive' activities. Males tend to have higher VO_2 max ratings than females of similar ages due to their larger lung capacities, heart sizes and blood volumes.

Arteriovenous oxygen difference (aVO_2 diff.)

The arteriovenous oxygen difference (aVO_2 diff.) is an indication of the difference in oxygen concentration between arterial and venous blood. At rest, the aVO_2 diff. is approximately 5 mL of oxygen per 100 mL of blood. At rest, the blood retains a large amount of oxygen, about 15 mL O_2/100 mL blood, as a reserve in case demands for this suddenly increase, such as when exercise intensity increases. It is worth noting that as exercise intensity increases and the muscles extract more oxygen from blood flowing through them, that the aVO_2 diff. will increase as well.

Arterial blood concentration varies little from its value of 20 mL O_2/100 mL blood at rest throughout its full exercise range up to maximal values. However, venous blood concentration decreases sharply as exercise intensity increases. At rest, venous concentration values might be 15 mL O_2/100 mL blood but this can drop to 2–3 mL O_2/100 mL blood.

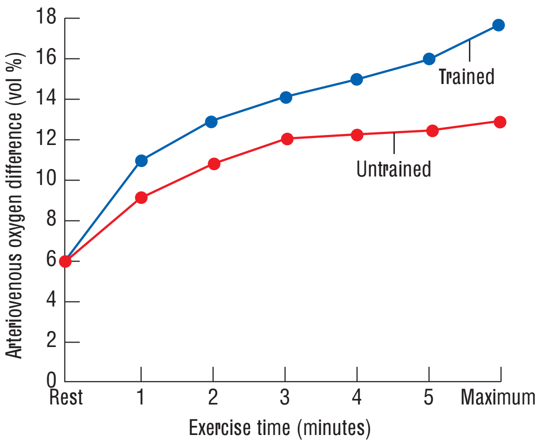

Figure 11.4 Aerobic training contributes to improved oxygen extraction from blood and increases aVO_2 diff.

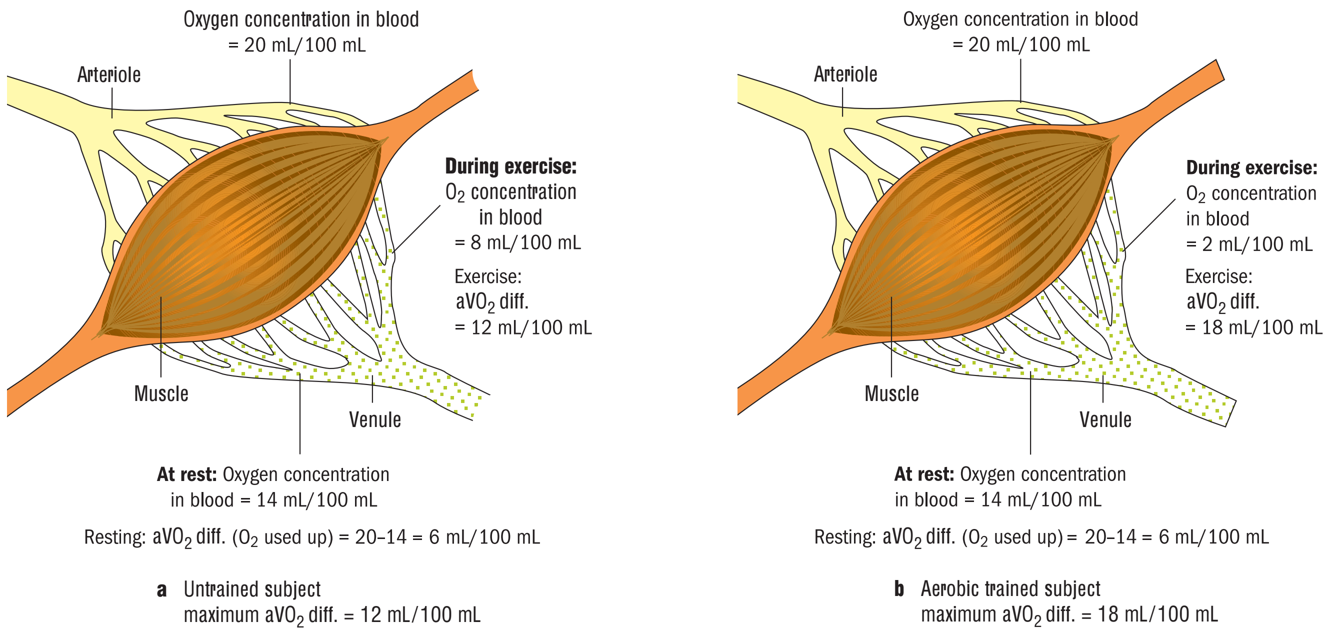

Figure 11.5 The arteriovenous oxygen difference increases in response to exercise (acute) and aerobic training (chronic)

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Table 11.4 aVO_2 diff. ($mL\ O_2/100\ mL$ blood)

State	Untrained	Trained	Triathlete
Rest	4.5	5.0	5.2
Moderate exercise	8.0	8.5	8.7
Maximal exercise	13.5	14.0	17.5

Checkpoints

1 Why is the arteriovenous oxygen difference greater when someone is jogging than when they are walking?

2 When people jog around the streets, suggest a reason why they continue jogging on the spot while they wait for the pedestrian lights to change when crossing a road. Your answer must focus on heart and respiratory rates.

3 Explain how it is possible for athletes to achieve multiple 'steady states' during the running of a marathon.

Chronic adaptations

The principle of adaptation

Athletes train the various physiological systems to adapt to the demands of their sports or activities. They must ensure that their training is specific to their sport and that the outcome of the adaptations is specific to their training program (see Chapters 13 and 14). Adaptations are present before, during and after exercise.

The training principle of adaptation is also referred to as the SAID principle (see margin). And it states that the particular physical activity we are involved in will encourage our bodies to adapt in specific ways to meet that activity's specific demands.

Adaptations are the result of specific demands placed on the body and are dependent on the volume, intensity and frequency of training. Physical training is beneficial only as long as it forces the body to adapt to the stress of physical work. If the training load is not sufficient to challenge the body, then no adaptations will result and a plateau will occur.

There are hundreds of small structural and biochemical changes that can occur when the body adapts to the stresses of exercise. This section will focus on adaptations, or long-term changes, that occur to the cardiovascular, respiratory and muscular systems, and consequently the associated energy systems.

The type of training undertaken will ultimately determine the nature of the adaptations that result. Essentially, training can be broken down into two discrete forms – aerobic and anaerobic (see Table 11.5).

S Specific
A Adaptation
I Imposed
D Demands

adaptation
a long-term physiological change in response to training loads that allows the body to meet new demands

plateau
commonly occurring when the body adjusts to new loads and maintenance of existing conditions/state prevails

Table 11.5 Aerobic and anaerobic training methods

Anaerobic training methods	Aerobic training methods
Plyometrics or ballistic stretching	Continuous
Weights/resistance	Fartlek
Interval (short and intermediate)	Interval (long)
Circuit: high work to rest ratio	Circuit: low work to rest ratio
Sprint	Flexibility

Adapted from Dawson *et al.* 1991

Table 11.6 summarises some of the diverse adaptations to aerobic and anaerobic training and compares typical metabolic and physiological values in trained and untrained men. Some of these adaptations will be discussed in greater detail throughout this chapter.

Table 11.6 Typical metabolic and physiological values for healthy trained and untrained men

Variable	Untrained	Trained	Percentage difference
Glycogen (nM)	85.0	120	41
Mitochondria volume (% muscle cell)	2.15	8	272
Resting ATP (mM)	3	6	100
Resting creatine phosphate (mM)	11	18	64
Aerobic enzymes – succinate dehydrogenase (mM)	5–10	15–20	133
Max lactate (mM)	110	150	36
Max stroke volume (mL)	120	180	50
Max cardiac output (L/min)	20	30–40	75
Resting heart rate (bpm)	70	40	– 43
VO_2 max (mL/kg/min)	30–40	65–80	107
Blood volume (L)	4.7	6	28

Adapted from McArdle *et al.* 2001

ATP–CP system
the first of the two anaerobic energy systems in which creatine phosphate (CP) is broken down to produce energy

creatine phosphate (CP)
also referred to as phosphocreatine (PC) and is a compound that transfers phosphate and energy to ADP to generate ATP; a source of energy for muscle tissue

glycolytic capacity
the ability to break down glycogen via key enzymes that facilitate glycolysis

Anaerobic energy system adaptations

Training that essentially calls on the ATP–CP and/or lactic acid system(s) will bring about specific improvements to these and any related fitness components. Anaerobic energy system changes include:

- increased levels of anaerobic enzymes and fuels including anaerobic enzymes, adenosine triphosphate (ATP), creatine phosphate (CP) and glycogen, along with an overall increase in glycolytic capacity (see Figure 11.6)
- increased amounts and activity levels of enzymes involved in anaerobic glycolysis (mainly occurring in fast-twitch fibres)
- increased ability to produce blood lactate during maximal exercise, which most likely results from increased glycogen stores and glycolytic enzymes (other fuel adaptations are discussed later).

Anaerobic training leads to improvements in both the ATP–CP and lactic acid systems, and noticeably at the muscular level. Not only do muscles become larger to produce more force, they also develop cellular adaptations to improve their anaerobic energy production.

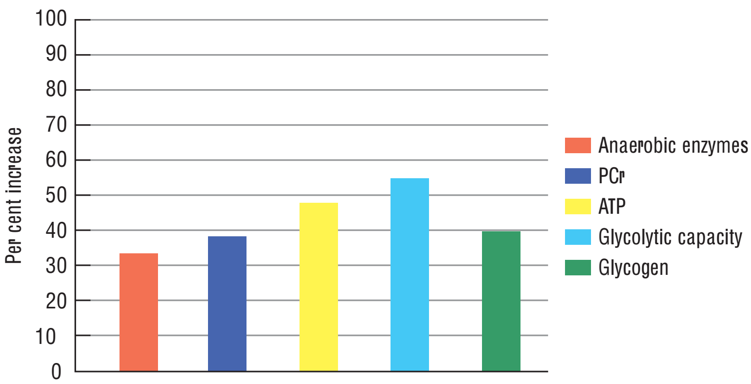

Figure 11.6 Hypothetical increases in aerobic energy metabolism of skeletal muscle with their load training

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Aerobic energy system adaptations

Aerobic training will essentially lead to improvements in oxygen uptake, transport and utilisation. Aerobic energy system changes include:

- enhanced fat breakdown resulting from increased fat-metabolising and fat-mobilising enzymes
- improved fatty acid oxidation and respiratory ATP production
- reduced total carbohydrate use (during submaximal exercise) due to less muscle glycogen, and production and use of blood-borne glucose.

These factors greatly assist glycogen sparing, which leads to enhanced endurance performance following aerobic training.

Aerobic training also causes important changes to the anaerobic threshold. This is the point where lactic acid begins to accumulate and it typically occurs at exercise intensities equal to 85% maximum heart rate. Aerobic training results in increased capillarisation, mitochondria density and oxidative enzymes, which, along with structural changes to the cardiovascular system, increase the anaerobic threshold closer to 90% maximum heart rate. Even the most elite endurance performers with the highest VO_2 max capabilities will see lactic acid begin to accumulate at these exercise intensities. The lactate threshold and ventilatory threshold occur simultaneously. OBLA (onset of blood lactate) occurs at higher intensities than the lactate threshold (see Figure 11.9).

It should be noted that the lactate threshold and lactic acid tolerance are two different things. Aerobic training will lead to increases in the lactate threshold, but not necessarily to lactic acid tolerance. As a result of producing lactic acid during training (typically via one of the anaerobic methods), the body will build a better tolerance to the effects of lactic acid over time. It is thought that anaerobic training improves the muscles' chemical buffers or alkaline reserves and hence improves the muscles' ability to work in the presence of increased amounts of lactic acid. The lactate threshold is best improved by training at or slightly above the intensity where this occurs.

Figure 11.10 shows the theoretical improvements in lactate threshold (LT) in response to aerobic training.

OBLA (onset of blood lactate)
the point where blood lactate concentration shows an increase equal to 4.0 mM, because the rate of lactate production exceeds the rate at which it can be oxidised (broken down); it accumulates at the muscle first and then moves into the bloodstream; sometimes confused with the lactate threshold, which is the point at which lactic acid begins to accumulate

Figure 11.7 Anaerobic training leads to improvements in the ATP–CP and lactic acid systems and noticeably at the muscular level.

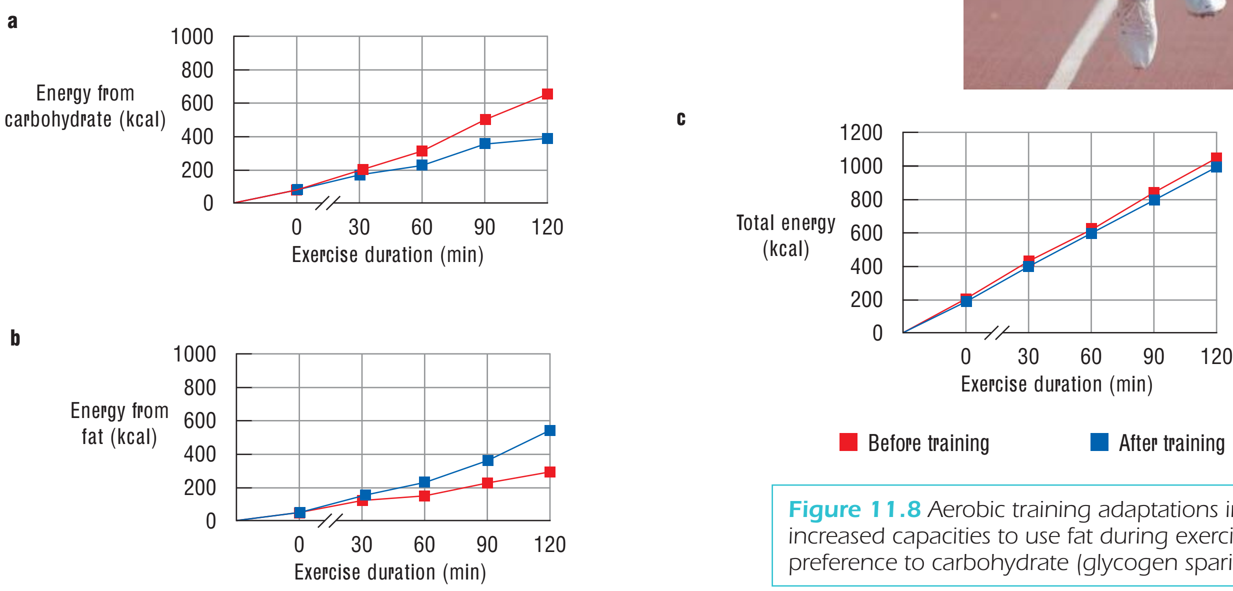

Figure 11.8 Aerobic training adaptations include increased capacities to use fat during exercise in preference to carbohydrate (glycogen sparing).

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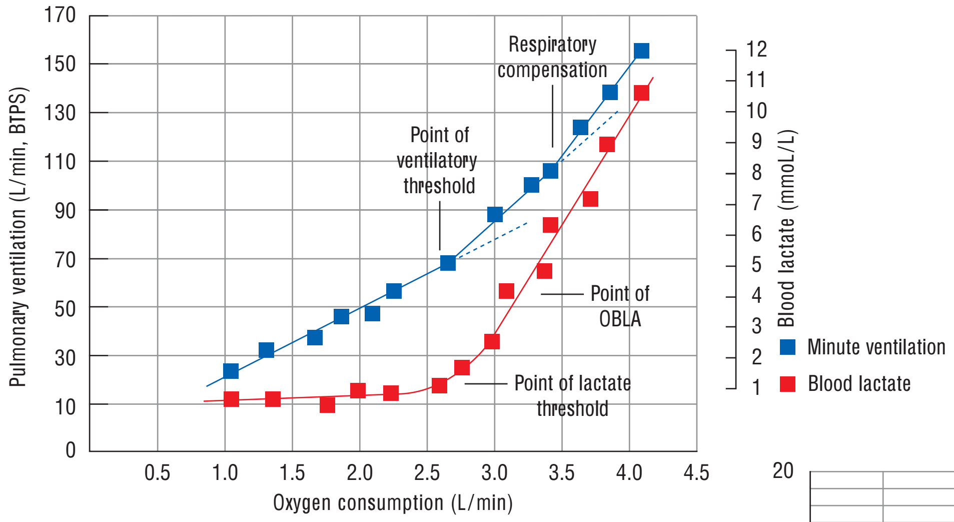

Figure 11.9 Pulmonary ventilation, blood lactate concentration and oxygen consumption in response to increasing intensity of exercise

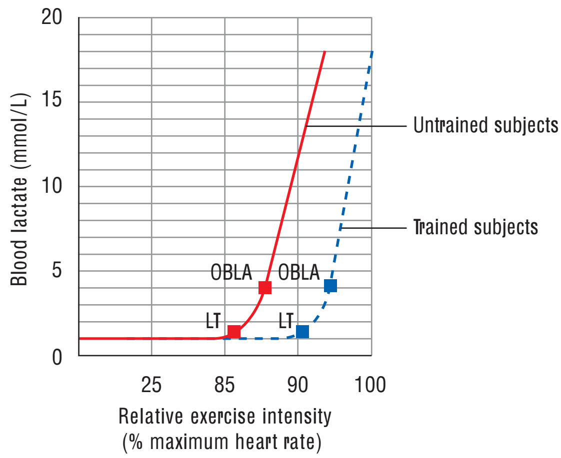

Figure 11.10 The theoretical improvements in lactate threshold (LT) in response to aerobic training

Checkpoints

1 **a** List three training methods that will predominantly bring about training adaptations to the aerobic energy systems.

b List three training methods that will predominantly bring about training adaptations to the anaerobic energy systems.

2 List two reasons why it is advantageous to use fat in preference to carbohydrate as a fuel when working under aerobic conditions.

3 What function do enzymes play in the human body?

4 Resting heart rate is one of the few variables that decreases as a result of training, in particular aerobic training. People often say this occurs as a result of the heart becoming more efficient. What does this mean?

Chronic cardiovascular adaptations

Cardiovascular adaptations refer to the heart and blood/blood vessels that essentially combine with the respiratory system to increase oxygen delivery to working muscles. Some of these changes are summarised in Table 11.7.

Table 11.7 Chronic cardiovascular adaptations as measured after 6 months

Test	Result 4 March 2009	Result 15 September 2009
Beep test	11.4	11.8
Running-based anaerobic sprint test (RAST)	12.4	9.2
60 seconds sit-ups	35	47
60 seconds push-ups	24	39

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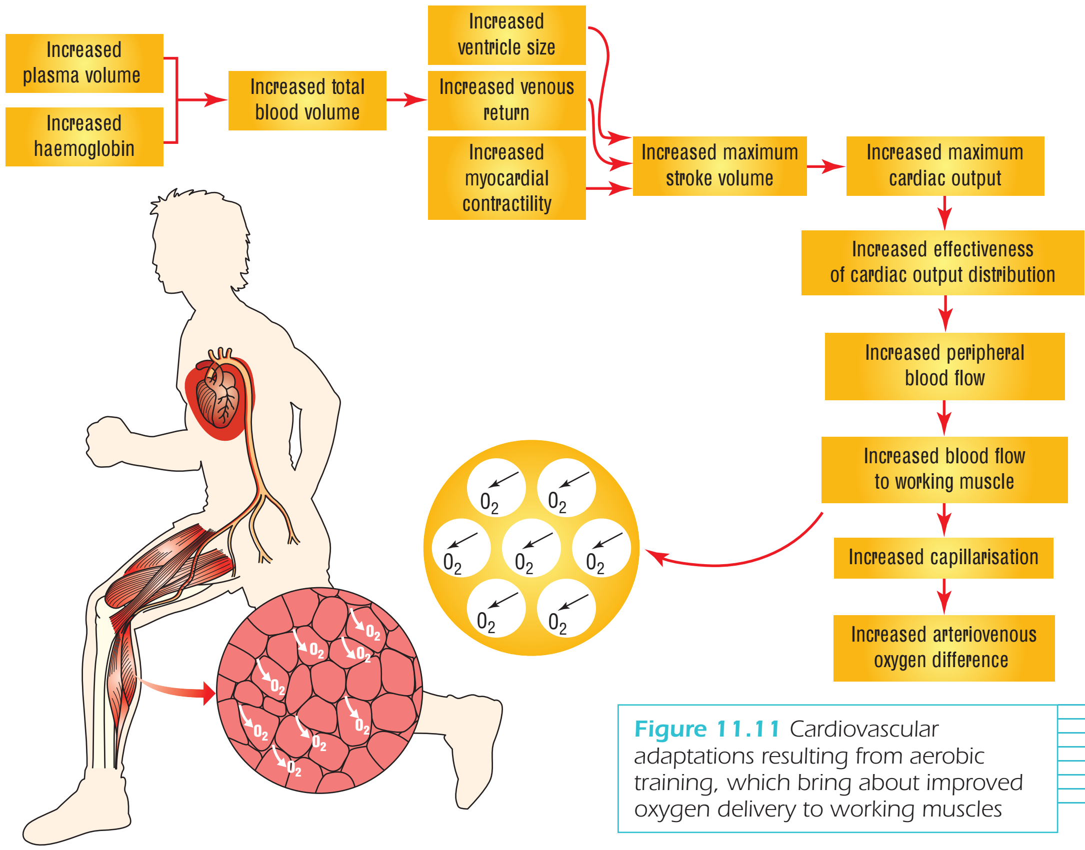

Figure 11.11 Cardiovascular adaptations resulting from aerobic training, which bring about improved oxygen delivery to working muscles

KEEP IT REAL!

Cardiac dimensions

Table 11.8 compares cardiac dimensions of non-athletes and athletes.

Table 11.8 Comparative average cardiac dimensions in normal subjects, AIS athletes and world-class athletes

Variable	Normal subjects	AIS swimmers (400 m)	AIS distance runners	World-class runners (5000 m)	AIS wrestlers	World-class shotputters
Left ventricle volume (mL)	101	181	154	160	110	122
Stroke volume (mL)	70	128	113	116	75	68
Left ventricle wall thickness (mm)	10.3	10.6	10.8	11.3	13.5	13.7
Left ventricle mass (g)	211	308	283	302	330	348

Adapted from Morganroth *et al.*, p. 521

Questions

1. Suggest one or more reasons why AIS swimmers would develop a greater stroke volume than AIS endurance runners.
2. When comparing AIS wrestlers with 'normal' subjects:
   a what is the variable showing the least difference?
   b what is the variable showing the greatest difference?
   Briefly provide reasons to account for these differences.
3. Why would AIS wrestlers have a higher stroke volume than world-class shotputters, even though they both participate in anaerobic training methods?

Cardiac hypertrophy

Endurance training results in an increased ventricular size (only a small change to ventricle wall thickness), allowing a greater amount of blood to be pumped into and out of the ventricles and resulting in increased stroke volume and cardiac output. The training program needs to be intense and extended over at least one year before these ventricular changes are brought about. It is worth noting that cardiac hypertrophy results in increased capillary density and blood flow to the heart itself (similar to other muscle hypertrophy), thus providing a coronary protective benefit.

hypertrophy
an increase in cell size that usually leads to an increase in tissue size as well

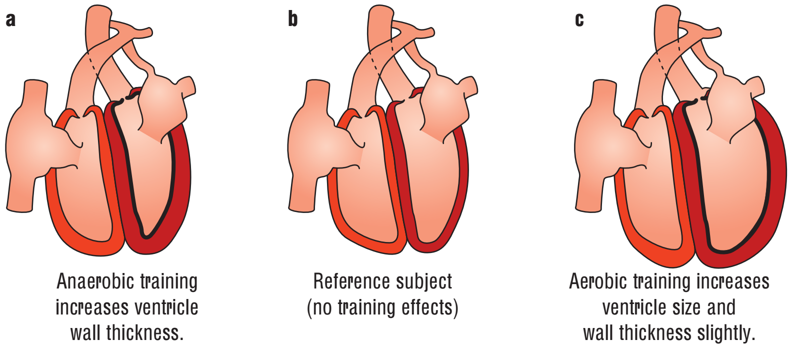

Figure 11.12 Cardiac changes to ventricle size and thickness resulting from different training regimes

Increased plasma, haemoglobin and myoglobin volumes

Oxygen is transported in blood by one of two methods – it is either dissolved in plasma or combined with haemoglobin. Increased haemoglobin volumes contribute to improved oxygen transport and increased plasma volumes are more involved in temperature regulation during exercise. Myoglobin is an oxygen-binding pigment similar to haemoglobin, but rather than transporting oxygen throughout the blood vessels, it assists in moving oxygen from muscle cell membranes to the mitochondria, where it is used. These all work together transporting increased amounts of oxygen and contribute to maximal oxygen uptake (VO_2 max).

Figure 11.13 As a result of extended and specific aerobic training, marathon runners develop a wide range of adaptations that allow them to produce peak aerobic performances with VO_2 max values around 85–90 mL/kg/min.

Heart rate, stroke volume and cardiac output

Both resting and submaximal heart rates will decrease as a result of aerobic training. This occurs because of increases in stroke volume and cardiac output. You will recall that cardiac output is the product of heart rate and stroke volume. To supply the same amount of blood and oxygen, the heart needs to beat fewer times per minute. When people say that the heart becomes more efficient as a result of aerobic training, they mean it pumps out the same amount of blood with fewer beats. Figure 11.14 shows training improvements after only

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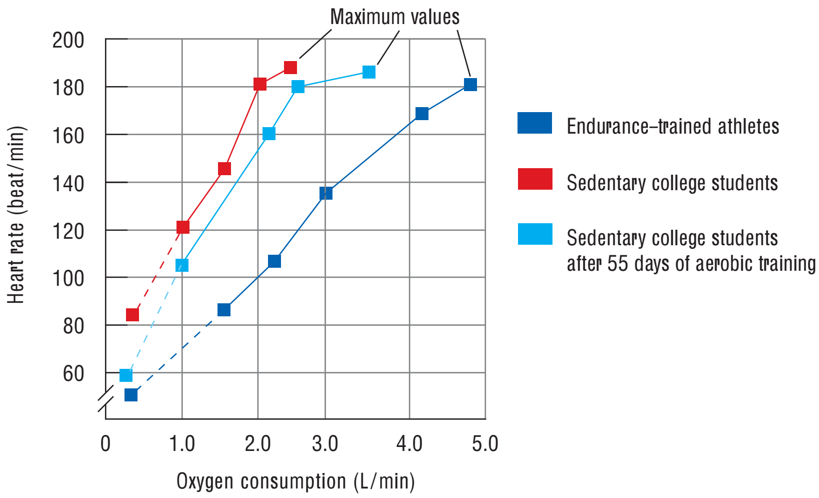

Figure 11.14 Heart rate and oxygen consumption for endurance-trained athletes and sedentary college-aged students before and after 55 days of aerobic training

55 days of aerobic training in sedentary college students, as well as reduced heart rates for corresponding workloads at rest and submaximal levels in response to the aerobic training. Note the increased oxygen extraction with reduced heart rates as a result of aerobic training that occurs in endurance-trained athletes.

Stroke volume increases result from the following adaptations:

- increased left ventricle volume and mass
- improved cardiac elasticity/contractile function
- greater diastolic filling time and associated bradycardia.

Cardiac output increases predominantly as a result of increases in stroke volume, rather than heart rate.

Blood pressure

People suffering from high blood pressure (hypertension) are often given an aerobic exercise program to help restore normal values and place less stress on the cardiovascular system.

Aerobic training will primarily lead to decreases in systolic and diastolic blood pressure during rest and submaximal exercise, with the greatest changes occurring in systolic pressure. The greatest changes occur for people with high blood pressure. Systolic pressure decreases as a direct result of:

- improved capillarisation
- improved elasticity of blood vessels
- increased high-density lipoproteins (HDLs) breaking down fatty deposits or plaque built up on the inside of arterial walls.

Coursework: Laboratory report

Investigation of heart rate and blood pressure

Aim

To investigate heart rate and blood pressure response during rest and exercise for different class members

Materials

Exercise bike (Repco, Monarch or similar), blood-pressure monitor (preferably electronic) or sphygmomanometer, heart-rate monitor (Manual readings are acceptable.)

Catchy fact

There is a direct link between increased stroke volumes and increased VO_2 max results. A 1% increase in stroke volume contributes to a 1% increase in VO_2 max and a 20% increase in stroke volume contributes to a 20% increase in VO_2 max.

Catchy fact
Some 25–30% of our population experience high blood pressure at some stage of their lives. Left unattended, hypertension will cause long-term stress on the cardiovascular system, resulting in damage to arterial walls, and after considerable time possibly contributing to heart disease, stroke and even kidney failure. The blood pressure of people who exercise is up to 35% lower than the blood pressure of sedentary people.

Method

1 Divide the class (wherever practical) into three groups:

Group 1 – students involved in no training
Group 2 – students involved in aerobic training
Group 3 – students involved in anaerobic training

2 A student takes a comfortable seated position on the bicycle and their blood pressure and heart rate are both recorded at rest. The student starts pedalling and maintains an even pace for 3 minutes when they attain 75 watts. Their heart rate and blood pressure are recorded over the last 15 seconds of this 3-minute period. The student should slow their pedalling rate down to be stationary over the next minute.

3 The student then increases the workload to 300 watts and maintains this workload for a further 3 minutes. Again the heart rate and blood pressure are recorded in the last 15 seconds of the 3-minute period. The student should slow their pedalling rate down to be stationary over the next minute.

4 Record the heart rate and blood pressure at the end of the first minute of 'cool-down' and then again at the 3-minute mark of rest/recovery.

5 Use a recording sheet similar to the following to enter your results.

	75-watt workload	300-watt workload
Heart rate		
Resting		
End of 3-minute exercise period		
First minute of recovery		
Third minute of recovery		
Systolic blood pressure		
Resting		
End of 3-minute exercise period		
First minute of recovery		
Third minute of recovery		
Diastolic blood pressure		
Resting		
End of 3-minute exercise period		
First minute of recovery		
Third minute of recovery		

6 Share the heart/pulse rates for the class.

Construct two graphs, one for each workload, showing the effect exercise has on both heart rate and blood pressure for each member of the different groups.

Discussion

1 What is the relationship between systolic blood pressure and exercise intensity?

2 Are there any differences in either heart rate or blood pressure response to the different workloads from students in each of the three groups?

3 Are there any advantages in having blood pressure increase minimally in response to exercise?

4 During recovery, which group took longest for heart rates and blood pressure to return to resting levels?

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Blood flow and distribution

Aerobic training assists the body in redirecting blood away from less active tissues such as the digestive organs and skin, to the active muscles and to the heart itself (see Figure 11.15). This redistribution leads to a 20% increase in blood flow to working muscles – primarily to slow-twitch fibres at the expense of blood flow to fast-twitch fibres. This further supports the principle of training specificity. Endurance training will also lead to increased capillarisation at the muscles – this increase in blood vessels provides more opportunity for blood and oxygen to be transported to, and used by, the muscles.

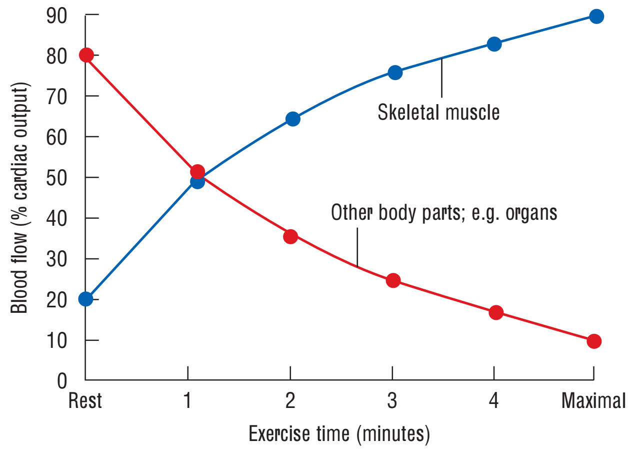

Figure 11.15 During exercise, more blood is sent to working muscles and less to other parts of the body.

Checkpoints

1 Aerobic training makes the heart more efficient. Outline two factors that contribute to this efficiency.

2 What is the relationship between cardiac output, stroke volume and heart rate?

3 How does the formation of more capillaries as a response to endurance training improve an athlete's VO_2 max?

Respiratory training adaptations

Respiratory adaptations essentially increase oxygen supply from the lungs to working muscles and are summarised below. You will notice that there are fewer adaptations than occur at the cardiovascular level because instead of dealing with two systems (cardio heart, vascular blood and blood vessels), the respiratory adaptations focus on one system (respiratory lungs).

Tidal volume

The respiratory system adapts to aerobic training by increasing the tidal volume (amount of air inspired and expired during normal breathing). This reduces the number of respirations per minute as the lungs become more efficient, so a larger volume of oxygen is supplied with the same number of breaths.

Minute ventilation

At submaximal levels, the tidal volume increases but the breathing frequency decreases. This results in air staying in the lungs for longer between breaths, which increases the oxygen extracted from inspired air, causing a corresponding decrease in ventilation.

Catchy fact
Smoking causes airway resistance to rise significantly, which in turn increases the cost of breathing and leads to decreases in extended endurance performance(s).

At maximal levels, both the tidal volume and breathing frequency increase, resulting in a higher ventilation and VO_2 max.

Ventilatory musculature

At submaximal exercise levels, oxygen consumption by respiratory muscles such as the diaphragm and intercostals actually decreases. This means that more oxygen becomes available for the working muscles to use. This is often referred to as having an increased ventilatory efficiency.

Improved lung function

Endurance training results in improved pulmonary function and larger lung volumes. This also sees a larger alveolar-capillary surface area form and directly increases the diffusion capacities found at the lungs. This occurs as a direct result of having an increased surface area for the gas exchange.

Aerobic capacity

aerobic capacity the maximum amount of oxygen the body can take in, transport and use

Aerobic capacity generally increases between 10 and 25% in the first 6 months of an intense aerobic training program and may improve by 40% over a two-year period of training. Endurance training sees improvements to VO_2 max values due to the body's ability to increase oxygen supply to working muscles. Improved oxygen supply, along with the muscles' increased ability to use oxygen, results in significant increases in the production of aerobic energy, and leads to increases in VO_2 max.

Table 11.9 Components of the oxygen transport system at rest and during maximal exercise for trained and untrained subjects and endurance athletes

Condition	VO_2 (mL/L)	Stroke volume (litres/beat)	Heart-rate (beats/min)	aVO_2 diff. (mL/min)
Untrained				
Rest	300	0.075*	82	48.8
Maximal exercise	3100	0.112	200	138.0
Trained				
Rest	300	0.105	58	49.3
Maximal exercise	3440	0.126	192	140.5
Endurance athletes				
Rest	302	0.122	50	49.5
Maximal exercise	5570	0.189	190	155.0

*Usually expressed in mL per beat, e.g. 0.075 litres per beat 75 mL per beat

Checkpoints

1 How does aerobic training make the lungs more efficient?
2 What are the two most important muscles that bring about respiration?
3 Aerobic training increases the alveolar-capillary surface area at the lungs. Briefly discuss how this improves oxygen uptake.
4 Aerobic training improves the VO_2 max of athletes as an adaptation to the training. List at least two changes that result in this improvement.

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Coursework: Laboratory report

Investigation of heart-rate response

Aim

To investigate the heart-rate response during rest, exercise and recovery for different class members

Materials

Heart-rate monitor (Manual readings are acceptable.)

Method

1 Divide the class (wherever practical) into three groups:

Group 1 – students involved in no training
Group 2 – students involved in aerobic training
Group 3 – students involved in anaerobic training

If possible, at least one student in each group should be wearing a heart-rate monitor. Otherwise, take heart-rate recordings manually and record them immediately. Work in pairs and repeat the activity twice, with students alternating between participants and recorders.

2 Each student should record their resting heart/pulse rate.

3 Each student needs to participate in a continuous activity that sees the whole class working at the same intensity for 4 minutes. The class should jog the width of a netball court, or equivalent, at this submaximal intensity. Take heart/pulse rates at the end of each minute.

4 Each student should then continue for a further 4 minutes at an increased intensity (three-quarters of running pace). This is quite brisk but still considered to be submaximal. Take heart/pulse rates at the end of each minute.

5 At the completion of the 8 minutes of exercise, students should perform an active recovery (such as walking) and record their post-exercise heart/pulse rate for a further 3 minutes.

Discussion

1 Share the heart/pulse rates for the class. Each student should graph the resting, jogging, three-quarter pace and recovery heart/pulse rates of a class member from each of the three groups.

2 Discuss differences observed by linking heart rates to training and likely adaptations that might account for the patterns observed.

a Are there any gender differences? Discuss briefly.
b Are there any differences among students who participate in aerobic or anaerobic training or activities? Discuss briefly.
c The whole class worked at the same intensity, yet it is likely that the contribution from the three energy systems was very different. Briefly discuss this by considering factors such as gender, somatotype, levels of training and existing adaptations.

Muscular training adaptations

Athletes train in order to induce specific changes within their muscles to improve their performance levels, and different training methods cause different adaptations to muscles. Even players on the same team need to choose specific methods to optimise their muscular adaptations and overall performance. For example, a centre player in netball performs more aerobic training than a goal shooter in the same team, who will most likely focus more on anaerobic training methods.

You should recall (Chapter 7) that muscles are made up of both slow-twitch (type 1) and fast-twitch (type 2) muscle fibres. At the muscular level, aerobic training has greater improvements in slow-twitch or type 1 muscle fibres and conversely in anaerobic training greater adaptations occur in fast-twitch or type 2 fibres.

Fast-twitch muscle fibres can be further classified as:

- fast-twitch type 2B   purely anaerobic
- fast-twitch type 2A   partially aerobic.

Researchers have confirmed that fibres cannot switch from slow-twitch to fast-twitch and vice versa; however, fast-twitch 2A fibres can take on slow-twitch characteristics in response to aerobic training. This means we will never see the slow-twitch fibres of a marathon runner take on the fast-twitch characteristics of a 100-metre or 200-metre sprinter. However, the fast-twitch 2A fibres of a 400-metre sprinter, after adapting to aerobic training, might increase their aerobic characteristics and better allow an athlete to compete in endurance events such as the 5000-metre or triathlon.

Many adaptations occur at the muscular level as a result of training, but it has not been demonstrated that training causes a substantial change in the distribution of these fibres in the muscle groups affected by training. For elite endurance athletes, their very high percentage of type 1 fibres (from 70 to 90%) can be accounted for genetically and are not considered to be an adaptation to training. The same is true for power athletes and their high percentage of type 2 fibres.

For more information on the characteristics of slow- and fast-twitch muscle fibres, see Table 7.2, page 110.

Anaerobic training adaptations at the muscular level

Strength/power and speed training call on the anaerobic energy systems. The greatest adaptations occur at the tissue level. These include the following.

Increased fast-twitch muscle fibre size

This shows itself in increased muscle size (muscular hypertrophy). Training with high intensity or loads and low repetitions results in greater hypertrophy of fast-twitch fibres. (Working with lesser loads and greater volumes results in hypertrophy of slow-twitch fibres.) The increases in size are greater in males (due to the presence of testosterone) than in females; however, females can achieve significant improvements in strength without fear of becoming ‘bulky’.

Increased energy substrate levels in muscle

The substrates ATP, creatine phosphate (CP), creatine and glycogen represent the most readily available fuel source of muscular energy. ATP and CP are crucial in activities only requiring a few seconds of explosive actions.

Increased ATP–CP splitting and resynthesis of enzymes

ATP is continually being broken down and reformed in the ATP–CP system, and sprint training tends to increase the level of enzymes responsible for this. This results in greater energy release and restoration when the systems are used.

Increased glycolytic capacity

The enzymes responsible for the break down of glycogen also show increased concentrations as a result of sprint training, resulting in a quicker and larger break down of glycogen to

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lactic acid. This means that the energy derived from the lactic acid system is also increased, enhancing performance that primarily calls on this system.

Increased ventricle thickness

We should not forget that the heart is a muscle as well – the cardiac muscle. Instead of increasing ventricle size and hence aerobic capacity, anaerobic training increases heart wall/muscle thickness and contractility, with insignificant changes in stroke volume.

Increased contractile proteins in muscles

Strength training (anaerobic) tends to add to the portion of the muscle that generates tension, the contractile proteins. This results in greater force being generated at any given speed.

Increased myosin ATPase

This is an enzyme that splits ATP to yield energy for muscular contractions. Having greater amounts of this enzyme allows more energy to be released at the actin/myosin level and directly increases the rate at which cross-bridges occur – all allowing contractions to occur faster, especially during anaerobic conditions.

Increased muscle buffering capacity

Our understanding of training adaptations is continually being refined and improved, and researchers all over the world are constantly working to supplement this. The adaptations of increased muscle buffering capacity and muscle hyperplasia are examples of this.

Athletes participating in vigorous anaerobic training are able to tolerate significantly high levels of muscle and blood lactate. While more research is needed in the area of lactic acid tolerance, it is thought that anaerobic training improves the muscles' chemical buffers or alkaline reserves, which both improve the body's capacity for acid–base regulation.

Muscle hyperplasia

Researchers have evidence that muscle fibres increase in size, but up until recently they had not found evidence to suggest that they increase in number. Recent studies on animals suggest that new muscle fibres are formed (hyperplasia) from either satellite cells or longitudinal splitting. These changes occur in response to a chronic overload of skeletal muscle.

However, researchers cannot simply take the data found on animal species and apply it to human beings. The possibility of hyperplasia existing in human beings in response to resistance training is likely, but more supportive findings are needed.

Even if future studies on human beings replicate training-induced hyperplasia, increases in cross-sectional areas of individual muscle fibres will still represent the greatest increases in muscle size resulting from adaptations to overload.

High-intensity, short-duration resistance training for men and women leads to similar strength gains in percentage terms, while significantly increasing muscle mass in women. Excessive high anaerobic workouts have been linked to increased susceptibility to upper respiratory tract infections (URTI) and training frequency and recovery both need careful consideration.

Aerobic training adaptations at the muscular level

Continuous or endurance training calls on the aerobic energy system. Many adaptations occur at the cardiovascular level. Significant changes at the tissue level include the following.

Catchy fact

The heart is a muscle (myocardium) and it needs a constant supply of oxygen. Impaired blood flow to the heart leads to chest pains known as angina. Blockage of a coronary artery may cause irreversible damage to the heart muscle itself (myocardial infarction).

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Increased mitochondria density and number

Mitochondria are referred to as the aerobic powerhouses of the body and are where aerobic production of ATP occurs. There is an increase in both size and number of mitochondria throughout trained muscle fibre. This results in an increased capacity for aerobic metabolism from oxidation of fatty acids and carbohydrate for endurance-level work. Mitochondria numbers may double depending on training duration and other variables.

Note: Heavy resistance training reduces the mitochondria density in the muscle, most likely due to an increase in muscle volume.

Increased myoglobin stores

Myoglobin is similar to haemoglobin in that it attaches to oxygen. The difference between the two is that haemoglobin transports oxygen in the blood and myoglobin provides for intramuscular oxygen storage. Increased myoglobin stores mean that more oxygen can be stored, and hence more ATP produced aerobically, at the muscles.

Improved oxidative capacity via increased oxidative enzyme

There is an increase in the key enzymes responsible for aerobic production of energy such as citrate synthase, pyruvate dehydrogenase and succinate dehydrogenase – what a mouthful! Rather than trying to remember their names and looking up their roles, simply know that these, along with other Kreb's cycle enzymes, increase in number. They all contribute to greater and faster amounts of ATP being released and resynthesised and thus more energy being made available under aerobic exercise conditions.

Increased capillary density

As the muscles' demand for blood flow increases during exercise and training, the body adapts by increasing the number of capillaries surrounding individual muscle cells (primarily slow-twitch fibres). This greatly improves the oxygen exchange capacity between capillary and fibre by providing a greater surface area for the gas exchange and by reducing the distance oxygen molecules must travel after they are released from haemoglobin. Increased capillary density and uptake of oxygen by active muscle tissue accounts for much of the increase in maximal oxygen consumption and improvements in VO_2 observed in endurance athletes.

Increased use of fat during submaximal exercise

The increased use of fat appears to inhibit carbohydrate use during the first 30 minutes of exercise, especially at submaximal levels. This results in glycogen sparing and also makes more glycogen available later during endurance performance.

Increased stores and use of intramuscular triglycerides

Having a greater number of triglycerides also adds to the glycogen-sparing possibilities of slow-twitch muscle fibres. Combined with a large blood flow and high mitochondria density, these triglycerides are an ideal fuel when performing low-intensity and submaximal exercise.

Increased muscle glycogen synthase and storage

Glycogen synthase is the enzyme responsible for converting glucose to glycogen. Aerobic training leads to increases in its concentration and thus the ability to convert and store glycogen. This occurs more readily in slow-twitch fibres but is also seen in fast-twitch fibres. Glycogen can be broken down aerobically (aerobic glycolysis) or anaerobically (anaerobic glycolysis) to supply ATP. Aerobic glycolysis is preferable because it doesn't result in fatiguing by-products, it occurs more quickly and easily, and it allows performance to continue with little disruption.

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Oxygen extraction (arteriovenous oxygen difference)

Aerobic training results in greater amounts of oxygen being extracted from the blood. This increase in the arteriovenous oxygen difference (aVO_2 diff.) results from:

- more blood being pumped to active muscles (especially slow-twitch fibres)
- muscle fibres being better able to extract and process transported oxygen as a result of increased mitochondria numbers, more oxidative enzymes and increased levels of myoglobin.

Because more oxygen is being extracted by the muscles, aVO_2 diff. must increase. (The arteriovenous oxygen difference remains unchanged at resting levels as the muscles having sufficient oxygen to meet the low-level demands.)

The arteriovenous oxygen difference is a direct measure of how much oxygen working muscles are using. It is expressed as the difference in oxygen concentration between the arterioles and the venules, after passing through muscles (see Figure 11.5, page 202).

KEEP IT REAL!

Fitness test results case study

The following fitness test results were obtained from a 17-year-old triathlete who is currently training to improve her results in an effort to qualify for the Australian under 23 team to compete in the World Championships.

Note: Not all test results are presented in this profile. Results for the same tests undertaken eight months after pre-testing are also provided.

Fitness test	Pre-test result	Post-test result
20 m shuttle run	Level 11 Shuttle 6 Predicted VO_2 max 52 mL/kg/min	Level 13 Shuttle 12 Predicted VO_2 max 60 mL/kg/min
Phosphate recovery (long course)	17% decrement	8% decrement
Body composition (% fat)	13%	9%
60 seconds sit-ups	42	51
1/2 squat trust test	47	115
Margaria stair climb	120 kg/m/s	129 kg/m/s
Repco peak power	17 watts/kg	19 watts/kg
Running (40 m)	4.8 s	4.6 s

Questions

1 What does each of the fitness tests in the case study of the triathlete assess?

2 Based on the above changes observed in the 8-month period under consideration, justify the type(s) of training the athlete is likely to have undertaken. Assuming that she undertook a variety of training methods, which type of training would have taken up the majority of her sessions?

3 By using other information provided in this chapter, look at each of the changes listed above and outline the structural or physiological changes likely to have occurred over the 8-month period that could have contributed to the change (consider these at the cardiovascular, respiratory and muscular levels).
For example, VO_2 max increased by 5% and is likely to have resulted from increases in stroke volume (cardiovascular) and alveoli surface area as well as changes to slow-twitch or fast-twitch type 2A fibres including increased oxidative enzymes and capillarisation (muscular and physiological).

4 Discuss any changes to the energy systems' capacities likely to have occurred over the course of the 8 months.

Adaptations are reversible

When people stop participating in regular exercise or training, they experience rapid loss of their acquired adaptations: this is known as detraining. A person's VO_2 max may increase by up to 40% after two years of regular aerobic training and conditioning, and yet see rapid reversals with inactivity. Researchers found that endurance-trained athletes confined to bed for three weeks saw their maximum stroke volume, cardiac output and aerobic capacity all decrease by an average of 1% per day! Additionally, the capillary density within their trained muscles decreased in the order of 15–20%.

Table 11.10 Changes in physiological and metabolic functions with various durations of detraining in primarily aerobic trained athletes (averages in reported literature)

Variable	Short-term (<3 weeks of detraining) % decrease	Longer term (3–12 weeks of detraining) % decrease
VO_2 max (mL/kg/min)	20	35
Cardiac output (L/min)	8	20
Stroke volume (mL)	9	25
Capillary density (cap/mm)	17	29
Glycogen (mM)	24	50
Phosphocreatine (mM)	15	27
Oxidative enzyme capacity	29	32
Lactate threshold	7	18
Muscle glycogen synthesis	29	40

It is evident that adaptations take a long time to build up, yet are reversed very, very quickly when training stops. This is also known as the reversibility principle. This is one of the reasons athletes commence a reconditioning training phase (pre-season training) several months before the competitive phase of their year. They do this as well as participating in moderate levels of off-season sport-specific activity/training to minimise the decrease in adaptations that will result from detraining and reduced competitive training loads.

Checkpoints

1. Muscle hypertrophy occurs in response to both aerobic and anaerobic training. Briefly discuss what this means and how it brings about improved performance levels under each exercise situation.
2. How do more mitochondria bring about improved aerobic performances?
3. As a result of aerobic training, muscles 'learn' to make earlier and greater use of fats as a fuel (especially under submaximal exercise conditions). Explain how this leads to improved endurance performances.
4. Discuss at least two differences between aerobic and anaerobic glycolysis.

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Table 11.11 summarises the chronic adaptations at the cardiovascular, respiratory and muscular levels and how the adaptations contribute to improved performances.

Table 11.11 Chronic adaptations at the cardiovascular, respiratory and muscular levels

	Adaptation long-term change	How the change contributes to improved performance
Aerobic training		
Cardiovascular	**Heart** ↑ ventricle size ↑ stroke volume (surface area) ↑ cardiac output (*Q*) ↓ rest and submaximal heart rates ↓ steady state heart rate ↓ recovery heart rates	**Heart** Increased ventricle size contributes to increased cardiac output, which allows more blood, oxygen and fuels to be pumped to working muscles and more efficient/speedier removal of by-products. Heart able to reach steady state quicker and hence limit oxygen deficit and reliance on anaerobic energy systems. Less 'work' required up to maximal levels and more oxygen available to working muscles. Quicker return to resting levels and smaller/faster oxygen debt.
	Blood vessels ↑ capillary density to heart muscle ↑ blood flow (20%) away from organs to working muscles ↑ capillary density at muscles, mainly slow twitch ↑ HDL (more high density lipoproteins) ↓ LDL (less bad cholesterol)	**Blood vessels** More blood pumped to actual heart and working muscles, lowering likelihood of anaerobic by-products causing fatigue. Increased HDL acts to remove plaque from arteries and lower cholesterol levels. This decreases amount of resistance in blood vessels.
	Blood ↑ blood volume ↑ plasma levels ↑ red blood cell count ↑ haemoglobin ↑ myoglobin ↑ OBLA ↓ blood pressure (rest and submaximal)	**Blood** Greater blood volumes increase amount of oxygen transportation to and by-product removal from working muscles. Increased plasma slows fatigue caused by dehydration and elevated body temperature. Increased myoglobin increases rate of oxygen transfer from cell membranes to mitochondria where aerobic energy can be produced. Decreased blood pressure has a cardio protective effect
Respiratory	↑ lung/vital capacity ↑ aerobic capacity ↑ tidal volume ↑ alveolar – capillary surface area ↑ pulmonary diffusion ↑ ventilation (max intensity) ↓ oxygen cost to ventilatory muscles (intercostals and diaphragm) ↓ ventilation (rest and submaximal)	Increased lung capacity allows for more O_2 to be taken in to the body to then be transported to muscles. Increased aerobic capacity improves restoration of CP as well as allowing body to use aerobic system for greater part of the activity. Greater surface area of alveoli combined with capillary density makes for a larger diffusion site allowing greater amounts of gases to be exchanged at the lungs. Decreased oxygen cost means more oxygen available to be sent to working muscles.

	Adaptation long-term change	How the change contributes to improved performance
Aerobic training		
Muscular	**Slow twitch** ↑ aVO_2 diff. ↑ capillary supply/density ↑ myoglobin stores ↑ mitochondria (size, number and surface area) ↑ oxidative enzymes ↑ glycogen stores ↑ triglyceride stores ↑ fibre size ↑ glycogen sparing ↑ glycogen synthase **Fast twitch** type 2A – as above but to a much lesser extent	**Slow twitch** Improved aVO_2 diff. means more oxygen can be extracted by working muscles and increased surrounding capillaries will further enhance this supply as well as facilitate removal of by-products. Increased mitochondria will allow for greater aerobic ATP release and oxidative enzymes will contribute to this as well. Greater glycogen and triglyceride stores will enable muscles to work for longer. Muscles 'trained' to first use available triglycerides and then use glycogen later in the performance and hence glycogen spare. This allows for higher intensities later in the performance. Glycogen synthase assists storing of glycogen from glucose.
Anaerobic training		
Cardiovascular	**Heart** ↑ ventricle thickness (small increase to stroke volume via more forceful systole/contraction) **Blood vessels** ↑ vascularisation (not as much as per O_2 training) **Blood** ↓ blood pressure (rest and submaximal)	**Heart** The heart wall thickens and thus contracts more forcefully to squeeze out more blood per systole, and hence create smaller increases in stroke volume than those brought about by increased ventricle size. **Blood vessels** Increased capillary density results from anaerobic training, but given the fact that muscle size increases, the ratio of capillaries to muscle tissue actually decreases.
Respiratory	**negligible**	**N/A**
Muscular	**Slow twitch** negligible **Fast twitch** (mainly occurring to type 2B) ↑ fibre size and possibly number (hyperplasia) ↑ ATP stores ↑ CP stores ↑ glycogen stores ↑ glycolytic enzymes ↑ contractile proteins ↑ myosin ATPase ↑ muscle buffering capacity/by-product tolerance ↑ improved motor unit recruitment ↑ neural transmission ↑ speed of contraction ↑ force of contraction ↑ size of connective tissue/tendons ↓ lactic acid production (submaximal) ↓ recovery times	**Fast twitch** Increased size/contractile proteins allows for greater contraction forces to be applied. Greater size allows for greater storage of ATP and CP and extends use of the ATP–CP system contributing to lower reliance on lactic acid system and less lactic acid produced. Greater glycogen stores used by lactic acid system and accessed by glycolytic enzymes. More myosin ATPase allows for rapid attachment to actin and contractions to take effect. Muscles learn to work as by-products accumulate, rather than 'fatiguing' as soon as they are present. Nervous system and muscular system work more 'in sync' with each other to allow for more efficient movements, greater force summations etc. Increase connective tissue accompanies increased muscle size to provide greater attachment to muscles and hence assists in force production. Recovery from anaerobic performance is improved as body learns to resynthesise used fuels.

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TEST YOUR KNOWLEDGE

>> multiple choice

1 Increased ventilatory efficiency occurs when the:

A alveolar surface area increases
B arterio-ventilatory difference increases
C intercostals and diaphragm require less oxygen than previously to perform the same tasks
D minute ventilation increases as the tidal volume decreases.

2 Increased cardiac output occurring at maximal intensity is primarily brought about by:

A increased stroke volume
B increased heart rate
C increased systolic blood pressure
D increased diastolic blood pressure.

3 Glycogen sparing results when the following training method is undertaken for more than 18 months:

A Continuous
B Short interval
C Resistance
D Circuit

4 Increased muscle buffering capacity is most likely to occur at the following muscle fibres:

A Type 2A
B Type 2B
C Fast twitch
D Slow twitch

>> short answer

5 Up until 15–20years ago, patients who had suffered a heart attack were instructed to 'take it easy' and avoid exercise because of the strain it might put on their heart muscle.

a Outline three reasons why regular aerobic exercise is now often recommended to patients who have suffered a heart attack.
b Why are high-intensity workloads not recommended as part of a recovery program for heart-attack patients?

6 Outline how and why blood is distributed away from major organs to working muscles as exercise intensities increase.

7 Aerobic training increases the arteriovenous oxygen difference.

a Briefly outline how trained athletes have greater aVO_2 diff. than untrained athletes.
b How is it possible for the amount of oxygen arriving at working muscles to increase (concentration levels) in response to aerobic training?
c If aerobic training increases the amount of oxygen extracted at the muscular level by athletes, what effect does this have on reliance on the three energy systems for ATP?

>> essay style

8 Peta is an outstanding netball player and while completing her Year 12 she studies regularly trains with the West Australian Wasps. She possesses outstanding speed and agility, and a muscle biopsy has revealed she has more fast-twitch fibres than slow-twitch fibres in her leg muscles. Her coach is concerned that, despite showing promise in the position of centre, she finds it difficult to 'run out games' and usually tires in the last quarter.

a Outline how it is possible for Peta to train her fast-twitch fibres to become more endurance-like in nature.

b Aerobic training will lead to changes at cardiovascular, respiratory and muscular levels. Discuss two cardiovascular and two respiratory adaptations that occur as a result of aerobic conditioning that would allow Peta to be able to 'run out games'.

c Outline why it is important for Peta to maintain a basic level of conditioning during the holiday period, which coincides with the netball off-season.

9 A person sets out on a 5-kilometre run on the weekend.

a List two acute respiratory responses.

b Outline how each response listed contributes to increased oxygen supply to working muscles.

10 Having more glycogen ultimately means that more lactic acid will be produced as a result of anaerobic glycolysis. Discuss how the lactate formed in fast-twitch fibres as a result of this can be used to supply fuel to other muscle fibres. Hint: Consider what lactic acid is broken down to and then how this can be used as a fuel for other muscle fibres (lactate shuttling).

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12 Foods, fuels and energy systems

Have you ever wondered where muscles get the energy for providing movement? Energy is fundamental to the study of physical activity and sports performance, and this chapter will provide you with a basic understanding of the sources of energy for muscular contraction – in particular the role of adenosine triphosphate (ATP) and the food fuels. You will become familiar with how ATP is resynthesised via the three energy systems and how all three systems work together to provide energy, also known as the energy system interplay.

Food fuels

We eat foods to provide us with energy to keep us going. Our food intake consists of three basic nutrients:

1 Carbohydrates (CHO) (sugars and starches such as fruit, cereal, bread, pasta and vegetables) are the body's preferred source of fuel, particularly during exercise.

2 Fats (for example, butter, margarine, cheese, oil, nuts, pork and fatty meats) act as concentrated fuel storage in muscles and the body's adipose tissue. It is the body's main source of fuel at rest and during prolonged submaximal exercise.

3 Protein (for example, meat, fish, poultry, legumes, eggs, grains) makes a negligible contribution to energy production during exercise (5–10% in prolonged endurance events). It is used mainly for growth and repair.

Our digestive system breaks down carbohydrates to glucose (stored in the liver and muscles as glycogen). It breaks down fats/triglycerides to free fatty acids (stored as adipose tissue) and proteins to amino acids (stored at muscles).

Water, minerals and vitamins are the other essential dietary ingredients. However, carbohydrates, fats and protein are the only sources of food energy or fuel. Table 12.1 shows the proportions of carbohydrate, fat and protein in a balanced diet that meets the needs of an average athlete.

Nutrients are carried away in the bloodstream surrounding the digestive system to the cells of the body. Some of this fuel is used immediately for energy production. The remainder is stored around the body.

carbohydrates
chemical compounds consisting of carbon, hydrogen and oxygen atoms; they are the body's preferred food fuel during exercise

fats
components of foods containing fatty acids and glycerol; they are the body's preferred fuel at rest and during prolonged submaximal exercise

protein
the fuel source used predominantly for growth and repair and as an energy source under extreme conditions; makes a negligible contribution to energy production during exercise and is mainly used for growth and repair

Table 12.1 Recommended daily consumption of average athlete

Food	Recommended daily intake (RDI) for balanced diet (%)	Food fuel that it is converted/ digested to	Form stored in and location
Carbohydrates – sugars and starches such as fruit, cereal, bread, pasta, brown rice, peanuts and vegetables	55–60	Glucose	Glycogen – muscles and liver
Fats/triglycerides – butter, margarine, cheese and full-cream dairy products, oils, nuts, pork and fatty meats	25–30	Free fatty acids (FFAs)	Adipose tissue – various body sites
Proteins – lean meat, fish, poultry, legumes, eggs, lentils, grains and seeds, cheese, seafood	10–15	Amino acids	Muscles – various body sites

Checkpoints

1 Provide three examples of foods not shown in Figure 12.1 that are high in carbohydrates, fats or proteins.

2 **a** Outline several situations where the recommended food intakes in a balanced diet would vary.

b Compare the different food intakes of an endurance performer such as a triathlete with those of a field athlete such as a pole vaulter or discus thrower.

3 Vegetarians do not consume animal products. Produce a table listing foods that vegetarians could include in their diet to obtain their carbohydrate, fat and protein requirements.

Foods as energy sources

All foods are broken down and stored as chemical energy, which must be converted to mechanical energy to allow muscular contractions and movement to occur. The major source of energy that keeps every cell in the body going, including muscles, is adenosine triphosphate (ATP). This is the most important way we store and use energy.

Figure 12.1 Examples of foods high in carbohydrates, fats and proteins

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ATP energy!

ATP is a chemical fuel source. ATP consists of an adenosine molecule with three phosphates joined together in a row. The bonds holding the atoms together store energy. When the outermost phosphate bond is broken, energy is released to fuel all processes within the body, in particular muscular contractions (Figure 12.2). Energy is released when phosphate splits off and ATP is broken down to adenosine diphosphate (ADP) and a free inorganic phosphate molecule (P_i).

Only a very small amount of ATP exists at the muscles – sufficient for a few maximal contractions (for example, powerful, explosive actions such as jumps or 5–10 metres of sprinting). ATP must be continually rebuilt or resynthesised so that energy can be provided for longer periods of time. This process involves the breakdown of stored nutrients, releasing energy and causing the free phosphate molecule to rejoin ADP, making ATP available to release more energy. Essentially, ATP is broken down and rebuilt many times as energy for muscular movement to be made available.

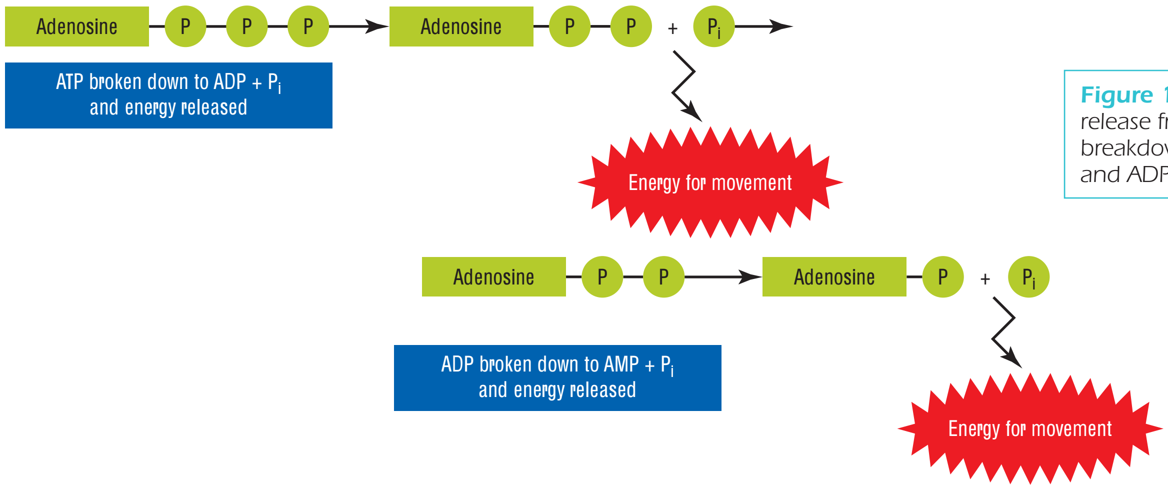

Figure 12.2 Energy release from the breakdown of ATP and ADP

The chemical reaction that turns the energy contained in ATP into energy for use in muscular contraction can be summarised as follows:

- Chemically, ATP is an adenine nucleotide bound to three phosphates.
- There is a lot of energy stored in the bond between the second and third phosphate groups that can be used to fuel chemical reactions.
- When a cell needs energy, this bond breaks, releasing a large amount of energy and forming ADP and a free phosphate molecule.
- When the cell has excess energy, it stores this energy by forming ATP from ADP and phosphate.
- Creatine phosphate (CP) is another chemical fuel source similar to ATP in that it contains a high-energy phosphate bond. Energy is constantly transferred when energy is released from the breakdown of CP, glucose, FFAs and amino acids and their stored energy is released when bonds are broken.

Fuel sources

At rest, fat is used in preference to carbohydrate as a fuel source. Note that both contribute to energy production.

Fuel sources at varying exercise intensities will differ. Carbohydrate is the only source of energy during maximal intensity exercise. You will notice that fats are used increasingly during prolonged submaximal/endurance activities. It is worth

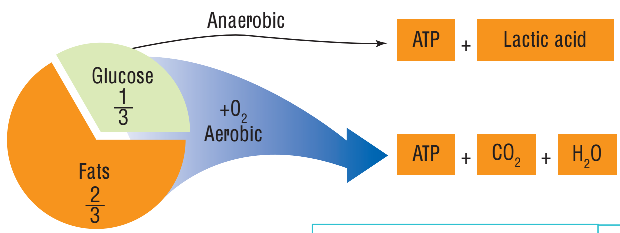

Figure 12.3 Food fuel sources at rest

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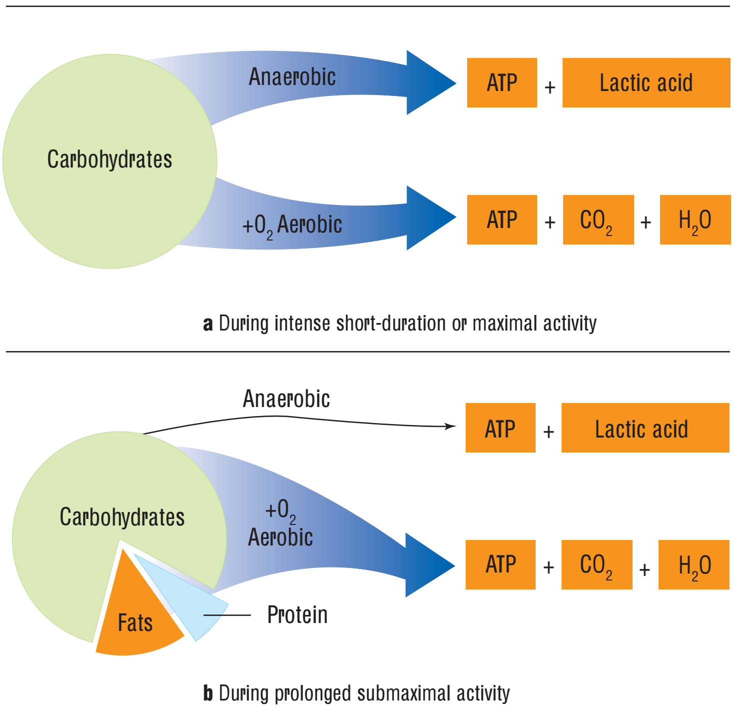

Figure 12.4 Food fuel sources during maximal and submaximal activity

Catchy fact

On average, an 80-kilogram person can only store 100 grams of glycogen in their liver and approximately 400 grams of glycogen in muscles throughout the body (15 grams of glycogen per kilogram of muscle). This would be sufficient to fuel a 25-kilometre run! Approximately 50% of the body's energy for everyday activities is supplied by fat.

noting the differences between aerobic glycolysis and anaerobic glycolysis in Figure 12.4 and the resultant end products. It is also worth noting that once glycogen stores start to deplete during an endurance event (at approximately 2 hours), there will be a transition to fats as the major fuel supplying energy.

The contribution of carbohydrates, fat and protein to energy production

Carbohydrates

Energy for muscular contraction stems from muscle and liver glycogen. The level of carbohydrate intake varies according to the nature of the activity, with prolonged endurance activities requiring as much as 80% of the diet as carbohydrate – a part example of a carbohydrate loading regime.

It is important to have a carbohydrate-rich diet in order to increase glycogen stores. These glycogen stores facilitate high-intensity efforts via the lactic acid energy system, as well as aiding endurance performance (relying on the aerobic energy system). They also provide energy for phosphocreatine resynthesis/restoration.

Recognition of the vital role that carbohydrates, and more specifically glycogen and glucose, play in the performance of high-intensity exercise has been a major step forward in sports science and nutrition. The diets of athletes and sedentary individuals are basically the same; however, an athlete requires a greater energy intake. During anaerobic (high-intensity, short-duration) exercise, carbohydrates are the primary energy source. During aerobic (moderate-intensity, longer duration) exercise, carbohydrates and fats are the sources of energy. Carbohydrates are preferred over fats as a source of energy during exercise because they require less oxygen to produce the same amount of energy.

Appropriate dietary management must take into consideration the demands of the event, particularly the duration of the activity. Events lasting less than 1 hour require only normal carbohydrate reserves. Events of a strenuous intermittent nature or continuous events lasting around 90 minutes require well-filled glycogen stores, while prolonged endurance events of 2 hours or more require 'super-filled' glycogen stores.

Fat

Fats play an important role in the diet of athlete and non-athlete alike. Fats in the form of triglycerides are stored throughout the body in fat cells (adipose tissue) and in skeletal muscle. Triglycerides are broken down into free fatty acids. Free fatty acids in turn are broken down aerobically to provide energy for movement. The transport of free fatty acids to muscle fibres is slow, and the breakdown requires a greater amount of oxygen than that required to break down glycogen. This puts added stress on the oxygen transport and delivery system; hence, glycogen is the preferred fuel during exercise, especially where limited oxygen is available. Hence, higher-intensity aerobic exercise predominantly uses carbohydrate as the preferred fuel.

Fat becomes an increasingly important energy source as glycogen becomes depleted due to prolonged submaximal exercise. Trained athletes use fat as an energy source to a greater extent than untrained individuals. Even so, fat should not contribute more than 25–30% of the total energy requirements of the body. Fat acts as a large energy store and source, and provides the source and transport medium for the fat-soluble vitamins A, D, E and K. However, athletes are equally susceptible to the adverse health effects of diets high in

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saturated fat such as obesity, cardiovascular disease and atherosclerosis, despite the positive health benefits of exercise.

Protein

Protein is required in the diet as it forms the building blocks of tissue (growth and repair). All enzymes (which speed up chemical reactions) are proteins. Protein is also important in the synthesis of hormones and antibodies (the body's immune defence system). The basic structural units of proteins are amino acids.

There are two schools of thought regarding the protein requirements of athletes. Since protein is not normally used as an energy source, its consumption is much less than that of fats or carbohydrates (12–15% of the average diet). Large amounts of oxygen are required for breaking down protein. It is only used in extreme circumstances; for example, extended-duration exercise.

The conservative viewpoint is that the average diet supplies sufficient protein and essential amino acids to meet an athlete's requirements. Higher recommendations are based on the theory that amino acid requirements may be greater than originally estimated and that endurance exercise significantly increases the turnover of protein. Many athletes consume more than 15% of their diet as protein, while some power athletes consume more than 30% as protein. There appears to be no real advantage for intakes exceeding 10–15%. In fact, there may be some disadvantages, such as the:

- displacement of more carbohydrate-rich foods from the diet
- excess fat intake associated with animal protein
- additional nitrogen excretion, which increases urinary water loss (leading to dehydration/constipation).

Proteins and fats contain no carbohydrate and as such have minimal effect on glucose production. These foods must be considered as low glycaemic index (GI). Foods that are high in fibre increase the time it takes our bodies to break down foods and as a result are also considered to have a low GI. Sports drinks and other foods with a high concentration of glucose (thus needing no further breakdown) cause blood glucose levels to rise quickly and are thus considered to be high GI. Fruits (fructose) are slow to be broken down, as are most dairy products containing lactose and hence both are considered to be low-GI foods. Sucrose has a medium release and an equivalent moderate GI rating.

glycaemic index (GI) a ranking of foods based on their immediate effect on blood glucose levels

The National Heart Foundation of Australia and the Australian Institute of Sport make recommendations for dietary intake for athletes and non-athletes. Visit their websites and compare your dietary food intake to those suggested. How does it compare? How can you account for any differences? Are there any changes you might consider making to your diet to better meet recommendations from these two sources?

Recommended dietary intake for Australians

Dietary requirements for athletes

Tables 12.2 and 12.3 summarise the nutrition and hydration guidelines for athletes and some non-nutritional aids to improving performance.

Table 12.2 Summary of nutrition and hydration guidelines for athletes

3–4 days before competition	3–4 hours before competition	1–2 hours before and during competition	Post competition
Nutrition			
Carbohydrate loading for longer duration events Reduce fats and high-protein foods (1–2 days before competition).	Low GI foods to provide slow release of glycogen	High GI foods to boost readily available glycogen	High GI foods required initially Salty foods to help sodium replacement

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Examples: Pasta meals, bread	Examples: Crumpets with jam or honey, baked beans on toast, breakfast cereal with milk, fruit salad and yoghurt, pasta and vegetables	Examples: Liquid meal supplement, fruit smoothie, sports bars, fruit-flavoured yoghurt, fruit, sports drink, jelly lollies, carbohydrate gel	Examples: Banana sandwich on wholemeal bread, high-sugar drinks
Hydration			
	200–600 mL prior to competition Have fluid with all meals and snacks.	Use 200 mL per 15 min of exercise as guide to rehydration.	Will need to drink 150% of any fluid deficit in the 4–6 hours after exercise to account for ongoing sweat and urinary losses.
	Measure pre-game weight to determine post-game fluid quantities.		Measure post-game weight to determine post-game fluid quantities.
Examples: Water and sports drinks are the best options.			

Table 12.3 Non-nutritional interventions

Aid	Characteristics	Example
Physiological aids	Aim to enhance the physiological processes that occur naturally in the body	Altitude training and physiotherapy
Mechanical aids	Designed to improve energy and biomechanical efficiency	Specialised equipment and clothing
Pharmacological and hormonal aids	Broad category that covers a range of substances that are generally considered illegal when taken for the purpose of improving sports performance	Anabolic steroids and human growth hormone
Psychological aids	Activities and skills that aim to improve mental strength	Mental imagery and goal setting

Catchy fact
Complete oxidation of a glucose molecule results in a total of 36 ATP molecules; complete oxidation of a triglyceride molecule yields a total of 460 ATP molecules.

hitting the wall
when a person depletes their glycogen stores and primarily uses fat as an energy source

The carbohydrate/fat fuel 'mixture' during prolonged endurance events

There is an increased reliance on fats as a fuel source as the intensity of exercise drops from maximal and the duration of activity increases significantly. During prolonged activities such as a marathon or triathlon, the body uses a mixture of carbohydrates and fats. In the early stages of the race, an athlete's body predominantly uses glycogen as a fuel source, but because fats are the preferred fuel under these conditions, the quicker the athlete can use free fatty acids as a fuel, the greater the capacity of the body to reserve glycogen for the later stages of the race when the intensity tends to increase.

The athlete must try to conserve glycogen during the race to avoid 'hitting the wall'. Several factors contribute to 'hitting the wall'. Increased reliance on free fatty acids as a fuel due to glycogen depletion requires plenty of oxygen. The heart must work harder to increase oxygen carrying blood to muscles. In addition, fatty acid metabolism requires glucose.

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Fats as a fuel source

A problem occurs when liver glycogen is depleted and an athlete is unable to sustain blood glucose levels. Hypoglycaemia sets in and again the athlete depends heavily on fat to supply energy. This is quickly remedied by ingesting soluble sucrose (sugary drinks). Endurance athletes, through aerobic training, tend to increase their ability to use fatty acids for ATP resynthesis by increasing the number of mitochondria they develop, and by glycogen sparing.

hypoglycaemia
a condition created when blood glucose levels are significantly reduced, often during extended endurance activities, calling upon glycogen reserves in the liver

glycogen sparing
a long-term adaptation resulting from aerobic training that allows fats to be used more readily and earlier during performances. This in turn results in less use of the lactic acid system and allows glycogen to be used much later in performances

Checkpoints

1 How does glycogen sparing assist endurance athletes?

2 Summarise three different carbohydrate-loading regimes or practices, clearly identifying what athletes undertaking them need to do leading up to the event they are loading for. Which one of these regimes is recommended by both coaches and athletes, and provides the best performance improvements?

3 High-protein diets are often recommended for athletes who need to repair and regrow muscle tissue as a result of high resistance training or demanding training workouts. List three disadvantages associated with high-protein diets.

The three energy systems

There are three pathways or energy systems responsible for the resynthesis of ATP and hence the supply of energy. Which of the three systems operates during exercise depends on:

- the duration of the exercise
- how urgently the energy is required
- the intensity of the exercise
- whether or not oxygen is present.

Table 12.4 clearly shows the influence intensity, duration and availability of fuels have on the predominant energy system utilised to supply energy as well as the major fuels directly called upon to resynthesise ATP.

Table 12.4 Energy systems versus food fuels at various exercise intensities and durations

Intensity	Total event duration	Dominant energy system	Food/chemical fuel
Rest	NA	Aerobic	Glucose and FFAs
Submaximal	30 seconds	Aerobic	Glucose and FFAs
Submaximal	30 minutes	Aerobic	CHO
Submaximal	3 hours	Aerobic	FFAs
Maximal	1–3 seconds	ATP–CP	Stored ATP
Maximal	5 seconds	ATP–CP	Remaining stored ATP CP
Maximal	30 seconds	Lactic acid	CHO
Maximal	75 seconds	50% ATP–CP and lactic acid, 50% Aerobic	CHO

The three energy systems – a closer look

The energy for muscular contractions and movement is produced either anaerobically or aerobically via three energy systems. Two of these are anaerobic systems: the ATP–CP system (also known as the alactacid, creatine phosphate or phosphogen system) and the lactic acid (LA) system (also known as the anaerobic glycolysis or lactacid system). The aerobic system (also known as the oxygen system or aerobic glycolysis) completes the trio responsible for energy production. The three systems do not function independently or one at a time; all three energy systems are activated at the start of exercise and their relative contribution is essentially determined by the intensity and duration of the exercise.

At rest, our demands for ATP are low and can be met aerobically. However, as we start to exercise, the demand for ATP increases quickly, especially during explosive or maximal activities. Because we cannot increase our oxygen intake and transport to working muscles as rapidly as is required for explosive activities, our body calls on the two anaerobic systems in the early stages of exercise to supply ATP. However, if an activity is less intense and of longer duration, the aerobic energy system is able to supply most of the energy.

The ATP–CP energy system

The ATP–CP energy system produces energy by breaking down creatine phosphate (CP) (also known as phosphocreatine (PC)) to resynthesise adenosine ATP. ATP is resynthesised through chemical reactions that do not require oxygen (anaerobic). It is worth noting that all activities that are carried out above 100% VO_2 max depend on an anaerobic energy supply, and if CP has not had time to replenish, this will be 'powered' by the lactic acid system.

As long as the use of ATP is balanced by its resynthesis, it is possible to continue performing for a long time. But the amount of ATP stored in muscles is limited to a couple of seconds (2–3 seconds maximum) it must, therefore, be constantly regenerated if the activity is to continue.

CP, like ATP, is stored in muscle cells and contains phosphate bonds, which when broken provide large amounts of energy. CP 'splits' into creatine (C) and inorganic phosphate (P_i). The energy that results from the splitting off of the phosphate is linked to the resynthesis of ATP. As rapidly as ATP is broken down by muscular contractions, it is continuously reformed from adenosine diphosphate (ADP) and P_i by the energy released by the breakdown of CP stored at muscles.

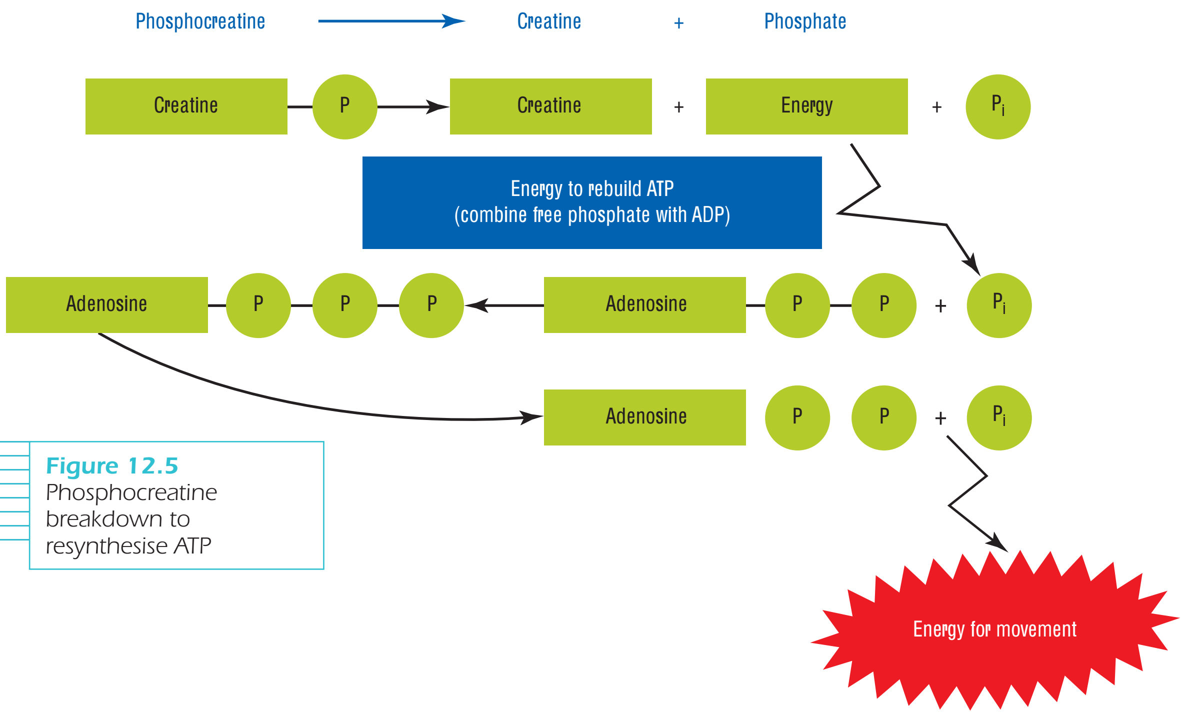

Figure 12.5
Phosphocreatine breakdown to resynthesise ATP

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This is the most rapidly available source of ATP for muscles because both ATP and CP are stored within muscles and they do not depend on oxygen to be created in the short term. Energy released by this system is exhausted very quickly, after only 6–10 seconds of intense muscular activity. CP is replenished within 3 minutes of the activity ceasing and a passive recovery being undertaken.

Summary of the ATP–CP energy system

- The ATP–CP energy system does not require oxygen to liberate energy (anaerobic)
- The ATP–CP energy system provides the most rapidly available source of ATP for energy because it depends on simple and short chemical reactions and ready availability of CP at muscles (CP being broken down to P C).
- The ATP–CP energy system is anaerobic and so does not depend on oxygen being transported to working muscles to release energy
- A limited amount of CP is stored at the muscles (about 10 seconds' worth at maximal intensity), with larger muscles capable of storing slightly more CP than this (12–14 seconds at maximal intensity).
- ATP and CP are stored at the muscles and available for immediate energy release. This system is limited by the amount of CP stored at the muscles – the more intense the activity, the quicker this is utilised to produce ATP. After approximately 5 seconds of maximal activity, the CP stores are 40–50% depleted and the lactic acid system becomes the major producer of ATP.
- There is approximately four times as much CP stored at muscles as there is ATP.
- Once CP has been depleted, it can only be replenished when there is sufficient energy in the body, and this usually occurs through the aerobic pathway or during recovery once the activity has stopped.
- Once phosphocreatine has been depleted at the muscle, ATP must be resynthesised from another substance – typically glycogen, which is stored at the muscles and the liver – via anaerobic glycolysis using the lactic acid system.

The lactic acid energy system

Anaerobic glycolysis refers to energy provided by the incomplete breakdown of glucose when oxygen is not available. Theoretically, there is enough glycogen stored at muscles to maintain maximum effort for approximately 90 seconds. Yet maximal efforts can only be sustained for approximately 20 seconds. All of the pyruvic acid produced during anaerobic glycolysis is converted into lactic acid. A by-product of this process is hydrogen ions, which cause the muscle pH to fall (become more acidic), thereby inhibiting glycolysis. These hydrogen ions are therefore responsible for the inability of muscles to contract maximally – due to a decrease in the activity of certain enzymes – after a short period. This is a safety mechanism to prevent the cells being destroyed under extremely acidic conditions. The hydrogen ions combine with pyruvate to form lactate, which is then converted to glycogen and made available to release further energy.

Although about 80% of the lactic acid diffuses from the skeletal muscles and is transported to the liver for conversion back to glucose or glycogen, some H accumulates in muscle tissue, making muscle contraction painful and causing fatigue.

The lactate inflection point (LIP) refers to the moment when the body is unable to prevent the accumulation of the hydrogen ions associated with the conversion of lactic acid to lactate in the working muscles and typically occurs around 1 mmol/L. When the rate of lactic acid accumulation is greater than the rate at which it can be oxidised or broken down, lactate will accumulate in the blood and typically this is known as onset of blood lactate (OBLA) and occurs at 4 mmol/L.

Bicarbonate soda – an alkali – has been shown to improve performance in events lasting 3–10 minutes as it buffers some of the hydrogen ions produced during anaerobic glycolysis.

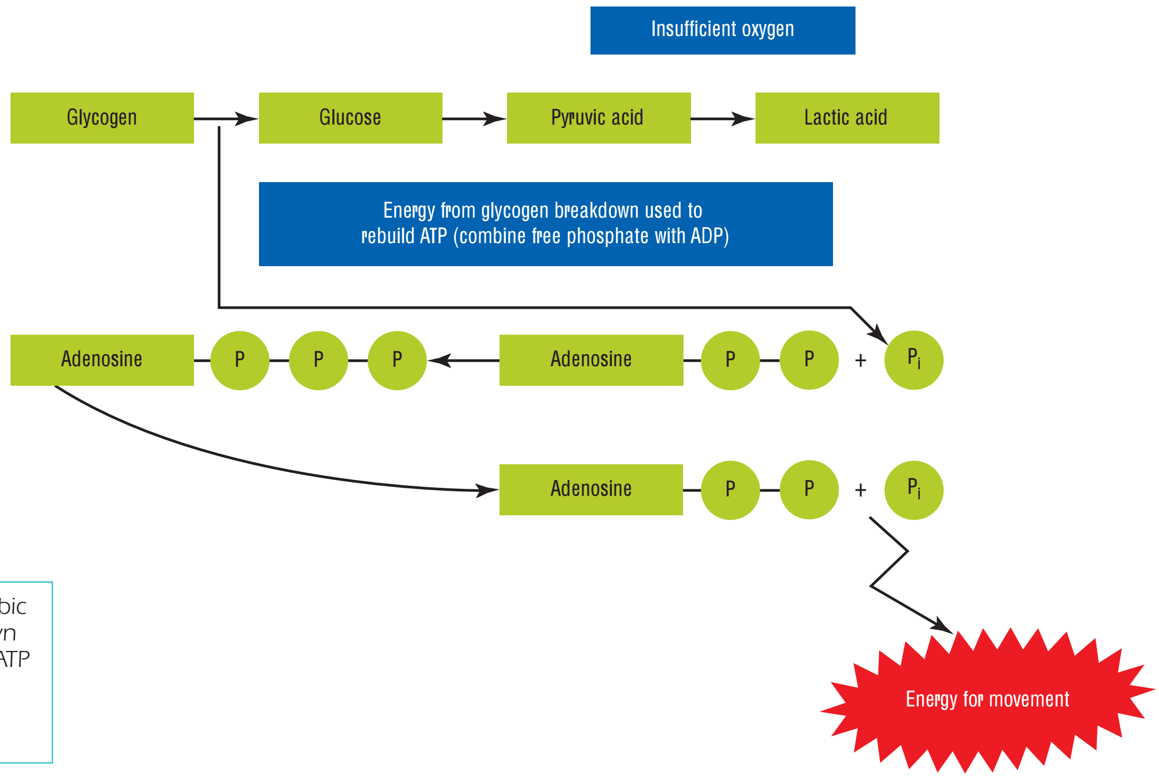
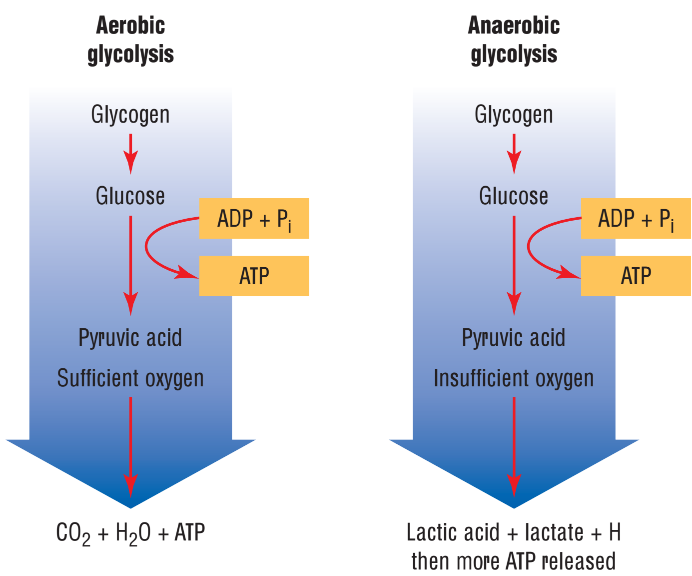


Figure 12.6 Anaerobic glycolysis breaks down glycogen to re-form ATP without oxygen. This is how the lactic acid system functions

Summary of the lactic acid energy system

- The lactic acid system produces ATP without oxygen; hence it is referred to as anaerobic glycolysis.
- The lactic acid system is also anaerobic (does not require oxygen to liberate energy) but involves more complicated and longer chemical reactions than the ATP–CP system to release energy.
- It also supplies energy from the start of intense exercise, and peak power from this system is usually reached at 5–15 seconds and will continue to contribute to ATP production until it fatigues (2–3 minutes).
- During maximal exercise, the rate of glycolysis may increase to 100 times the rate at rest.
- It produces lactic acid, which can be broken down to glycogen to provide further energy.
- About 12 chemical reactions take place to make ATP under this process, so it supplies ATP at a slower rate than the ATP–CP system.
- It provides energy for longer during submaximal activities when CP is depleted and lactic acid accumulation is slower. This provides a stop-gap until sufficient oxygen is transported to working muscles for the aerobic system to become the major energy contributor.
- It provides twice as much energy for ATP resynthesis as the ATP–CP system.
- It increases its ATP contribution if performance intensity exceeds the lactate inflection point.

Figure 12.7 Aerobic vs anaerobic glycolysis



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The aerobic energy system

Aerobic glycolysis refers to energy provided by the complete breakdown of glucose when plenty of oxygen is available. The aerobic energy system produces energy by breaking down glycogen (preferentially during exercise), or free fatty acids (preferentially at rest) or amino acids (as a last resort energy source) to resynthesise ATP. Theoretically, we are able to reach 90% of our VO_2 max within approximately one minute and even when working maximally, there is 50% contribution from the aerobic energy system at the 75-second mark.

It is important to note that when using the aerobic energy system, any accumulated lactic acid and other metabolites have the opportunity of being oxidised / removed or re-converted back into glycogen to be again used as an energy source. Fats are able to release more energy than carbohydrates in the presence of oxygen, but require greater amounts of oxygen to do so.

As a result of the increased oxygen cost, the aerobic system is unable to meet the demand and less oxygen becomes available to working muscles and the risk of working anaerobically increases. This possibly explains why, when fats are used during high intensity activities, or increasingly as activity duration increases, performers are forced to 'slow down'.

Catchy fact
After only 60 seconds of maximal activity, it is possible to reach 90% of one's VO_2 max. In a maximal activity lasting 75 seconds, equal amounts of energy are provided by the two anaerobic energy systems and the aerobic energy system.

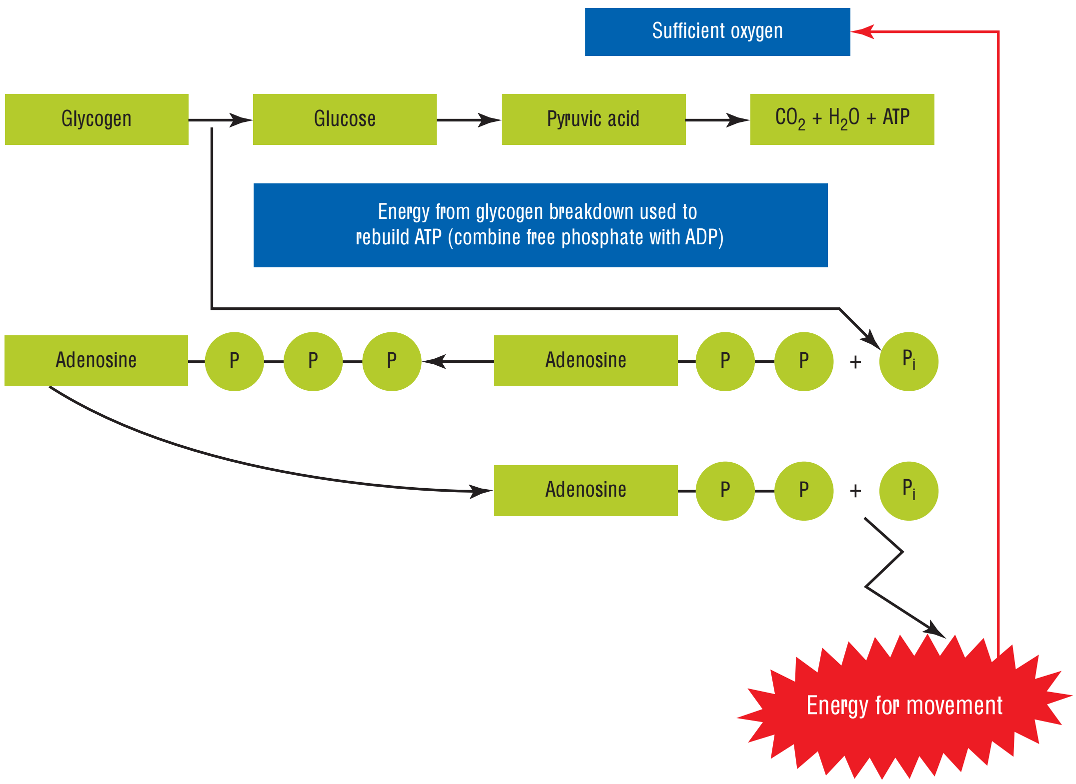

Figure 12.8 Aerobic glycolysis: the breakdown of glycogen with sufficient oxygen

Summary of the aerobic energy system

- The aerobic system is the slowest system to contribute to ATP resynthesis due to the complex nature of its chemical reactions.
- It is capable of producing the most energy compared to the other two energy systems – 30–40 times more.
- It requires oxygen, which can be provided (90% of VO_2 max) within 60 seconds.
- It involves many more complex chemical reactions than the ATP–CP and lactic acid systems to release energy.
- It preferentially breaks down carbohydrates rather than fats to release energy.

- Fats can produce more ATP than carbohydrates but they require more oxygen to produce an equivalent amount of ATP.
- It releases no toxic or fatiguing by-products and can be used indefinitely.
- It provides 50 times as much ATP as the ATP–CP and lactic acid systems combined.
- It contributes significant amounts of energy during high-intensity / maximal activities lasting 1–2 minutes.
- The aerobic system is also activated at the start of intense exercise, and peak power from this system is usually reached by 1–2 minutes and will continue to be the major ATP contributor as the lactic acid system decreases its contribution.

Table 12.5 Relative contributions of anaerobic and aerobic energy to maximal exercise of different durations

Duration of exhaustive exercise (s)	Anaerobic (%)	Aerobic (%)
0–10	94	6
0–15	88	12
0–20	82	18
0–30	73	27
0–45	63	37
0– 60	55	45
0 –75	49	51
0–90	44	56
0–120	37	63
0–180	27	73

Adapted from Gastin and Rosignol 2001

After approximately 1 minute of maximal-intensity exercise, the energy is being released almost equally by the aerobic and anaerobic systems. The '50:50' mark representing 50% aerobic and 50% anaerobic energy contribution occurs at 75 seconds.

After only 30–60 seconds of maximal exercise, oxygen uptake can be as high as 90% of an athlete's maximum. Thus, the aerobic system is very important in providing energy for extended high-intensity activities.

Aerobic energy production takes even more chemical reactions to produce ATP than either of the two anaerobic energy systems. Aerobic ATP is produced at the slowest rate of the three systems, but can continue to supply energy for many hours as long as sufficient fuel supplies exist. When sufficient oxygen is supplied to meet demand, the body is said to have reached 'steady state'; this can occur at various levels up to the lactate inflection point.

KEEP IT REAL!

Michael Johnson – a great athlete

Michael Johnson was born on 13 September 1967 and retired from athletics in 2001 at the top of his field. He is still considered to be one of the finest athletes to have competed in the modern era.

In 1996 at Atlanta, he became the first man to win the gold medal in the 200 and 400 metres in the same Olympic Games, by smashing the world record in 200 metres (19.32 seconds) and setting an Olympic record in the 400 metres (43.49 seconds).

During his athletic career, he was the two-time world champion in 200 metres (1991 and 1995) and the four-time world champion in 400 metres. He also won the 400 metres in Sydney in 2000 to become the only man in history to win the event in two consecutive Olympic Games.

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Table 12.6 Michael Johnson's speed breakdown during his 400-metre run at the Prefontaine Classic at Hayward Field (Oregon, June 2000) prior to running at his second Olympic Games in Sydney later that year

Stage of race (m)	Time at each 50 m (s)	Speed at each 50 m (km/h)
0		
50	5.6	32.3
100	10.4	36.8 (top speed)
150	15.4	36.3
200	20.6	34.4 (decreases stride length and increases frequency)
250	26.0	33.3
300	31.6	32.2
350	37.4	31.2
400	43.92 (Current world record 43.18 s, set by Johnson in Seville 1999)	27.5

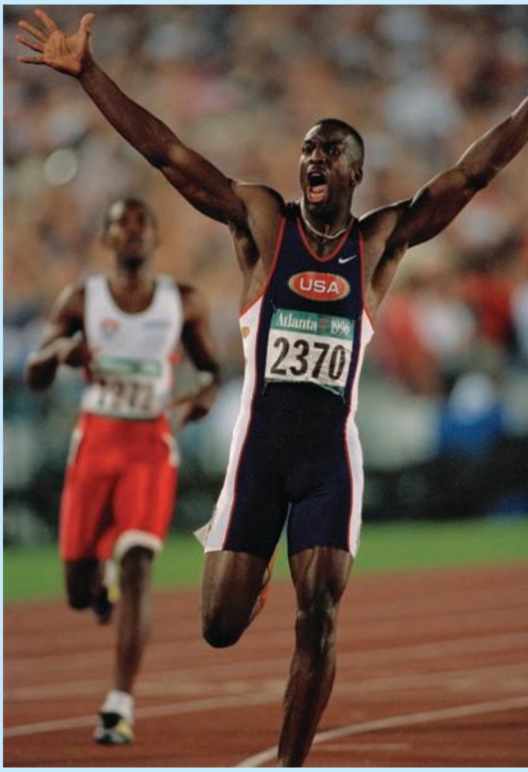

Figure 12.9 Michael Johnson, one of the world's greatest athletes

Hirvonen et al. (1992) investigated fatigue during the 400-metre sprint by measuring muscle ATP, CP and lactate before and after four experimental sprints (Table 12.7).

Table 12.7 Average substrate and metabolite changes during a 400-metre sprint

First 100 m		After 200 m		End of 400 m		
CP	**Lactate**	**CP**	**Lactate**	**ATP**	**CP**	**Lactate**
Decreased from 15.8 to 8.3 mmol/kg	Increased to 3.6 mmol/kg	Decreased to 6.5 mmol/kg	Increased to 8.3 mmol/kg	Decreased by 27%	Decreased by 89%	Increased to 17.3 mmol/kg

Note: After the 200-metre mark, the speed of running decreased although CP was not actually depleted and lactate concentration was not maximum.

Questions

1 In Table 12.7, why has the muscle lactate doubled in the second half of the race (200–400 metres)?
2 Describe the rate of CP depletion when considering the first 200 metres and compare this to the rate of loss during the second 200 metres.
3 a What is the rate of ATP depletion compared to that of CP depletion?
  b How do you account for the difference described in part a?
  c Why do physiologists often express lactate build-up in the muscles in preference to blood lactate?

Coursework: Class activity

Aim

To record running times for each section of a 140-metre race, run at maximal effort. Energy system contributions will be investigated.

Method

1 Mark out a 140-metre track and position a student with a stopwatch at each 20-metre interval.

2 The starter signals the start of the activity by calling out ‘Go’ and waving their arm. When this occurs, all timers should start their stopwatches.

3 As the sprinter passes each 20-metre interval, the timer should stop the stopwatch and keep the time on the display until it has been recorded. (See the chart below.)

4 Repeat steps 1–3 until every student has completed the race.

Results

1 Share your times with at least two other members of your class for comparison.

Distance covered (m)	Time at this point (s)	Time in previous 20 m
0	0.00	
20		
40		
60		
80		
100		
120		
140		

2 Plot a graph of distance (*y*-axis) versus time (*x*-axis) for your results and those of two other classmates.

3 Mark on the graph any straight (or almost straight) portions. Remember not to link each point, but draw a line of best fit.

4 Parts of the graph might be curved rather than straight. Draw these sections of the graph as a line of best fit as well.

5 Calculate the slope/gradient (rise/run) of the graph at the 5-, 10- and 15-second marks.

Catchy fact
To maintain running speed, it takes less energy to shorten one’s running stride and increase stride frequency than to lengthen the stride and reduce the frequency.

Discussion

1 a Are there any differences in the slopes (running speeds) at the 5-, 10- and 15-second marks for your performance?
b Did any students maintain the same speed throughout the run? Briefly discuss what this means in terms of energy system contribution and performance.

2 a At what point of the sprint did you slow down?
b How do you account for this slowing down?

3 a Comment on your performance in terms of energy system contribution (interplay) at different stages of the race, as well as the overall performance.
b Compare your results with those of your classmates in terms of similarities and differences between energy system contributions.

4 Is there any link between performance in this sprint, energy system contribution and adaptations that may have occurred as a result of participating in outside activities? (For example, did people who play netball differ from people who row, or did people who play hockey differ from those involved in athletics?)

Note: Make sure you revisit this data/discussion when you are considering fatigue mechanisms.

Extension

Try to convert your running speeds into km/h and compare them to Michael Johnson’s times up to the 150-metre mark.

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Coursework

This exercise explores the relationship between energy system contribution and participation in an activity requiring different intensities and duration throughout the performance.

The class should participate in a team game performed on a moderate-sized playing area, to allow for data collection, observation and class discussion. Recommended activities include netball, indoor soccer, basketball, indoor hockey, European handball and badminton.

The class elects one or more student(s) to collect heart-rate data during the game. Ideally this should be obtained via a heart-rate monitor, or at regular intervals during the game, and recorded by someone on the sidelines. (See Chapter 8 for more ideas on effective heart rate data collection and its uses.)

It would be advantageous for more than one student to collect heart-rate/intensity data. This will allow for comparisons between energy system contribution to the activity and different players and positions, and can also potentially introduce the notion of energy system adaptations to training and limits to energy systems.

During the activity, stop play at regular intervals (every five minutes) or so to discuss:

- which system is the major energy contributor at various stages of the game and why. The discussion should be linked to playing intensity and duration
- which foods or fuels would be responsible for supplying energy
- what limits the use of certain energy systems during the game. Does player level of training affect energy-system use?
- how the three energy systems work together (interplay) to supply energy during the game
- whether the energy system contribution differs for different players (mobile versus 'fixed')
- which energy system is the major ATP producer during the break in play and what is being recharged.

Analyse your collected data. Share the data among the class and plot a graph outlining heart rates during the activity.

The graphs should identify key points on the heart-rate axis such as the aerobic training zone, the lactate threshold and the maximum heart rate. Use this information and playing times when discussing the energy system interplay for different class members.

Comparing the three energy systems

The most obvious comparison to be made between the three energy systems is their energy production. A unit of measure for quantifying chemical compounds, called moles, is used to compare the amount of energy available from each of the three energy systems. One mole of ATP provides approximately 10 kilocalories (kcal) of useful energy (1 mole = 1000 millimoles (mM) provides 10 kcal = 10 000 calories of useful energy).

Catchy fact

Swimmers can use up to four times the energy a runner would use to cover the same distance. This is because more muscles are used in swimming and more energy is required to keep the body buoyant and overcome resistance to forward movement.

The ATP–CP system

Within the body's total muscle mass, there are 570–69 mM of ATP and CP, which can provide 5.7–6.9 kcal of useful ATP energy.

The lactic acid system

The lactic acid system can potentially resynthesise 3 moles of ATP (three ATP) or 3000 mM from 1 mole of glycogen (180 grams). If all 180 grams of glycogen were broken down, 180 grams of lactic acid would be formed. Since the muscles and blood can only tolerate 60–70 grams of lactic acid before fatigue sets in, only 1.0–1.2 moles of ATP (1000–1200 mM) can actually be resynthesised. Note that 1000–1200 mM equals 10–12 kcal of useful energy. This is approximately twice as much useful energy as that made available via the ATP–CP system (5.7–6.9 kcal).

Table 12.8 Energy system comparisons and characteristics

Energy system	Maximum ATP production (moles)	Maximum useful energy (kcal)	Peak power (during maximal events)	Typical events	Chemical/ food fuel	By-products	Intensity (% HR max)	Recovery time
ATP–CP	0.7	7	5 s	100 m sprint Jumps Throws Diving All field events	CP	Nil	95–100	70% in 30 s 100% in 3 min
Lactic acid	1.2	12	5–15 s	200–400 m sprints 50 m swim	Carbohydrate glycogen	Lactic acid, lactate, H^+ ions	85–100	20 min – 2 hours
Aerobic	98 (38 per mole of glycogen)	980 (380 per mole of glycogen)	1–2 min	Archery Diving Marathon Cross country skiing Road cycling	Carbohydrate/ glycogen Fats/ triglycerides Protein (extreme conditions)	CO_2, H_2O, heat	60–85	Up to 2–5 days depending on depletion rates and post activity diet

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The aerobic system

The aerobic system will, after hundreds of complex chemical reactions, yield a total of 38 moles of ATP from the breakdown of 1 mole of glycogen (or 87–98 ATP from the breakdown of all the stores of glycogen in the muscles). A further 80–100 grams of glycogen (17–22 moles of ATP) is stored in the liver. Provided an exercise intensity is submaximal, approximately 13 times the amount of energy can be released aerobically as is possible anaerobically (from a given amount of glycogen) without the accumulation of fatigue-causing lactic acid.

While the aerobic system is clearly the most powerful of the three energy systems (i.e. it has the greatest capacity to supply ATP), it is dependent on the body's ability to take in, transport and consume oxygen. Aerobic fitness programs aim to improve the body's capacity in this regard. Note: This does not include the aerobic metabolism of fat or protein as an energy source. Metabolism of fat and, in extreme circumstances, protein, provides an almost unlimited source of energy for submaximal activity.

Table 12.8 confirms that when the aerobic system is activated and becomes the major energy contributor, it provides 50 times more energy (moles of ATP) than the ATP–CP and lactic acid systems combined.

The energy system interplay or continuum/overlap

Virtually all physical activities derive some energy from each of the three energy systems. Each system is best suited to supplying energy for specific types of events or activities. The three systems contribute energy sequentially but in an overlapping way, depending on the type of activity and exercise demands. The energy systems do not simply turn themselves on and off when required. In fact, all three systems supply energy for ATP resynthesis during exercise. What does differ is the relative importance and contribution that each system makes to rebuilding ATP and supplying energy.

Figure 12.10 shows how the three systems vary in their percentage contribution to energy / ATP production depending on the duration of the activity.

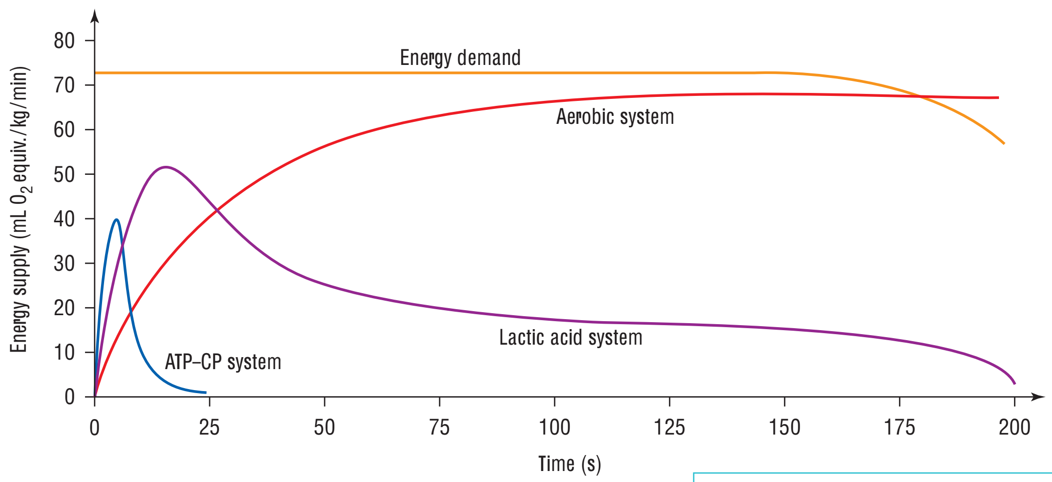

Figure 12.10 *Energy system contribution during cycling at 110% VO_2 max*

As you can see, these three systems overlap to provide an energy continuum to fuel a full range of activities and performances. Another way of thinking about this is that the three systems all work together but vary the amount they each contribute at various stages of the activity. The longer the activity lasts for, the more likely it will be that the ATP–CP system will contribute less unless it is given the opportunity to 'recharge', as occurs in most team sports and activities.

Continuous versus intermittent activity

The following examples compare the energy system interplay/continuum during an intermittent team sport with that during a continuous activity.

Intermittent team sport – netball

Netball is characterised by repeated bouts of high-intensity action interspersed with periods of moderate activity and active rest (during play stoppages). When the whistle blows to start play, all three systems start contributing, but most energy is derived from the ATP–CP system in the first 3–5 seconds. During the same time the LA system is increasing its contribution to energy production, but is slower than the ATP–CP system due to more complex chemical reactions required to break down glycogen as compared to CP. If efforts above 85% maximum heart rate last for longer than five seconds, the LA system will increase its contribution.

There is sufficient CP to 'power' efforts for up to 10 seconds and following each explosive burst, this will be drained and deplete the ATP–CP system. Restoration of CP will occur at very low intensities, but it is likely that until a 60+ second break occurs (quarter/half time or bench) this system will not have adequate opportunities to totally rebuild/restore CP, and increasingly high-intensity efforts will be driven by the LA system as the match progresses, especially for mobile players such as centres and wing attacks/defence.

The aerobic energy system only supplies a small portion of the energy needed during these initial intense efforts, but its contribution increases as CP has less time to resynthesise and the game progresses.

The aerobic system provides most of the energy needed during moderate activity during the game after the two-minute mark, and it is critical for efficient recovery between play stoppages, during time on the bench and quarter- or half-time breaks. During a quarter, even if high-intensity efforts are required, once the aerobic system has established itself as the major ATP producer (2+minutes), it still contributes more to ATP production than the LA system which despite increasing its contribution, can only produce one-seventh to one-fifth as much ATP in total as the aerobic system, i.e. at the five-second stage the contribution from the three systems for a centre might be:

ATP–CP – 90%; LA – 5-7%; aerobic – 3–5%

At the 2-minute stage the contribution from the three systems for a centre might be:

ATP–CP – 25%; LA – 15%; aerobic – 60%

Continuous individual activity – marathon

The marathon is a continuous activity that lasts for just over two hours at the elite level. When starting, all three systems supply energy but at a slower rate than that required by someone who is working at a higher intensity such as a netball centre. CP will be used at a slower rate and hence it will peak later; i.e. 8–10 seconds. The LA and aerobic systems are also contributing to ATP production, and from the first step increase their contribution, but because the activity will not exceed the lactate inflection point in the early stages, the aerobic system quickly takes over as the major ATP producer.

During any surges in the race, where the LA system increases its contribution, it still cannot produce the same amount of energy as the aerobic system (2–3 moles ATP compared to 30–36 moles ATP). During surges, the LA system is not the major ATP provider; rather, it is the system that provides the extra energy required to allow an increase in intensity/work output.

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Once CP is depleted it does not have the chance to replenish itself so the ATP–CP contribution is limited to the first few seconds of the race. The aerobic system is not only important to producing ATP during the race but it also plays an important role in breaking down any metabolic by-products that accumulate when the LA system increases its contribution, as well as converting any accumulated LA back into glycogen to be used either aerobically or anaerobically.

For any activity, rather than considering the overall contribution of the three energy systems, it is probably more accurate to consider the energy system contribution and interplay at various stages of performance by considering the key factors of intensity: duration (how far into the activity the event has progressed) and availability of fuels. For example, at the five-second stage the contribution from the three systems might be:

ATP–CP – 80%; LA – 15%; aerobic – 5%

At the 1-hour stage the contribution from the three systems might be:

ATP–CP – 0%; LA – 5%; aerobic – 95%

Checkpoints

1 Why do our bodies call on the ATP–CP system at the commencement of exercise?

2 **a** Even though all three systems contribute to energy production, why does the lactic acid system take longer than the ATP–CP system to peak?

b How is it possible to use the lactic acid system repeatedly during continuous exercise (which is not possible for the ATP–CP system) without recovery?

3 Why is it advantageous to increase the number of mitochondria present at the muscular level if aerobic or endurance performances are to be improved?

4 **a** How is it possible for athletes to work above 100% VO_2 max?

b How can athletes extend the amount of time they are able to work at above 100% VO_2 max?

5 **a** Figure 12.10 (p. 239) shows the energy system interplay for a sprint cyclist. Why would the interplay of a 400-metre runner vary from that shown in the graph, assuming the same performance time was considered?

b Would the graph be any different if the data was obtained on a sprint cyclist working at 95% VO_2 max? Briefly explain your response.

TEST YOUR KNOWLEDGE

>> multiple choice

1 The energy system continuum is best described as occurring when:

A the ATP–CP systems provide the initial energy for activities and this is then taken over by the lactic acid and aerobic systems
B the energy systems all supply energy continuously
C all three energy systems contribute to ATP production, but at any stage one is the major contributor.
D None of the above.

2 During submaximal activities lasting up to 30 minutes, the majority of the ATP is resynthesised by breaking down:

A phosphocreatine
B glycogen
C free fatty acids
D proteins.

3 When switching from glycogen to free fatty acids as the major fuel source in a marathon, the performer must slow down because:

A more oxygen is required to resynthesise ATP and less is available to working muscles
B more processes are required in breaking down free fatty acids and hence ATP is resynthesised at a slower rate
C it is likely that the performance will increasingly start to become anaerobic.
D All of the above.

4 The ATP–CP system provides energy mostly at the start of an explosive/maximal activity because:

A it is impossible to release ATP using the aerobic system in such a short period of time
B it requires the least number of chemical reactions to break down CP and resynthesise ATP
C it is readily available at the muscle site.
D All of the above.

>> short answer

5 Fats can provide more ATP than carbohydrates, yet they are not our preferred exercise fuel. Briefly discuss why.

6 **a** The lactate threshold is also the point at which lactate production exceeds removal. Outline three advantages an athlete has by being able to increase their lactate threshold.
b Discuss any changes likely to be experienced in energy system contribution to activity if a person's lactate threshold increases from 85% maximum heart rate to 90% maximum heart rate.
c The lactate threshold increases as an adaptation to aerobic training. How might participation in intermittent training increase a person's lactate threshold?

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7 **a** The phosphocreatine system is said to last 10–15 seconds. Discuss how it is possible for athletes to increase their CP stores by:
i training
ii diet manipulation
and hence increase usage of this system.
b Discuss the advantage of a 200-metre hurdler who can use their ATP–CP system 15–20% longer than their opponents in terms of energy production, fatigue and overall performance time.

>> essay style

8 Briefly discuss what you understand the ‘energy system interplay/continuum’ to mean. Choose a sport to clearly demonstrate your understanding. (It is probably best to choose a sport that has varying intensities and duration of effort/s.)

9 Discuss the energy system usage and food fuel contribution to the running of a marathon. Assume the performer runs predominantly at 80–85% max. heart rate with the exception of uphill sections of the course where the workload increases. The total time of the event is 2 hours and 25 minutes.

13 Methods of training

There is large range of training methods that an athlete and a coach can choose from to prepare for competition. When looking at which method is most appropriate, a number of things should be considered:

- Type of activity (aerobic versus anaerobic)
- Time in the season (pre-, early, mid-, late or post-season)
- Available time and equipment
- Athlete's fitness level
- Competition

Resistance training

resistance training by providing a resistance to the muscle, we attempt to improve muscle strength and power

There are various types of resistance training; the most popular involves lifting some form of weight. (This includes both weight training and body weight exercises such as push-ups.) Intensive resistance or weight training can produce a two- to three-fold increase in muscle size.

Catchy fact
There is no difference between males and females in the area of muscle strength. The strength of any particular muscle relates directly to the cross-sectional area of the muscle; i.e. the bigger the muscle the stronger it is.

Figure 13.1 Resistance training in the gym

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Muscle training

All muscle actions fall into three categories:

- Isotonic contractions
- Isometric contractions
- Isokinetic contractions

Isotonic contractions

In an isotonic contraction, the muscle length changes against a constant load. Nearly all movement is isotonic where the shortening and lengthening of particular muscles and groups of muscle instigate movement.

Performing a bicep curl with a dumbbell is an example of an isotonic contraction. The load (barbell) is constant and the muscle (biceps) shortens to lift the weight and lengthens to lower the weight.

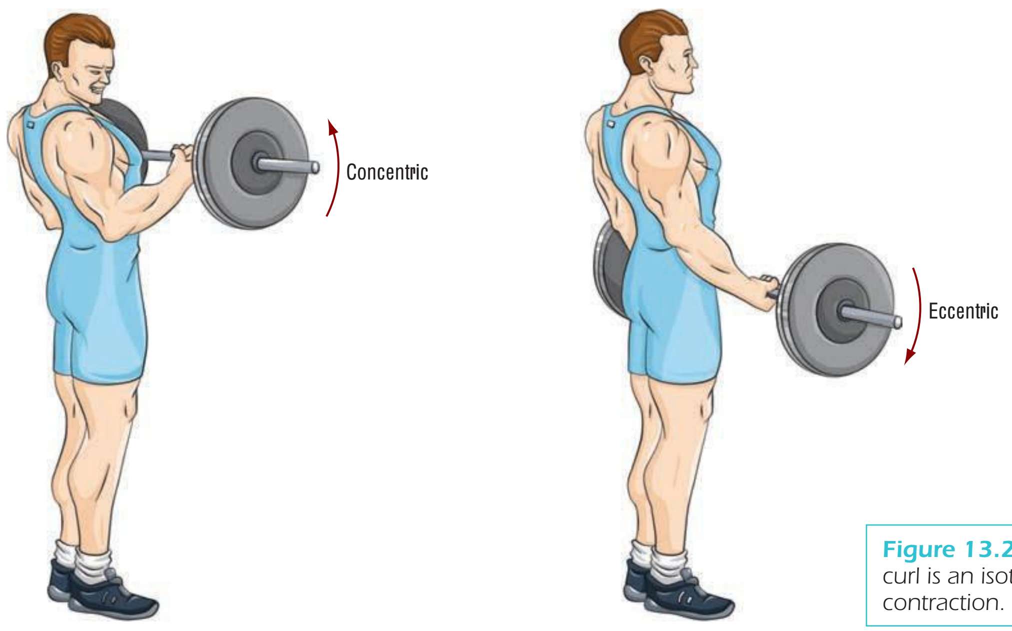

Figure 13.2 A bicep curl is an isotonic contraction.

Isotonic contractions can be further broken down into two subgroups – concentric and eccentric contractions.

Concentric contractions

A concentric contraction occurs while the muscle shortens (decreasing the angle at the joint) and tension is developed. In the bicep curl example, this would be when the weight is lifted from the leg to the shoulder. Here the biceps is shortening and the joint angle at the elbow is decreasing from around 180° to about 25°.

Eccentric contractions

An eccentric contraction occurs when the muscle lengthens (increasing the angle at the joint) while developing tension. Again using the bicep curl example, this is when the weight is slowly lowered, to resist gravity. It is important to remember that tension must be created in the muscle for an eccentric contraction to occur.

Isometric contractions

An isometric contraction occurs when the muscle attempts to change length but cannot overcome the resistance. The classic example used here is pushing against a wall. Another

Figure 13.3 *The rugby scrum is an example of an isometric contraction.*

example is in a rugby scrum when there is no movement. Both teams are producing enormous amounts of force and tension but there is no change in length of the muscles – so this is an isometric contraction. If one team manages to overcome the resistance of the other and their joint angles change, then they would have moved to an isotonic contraction.

Isokinetic contractions

For an isokinetic contraction to occur, an athlete would need to use specialised equipment. The equipment ensures that the speed of the movement is constant throughout. The advantage of such equipment is that the muscle gains strength evenly throughout the movement. Often an isotonic contraction develops maximum tension at the start of the movement. Then the tension decreases; hence the muscle does not get the same work-out over the whole range of movement.

isokinetic contraction a contraction in which the muscle shortens with varying tension while lifting a constant load, so that muscle strength remains even throughout the movement

RM (repetition maximum) the most weight an individual can lift a given number of times

Table 13.1 is a comparison of training for muscle strength, power, speed and endurance. Each type of training is very specific to the particular muscle requirement. The repetition maximum (RM) is the most weight an individual can lift a given number of times. For example, a 10 RM of 80 kg means that 80 kg is the heaviest weight the person can lift ten times. A 1 RM will be far greater than a 10 RM – it is the heaviest weight someone can lift once. Endurance sports use a low RM, power sports a medium to high RM and strengths sports a very high RM.

Table 13.1 Comparison of training types

	Contraction speed	Resistance	Volume	Rest intervals
Strength	Slow	80% of 1 RM	3 sets of 3–6 repeats	2 minutes
Hypertrophy	Medium	70% of 1 RM	3 sets of 12–15 repeats	1–2 minutes
Power	Fast	Some strength work Velocity work at 30% of 1RM	3 sets of 3–6 repeats	2–3 minutes
Endurance	Slow–medium	50–70% of 1 RM	3 sets of 15 repeats	1 minute

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Coursework: Laboratory report

Performing various bicep curls

Materials

One set of dumbbells (to provide moderate resistance performing a bicep curl) per pair

Method

1 Both partners perform a normal bicep curl with the dumbbell.
  - a What type of contraction is this?
  - b Are there any points within the movement that are easier than others?
  - c Why is this?

2 Now lower the dumbbell controlling the speed rather than just letting gravity pull it down.
  - a What type of contraction is this?
  - b Are there any points within the movement that are easier than others?
  - c Why is this?

For the next part of the experiment, you will need to try to lift an immovable structure like a bolted-down table or railing.

3 Grab the table in the same manner as you would when performing a bicep curl. Try to lift the table.
  - a Are you creating tension in the muscle?
  - b Is the object moving?
  - c What type of contraction is this?
  - d Why is this type of contraction not as effective as the previous one in training the muscle?

4 While performing a bicep curl with a dumbbell, your partner should now attempt to be an isokinetic machine. They will attempt to regulate the speed at which you lift the dumbbell. (Caution needs to be displayed here so that no one is injured.)

  Did you notice any difference between the tension created in this lift and the lift in step 1?

Extension

1 Some gyms attempt to create isokinetic equipment by using machines based on hydraulics. They are not perfect isokinetic machines but are quite close. When you next visit a commercial gym, try some of these machines and compare the difference in overall tension in each machine.

2 Performing a squat with a large chain on the end of the bar is another way weightlifters have attempted to keep the tension high throughout the lift. As you stand in the squat lift, you are lifting more and more of the chain. Only perform such lifts under the guidance of a qualified strength and conditioning professional.

3 The University of Western Australia has specialised isokinetic equipment. Check them out if you visit the Department of Human Movement and Sports Science.

Interval training

Interval training uses different work and rest periods in the one session to enable the athlete to do a large amount of high-intensity exercise. This same level of intensity would not be possible if the session was continuous in nature. Imagine how well you would perform in the beep test if after each level you had a 1-minute rest. (Each level takes 1 minute to complete so this would be a 1:1 work–rest ratio.)

By changing the work–rest ratio in interval training, you are altering the energy system you are training. Before considering which ratio to use it is important to have a good understanding of the work–rest ratio of your particular sport. It is also important to understand the differences various positions have within a sport. For example, in Australian Rules football, a full forward would be considerably different from a mid-field player. Table13.2 highlights the important terminology used when describing an interval training session.

Table 13.2 Terminology used when devising an interval training program

Work interval	Rest interval	Work intensity	Repetition	Set	Interval distance	Work–rest ratio	Total distance	Recovery method	Training frequency
Period of time work is undertaken	Relief time, interspersed between work intervals	Level of intensity of the work intervals expressed as percentage of HR max	Number of times the work interval is repeated	Number of work intervals presented in a series (a unit)	Distance of each repetition in metres	Work interval divided by rest interval expressed as a ratio	Distance of each rep. no. of reps no. of sets	Method used by athlete to recover (active or passive)	Number of times per week the training session is repeated
6 s	30 s	95–100%	8	3	50 m	6 30 1 : 5	50 m 8 3 1200 m	Passive/ rest	3

Consider the following example. An elite time for 5 km is less than 15 minutes. Very few people can maintain 3 min/km for 5 km. If we asked them to complete 1 km in 3 minutes and had a work–rest ratio of 1:3, those with good running fitness should be able to run 5 km in 15 minutes. There are some differences in energy systems used and, although not exactly the same as a continuous 5 km run, it does highlight the potential of interval training to keep intensity high.

Interval training is more likely to be utilised when training the ATP–CP and the lactic acid systems. These systems provide most of the energy when there are short bursts of high-intensity exercise followed by a rest or recovery period. The 5 km example above would train the O_2 system and the lactic acid system. Table 13.3 shows the work–rest ratios of an elite 100-metre runner in three different training sessions. Table 13.3 describes the required intervals to train each particular energy system.

Catchy fact

Studies have shown that when athletes participate in interval training and they do not have a very strong aerobic base, they may cause their immune responses to be suppressed. Thus, they are more likely to become ill. This is an important consideration for those who have missed the preseason conditioning time.

Applying specificity and overload to interval training

When designing an interval training program, the following are the major considerations:

- Intensity of each interval
- Duration or distance of each interval

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- Length of rest or recovery period
- Number of repetitions to be performed
- Frequency of this method of training
- Recovery type – active or passive

Changing these variables will affect the energy system use. Table 13.4 shows the effect on each training system of changing the variables. Table 13.5 shows a sample training session for speed/endurance in running.

Table 13.3 Application of interval training in the development of the energy systems

Interval training method	Energy system(s)		Fitness component		Work interval (s)		Rest interval (s)	Intensity (HR max %)
	Predominantly anaerobic (ATP–CP/LA). Also benefit to aerobic (O_2)		Anaerobic power/speed; muscle power; LME; cardio-respiratory endurance		3–15		15–45	95–100
Intermediate	LA/O_2		Anaerobic power/speed; LME; cardio-respiratory endurance		15–45		45–150	85–90
Long	LA/O_2		LME; cardio-respiratory endurance		Interval training method		240	75–90
Interval training method	**Repetitions**	**Sets**	**Interval distance (m)**	**Work–rest ratio**	**Total distance (m)**	**Recovery**	**Suitable sports**	**Training frequency (times per week)**
Short	6–15	3	10–50	1 : 5	1800	Rest	100 m sprints; team sports	3
Intermediate	6–10	2	120–300	1 : 3	3600	Jog	200 m, 400 m sprints; team sports	3
Long	2–4	1–2	1200	1 : 1	4800	Jog	800 m, 1500–5000 m; team sports	4–6

Adapted from Rushall and Pyke 1991

Table 13.4 The effect of manipulating interval training variables

Variable	Effect
Increase duration of work	Provided intensity is maintained, an increase in duration will result in overload as the athlete will cover more distance.
Decrease duration of rest interval	Results in an increase in intensity, placing greater demands on the anaerobic systems (ATP–CP and LA). Note: This is not a preferred strategy due to the resultant change in work–rest ratio and consequent loss of specificity.
Increase number of repetitions/sets	Will result in increased demands on the targeted energy system(s). This is the preferred option. Once the number of repetitions is doubled, the number of sets can be increased.

Table 13.5 100-metre training session – early season speed–endurance

Session 1	After appropriate warm-up, drills and stretching etc. two sets of 5 150, intensity at 95%. Time taken, 15 seconds one every 3 minutes
Session 2	After appropriate warm-up, drills and stretching etc. Sand dune session; 3 sets of 4–10 seconds effort on 1 minute 20 seconds recovery
Speed session – specific prep.	After appropriate warm-up, drills and stretching etc. 3 flying 30 – 3 seconds apart – 7 minutes rest. Start over 30 m – four of 4 minutes in between. One standing start at the end over 60 m
Rest/recovery phase	Stretch, walk and do some bounding drills. The athlete performs these to stay warm and to keep neuromuscular activation high. It is important to limit lactate production during this time. The recovery of a 100 m runner will be passive compared to that of a 400 m runner.

Benefits of interval training

Interval training has several advantages:

- Specific energy system training can be completed for all energy systems.
- Recovery time allows the athlete to maintain high-intensity work for longer periods.
- It is possible to closely mimic the demands of particular sports with specific interval programs. This is particularly relevant in sports such as Australian Rules football, soccer, basketball and rugby.
- It is easy to assess development or otherwise of athletes.
- There is a psychological benefit when compared to continuous training for many athletes. This is because there is a positive impact on the athletes caused by rest periods. Many athletes also enjoy using the smaller goals that interval training provides.

Checkpoints

1 What is the significance of the different types of recovery suggested in Table 13.3?

2 Why is there a different work–rest ratio between short duration, intermediate duration and high duration events?

3 Why would a 100 m runner (Table 13.5) have such long rest periods between high-intensity work bouts?

4 Why is the volume of training quite low for the 100 m runner?

Coursework: Laboratory activity

Have someone in your class try and complete the 5 km test described on p. 248. You will need about 2 hours to do the whole test. They should wear a HR monitor. Track their HR throughout the test.

1 Graph the HR against time.

2 What do the results highlight?

3 Would an active or passive recovery be best in this situation? Why?

4 What would the impact be if we made the work–rest ratio 1 : 1?

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Continuous training

Continuous training is also referred to as long, slow, distance (LSD) training. It involves the athlete working at a steady pace for a time, generally more than 30 minutes. It is usually performed at a moderate intensity or around 75% maximum HR, and, therefore, predominantly works the aerobic energy system. Training at intensities above 75% maximum HR are likely to increase the utilisation of energy via anaerobic pathways. This will depend on the fitness of the individual, as each person will have a different point at which they increase the use of the lactic acid system. As for interval training, the duration of the training time depends on the demands of the sport for which the athlete is training.

Continuous training is important in causing training adaptations to the cardiovascular system. Improvements made here have important ramifications for the body's ability to both recovery from all types of exercise and work at high intensities. These are the major reasons why continuous/aerobic training is considered an important base for all exercise demands.

The intensity of training (as measured by the athlete's pulse) depends on the athlete's motivation, which can mean athletes train sometimes below the required intensity. Many teams and individuals use heart rate monitors and GPS systems to ensure athletes train at the required intensity. By keeping the HR between the following limits, the aerobic system will be the dominant system trained:

- Upper limit – 80–85% of maximum HR (equal to 60–70% VO_2 max).
- Lower limits – 65–70% of maximum HR (equal to 40–50% VO_2 max).

Most HR monitors can allow the athlete to set upper and lower limits. When the athlete goes outside their pre-set limit, the watch starts to beep. This helps them stay in the aerobic training zone.

Catchy fact
Continuous training below 50% HR max has some benefits in terms of utilising fat stores by converting them into ATP, via the aerobic pathway. To burn fat, the duration of an activity would need to be quite high.

aerobic training zone considered to be 65–85% of an individual's maximum heart rate

lipolysis breakdown of fat for energy

Benefits of continuous training

Continuous training is less demanding on the body, as it is less intense and less stressful than anaerobic training. It provides health benefits as well as fitness benefits, and there is a lower risk of injury than in interval training. The athlete can train specifically at the same pace as a particular event.

Continuous training provides a strong base for athletes by improving efficiencies in the body. These cellular efficiencies are important to help the body withstand high training volumes and help during the recovery process. Recovery during a match is as important as recovery after a match.

Other benefits include:

- a lower than normal resting heat rate – suggesting improvements in efficiency
- increased fat lipolysis
- increased blood to the muscle
- larger slow-twitch muscle fibres
- increased ability to generate ATP aerobically
- heart hypertrophy – increase in plasma volume.

Figure 13.4 Monitoring heart rate

Circuit training

Circuit training is considerably different from weight or resistance training. Circuit training is designed for general conditioning. An elite athlete is more likely to have a specific training program than partake in circuit training.

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Catchy fact

1 RM is the maximum weight a person can lift in one effort. The following formulas can be used to calculate 1 RM for athletes:

Untrained
1.55 7 10 RM weight (kg) 5.181

Trained
1.172 7 10 RM weight (kg) 7.704

There is a small rest period between each workout period and generally participants lift weights at lower than 1 RM. The use of circuits is popular in settings where people wish to maximise the use of the space and equipment. A circuit also can have all participants active at once. Circuits are utilised regularly in commercial gyms and school settings.

A circuit generally involves 15–20 stations. Participants move around the circuit at dictated times, usually 45–60 seconds. There is a short time of around 15 seconds to allow the participant to get ready at the next station (adjust the machine). Many gyms use lights or a change in music volume to control this.

A circuit could also include stations outside of a gym. Stations may include skipping, jumping, medicine balls, sit-ups, boxing etc. This type of training has become quite popular with group trainers who look after groups of people at the local park or beach. The trainer makes maximum use of each person's limit time. The general fitness workout of circuits is ideally suited to this situation. The general conditioning may also be of some advantage with sport teams in the pre-season.

Individuals can complete circuits and they can have more control over the duration they spend at each station.

The type of workout a participant will have will depend on the following factors:

- The length of intervals between workouts
- The number of circuits performed
- The intensity of each workout
- The type of activity at each station

Benefits of circuit training include:

- time efficiency
- aerobic and strength work can be included in one session
- efficient use of space and resources (especially in a commercial setting)
- exercise variety.

Coursework

1 Design two circuits that could be used at your school. Each should include 15 stations or enough for a PE class. There should be a combination of strength and aerobic exercises.

a Design one for indoor use (perhaps in a weights room or gym).
b Design another to be used on the oval.

Extension

2 What changes would you need to make to your circuit design if it was to be used in a retirement village?

Fartlek training

Catchy fact

Fartlek is a Swedish word meaning speed-play.

Fartlek training is a combination of continuous and interval training. It originated in the 1930s in Sweden as a method to train cross-country runners. In its original form, athletes ran over hilly terrain at varying intensities. Although unproven scientifically to have any more benefits than continuous training, it is still utilised today and has since been adapted for use across a wide range of sports.

Fartlek training involves regular changes of pace/intensity throughout an exercise session. The intensity of the various parts of the session will determine if the training session is more interval (generally anaerobic) or continuous (generally aerobic) in nature.

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Benefits of fartlek training

Benefits include the following:

- Both aerobic and anaerobic systems can be trained.
- It allows for freedom of workouts.
- The variety such a program allows has psychological benefits.

Coursework: Laboratory activity

Choose one of the following methods of fartlek training to participate in either individually or as a class. Prepare a written report that discusses:

- strategies for recording fitness gains by this method
- approaches to applying overload
- suitability of this method to various sporting events.

Compare the method with one other method of training (of your choice), discussing the advantages and disadvantages of each one.

Saltin fartlek (for events between 1.5 and 5 km)

- 10-minute warm-up jog
- Stride hard for 3 minutes with 1-minute recovery (repeat six times)
- 10-minute cool-down recovery

Astrand fartlek (for 800 m runners)

- 10-minute warm-up jog
- Maximum effort for 75 seconds, 150-second jog run, maximum effort for 60 seconds, 120-second jog run (repeat three times)
- 10-minute cool-down recovery

Gerschler fartlek

- 10-minute warm-up jog
- Stride hard for 30 seconds, jog 90 seconds. Repeat with 15-second decreases in recovery jog – i.e. 30-second stride, jog 90; 30-second stride, jog 75; 30-second stride, jog 60, and so on (repeat three times)
- 10-minute cool-down recovery

Whistle fartlek

- The coach, using a whistle, controls the session over a 1.2 km grassed area.
- 10-minute warm-up jog
- When the whistle is blown the athletes run hard until the whistle is blown again. Pyramid session of 3 minutes, 2 minutes, 1 minute, 2 minutes, 3 minutes, with a 60-second jog recovery between each run
- 10-minute cool-down recovery

For swimmers doing a 2000 m swim, five bursts of 100 m could be interspersed at 300 m intervals, or they could simply sprint at regular intervals over a short distance throughout a longer course.

Flexibility

flexibility
a measure of the range of motion about a joint

Having a very high level of flexibility, in isolation, is not necessarily ideal for athletes. Most activities require athletes and also non-athletes to combine a high level of flexibility with a high level of strength and balance.

Australian Rules football and rugby players need to be careful that they do not have too much flexibility about their shoulder joints. Swimmers, on the other hand, need more flexibility. Too much swimming, especially butterfly, may be detrimental for contact sport athletes as it could make them more susceptible to shoulder injuries.

It is important to distinguish between a warm-up and flexibility training. (See page 48 for more specific warm-up information.)

Flexibility training has an important part to play in everyone's life. Lower back pain is one of the most common debilitating ailments and is often connected to issues with poor flexibility. An athlete's training program will have a significant emphasis on flexibility and strength training. Developing flexibility combined with strength and core strength, in particular, is the goal. The area that is most important to train is determined by the requirements of the sport.

Imagine a gymnast performing on the rings and not being able to combine strength, flexibility and balance. This area highlights how no single area of training is important in isolation. All stretching should be completed only when the body is warm.

Static stretching

A static stretch is when a person stretches to a position and holds it for 10 seconds or more. An example of this is the sit and reach or hamstring stretch. There has been considerable research completed on the benefits or otherwise of stretching. Significantly, static stretching is not recommended before a training session or as a part of a warm-up. Static stretching decreases the eccentric strength of a muscle, which actually may lead to an injury. Static stretching may be beneficial to help align muscle fibres after injury or performance. This type of stretching is better for use during a cool-down after a performance or during a recovery phase during the week.

Figure 13.5 Static stretching is best used during a cool-down

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Dynamic stretching

Dynamic (ballistic) stretching moves the joint through a large range of motion. As this type of stretch can be designed to be very similar to the activity we are about to play, it is more suited to be used before a game. Again, it is important that the body is warm before doing dynamic stretches.

A common dynamic stretch that can be used in a number of sports is an athlete kicking their leg through to simulate the normal kicking action. These types of stretches are good at preparing the muscles and tendons for the demands of the up-coming activity.

Proprioceptive neuromuscular facilitation

Proprioceptive neuromuscular facilitation (PNF) stretching (also called assisted stretching) is very effective in improving flexibility. A partner (or wall or bench) is needed to perform the exercise. It involves fully lengthening the muscle. Your partner provides the resistance as your muscle is contracted isometrically for 6 seconds. Muscle tension must not overcome the resistance. A cycle of contraction and relaxation is performed. This type of stretching is used extensively in sports like gymnastics. It should only be performed under the guidance of professionals.

Yoga

Yoga is becoming more popular as a tool in helping athletes to improve their flexibility. The main benefits of yoga are that it not only works on flexibility but also helps to improve balance and strength. Many professional sports people will do a number of yoga sessions each week. Many athletes also find psychological benefits from the meditation aspects of yoga.

Checkpoints

1. Define flexibility.
2. What joint(s) in the body, if too flexible, would be susceptible to injury in impact sports like basketball and netball?
3. Why is it not recommended for athletes to do static stretching before a performance?
4. Apart from gymnastics, what other sports may require the use of PNF stretching and why?
5. What is the importance of having the body warm before commencing any stretching program?
6. Describe the significance of having a combination of good flexibility and strength.
7. Choose a sport, and design two flexibility-training programs as a part of a warm-up. The first should be a comprehensive program for a week during the season. The second should be the flexibility exercise you would do during a warm-up before a game.

Coursework

1. Perform a range of the various types of stretches (static, ballistic and PNF) to tell the difference each type is having on the body.
   - a At what time in a training program should each type of stretching be used?
   - b Have you seen where a coach has used the wrong type of stretching for a particular situation?
2. Participate in a yoga class. You may be surprised to see how hard some of the positions are to get into and how physical the class is.

plyometrics
the term used to describe explosive jump training

ergogenic
something that increases muscular work capacity; i.e. is performance-enhancing

Plyometrics

Plyometrics has again become a popular training method in power sports across the world. It first came to prominence in Eastern Europe in the late 1950s and was considered an important part of their dominance in many power events at the Olympics.

Unfortunately, at this time a number of countries also combined this type of training with illegal ergogenic drug use.

Plyometrics involves athletes doing various jumps and then rebounding. Plyometrics utilises the stretch reflex in the body; it is activated during the eccentric contraction (jumping down). When a concentric contraction (muscle shortening or jumping up) immediately follows, a more powerful contraction can be performed compared with an athlete who does not jump from a height.

This energy that is added to the concentric contraction is because of the stretch–recoil characteristics of skeletal muscle. If the subsequent concentric muscle contraction is not vigorous and immediate, the 'energy boost' is lost.

No athlete should begin a plyometrics program unless they are well conditioned and have adequate strength and stability in all major joints. The forces developed are considerable and, as such, there is an increased chance of injury. Correct technique when performing plyometric drills is most important.

Plyometrics should be used as an additional training technique for power athletes just as weights are. Athletes still need to complete 'normal' training volumes in all other areas. Research suggests that plyometric drills will have their greatest positive impact towards the end of a training session. The training frequency should be between two and three times a week. Any more than this will not allow the body enough time to recover and adapt.

Benefits of plyometric training

The benefits of plyometrics include the following:

- Plyometrics specifically trains the neuromuscular system.
- It develops power (strength and speed).
- It allows an athlete to replicate the movements performed in a competition situation.
- Because it uses the athlete's own body weight, minimal equipment is required.

core strength/ stability
having strength in those muscles that stabilise, align and move the trunk of the body. Major muscle groups here include lower back muscles and abdominal group

Pilates

Pilates has become a popular exercise or training method in the last decade or so. Being popular with celebrities, it has gained considerable exposure in the media.

Pilates is a training method that concentrates on improving core strength, balance and flexibility. It has been described as a cross between yoga, stretching exercises and tai chi. Today, pilates exercises use spring-loaded machines like the one in

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Figure 13.6 *Pilates concentrates on improving core strength.*

Catchy fact
Pilates is named after Joseph Pilates, who developed the training method when he was interned as a prisoner in Scotland during World War 1. Pilates was considered an enemy alien because he was born in Germany.

Figure 13.6 (these have changed little from Joseph Pilates' original ideas), swiss balls and exercises on the floor.

The exercises performed not only concentrate on developing those muscles that are important for core strength but also work on overall posture and breathing. The exercises combine physical conditioning with mental conditioning.

Having good core strength is important when trying to reduce the number of injuries athletes get. This is one of the major reasons pilates has become so popular in elite sport today.

All sports can benefit from pilates, especially where there is high-speed running (requires great core stability) and trunk rotation. Sports that use one side of the body more than the other benefit greatly from the postural work.

Additional benefits of pilates include:

- stress relief
- increased self-confidence
- reduction in feelings of fatigue.

TEST YOUR KNOWLEDGE

>> multiple choice

1 An example of an eccentric contraction is:

A running down hill
B a bicep curl
C holding a static position
D one that requires specialised equipment.

2 A weight-training program that is concentrating on hypertrophy is attempting to increase:

A muscle size
B aerobic muscle ability
C red muscle fibre types
D muscle capillarisation.

3 Plyometrics training is best suited to:

A aerobic sports
B lactate sports
C individual sports
D power sports.

4 An endurance triathlete is more likely to participate in a weights program involving:

A high reps and a high percentage of 1 RM
B low reps and a high percentage of 1 RM
C high reps and a low percentage of 1 RM
D low reps and a low percentage of 1 RM.

>> short answer

5 Why would athletes who play cricket or tennis be advised to include pilates in their training program?

6 Why wouldn't you do static stretch as a part of a warm-up?

7 How does plyometric training increase the size of a muscle contraction?

8 Explain what happens to the adaptations of the body when the rest period is increased.

>> essay style

9 You are the coach of a 10 km track and cross-country runner.

a Why would you use continuous training with this athlete?
b What would be the advantages of using interval training?
c Explain why an endurance athlete can train more frequently than a sprinter.
d What sort of recovery activities would be advantageous for this athlete?
e How would you monitor that the athlete was working at the required level?
f How would you monitor the success of your program?

10 You are the strength and conditioning person for a team sport of your choice.

a What is the sport?
b What are the major energy requirements of the sport?
c How would you have assessed these?
d What type of training are you going to employ for this team and why?

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14 Principles of training

This chapter outlines the major principles of training, which should be the base from which all training programs are developed. When a coach or athlete plans a training program, it is important they adhere to proven scientific research in this area. That does not mean that they cannot be creative, but they should use these principles as the starting base for any program.

Adhering to a structured program that is based on sports science will give the athlete the best chance of reaching their fitness and performance goals. All coaches and athletes should be educated in this area.

The major training principles are:

- specificity
- intensity
- duration
- frequency
- progressive overload
- detraining (reversibility).

Additional principles include:

- individuality
- the law of diminishing returns
- variety
- maintenance.

Figure 14.1 *A structured training program gives athletes the best chance of reaching their goals*

Specificity

When an athlete participates in a training program, they are trying to make adaptations to better prepare them for successful performance. Improving power (100 m) and improving their VO_2 max (marathon) are examples of adaptations the athlete is looking for. Of course the adaptation sought will depend on the requirements of their particular sport.

When we train our bodies, the adaptations will be very specific. An endurance cyclist will improve their VO_2 max but it will be different from a marathon runner. Both will be seeking to improve their ability to take up, transport and utilise oxygen. This has them working the three main systems – respiratory, circulatory and muscular. The cyclist,

vastus lateralis
a major quadriceps muscle on the outside of the thigh

however, will obtain specific improvements in the muscles that are important for cycling and likewise the marathon runner will improve the specific running muscles. One muscle that the cyclist develops significantly more than a runner is the vastus lateralis.

Power athletes also need to adhere to the specificity principle. A 100 m runner would do different exercises from a javelin thrower, although they may choose resistance or plyometric training methods. Both athletes will do a considerable amount of training in the gym. Their programs need to be such that they improve the power of the muscles required. This is the principle of specificity.

Before considering what a program should involve and obviously trying to make it specific, it is important to understand what the requirements of the particular sport are. In most team sports, different positions require different energy demands. There is marked difference in the specific training of a soccer goalkeeper and a mid-field player. It is therefore important that these two players have vastly different training programs that are specific to their particular requirements.

Games analysis is useful in determining the specific energy systems used. Further information on games analysis can be found in *Nelson Physical Education Studies for WA 3A, 3B*.

Catchy fact
There is evidence to suggest that the brain also takes on the specificity principle. If an athlete trains at the same time each day, they will probably perform in an event better if it is at the same time as their training.

Specific adaptations

Specific adaptations of aerobic training to specific muscles include:

- increased O_2 transport
- increased ability to generate ATP aerobically
- increased capillarisation
- increased fat metabolism.

Specific adaptations of anaerobic training to specific muscles include:

- increased levels of ATP
- increased levels of creatine phosphate (CP)
- increased strength
- increased ability to tolerate high levels of blood lactate.

It is important to have a training program that is specific to the skill and physiological requirements of the sport. A football player would be better off to spend more time training on the ground doing skill work and running than working hard in the pool. Within a sport, there are considerable differences between positional requirements. A goal shooter in netball has considerably different skill and physiological requirements from the centre player. Shooting percentage is probably the most significant part of the goal shooter's game and she would need to spend considerable time in this area. Professional sports today have specific coaches for different positions so that training can be specific to the different demands of each individual position. The strength and conditioning coach would also tailor different training programs for each player.

Cross-training or having a session away from the sport, although not specific, can have some psychological benefits to the athletes. These sessions are often primarily fun with some conditioning and also help to bond the team together. An example would be a rugby team playing soccer at training but using a rugby ball.

Figure 14.2 Training programs should be specific to the requirements of the sport.

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KEEP IT REAL!

Who is stronger – a bodybuilder or a weightlifter?

As a general rule, the larger the cross-sectional area of muscle, the greater the muscular strength. This is true for men and women. When it comes to comparing the strength of a bodybuilder with that of Olympic weightlifters and power lifters, some interesting facts emerge. In general, Olympic weightlifters and power lifters are much stronger than massive bodybuilders. To understand this phenomenon, we need to look at the type of training the bodybuilder and the weightlifter undertake.

The bodybuilder undertakes weight training that emphasises hypertrophy (enlargement) of the non-contractile elements of muscle, the sarcoplasm. Weightlifters and power lifters undertake weight training that emphasises hypertrophy of the contractile structures, the actin–myosin. The type of training used by weightlifters, with very heavy weights in the 1–5 rep range, has been shown to contribute little to muscular hypertrophy. Training with submaximal loads has been proven to be more effective for gaining muscle mass.

The number and pattern of nerve impulses exciting the muscles determines the force the muscle can produce. The weightlifter undertakes training that stimulates these nerve impulses so that the maximum number of muscle fibres can be recruited to perform a maximum lift. The ability to perform the lift also requires intramuscular coordination (the ability to utilise multiple muscles in synergy to carry out a movement). Weightlifters and power lifters are able to coordinate their muscles in such a way as to lift seemingly impossible weights off the ground and above their heads.

According to Jamie Hale, the massive hypertrophy achieved by bodybuilders is a result of great genetics, an appropriate training regimen, a surplus of calories and often supplementation with illegal drugs.

The combination of specific training that results in hypertrophy of the parts of the muscle that do the work, the ability to recruit more muscle fibres when needed, and the superior coordination result in the weightlifter being able to lift greater weights than the often more muscular bodybuilder.

Adapted from www.brianmac.demon.co.uk/articles

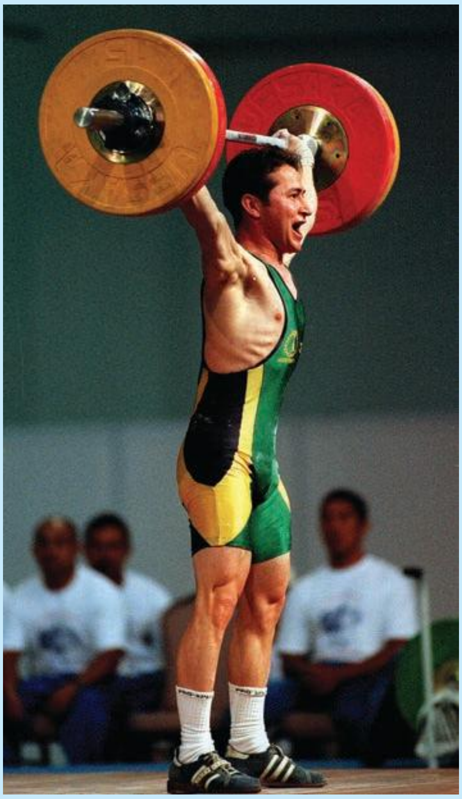

Figure 14.3 *Bodybuilder or weightlifter – who is stronger?*

Checkpoints

1 Compare the following positions:
   - **a** Goal shooter and centre in netball
   - **b** First base and pitcher in baseball
   - **c** Full back and midfielder in Australian Rules football
   - **d** Forward and a back line player in rugby union
      - **i** Decide what the energy demands of each position are. (Hint: Think in terms of intensity and work versus rest or recovery time.)
      - **ii** List three specific training drills each position would use.
      - **iii** List three adaptations each position will gain from a specific training program.

2 With regard to the specificity principle, discuss what teams need to do when they travel interstate or overseas.

3 How could a weights program be utilised by a marathon runner and a sprinter?

Intensity

Intensity is the single largest determinant of how much adaptation will result from a training program. Intensity refers to how hard the training session is. Intensity can be measured in various ways and will depend on what energy system the session is trying to tax and therefore adapt. One of the simplest methods of assessing intensity is to work at a percentage of HR max. The HR max has a direct relationship with VO_2 max.

Table 14.1 Various methods used to test an athlete's training intensity

	Training intensity tests
ATP–CP system	Electronic timing, weights lifted, perceived rate of exertion, HR
Lactic acid system	Blood lactate, electronic timing, perceived rate of exertion, HR
Aerobic system	HR, GPS, perceived rate of exertion

Training zone

Various books and posters found in gymnasiums show HR and various training zones. The 'training zone' often refers to a training intensity of any particular session, which is measured as percentage of maximum HR.

Table 14.2 Three major training zones, as a percentage of HR max, where age-predicted maximum HR = age – 220

Above 85% max HR (above lactate threshold)	Training anaerobic systems
Between 70–85% max HR	Aerobic training zone
Below 50% max HR	Aerobic – fat training zone

A 400 m runner would spend a considerable proportion of their training time above the lactate threshold. Aerobic training will occur between 50% HR max and 85% HR max.

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However, to obtain significant adaptation, training should be at an intensity of above 70%. It is important to realise that this is a guide and is dependent on the fitness and health of the individual and the mode of exercise undertaken.

The body will use fat, through aerobic lypolysis, as a primary energy source below 50% HR max. Training at this intensity will burn more fat than at higher intensities but it will require a considerable increase in duration to be effective.

Caution

Sudden and dramatic increases in intensity within a training program result in a higher risk of injury. The most common injuries are overuse injuries such as shin splints or tendonitis at various joints. When starting plyometric training, coaches and athletes must be cautious and also ensure that the correct technique, warm-up and cool-down are all followed.

Catchy fact
Swimming and other upper body HR max are generally 13 bpm below that of running.

Perceived rate of exertion

Perceived rate of exertion (PRE) is a commonly used method to monitor exercise intensity. During exercise or at the completion of exercise athletes rate their feeling about how hard they believe they are/were working. There is a correlation between PRE and HR levels, lactate levels and breathing rates.

A table such as Table 14.3 is shown to the athletes and they are usually asked to call out the number that relates to their exertion or intensity level. When an athlete is performing a VO_2 max test and is unable to talk, they will point to the corresponding number on the chart.

Table 14.3 Perceived rate of exertion chart

6	No exertion at all
7	Extremely light
8	
9	Very light
10	
11	Light
12	
13	Somewhat hard
14	
15	Hard
16	
17	Very hard
18	
19	Extremely hard
20	Maximal exertion

To train the aerobic system, a coach would be trying to keep their athletes at a PRE of 13–15. After a short period of time, an athlete is able to accurately assess their own exertion/intensity levels. This can be a very useful tool for coaches to keep a check on training intensity levels.

Catchy fact
Athletes who are suddenly finding a normally light session hard or very hard could have an illness or have been over-training.

Coursework: Laboratory activity

HR and PRE during the beep test

Materials

Beep CD, heart rate monitor, PRE chart on an A4 sheet, paper to record

Method

1. Divide the class into groups of no fewer than four.
2. Each group will have one subject who will complete a slightly modified beep test. The subject will need to wear a HR monitor.
3. Assign one person to recording the HR, one to hold the PRE chart and one to record the PRE.
4. One person in the class will need to pause the CD at the end of each level.
5. The beep test is to be completed with a slight pause at the end of each level (levels change every minute) to allow for HR and PRE to be recorded. The pause should only be for a few seconds.

   It is important that the subject does not look at their HR watch and is not made aware of their HR.

Results

1. Graph the results on the same graph (bottom axis levels/time, left axis PRE, right axis HR).
2. Describe any significance you found between the HR and PRE results.
3. Do you believe PRE is a good guide for exercise intensity? Why or why not?
4. How would you modify the experiment if you were to perform it again?
5. Were there any positive or negative effects on beep test results by having a short pause at the end of each level?

Extension

6. How can you tell if the subject reached their VO_2 max during the test?
7. Why may it be that they did not?

Duration

Duration refers to both how long a single session will last and how long a training phase will last.

If a person is trying to improve their general fitness or aerobic fitness and is starting from a low fitness base, they will generally need to exercise at an intensity of around 70% max HR for at least 30 minutes three times a week. If the intensity of exercise drops, then the duration of each session will need to increase. As you can see, duration, intensity and frequency are very much inter-related in any training program.

Optimal training durations depend on both the demands of the sport and the time available to the athlete. In professional sports, the duration and frequency of training is quite flexible. The duration of a training session should be such that it works the required energy systems for the particular sport. A continuous-sport athlete will have training sessions considerably longer than a sprint athlete. For an amateur athlete, however, work and family commitments often have a large impact on the time available to train. The traditional amateur program for team sports is 1.5 hours each Tuesday and Thursday and competition on Saturday.

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KEEP IT REAL!

Interview with Kate Bevilaqua

Kate Bevilaqua is a 31-year-old professional triathlete. Her home is Perth, where she went to All Saints College and then completed a human movement degree at the University of Western Australia. Her best time is 9 hours 20 minutes and her best result is second place in Ironman New Zealand 2008. (The Ironman competition consists of a 3.8 km swim, 180 km bike ride and 42.2 km run.)

Is triathlon your job?

Yes, I do not have much time for 'normal' work. Unfortunately, there is not a lot of money in triathlon and, being an Ironman professional, I am only able to compete in a couple of races a year.

Why is this?

It takes so long to recover from a race.

How do you organise your training?

I work on a 3-week cycle. Every new cycle is slightly harder than the previous. Week 1 is hard, week 2 very hard and week 3 is my adaptation and recovery week.

What does a normal training week entail?

- Swimming 20 km split across four sessions
- Running 80 km across four sessions
- Riding 400 km across four sessions
- Pilates for flexibility for two sessions
- Core strength work for three sessions
- At least one recovery massage per week

Are you tired?

A lot of the time – that is why I really need the recovery/adaptation week.

What is the difference in the recovery week compared with a normal week?

I do about half the volume in running and riding over one less session for each. I keep swimming the same, as it is less taxing on the body.

How do you measure the intensity of each workout?

With swimming and running, I work on time per distance. With cycling, I use a wattmeter.

How much do you sleep?

I try to get 9 hours each night. That means being in bed at 8 pm, as I need to be up at 5 am for training. I also try to have a power nap for an hour each afternoon.

Do you think overtraining is an issue for you?

It would be if I did not have a coach. He is very good at knowing when I am fatigued and he forces me to have rest days. I have the personality that would probably train too much. To be an Ironman triathlete you need to be somewhat obsessive.

What is the worst injury you have had?

I am recovering from a stress fracture in my back in the sacrum bone.

What caused it?

A combination of running technique issues and amenorrhea [the stopping of the menstrual cycle]. This caused a hormone drop and slightly weaker bones.

What is the treatment?

Firstly, rest and taking the birth control pill, to regulate my hormones. Also a change in footwear, calcium supplements and further core strength and stability work to help stabilise my hips when I run.

What recovery practices do you do?

After an Ironman, I normally have a drip as I have lost so much fluid. I then rest for the next couple of weeks before slowly getting back into training. After a hard run or race, I have an ice-bath. One minute in and 3 minutes out. Nutrition is such an important part of my recovery, after hard sessions I need to replace carbs quickly so that my body is ready for the next session.

What is your hardest training day?

Saturday by far. Six to seven hours on the bike, straight into a 10 km run and then swimming in the afternoon.

What does your taper consist of?

It depends on the event. Olympic course – 1-week taper, Half Ironman – 2-week taper, Ironman – 3-week taper. In the taper, I try to hold the intensity and dramatically cut the volume.

www

Kate Bevilaqua

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Frequency

Frequency of training is the number of session in a week. There is still some debate as to the ideal frequency for training. Some research suggests that swimmers do not need to train any more than five or six sessions a week to achieve the same results as training for ten sessions.

When comparing different sports, it tends to be the intensity of the sport and the training sessions that dictate the frequency of training. A power sport athlete training at a very high intensity will need considerable recovery between sessions, thus limiting the frequency of training.

Aerobic exercises will require a minimum of 3 days' training ,a week to illicit a training response. Aerobic events can achieve greater adaptations with more sessions. An athlete is able to complete more aerobic sessions than anaerobic sessions in a week as less stress is placed on the body; therefore, the athlete requires less time to recover. To maintain fitness at least two sessions a week are required. Volume and intensity, however, are better predictors of training adaptations.

Catchy fact
One day of training per week is unlikely to provide any positive change to the body.

Many sports, especially team sports, have a high frequency of sessions that primarily work on skill development. These sessions will have only a minor, if any, physiological impact.

We have already looked at some of the inter-relationships between intensity, duration and frequency. It is difficult to compare the training principles across all sports as the particular demands of all sports are so different. Table 14.4 compares sports that require similar time to complete.

Table 14.4 Training principles of some sports

Sport	World record	Intensity	Duration	Frequency
400 m swim	Male: Ian Thorpe (2002) 3.40.08 Female: Federica Pellegrini (2008) 4.01.53	Cannot reach HR max because of the water HR max on average 13 bpm below 'normal' A proportion of each session below race intensity	Able to swim longer as submersion in water aids recovery Generally 2 hours per session	Due to the low impact of swimming, athletes are able to do around 12 sessions per week. It easier with swimming to get variety into program with a change of strokes.
1500 m run	Male: El Guerrouj (1998) 3.26.00 Female: Qu Yunxia (1993) 3.50.46	The eccentric cycle of running adds to the intensity of this pursuit. Many sessions on race intensity or even above race intensity	The runner's training duration will be the least of the three sports due to a combination of the impact in running and the intensity required. After warm-up and stretching etc. around 1 hour per session	Runners will do 5–6 sessions on the track. They will need to do other cross-training sessions that limit the impact on the legs.
Pursuit cycling	4000 m (male) Chris Boardman (2008) 4.11.11 3000 m (female) Sarah Ulmer (2004) 3.24.53	The smaller muscle mass involved in movement compared with running lowers the intensity of cycling. Less resistance than running, more than swimming	Need to adjust duration to protect wear and tear on the knee joint.	Pursuit cyclist will do 8–9 sessions on the bike. Hard to add variety Too many sessions may cause tendonitis in the knee.

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KEEP IT REAL!

Australian Olympic cyclist Cameron Myer is also a member of the GARMIN-Slipstream Team. Cameron has already represented Australia at the Olympic Games and World Championships. Cameron attended La Salle College in Middle Swan, Western Australia. Cameron won a gold medal in the 2009 World Championships in the points race.

Interview with Cameron Myer

When did you take up cycling seriously?
I started cycling at the age of 12. I started seriously, however, when I attended my first Junior National Championships when I was 14.

What is the highlight of your cycling career thus far?
The biggest highlight of my cycling career so far would be competing at the 2008 Beijing Olympic Games. It was the most unbelievable experience and to achieve such a goal that I had wanted since a little kid, was just out of this world. [Cameron finished fourth in the points race on the track.]

How many hours a week do you spend on the bike? What is that in kilometres?
A small and easier week would be somewhere around 15 hours (400 km). A big week would be around 35 hours (900 km). So on average it would be around 23 hours (650 km).

At what intensities do you train?
Depending on what training is relevant to the event I am focusing on, the intensities in a session can vary from easy short to easy long, or short and hard to long and hard.

What do you use to measure intensity of workouts?
There are many different ways we measure the intensity of our workouts. Many times I will use more than one measurement. They can be heart rate, power (watts), cadence (rpm), speed, distance, time. For this I use a heart rate monitor and a Garmin 705 Edge which tells me my power, speed etc.

How do the previous three questions vary from the track to the road?
Track requires a more powerful aspect to its training and a higher pedalling cadence. For this, the training is different from the road. The efforts and sessions are shorter but more intense and quicker than that of the road. In measuring the intensity on the track, I use the same as I do on the road.

What would a typical training week at Slipstream look like?
[Slipstream is the professional team Cameron has a contract with.]

Monday: 3 hours with hill strength endurance efforts

Tuesday: 4 hours of nothing specific, just E1 and E2; you choose a ride but not too hilly

Wednesday: 3 hours with a gym session

Thursday: 5 hours E2 on climbs, and if you want to chuck in some sprints keep them short and sharp: 10-second explosive bursts

Friday: 2 hours on time trial bike

Saturday: 3 hours with 5 × 7 min hill strength endurance efforts at E2 heart rate, 60 rpm cadence and equal recovery

Sunday: 4 hours with ten sprints during the ride at random

[E1 and E2 relate to efforts. E1 is less than 75% of HR max (easy) and E2 is 75–85% of HR max (comfortable).]

What sort of things do you do to recover from training and racing?
I will frequently get a massage to help recover from racing or training. Eating the right foods and having a protein drink after training or racing is most important for recovery as is wearing compression tights post hard exercise.

What sort of food do you eat on a weekly basis?
I do not have any special diet. Of course, you won't see me at the fast food stores during the season. Many pasta and rice dishes which are high in carbs during heavy phases of racing and training. Fish, meat, salad and vegetables, all the good stuff on a regular basis.

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Cameron Myer

Has over-training ever been an issue for you?
No. I always know when I have done a bit too much and my body tells me to back it up a little so you must know when to listen to it and to take it easy.

What is the worst injury you have had? How long did it take you to recover?
I have dislocated both my shoulders on a number of occasions. The first time was probably the worst. I had 5 days off the bike and then was on a stationary trainer for a week. Other than this, I have not been too bad with injuries.

What is your goal in cycling?
To compete in the Grand Tours (Tour de France, Tour of Italy and Tour of Spain). To also continue to represent Australia at such events as the Olympic Games, Commonwealth Games and World Championships.

Progressive overload

The principle of progressive overload states that for the body to continue to improve fitness levels (obtain adaptation) the body needs to be overloaded. This should be done in a considered and managed way. Early in an individual's program, the overload can be up to 10% per week. To overload a training program increases can be made to intensity, frequency and duration. It is important that when an athlete is considering progressive overload that they ensure specificity of training. If intensity is increased too much then the session my no longer train the body in the specific requirements of the sport. A marathon runner would not spend too much time working the ATP-CP system.

If the duration of the training program is increased by up to 10% in the second week there should be no increase to the intensity or frequency. Early in the program it is probably better to work on increasing duration rather than intensity. Frequency should be left at three times a week to allow adequate recovery time.

As the base level of fitness of the individual improves, adjustments can be made to intensity. Again only increments of up to 10% per week should be added.

If no overload is added to a training program an individual will not gain any further adaptations. This type of a training system is referred to as a maintenance program.

A training program for an elite athlete will generally not be able to have such large increases. Some athletes will be working very hard in a maintenance program ensuring that they do not get injured. Here, adequate rest, recovery time between sessions, diet and sleep are all important. Coaches have a critical role to monitor this. It may also be that at such a level it will be subtle skill changes that make a greater difference.

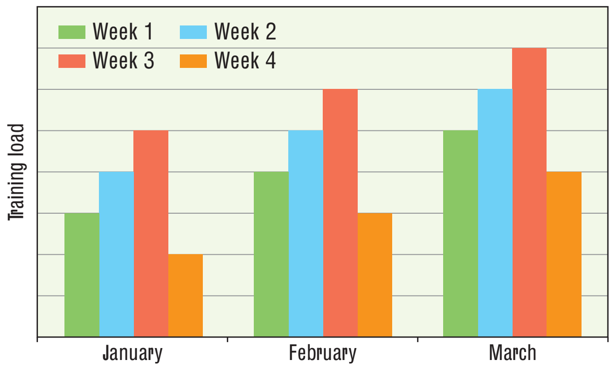

Figure 14.4 The overload principle; week 4 is a recovery and adaptation week.

Detraining (reversibility)

Once a person stops training the physiological adaptations that they have made will be reversed quickly. This will start in the first 1–2 weeks that training is either stopped or scaled back. Table 14.5 shows the impact of detraining on the body after around 12 weeks.

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Table 14.5 The impact of detraining on aerobically trained athletes after 12 weeks

Variable	Loss (%)
VO_2 max	18
Stroke volume	13
Glycogen stores	50
Capillary density	2
Lactate threshold	18
ATP stores	15
CP stores	27

Adapted from McCardle *et al*, 2001

Elite athletes and non-athletes will both suffer the effects of detraining. The longer an athlete spends in an 'off-season' the greater the effects of detraining. This is one of the reasons why the preseason is so important for conditioning. Today an off season generally means time away from the particular sport, with true professional athletes continuing to train. Training through the off season will often require the athlete to rest specific muscles and joints and participate in exercises that attempt to limit the effects of detraining. For example, an AFL player may need to limit the impact of running on the joints so will do extra swimming and cycling. Athletes will need to retain their aerobic base so that they are able to return to competitions earlier in their program. Research suggests that speed and power will be the first adaptations to be lost in an off season and it may be better for athletes to work at holding these levels all year.

Individuality

An individual's ability to improve while involved in a training program is linked to their genetic make-up. Some individuals will improve considerably more than others when participating in the same program.

Professional teams now have training programs that are specifically tailored for the individual. They consider the following variables before deciding on a specific program:

- Athlete training history
- Injury concerns
- Positional requirements – whether the athlete is a midfielder or a striker/forward
- Next competition
- Age of the athlete

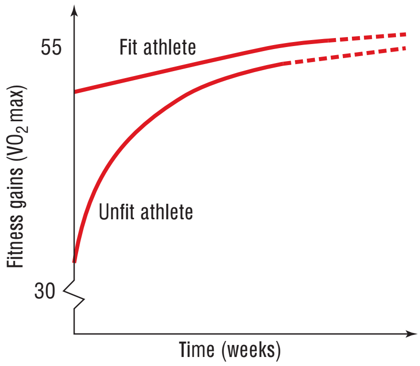
Professional teams also spend a considerable amount of time training as a unit. This time can also have a positive impact on the fitness of individuals and allows for the development of:

- team members' understanding of each other
- team tactics
- friendship
- competition within the team
- increase in energy
- commitment to the team.

Law of diminishing returns

Throughout a training program it is not possible to continue to improve at the same rate. Nor is it possible to add 10% every week. Overloading should only occur when adaptations are occurring; this is generally evident when training becomes easier. An untrained person will gain considerably more from a training program than a person who is nearing their maximal fitness.

Figure 14.5 The law of diminishing returns: expected pattern of improvement for a trained and untrained athlete using an identical training program



Variety

When developing a training program, it is important to consider if there can be some variety. Variety can help keep athletes motivated, especially when there is a fun element to the activity. It is important to remember that more important than variety is the principle of specificity. If you were the coach of the Perth Wildcats, then you would need to have your team spending most of their time involved with basketball. On the other hand, a personal trainer will use a lot of variety to keep her clients interested and enthusiastic about gaining general conditioning. Often during different sessions, intensity will be kept at the same level; however, non-specific muscles are used and actions are undertaken.

Figure 14.6 When training is fun, athletes stay motivated.

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The major benefits to athletes of variety in their programs include the following:

- It is refreshing psychologically to have a change.
- It allows the over-stressed parts of the body recovery time.
- It is fun.
- It provides a different challenge.
- It builds team morale.

Maintenance

When a person has reached a desired fitness level or is at their maximum level, they tend to move into a maintenance program. In a maintenance program, it is possible to decrease the frequency of training to hold the current fitness level. A professional athlete tends to do this during the season. It may also be that further overload will result in more injuries and thus limit performance. The negative impact of injury on an athlete's fitness can be quite large. A trainer or physiologist will spend considerable time trying to maintain an injured athlete's conditioning. A person who has had a goal to lose weight and has reached it can also cut back their frequency. It is important that the intensity of training remains high, as this is the major determinant in holding the desired fitness level.

Catchy fact

An elite cyclist will be able to produce 6 watts per kilogram of body weight and hold this at a threshold level for around 90 minutes.

KEEP IT REAL!

Ted Polglaze is the senior sports physiologist at AIS. He is the coordinator for men's hockey and women's water polo.

Interview with Ted Polglaze

When planning a training program, for WAIS or Australian athletes, which principle do you have at the forefront of your thoughts and why?

The most important principle is specificity. The adaptations that you make at training need to be specific to the actual muscles that your sport primarily uses. Skill adaptation and fitness adaptations are very specific to what you do at each training sessions. Even doing small things differently has an impact on the adaptations of the muscles and energy systems.

To iron out deficiencies, you do additional training that is relevant to the specific activity or sport. Hockey players don't run up and down on balance beams.

How do you decide on which method or type to use?

It is difficult to provide a brief answer to this question.

- Characteristics and demands of the sport – i.e. a weightlifter who only does one-off efforts – has a long rest before performing rather than continuous types
- Stage or phase of training – preseason, mid-season etc.
- Individual status – what your training state is; i.e. level of preparation, whether the athlete has a long training history or short training history
- Their experience
- The type of training may be a building block before you do specific work; for example, preseason continuous aerobic work as a base will allow higher intensity in the specific areas later in the program.

- a Variety for mental stimulation and fun. It also allows the athletes to rest areas that may be susceptible to overuse injuries. The Australian men's hockey team have played dodge ball. They were just 6 months out from the Olympics. The major benefits of this was that it was a high-intensity activity, it was interesting, the athletes were more committed because of the excitement factor, we avoided them being bent over (strain on hamstrings – hockey). There are also some transferable positives; i.e. agility, balance, timing, tactical thought process, including pattern recognition of opposition tactics.

How important is periodisation in your planning?

It is absolutely vital! Two main reasons:

- Variety is required as it is too taxing mentally and there is too much wear and tear on joints and muscles etc. You can't just play hockey 14 times a week.
- Specific fitness requires a building block approach. It is a little bit like baking a cake – you need all the right ingredients combined to get the right outcome.

What activities do you instigate to improve flexibility?

Yoga is currently the most common used. Although strength and flexibility are at opposite end of the continuum, many athletes that come into programs at WAIS are often good at either strength or flexibility. Yoga increases both flexibility and the strength to hold that flexible position. We are aiming to develop strength through the full range of motion.

What methods do you use to test the athlete's intensity at training sessions?

We use a combination of things; it depends on the nature of the sport.

- Racing type sport – velocity; i.e. electronic timing in swimming, impellors for rowing, GPS units in canoeing. In cycling, we measure an athlete's power output with a device called a power crank, which measures power in watts. Velocity is a combination of power and efficiency and in cycling; we compare power produced with velocity to assess efficiency. This is not as easy in some sports.
- HR, blood lactate, rate of perceived exertion
- Team sports – Global positioning systems (GPS) to track all types of running (fast to slow), work–rest ratios etc., video analysis. (GPS does not work indoors so many sports require the use of notation analysis.)

The difference between racing and team sports is that your strategy and tactics generally have no influence on the opposition. In team sports there is considerable interaction and influence on your strategy and tactics.

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TEST YOUR KNOWLEDGE

>> multiple choice

1 Detraining could be best described as the principle of:

A specificity
B overload
C reversibility
D diminishing returns.

2 To make adaptations to the aerobic system, a person would need to participate in a minimum of:

A three sessions per week
B two sessions per week
C four sessions per week
D one session with very high intensity,

3 Which of the following is *not* an adaption of aerobic training to specific muscles?

A Increased O_2 transport
B Increased ability to generate ATP aerobically
C Increased CP stores
D Increased capillarisation

4 Perceived rate of exertion is a common method to rate intensity of exercise. Which of the following is it closely linked to?

A Lactate threshold
B Heart rate
C VO_2 max
D Muscle tension

>> short answer

5 What are the advantages of using PRE to identify intensity during a training session?

6 What is the most significant training principle for improving physiological responses? Why?

7 What are the major reasons an athlete would be in a maintenance program?

8 Discuss the significance of specificity of training with the sport you are currently participating in with your class.

>> essay style

9 In a sport of your choice, describe an appropriate preseason program. The program will last 6 weeks and you are to assume that all athletes have a long history in the sport.

10 Describe the various methods of testing an athlete's intensity for each workout. For your particular sport, describe which method you would use and why it is the most appropriate.

15 Components of fitness

Fitness is not just a single entity – it is a combination of many components. Most people will vary in their level of fitness across these components. The average person requires a good level of fitness across all components to allow them to participate actively in life and to limit the chance of illness and disease. For non-athletes the most important component of fitness is cardio-respiratory fitness, which is closely associated with body composition. An athlete will have quite different fitness demands, which is determined by the nature of their particular sport. A shotput thrower will work very hard on improving the components of power, speed and agility, whereas an endurance swimmer will work on flexibility and cardio-respiratory endurance.

The major components of fitness are:

- cardio-respiratory fitness
- muscular strength
- muscular endurance
- power
- flexibility
- body composition
- agility
- balance
- coordination
- reaction time
- speed.

Catchy fact
Cardio-respiratory fitness is an important factor in the body's ability to convert lactic acid back into useable energy.

Cardio-respiratory fitness

Various terminologies are used to describe cardio-respiratory fitness; the most common is aerobic fitness. Cardio-respiratory fitness is the efficiency at which the cardiac and respiratory systems work. Specifically, it is the efficiency with which they deliver nutrients and oxygen to the body and the efficiency with which they remove waste products.

Exercise that improves the cardio-respiratory system helps to ensure that all of the body's systems work efficiently. Training this system is discussed in detail in Chapter 9.

Benefits of a trained cardio-vascular system include:

- improved efficiency of the heart, resulting in a lower resting heart rate
- increased stroke volume – more blood per heart contraction
- increased plasma volume – important for exercise, especially in the heat
- increased volume of haemoglobin – increases the amount of oxygen that can be carried

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- increased capillarisation of muscles – more blood around the muscle increases energy supply and waste removal.

All of these benefits help during exercise and in speeding up the recovery process.

Muscular strength

The simple definition of muscular strength is the ability of a muscle to produce force. This may be a single movement like lifting a box or a more dynamic movement such as being able to tackle a large opponent in rugby.

Figure 15.1 Muscle strength is affected by many factors.

Factors that affect muscle strength

Muscle strength is affected by:

- **age** – males and females are both strongest in their late 20s and peak around 30. After this, there is generally a drop of around 1% per year. This is very much determined by individual training patterns and training history.
- **sex** – when all factors are equal, there is no difference in the strength of males and females. Strength is based more on the cross-sectional area of the muscle. Males, due to elevated hormone levels, tend to have a greater potential to have an increase in muscle cross sectional area.
- **cross-sectional size** – the larger the cross-sectional area of a muscle, the greater the strength.
- **muscle fibre type** – the more fast-twitch muscle fibres, the stronger the muscle.
- **recruitment of fibres** – the larger the nerve impulse, the more muscle fibres that will be recruited.
- **joint angle** – as muscles work in combination with joints, biomechanical principles affect muscle strength. Each joint will have an angle at which the muscle is said to have its greatest mechanical advantage. For a bicep curl, this is around 120°.
- **type of contraction** – the greatest force is produced during an isometric contraction (no shortening).
- **neural adaptations** – most people operate under a system of neural inhibition, and when this is adjusted, strength gains are made. Things such as loud noise, hypnosis and the excitement of competition can all lead to an improvement in muscle strength.
- **training** – helps the body to 'fire' motor units in a coordinated manner. An untrained person will do this in a random, less efficient manner.

Catchy fact
Rather than testing absolute strength, comparing scores as a percentage of body weight is a good way to compare muscle strength of individuals of different sizes.

neural inhibition
the limiting of the motor neuron output, which has many causes, including fear of injury and low confidence; training is very important in decreasing neural inhibition

Muscle endurance

Muscular endurance, on the other hand, is the ability of a muscle or a group of muscles to sustain force production over an extended period of time. A classic test of local muscle endurance in the shoulders is how many push-ups a person can do. Muscle endurance activities are primarily anaerobic in nature.

Local muscle endurance generally only lasts a short period of time before fatigue sets in. Although with such an activity there will be a large rise in the amount of lactic acid in the blood, this is not believed to be the cause of fatigue. Fatigue is more likely to be the build-up of phosphates, ADP and hydrogen ions from anaerobic glycolysis. These compounds limit the ability of the muscle to contract.

Factors that affect muscle endurance

Figure 15.2 A vertical jump is a test of power using anaerobic energy.

Muscle endurance is affected by:

- **age** – recovery of the lactic acid system is not as efficient as you age, so fatigue onset will be sooner the older you get. Muscle strength and contraction efficiency also diminish with age. The age at which an individual reaches maximum muscle endurance is difficult to predict. Some research suggests it is similar to muscular strength (between 25 and 30); however, it is not conclusive.
- **sex** – when muscle size, strength, weight, age etc. are equal, there is no difference in muscular endurance between males and females. A more muscular person, with good fitness, will perform better than a less fit person regardless of the sex of the individuals.
- **temperature** – muscles tend to perform at their optimum at 37°C.
- **muscle capillarisation** – an increase in the amount of blood flow to the muscles will increase performance.

Power

Power is the speed at which we perform a task. It is the combination of the amount of the force produced and the rate with which the force is produced. In biomechanics, power = force × distance ÷ time. The difference between strength and power is, therefore, related to time. Carrying a heavy object up stairs requires strength; how fast you can do it relates to power.

As power is normally an effort completed very quickly, when we talk of power we are generally looking at the anaerobic energy pathways. A vertical jump is a test of power using anaerobic energy.

Catchy fact

The more power and strength work individuals undertake, the more dense bones they have. This is significant in counteracting the effects of osteoporosis.

Course work: Laboratory report

Margaria stair climb test

This is a test of your anaerobic power.

Materials

Stopwatches or switch mats, chalk, bathroom scales

Method

The following procedure is to be followed exactly so that your results can be compared accurately with previously developed norms (Table 15.1). Each person in the class should complete the test.

1 Each student should weigh themselves accurately.

2 The subject stands 6 metres from the stairs.

3 On the command of 'Go', the subject runs up the stairs as rapidly as possible, taking three steps at a time. (Marking them with chalk may help the subject.)

4 Time is recorded as the person steps on the third step and is stopped as they step on the ninth step.

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5 Administer three tests and use the average of the last two in your calculations.

Note: There is always some human error when using stopwatches; switch mats are more accurate.

Table 15.1 Results of Magaria stair climb

Muscle power mass of the subject vertical distance time		
	Males 15–20	**Females 15–20**
Poor	Under 113	Under 92
Fair	113–149	92–120
Average	150–187	121–151
Good	188–224	152–182
Excellent	Over 224	Over 182

Adapted from Margaria *et al.* 1966

Results

1 Calculate your muscle power and compare your results to those in Table 15.1.

2 Across the class, are those with the best results the best sprinters? Why or why not?

3 On the basis of this test, what sport(s) would or would not suit you?

4 What parts of the experiment would you change if you were to do it again?

Extension

Compare the class results with 40-metre sprint times and vertical jump to see if there is a correlation between the tests.

Flexibility

Flexibility refers to the range of motion about a joint. Different joints vary with the amount of flexibility that is possible. The shoulder joint has a large range of movement especially when compared with the wrist joint.

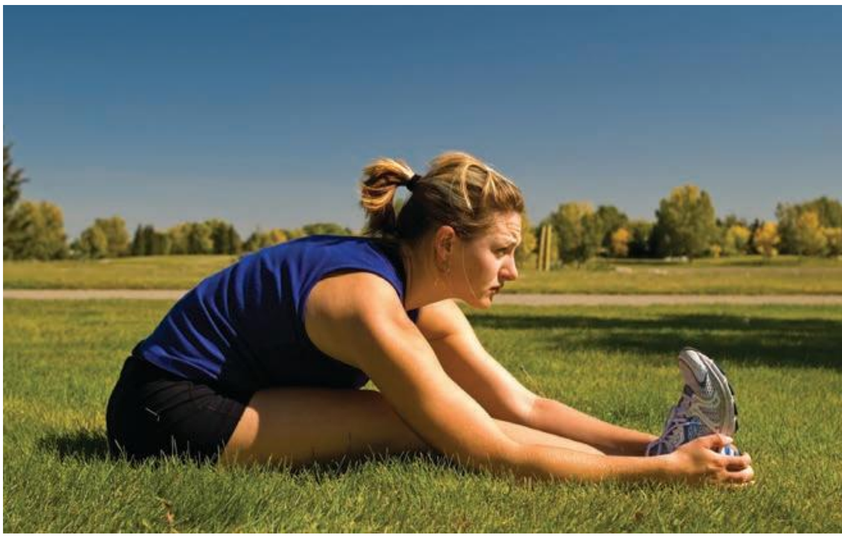

Figure 15.3 Improving flexibility is important for reducing the risk of injury.

Factors that influence flexibility

Flexibility is influenced by:

- **joint structure** – the type of joint is the single biggest determinant of the amount of flexibility there is at each joint.
- **age** – without considerable work, flexibility will continue to decline with age.
- **sex** – females, on average, have better flexibility than males. This is primarily caused by lower levels of testosterone, resulting in less muscle bulk about the joints and higher levels of oestrogen and progesterone, resulting in an increase in joint flexibility.

Catchy fact
Females are more likely to rupture an anterior cruciate ligament than males where increased joint flexibility is a significant contributing factor.

- **body temperature** – an increase in muscle and ligament temperature has a significant positive impact on flexibility. A hot bath will have the same effect as a warm-up run.
- **structure surrounding the joint** – the more muscle tissue and/or adipose tissue there is around a joint, the less flexible it will be.
- **joint damage** – through injury or illness such as arthritis.

Flexibility is a significant issue for many Australians. One of the most common injury complaints in middle-aged men is of the lower back. Much of this can be attributed to poor lower back and hamstring flexibility. For most people, improving flexibility is important in reducing the risk of injury.

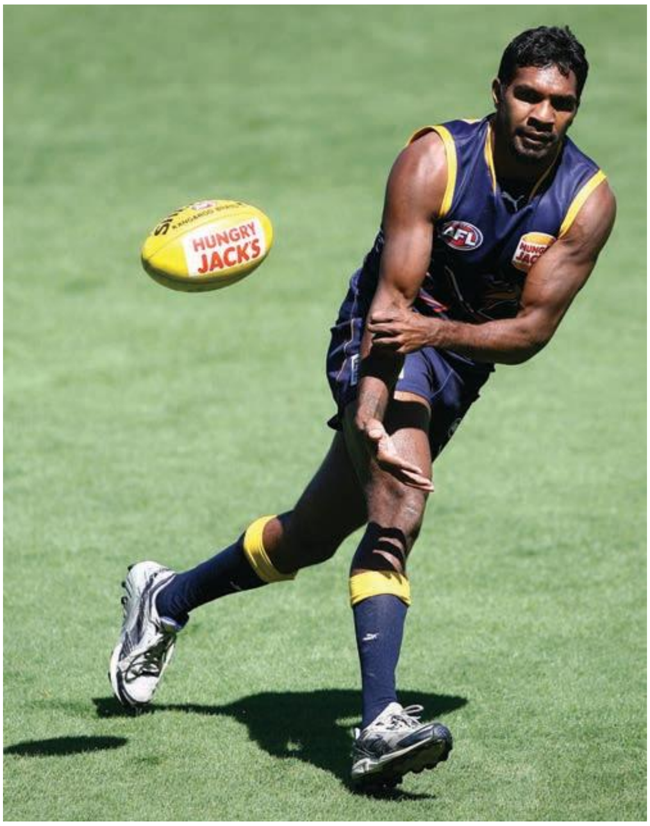

Figure 15.4 David Wirrpanda has a BMI of 28.1

Body composition

Body composition refers to the various proportions of bone, muscle and adipose tissue in the body. There are a number of ways that body composition can be assessed:

- Body mass index (BMI)
- Skinfold measuring
- Body fat scales
- Somatotype

BMI

The BMI method is used to assess if an individual's weight is in the 'normal' range for their height. The following formula is used to calculate BMI:

BMI   weight (in kg)   height squared (in m^2)

A normal range is considered to be between 20 and 25 for males and between 18.7 and 23.8 for females.

There are a number of limitations with this method. Most significantly an extremely fit and healthy person with a high muscle mass may be considered obese and a thin person with limited muscle mass and more fat could be considered in the 'normal range'.

The limitation of the BMI body composition method is highlighted by the example of David Wirrpanda from the West Coast Eagles AFL team. In 2009, he was 173 cm tall and 84 kg; which results in a BMI of 28.1. This classes him as overweight!

skinfold measurement
the use of calipers to measure two layers of skin and two layers of subcutaneous fat; adding a number of sites together gives an overall picture of body fat

Skinfold testing

Skinfold measurement provides an accurate assessment of an individual's body fat. It is a very useful base measure to assess fat loss over time. There are other methods of estimating body fat using a smaller number of sites; however, using these seven sites is more reliable:

- triceps
- biceps
- subscapular
- iliac crest
- abdominal
- thigh
- calf.

Catchy fact
Having too little fat can cause health issues. Many contact sport teams like their players to have skinfold measures of around 50 mm for the above seven sites. A score less than this makes them more susceptible to contact injuries and minor illnesses (colds and the flu).

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As we age, more fat is found internally. Therefore, a similar skinfold score for an older person and a young person would result in the older person having more overall body fat.

Obtaining a body fat percentage using skinfolds

It is possible to predict percentage body fat by using triceps and subscapular skinfold scores and the following equation(s). These equations (adapted from McArdle, Katch and Katch 1990) are suitable for individuals aged 17–26 years.

Males:

% Body fat 0.43 triceps skinfold 0.58 subscapular skinfold 1.47

Females:

% Body fat 0.55 triceps skinfold 0.31 subscapular skinfold 6.13

Catchy fact
When measuring skinfolds, plastic calipers are not very accurate and it recommended you only use quality anthropometric equipment such as Harpenden calipers.

The limiting factor with the use of skinfolds is the ability of the person using the calipers. This takes practice and knowledge. Small mistakes can have a marked influence on the results.

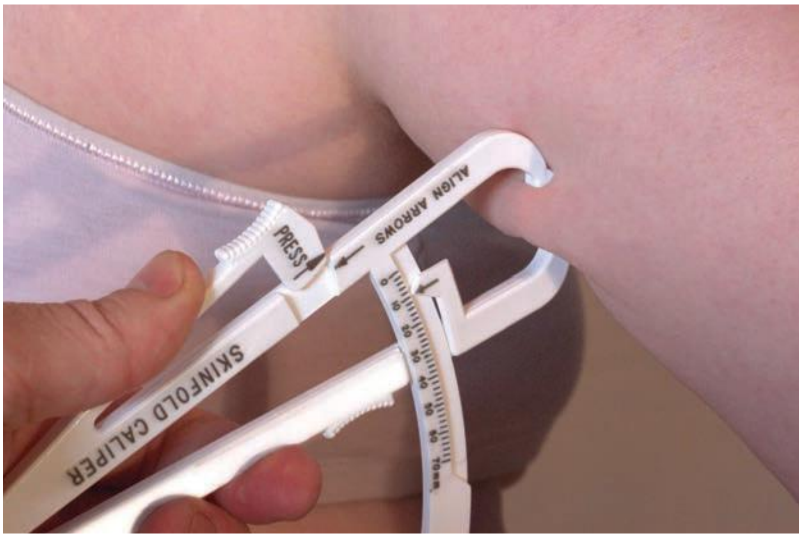


Figure 15.5 Skinfold calipers can be used to measure body fat.

Body fat scales

The last couple of years have seen the development of scales that measure body fat. They work by sending a low level electrical signal through the body, which can determine the percentage of body fat. As different tissues have different amounts of fluid, they conduct the signal at different speeds and strengths. This, combined with height, weight and sex, provides a body fat percentage.

The scales are quite effective; however, changes in body fluid levels will have quite an effect on results. Therefore, it is important to use them at the same time each day when fluid levels are very similar.

Body fat scales

Somatotype

Somatotype is a visual testing method to describe a person's body type. It is rather outdated and is the least effective of the methods. Rather than give an indication of the amount of fat in the body, it rates individuals across a three-way continuum.

People are assigned a score out of 7 in each category. The body types are:

- endomorph (711) – a lot of adipose tissue
- mesomorph (171) – a lot of muscle tissue
- ectomorph (117) – a slender frame.

Most people are not at the extremes and are a combination of the body types. Somatotypes are of most interest when examining what body type is suited to a particular sport or positions within a sport.

Somatotypes

Catchy fact
There is correlation between large abdominal size and the risk of stroke. A waist circumference of more than 102 cm for men and more than 88 cm for women is considered abnormal and a high risk.

Agility

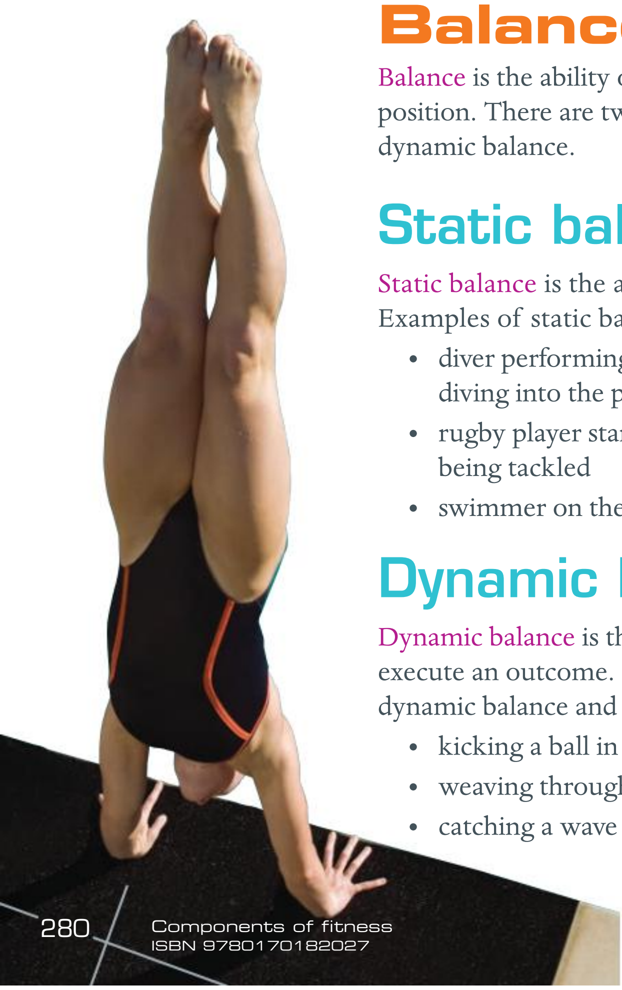
Agility is a combination of balance, speed, flexibility, strength and coordination. A coordinated person is able to combine all of the elements to successfully change direction as required. Muscle strength is critical in being able to stop the body from moving in one direction and quickly move in another.

Figure 15.6 *Slalom poles are used by sporting teams to improve agility.*

Sports that require a considerable amount of agility are evasion games such as netball, hockey, rugby and football.

Training for agility needs to be specific to the sport and most sports can adapt training drills so that they have agility elements within each drill. There are also specialised agility training drills and associated equipment being used by various sporting teams. Examples of equipment used include speed agility ladders and slalom poles.

Figure 15.7 An example of static balance



Balance

Balance is the ability of the body to remain in the desired state or position. There are two main categories of balance – static and dynamic balance.

Figure 15.8 An example of dynamic balance

Static balance

Static balance is the ability to hold a stationary position. Examples of static balance are a:

- diver performing a handstand on the tower before diving into the pool
- rugby player standing and holding position while being tackled
- swimmer on the blocks at the start of the race.

Dynamic balance

Dynamic balance is the ability to hold a moving position to execute an outcome. There is a very close relationship between dynamic balance and agility. Examples of dynamic balance are:

- kicking a ball in soccer
- weaving through opposition players in rugby
- catching a wave on a surfboard.

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Yoga is an excellent activity to help train both static and dynamic balance. There is also specialised equipment available to help with the training of dynamic balance, such as speed ladders and indo boards.

Coordination

Coordination is the ability of an individual to perform tasks accurately and smoothly. Many parts make up a coordinated movement. These include:

- the senses of balance, sight, hearing and feel
- muscle contraction, movement and feedback
- joint movement and feedback.

The development of coordination starts at a very young age, where infants develop general coordination through their experiences. At this time, it is important that parents provide many opportunities for their children to develop the neural pathways that are important for coordination.

Specific coordination skills are generally developed from the age of six. The most critical years of development occur between the ages of seven and 14. It is important that during these years young adolescents participate in as many activities as possible with appropriate coaching. In primary schools the 'Fundamental Movement Skills' approach to teaching is adopted in most schools that have a specialist PE teacher.

Figure 15.9 It is important that children participate in a variety of sports.

infant
a child aged from 28 days to 18 months, although it may be based on developmental age rather than chronological age

Reaction time

Reaction time is the time elapsed between a stimulus and a response. For example, the reaction time of a 100-metre runner is the time between the gun going off and the athlete beginning to move. In biomechanics, once the movement has commenced, this is called movement time.

Catchy fact
In athletics a reaction time of less than 0.1 second is considered a false start.

Figure 15.10 The time between the starter's gun and the athlete beginning to move is the reaction time.

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To improve reaction time, it is important to use the principle of specificity and adapt drills in your training program that focus on reaction time. In cricket, a coach can throw the ball at the batsman from a shorter distance to help improve reaction and movement times.

Speed

Speed is an important factor in a large number of sports. Speed simply is the quickness of movement. How fast a baseball pitcher can move his arm will be significant in determining the speed of the pitch. How fast a runner can move her legs will be significant in determining her running speed.

Technique has an important part to play in the development of speed for athletes. A swimmer who can move their limbs at high speeds will often be defeated by someone with slower-moving limbs but with a technique that pulls appropriately through the water.

Certain things can assist an athlete in improving speed:

- Train all year for speed as the neuromuscular adaptations required for speed is quickly lost. There should be no off-season for speed training.
- General conditioning will help. Having more useable body mass (lean muscle tissue rather than fat tissue) is important.
- Weight training at speed is useful.
- Plyometrics
- Technique work

It is important to remember that it is often difficult to improve the speed of an athlete because of the significant part genetic potential plays.

Figure 15.11 *Australian cyclist Robbie McEwen's technique is important in the development of his speed.*

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Fitness testing

To be able to measure the various components of fitness, an individual will need to undertake some form of fitness testing. The average person may use body composition test to see how they are improving, whereas athletes require specific tests, which may include some body composition tests.

Table 15.2 Tests suitable for each component of fitness

	Fitness test
Aerobic capacity	Cooper's 12-minute run (maximal)
	Harvard step test
	PWC 170
	Astrand-rhyming bicycle ergometer test
	20-metre shuttle-run test (maximal)
	Queens College step test (submaximal)
	Critical swim speed test
	One-mile (1.6 km) jog test (submaximal)
Anaerobic power/speed	Wingate's 30-second cycle ergometer test (maximal)
	Phosphate recovery test
	Running-based anaerobic sprint test (RAST)
	Repco peak power test*
	Sprint standing start tests • 15 metres • 40 metres • 55 metres
	Running 40-metre sprint test
	50-metre sprint test
	30-metre sprint test (maximal)
	Margaria stair climb test
Muscular endurance	Sit-ups
	Push-ups
	Pull-ups
	Modified pull-ups
	Flexed arm hang
Static flexibility	Modified sit-and-reach test
	Shoulder and wrist elevation test
	Trunk and neck extension test
	Ankle extension test
	Shoulder rotation test
	Ankle flexion test
	Hamstring and hip flexor flexibility
	Trunk and neck flexibility

	Fitness test
Muscular strength	Grip strength test
	Core muscle strength test
	Abdominal strength test
	Spring dynamometer
	Cybex dynamometer test
	Maximum bench press
Muscular power	Standing long jump test
	Vertical jump test
Agility	Illinois agility run
	Semo agility test
	Squat thrust test
	VicFit agility test
Body composition	Body mass index
	Percentage body fat: skinfold test
	Underwater weighing
	Somatotyping

Figure 15.12 Push-ups are often used in fitness tests for muscular endurance.

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TEST YOUR KNOWLEDGE

>> multiple choice

1 Which of the following would best be described as a static balance?

A A gymnast on the pommel horse
B A runner mid-stride
C A sprinter lunging for the line
D A swimmer on the blocks waiting for the gun

2 Muscles tend to perform better when the temperature is:

A 37°C
B 36°C
C 38°C
D above 38°C.

3 With regard to flexibility, which of the following is true?

A Males tend to have a higher range of flexibility than females.
B Flexibility tends to increase with age.
C Arthritis has no influence on flexibility.
D As temperature increases, flexibility increases.

4 The Margaria stair climb is a test that may be used to help assess athletes in the sport of:

A swimming
B triathlon
C rugby
D race walking.

>> short answer

5 For a sport of your choice, answer the following.

a List the components of fitness from 1 to 11 based on importance.
b What methods would you use to assess an athlete's fitness level across these components?
c What would be the difference between your assessment of a professional team and an amateur team?

6 What type of exercises would you participate in if you were trying to improve the following fitness components?

a Agility
b Muscular endurance
c Balance

7 In a sport of your choice:

a list three actions in the sport where agility is important
b describe an exercise that would help improve agility in the actions you have listed.

8 In a sport of your choice:

a describe a training drill/sequence where you are able to utilise at least three of the components of fitness
b In your chosen sport what is the most important component and why?

>> essay style

9 Many fitness organisations still use various forms of body composition to quickly evaluate an individual's fitness level. In detail, discuss the various methods available. Include in your answer any limitations of the relevant methods(s).

10 For the following age groups of the general population discuss the three most important components of fitness. Include why these are relevant at that time.

a 0–2 years
b 6–12 years
c 13–18 years
d 18–30 years
e 30–50 years
f 50+ years

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SECTION 6
SPORTS PSYCHOLOGY

Chapter 16 Mental skills for improving performance

2A.20 Understand the mental skills required for improving performance and achieving the ideal performance state ('the zone'); i.e.

- intrinsic motivation
- self-confidence
- stress management
- concentration or attentional control – Nideffer's model
- arousal regulation related to individual performance
- inverted U hypothesis.

2A.21 Understand the mental skills and strategies used to manage stress, motivation, concentration and arousal levels; i.e. self-talk, self-imagery, relaxation.

2B.17 Evaluate the influence of age, skill level and type of activity on mental skills in relation to motivation, arousal regulation (inverted U hypothesis) and concentration.

2B.18 Evaluate and reassess personal goals according to changing situations; i.e. age, skill level, type of activity.

16 Mental skills for improving performance

The ideal performance state ('the zone')

When athletes are in the ideal performance state, they feel totally focused, mentally and physically, on the sport performance at hand. This is often referred to as being in 'the zone'. Within this state, athletes feel confident that they will perform at their best. This chapter will evaluate the mental skills required for improving performance and achieving the ideal performance state. Research within the sport psychology area has consistently highlighted that elite athletes need to develop the following skills:

- Intrinsic motivation
- Self-confidence
- Stress management
- Concentration and attentional control
- Arousal regulation

To develop and refine psychological skills requires systematic training known as psychological skills training (PST), mental toughness training or mental skills training. For the purpose of this chapter, we will refer to PST as mental skills training.

psychological skills training (PST)
rehearsal or practice of a variety of psychological techniques

goal-setting
a set of short-term plans aimed at achieving larger long-term outcomes

Mental skills training

Mental skills training deals mainly with the cognitive behavioural aspects of sport psychology. Psychological skills are identical to physical skills in that they can be taught, learned and practised. Performance can be radically improved by employing mental skills training. Have you ever wondered why on some days you perform with ease and make few mistakes, while on other days mistake after mistake occurs? There is probably very little difference in your physical state or training so the difference must come from variations in your mental state.

Every PST program tends to be different in order to best match a participant's individual needs. PST programs can focus on one or more principles, depending on which areas need improvement. These might include goal-setting, arousal, mental rehearsal, confidence-building and concentration. Programs tend to have three common phases: the education phase, the acquisition phase and the practice phase. The following summary provides an insight into the phases and some ways psychology can improve performance.

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The education phase

This is short (1–2 hours) and involves gauging the level of mental skills practice currently being used by an athlete, and explaining the importance of developing mental skills. It typically involves discussion of how skills such as arousal regulation and imagery are used by elite athletes to maximise their performance levels, and getting the message across that 'it does work and is effective'.

imagery
use of thoughts and images seen through the mind's eye

overlearning
repeated practice of skills – both physical and psychological – which sees them becoming automatic

The acquisition phase

This takes more sessions than the education phase and focuses on how the psychological skills are to be learned by the individual. For example, an athlete prone to unregulated arousal states could be taught how to replace negative statements with positive statements. The next step would be to teach them how to use these positive coping strategies in real-life, competitive settings. This phase is very individualised. For example, if an athlete 'freezes' and suffers from increased muscle tension during competition, physically based relaxation techniques such as progressive relaxation would be taught.

The practice phase

It is best if mental skills become automatic through overlearning, that athletes make them an integral part of their training and that skills are practised to replicate real game scenarios. In the previous example, an athlete could enter the practice phase after they become confident and versed at using relaxation techniques. They could be taken through an imagined competitive situation requiring relaxation and coping skills. Their trainer would take them through a series of progressive relaxation techniques and these should then become self-guided and simulate real game settings. During this phase it is vital to keep a log that records the frequency and perceived effectiveness of the mental skills used in practice and competition and this needs to be part of systematic yearly planning. This then provides feedback for future improvements and training.

PST needs to be systematically planned using yearly planning instruments such as that in Table 16.1.

Motivation

Motivation is defined as the direction and intensity of one's effort (Sage 1977).

- The direction of effort refers to a person's tendency to approach, seek out or avoid a particular situation. Direction incorporates their vision, dreams, goals and reasons for playing sport.
- Intensity refers to how much effort on a continuum from low to high an individual devotes to the situation. The intensity is how 'pumped' or 'psyched up' an athlete is to perform their best.

There are numerous types and models of motivation; however, within this chapter we will focus on intrinsic motivation based on what is referred to as a person-centred model. Intrinsic motivation is the 'fire within' fuelling the determination to stay focused and has a lasting effect on the athlete. Extrinsic motivation is provided by others such as parents, coaches, captains, team-mates or opponents. While extrinsic motivation may provide the inspiration to spark or to light someone's internal fire and desire to perform well, it is unlikely to have a lasting effect. Sustained motivation must come from the athlete themselves, allowing them to set meaningful and challenging goals to achieve their dreams.

Table 16.1 Yearly planning instrument for planning PST

Yearly planning instrument

YEARLY PLANNING INSTRUMENT (for mental aspects)						
NAME OF ATHLETE:			**LEVEL:**		**DATE:**	
1	DATES	MONTHS	SEPTEMBER / OCTOBER / NOVEMBER	MAJOR COMPETITION	DECEMBER / JANUARY / FEBRUARY	MAJOR COMPETITION
2	EVENTS	Week date				
3		COMPETITIONS				
4						
5						
6						
7						
8						
9	Training	Training phases	BU / AC / TR		AR / BU / AC / TR / T	
10		Macrocycles	MACRO 1		MACRO 2	
11		Microcycles	1 2 3 4 5 6 7 8 9 10 11	12	13 14 15 16 17 18 19 20 21 22 23 24 25	26
12	Dev. of skills	Technique skills	STROKE TECHNIQUE / SPECIFIC STROKE TRAINING / STROKE SPEED / STROKE REFINE		STROKE TECHNIQUE / SPECIFIC STROKE TRAINING / STROKE SPEED / MAINTAIN STROKE	
13						
14	Mental prep.	Pace strategies	PACE JUDGEMENT / DEBRIEF / REVISE TACTICAL STRATEGIES		DEBRIEF / PACE JUDGEMENT / DEBRIEF	
15		Peri. routines	TEACH ROUTINES / APPLY ROUTINES		REVISE ROUTINES / IPS / APPLY ROUTINES	
16		Psych. train.	TEACH MENTAL SKILLS		TEACH REVISE MENTAL SKILLS: COPING SKILLS	
17		Weekends	PRESEASON INTERVIEW / PERSONAL CONSTRUCT MONITORING		EVALUATING / REFINEMENT	
18		Profiling	PROFILING		LOGBOOKS / TRAINING AND COMPETITION REFLECTIONS	
		Awareness exercises	AWARENESS EXERCISES / JOURNAL			
19	Mental training	Goal-setting	GOAL-SETTING PROCESS		RESET GOALS	
20		Relaxation	TEACH EMOTIONAL CONTROL / APPLIED SKILLS		PROBLEM-SOLVING / APPLIED SKILLS	
21		Self-talk	TEACH COGNITIVE CONTROL / RELAXATION		RELAXATION SKILLS / RELAXATION	
22		Imagery	TEACH IMAGERY SKILLS / SELF-TALK		TEACH AFFIRMATION / SELF-TALK	
23		Attention control	TEACH CONCENTRATION SKILLS / IMAGERY / ATTENTION		IMAGERY VIVIDNESS CONTROL / IMAGERY / ATTENTION	
24		Assessment	SELECT PSYCH TESTS		SELF-ESTEEM, CONFIDENCE	

Key: BU = Build-up phase; AC = Accumulative phase; TR = Transition phase; T = Taper phase; R = Recovery (A = Active: P = Passive)

Adapted from Spittle 2008

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To achieve success, athletes 'have to' and 'want to' train for long hours, even when they don't feel like it, and compete and reflect on their performances; this requires a high level of motivation. Motivation is closely linked to goal setting, which is described in *Nelson Physical Education Studies for WA 3A, 3B*, Chapter 16. Athletes need to determine what it is they want to achieve by developing sporting goals. When times get tough, it is the overall big picture or long-term goal that provides athletes with motivation to continue. Motivation is the foundation of all the other PSTs; without it, the other skills will not develop. Without sufficient motivation, the athlete will not train effectively or consistently or perform well under the pressures of competition.

Person-centred models (intrinsic motivation)

This model assumes athletes' personal factors, characteristics and underlying disposition (i.e. traits) determine the level of motivation. Player behaviour is considered a sign of their underlying traits and personal factors. In other words, a performer's interests, personality, needs and goals are the fundamental determinants of motivation. The person-centred model suggests that one either has motivation or hasn't and that it cannot be developed.

Situation-centred models (extrinsic motivation)

Within this model, situational factors and external influences such as the coach, spectators, opponents and captain cause a behavioural response by the performer. This model assumes all motivation is provided by factors external to the athlete and that they have no control over their level of motivation. While most athletes would agree that situations can affect motivation levels (such as a boring training session), there are also situations that do not provide motivation and yet the player's internal motivation means that they remain motivated. The situation-centred model is not widely accepted by sports psychologists.

behavioural
anything one does as a result of a specific situation

Interactional model (person situation)

The most widely endorsed view is that motivation is a function of the athlete's characteristics, the situation and the interaction between the two. The model is based on the assumption that there is an interaction between the performer and the situation and implies that people can change situations and that situations can change people. For an athlete to truly understand what motivates them, they must first know the reason they play sport.

Guidelines for building motivation

Table 16.2 provides a summary of five guidelines for teachers, coaches, trainers, exercise leaders and program leaders that can be employed to build motivation.

Table 16.2 Guidelines for building motivation

	Guideline
1	**Recognise that both situations and personal factors motivate people.** Sometimes low motivation is due to personal factors, other times it is due to the environment in which people are participating. It is usually easier to modify the situation (environment) than individual personal factors.
2	**People have multiple motives for involvement.** Attempt to understand people's reasons for participation. They may participate for several reasons and have factors competing for their time.
3	**Change the environment to enhance motivation:** • Provide both competition and recreation. • Provide opportunities for fun. • Tailor programs to cater for individuals within groups.
4	**Leaders influence motivation.** Enthusiasm is contagious.
5	**Use behaviour modification to change undesirable participant motives:** • Reward desirable behaviour. • Punish undesirable behaviour such as rough and dangerous play during games.

Sports psychology

Checkpoints

1 Athletes often refer to their best performances occurring when they are 'in the zone'. Describe the notion of an ideal performance state.
2 Describe the phases associated with mental skills training.
3 Define motivation and outline its components: direction and intensity.
4 Explain the difference between a person-centred model and a situation-centred model for motivation.
5 Outline the five guidelines for building motivation. Select one and provide an example of how you could apply one of these guidelines to your own participation in physical activity.

Self-confidence

Self-confidence is an individual's belief that they will be successful. Confident players believe in themselves and their abilities, both physical and mental, to reach their potential. Self-confident people exhibit positive emotions. They remain calm and focused under pressure, are more likely to work to achieve their goals and remain on task for long periods of time. Confident people are more likely to take calculated chances during their games and adopt a 'never give-up' attitude.

Confidence levels and performance attainment closely reflect the inverted U-shape demonstrated by the arousal theory (see Figure 16.1). It is therefore important that athletes reach the optimum confidence zone and are not under- or over-confident.

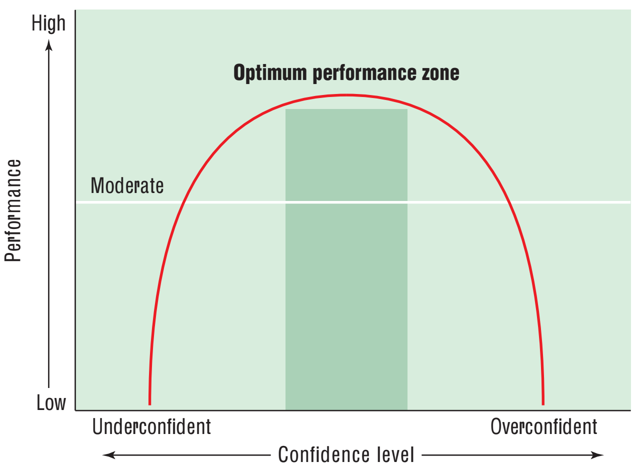

Figure 16.1 The inverted U, illustrating the relationship between confidence and performance

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Self-confidence and motivation are closely linked. Highly motivated performers tend to display a high level of self-confidence about their sporting ability. Within this chapter, we will see how self-confidence develops intrinsic motivation. It is essential that athletes develop both situation-specific self-confidence and global self-confidence. There are several models that are used to explain self-confidence. This chapter provides an overview of two of these models: Bandura's theory of self-efficacy and Harter's competence motivation theory.

situation-specific self-confidence
believing you can succeed at a specific task. For example, the golfer who enjoys situation-specific self-confidence truly believes that they can sink a putt from four meters away when they need to par the hole

global self-confidence
a disposition or personality trait; although someone can exhibit a great deal of global self-confidence they may not achieve success at a specific sport or task

Bandura's theory of self-efficacy

Self-efficacy was defined by Albert Bandura (1997) as 'belief in one's capabilities to organise and execute the courses of action required to produce given attainments'. Self-efficacy is an example of situation-specific self-confidence. To develop self-efficacy, an individual must feel in control and that their actions are intentional. If a person believes that they have control and the power to make things happen, this will motivate them to try. Figure 16.2 displays the relationship between factors leading to self-efficacy beliefs and sporting performance.

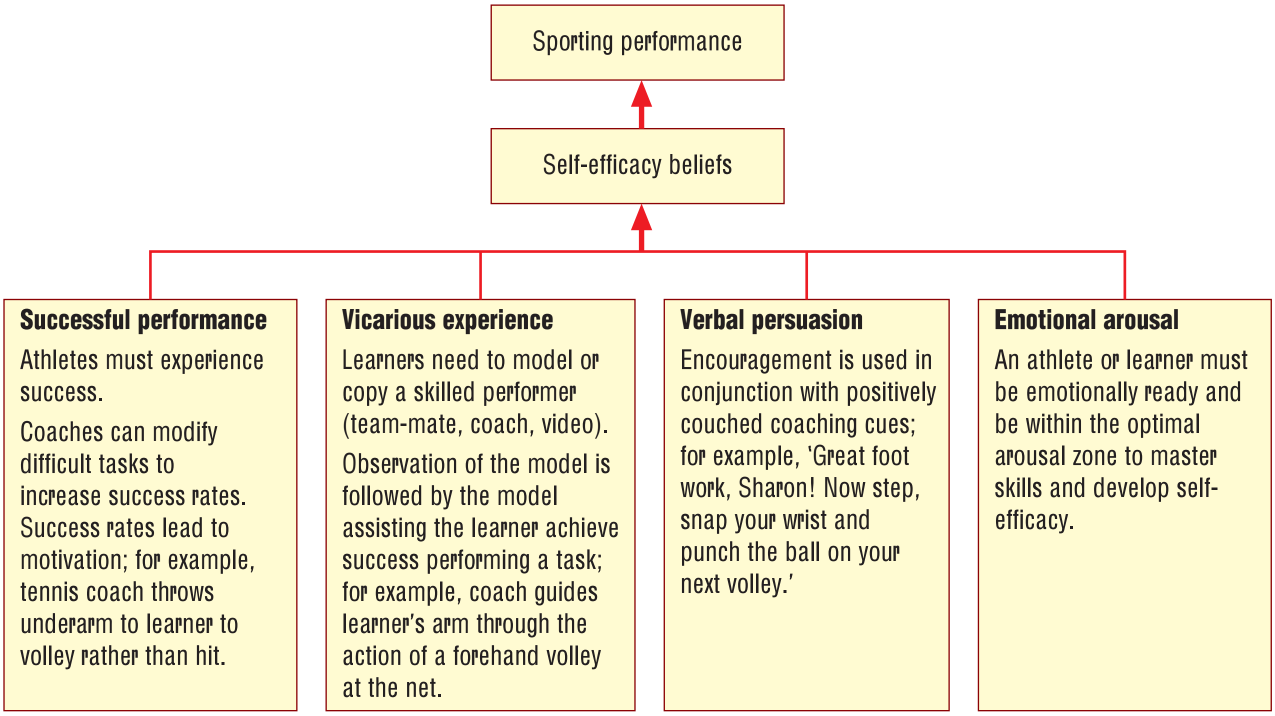


Figure 16.2 Factors influencing self-efficacy in sporting performance

Compared to athletes with poor self-efficacy, athletes displaying high self-efficacy:

- train harder
- persist at challenging tasks longer
- achieve greater success
- have higher global self-confidence.

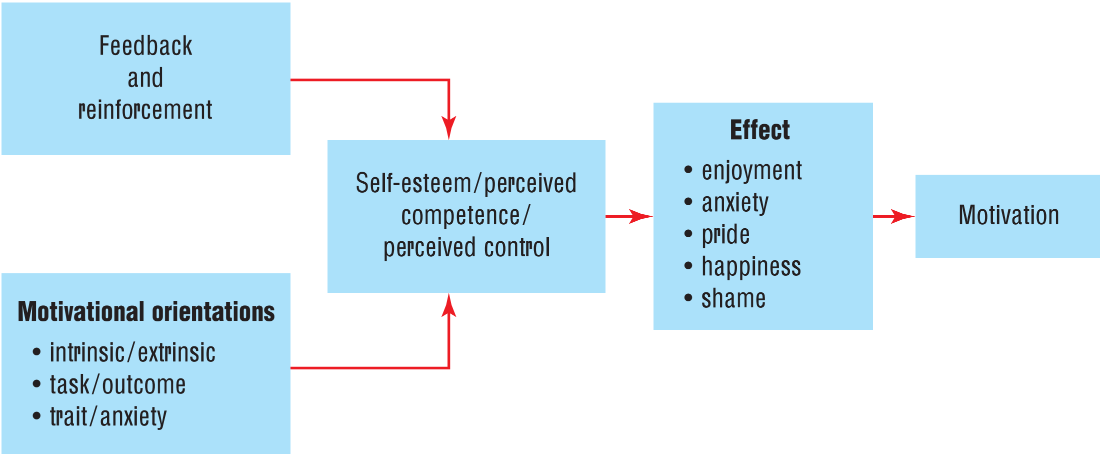
Strategies for increasing self-efficacy include:

- providing quality instruction
- acting confidently
- encouraging positive self-talk.

Harter's competence motivation theory

Previous research has demonstrated a link between competence and motivation. Developmental psychologist Susan Harter (1981) proposed a theory based on an individual's feeling of personal competence. Harter contends that people are innately motivated to reach mastery. Figure 16.3 illustrates that increased feelings of personal competence (perceived competence) affects a person's emotional state by increasing their enjoyment, pride or happiness. This in turn increases the motivation to continue to improve their competence towards reaching mastery.

Figure 16.3 Competence motivation theory



The competence motivation theory also explains what happens particularly to a learner when they experience low success rates and their perceived competence is low. This is associated with an increase in anxiety or shame and in turn can decrease the individual's motivation. An effective coach designs training programs to ensure athletes experience success; this increases the athlete's feelings of self-esteem, self-worth, perceived competence and control over their learning and thus motivates them to continue. Generally, a success rate of 80% is recommended to motivate learners to continue to try.

stressor
any stimulus or condition that causes physiological arousal beyond what is necessary to accomplish the activity

Stress and stress management

Before we think about how we manage stress, we need to have an understanding of what stress is. There are many theories of stress; however, according to physiologist Hans Selye, stress may be defined as a non-specific response of the body to any demand made upon it. His stress model is referred to as the general adaption syndrome. Within this model, Selye proposes three stages: alarm reaction, resistance stage and exhaustion. Table 16.3 characterises each stage within Selye's model.

Table 16.3 The three stages of stress in the general adaption syndrome

Stage	Description
Alarm	The body reacts to the stressor by releasing chemicals within the brain responsible for influencing heart rate, blood pressure and other physiological responses.
Resistance	Resistance develops if the stressor is not excessive and the body adapts to rebuild, adjust and repair itself in preparation to fight a similar subsequent stress.
Exhaustion	Exhaustion occurs when the exposure to the stressor is prolonged over an extended period.

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We all need desirable stress during our lives to function effectively. You will notice that most of the physiological reactions to stress shown in Table 16.4 are also acute responses to exercise. To build muscle and develop the cardiovascular and respiratory systems, the body needs to be put under regular desirable stress. It should be understood that stress is a perfectly normal human state. Usually the most rewarding emotions or greatest feelings of satisfaction or disappointment are associated with varying levels of stress. Excessive stress can result in anxiety.

anxiety
an emotional state characterised by negative feelings of nervousness, worry and apprehension

Table 16.4 Physiological and behavioural reactions to stress

Physiological reactions	Behavioural reactions
• Increased heart rate • Increased perspiration • Increased blood pressure • Dilated pupils • Increased stomach tension (knot in stomach) • Increased difficulty swallowing (lump in the throat) • Increased tightness of chest	• Change in normal speech patterns • Temporary loss of memory (mental block) • Distorted facial expressions (tics, twitches, grimaces, biting lip) • Frequent spitting • Shaking fists and flailing of the arms • Pacing around • Bashing chairs or equipment • Stomping the feet

KEEP IT REAL!

It feels good to win!

In the bottom of the ninth inning of the World Series deciding match, the baseball game is tied at three runs each, two batters out, bases are loaded with runners, and the winning run is at third base. The batter pops the winning hit over the left fielder's head to score the winning run and win the World Series. Immediately, one team experiences an extreme state of happiness and euphoria as a result of their brains releasing endorphins. In contrast, the losing team experiences intense feelings of depression as a result of the blood becoming saturated with depressive chemicals.

Figure 16.4 Winning often leads to feelings of elation.

A large array of factors could potentially cause an athlete to feel stressed; factors can be classified as players, performance factors, time and outside influences. For example:

- not feeling prepared due to inadequate preparation and training
- team-mates not performing well or lacking dedication

- team conflict
- opponents behaving poorly
- losing games that should have been won
- poor decision-making by the coach
- poor officiating
- criticism by other players or the press
- not having enough time for a social life.

Figure 16.5 *Poor officiating can increase athletes' level of stress.*

Checkpoints

1 Describe the inverted U relationship between self-confidence and performance.

2 How did Albert Bandura define self-efficacy?

3 Identify three strategies for increasing self-efficacy.

4 Describe Harter's competence motivation theory. Provide an example of a physical activity that you are competent at and comment on how this affects your level of motivation to participate in that activity.

5 Identify four factors that may cause an athlete to feel stressed and provide a specific example of how you have experienced stress due to one of these factors.

6 Explain the difference between a physiological and a behavioural reaction to stress. Provide three examples of each.

Stress-management strategies

Now you understand that stress is a natural part of life and competition and the causes are varied – some can be controlled by the performance but others cannot. Successful performers focus on the factors they can control and practise routines to develop stress-management skills.

The first key components of stress management are to maintain a healthy lifestyle that includes healthy eating, regular exercise, plenty of sleep and taking the time to relax

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mentally and physically. Relaxation is an important part of stress management. Relaxation occurs when one experiences deep muscle relaxation. This state involves lowering of brain and spinal cord activity as a result of a reduction of nerve impulses running between the brain and the muscles, joints etc. The following sections outline several techniques that can be used to assist people to relax and reduce their stress levels.

Progressive muscle relaxation

This technique is probably the most commonly used relaxation technique by athletes. Progressive muscle relaxation (PMR) involves comparing the difference between tension and relaxation. PMR involves several steps that need to be learnt over time and requires 20–30 minutes daily to be practised effectively. Some people practise these skills before going to work, others before going to sleep. It is essential to have a suitable comfortable location to practise these skills. Learning to identify which muscle groups exist and how to tense and relax them takes time. Muscles should be tensed for 4–8 seconds. Controlled deep and slow breathing should also be used during PMR.

The following is a method for progressive muscle relaxation.

KEEP IT REAL!

Progressive muscle relaxation (PMR) script: Muscles of the trunk

Included in this group are the muscles of the back, chest, abdomen, and pelvis. Here are ways you can tense some of these muscles:

1. Bring your chest forward and at the same time put your shoulders back with emphasis on bringing your shoulder blades as close together as possible.
2. Try to round your shoulders and bring them up to your ears at the same time as you try to bring your neck downward.
3. Give your shoulders a shrug, trying to bring them up to your ears at the same time as you try to bring your neck downward.
4. Breathe deeply and hold it momentarily and then blow out the air from your lungs rapidly.
5. Draw in your stomach so that your chest is out beyond your stomach. Exert your stomach muscles by forcing out to make it look like you are fatter in that area than you are.

Source: Humphrey *et al.* 2000

Coursework

1. Using the PMR script above, participate in a PMR session as a class.

Mental practice and imagery in relaxation

Mental practice involves the rehearsal of a physical activity in the absence of an overt muscular movement (Humphrey *et al.* 2000). An individual therefore imagines the way they will perform a specific activity. Imagery is the development of a mental image that will enhance performance of an activity. During mental practice, a swimmer may think through what they are going to do during a 100-metre freestyle race. Within imagery, the swimmer may form a mental image of the conditions and context of the race and how they will perform under these conditions. For example, they could imagine another swimmer in front of them before the turn and also imagine how they are going to perform the turn to gain ground and maximise their push off the wall for the final 50 metres. Imagery can be used to obtain a state of relaxation. The athlete could imagine they are going to relax various muscle groups, and then follow by doing so. Imagery could also be used to promote a relaxed state by using comparative statements such as 'Melt like ice into the chair' or 'Float like a feather'.

Figure 16.6 *Meditation is a powerful stress-management strategy.*

Meditation

Meditation has been used for more than 2000 years within eastern practices for its powerful impact on the mind, body and soul. Meditation involves the exercising of an individual's attention. Meditation gives the mind a rest while it allows a temporary shut-down of cognitive processes such as decision-making. Concentration is the most important factor to ensure success while meditating. Concentration must be highly developed to control the natural flow of the brain to go from one idea to the next and lower brain activity to eliminate all random thoughts that continually pop into the mind. There are many types of meditation used by athletes.

The process of meditation involves focusing your concentration onto one specific thing such as a sound or the shape of a bird or a beautiful peaceful place. Some people like to chant a word or phrase (mantra) during their meditation session. It is important to practise during a quiet time of day, not immediately after a very active state.

Reducing stress through biofeedback

This technique is used far less by athletes than the other relaxation techniques already mentioned. Biofeedback training is highly complex and can only be conducted in the presence of a trained person. PMR and biofeedback technique can also be used during arousal reduction. Biofeedback training involves electronic technology. This is a physically based technique used to modify physiological or autonomous body functions during training and carry this over into competition. Electronic instruments provide athletes with auditory or visual feedback on a range of physiological parameters such as heart rate, muscle tension and skin temperature. These electronic devices either give a direct reading or emit sounds relative to the intensity of the stimulus.

For example, during training a baseball pitcher might feel tension in their shoulder and neck muscles. Feedback from attached electrodes is provided via a loud beeping noise. By using relaxation techniques, the pitcher can try to reduce the intensity of the noise as their muscles become more relaxed. A log is kept, outlining which relaxation techniques are most effective at reducing tension and these are practised and implemented during game situations to bring about effective pitches. Rifle shooters also use biofeedback to improve performance. They become aware of their heartbeat (electronic signal/feedback) and after practice can fire in between beats, leading to improved performance levels. Essentially, after much training

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and experience, biofeedback enables athletes to become more tuned to their physiological functions and bring these under their control more effectively.

Behaviour modification and stress reduction

Some people display behaviour that can cause stress either within themselves or to people around them. Behaviour modification means trying to change undesirable behaviours via external influences such as environmental factors such as a teacher, coach or counsellor (Humphrey *et al*. 2000). A psychologist, for example, may assist an individual to undertake a journey of self-exploration to identify any concerns associated with meeting personal goals, self-esteem, changing values, social needs, personal competence and ability. Once an individual has a better understanding of their self-concerns they can be assisted with strategies to change their behaviours. Steps to behaviour modification include:

- identifying behaviours (e.g. athlete hanging their head after a poor shot in squash)
- counting the behaviour (e.g. how often is this occurring), identify what factors occur right before this behaviour is displayed and the consequence (what follows the behaviour) (e.g. a decline in performance and further frustration)
- changing behaviour, which requires a plan that usually involves a reinforcement schedule. For example, after a poor shot the athlete could use the positive self-talk 'Head up' to remind themselves not to hang their head. Many behavioural modification programs include the use of rewards for desirable behaviour and punishment for undesirable behaviour
- evaluating the intervention program; assessing whether the strategies used decreased the undesirable behaviours.

Concentration

One of the best definitions of concentration (Solso 1995) contains three parts:

- Focusing on relevant environmental cues – this is also known as selective attention and enables players to block out irrelevant cues such as spectators and other noise
- Maintaining attention focus over time – this involves maintaining focus over extended periods of time and not allowing concentration lapses to occur
- Having awareness of the situation – this is the ability to size up a game situation, opponents and other environmental factors and bring about the most appropriate response. For example, elite athletes are able to 'do the right thing at the right time' during games, even under pressure-packed conditions. This notion is also referred to as being able to 'read the play'.

You can see that concentration and attention are used interchangeably, and this commonly occurs in the field of psychology. Nideffer (1976) described attention in sport in terms of width and direction. The width describes how narrow or broad the attention is and the direction describes either an internal or an external focus.

With this model there can be four possible types of attention:

- Broad-internal focus – used to focus on thoughts and feelings (e.g. a fast bowler preparing to run into the wicket to bowl)
- Broad-external focus – used to focus outwards on an opponent's actions (e.g. watching an opponent try to make a fast break in a cycling race)
- Narrow-internal focus – used to focus thoughts and mentally rehearse upcoming movements (e.g. a springboard diver)
- Narrow-external focus – used to focus on very few external cues (e.g. a footballer waiting to take an unopposed chest mark focusing on the ball)

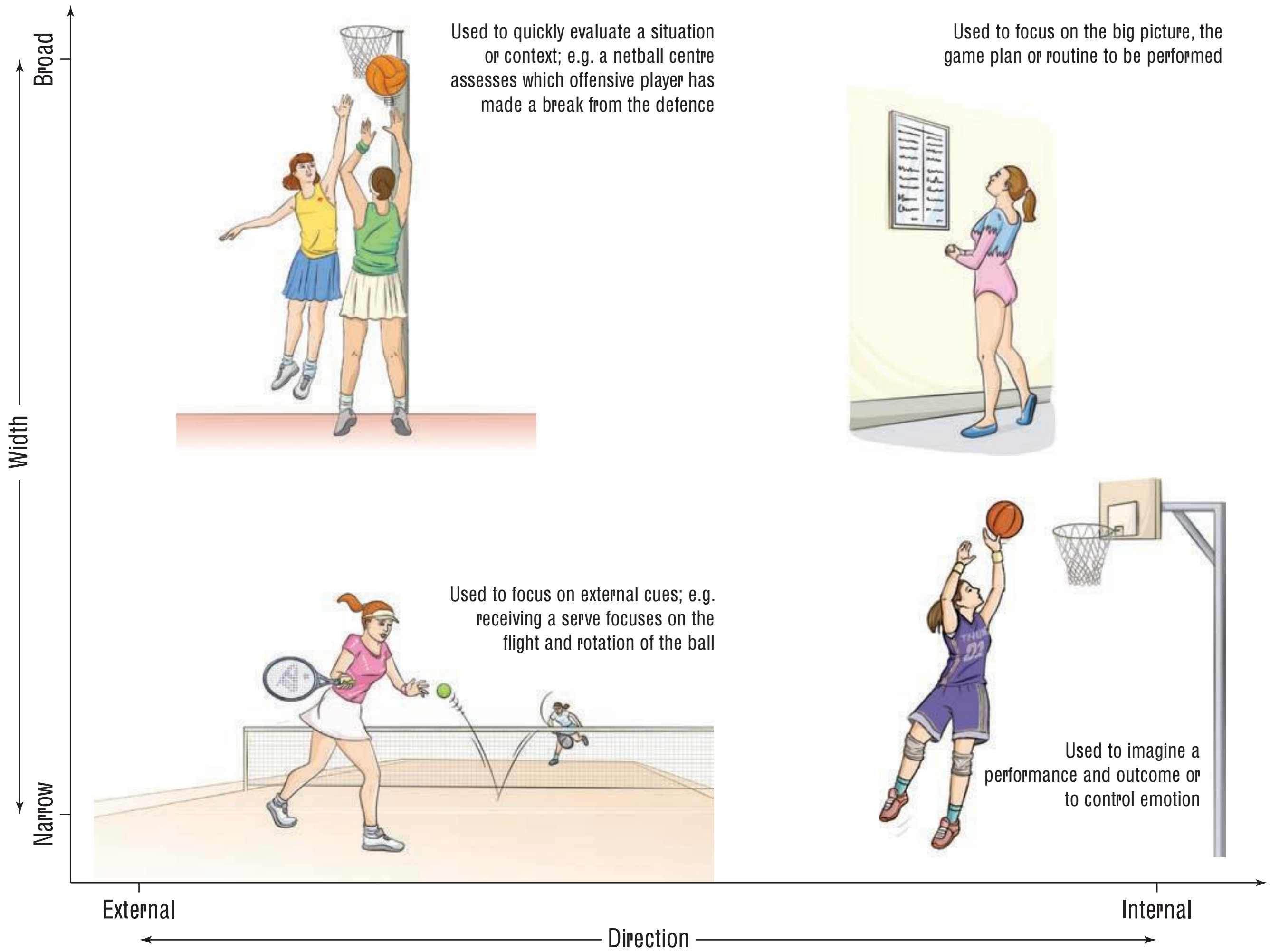

Figure 16.7 Four types of attention mode

future-oriented thinking
thinking ahead of time about what you are going to do and what might happen

In any situation an athlete needs to shift their attention to meet the demands of the environment. Many factors can lead to an athlete experiencing inappropriate attentional focus, and their performance can deteriorate as a consequence. This might occur because they focus on past performance errors and are not able to 'let things go'. It is easy to remember, 'The last time I did this, I made this mistake', or 'I hope that doesn't happen again'. Sometimes distractions are caused by future-oriented thinking. This is typically expressed by 'what if' thoughts: 'What if I get injured?'; 'What if I fail?'; 'What will the rest of my team think if …?' By focusing on the negatives, concentration drops, and performance follows suit. An example of future-oriented thinking is when a cricketer misfields the ball because they have already started to think about the throw to the wickets.

Niddeffer's theory of attentional and personal style

Robert Niddeffer's theory of attentional and personal style, developed in 1976, explains the relationship between cognitive processes, emotional arousal and performance (Howland 2006). The theory nicely incorporates the association between physical and mental components of performance. Physical components of performance might include the execution of motor skills and mental components could include decision-making or problem-solving.

The seven theoretical constructs of Nideffer's theory are as follows:

1 Attentional focus or focus of concentration shifts along two dimensions: width (broad to narrow) and direction (internal and external) (Figure 16.7).
2 Each person can develop all four attentional styles, and individuals have preferred attentional styles.

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3 Different performance contexts place different demands on the four attentional styles and require different amounts of shifting between the four styles.
4 With increasing levels of arousal, shifting between the four styles breaks down, resulting in an involuntary narrowing and more internal focus.
5 Perceived passage of time passed is associated with the amount of shifting that occurs between external and internal focus.
6 Being 'in the zone' and performance 'flow' depend on an individual's ability to move smoothly between physiological and cognitive transition points.
7 Interpersonal and intrapersonal performance-relevant characteristics are predictors of situations an individual will find emotionally stressful. Behaviours that athletes rely on most are exhibited during emotional stress.

Concentration and skill level

Research conducted in the United States (Castaneda and Gray 2007) examined the effects of attentional focus on baseball batting performance in players of differing skill levels. Subjects were less skilled and highly skilled (college) players. Batting performance during four dual-task conditions was assessed. The batter had to focus their attention on two skill-focused tasks and two environment-focused tasks:

1 Skill/internal focus – concentrating on the movement of the hands
2 Skill/external – concentrating on the movement of the bat
3 Environment/external – concentrating on auditory tones
4 Environment/external – concentrating on the ball leaving the bat

The findings of the research suggest highly skilled players performed best when their attentional focus was in the environmental external condition, whereas less skilled players performed best during the two skill focus conditions. In conclusion, the optimal focus of attention for highly skilled players is one that does not disrupt the performance of the skill but also allows the batter to focus on the environment (e.g. the flight path and rotation of the ball, the release point of the pitcher's hand, position of the fielders). In contrast, the optimal focus of attention for less-skilled players is one that allows attention to the step-by-step execution of the swing (Castaneda and Gray 2007).

Other research that has compared internal and external focus conditions in athletes with differing levels of experience or skill level has reported that experienced players benefit more within an external focus condition. This has been reported across a range of different types of activities including volleyball, tennis, soccer (Wulf *et al.* 2002) and golf (Perkins-Ceccato *et al.* 2003).

KEEP IT REAL!

Case study

An Australian study (Abernethy and Russell 1987) two decades ago made the unique finding that skill level was associated with attentional and anticipation tasks. The study compared 25 experts with 25 novice racquet sport players. The expert group participated in the 1982 Commonwealth Games badminton competition held in Brisbane in 1982. The novice group consisted of undergraduate physical education students.

Participants were shown a perceptual film of badminton strokes and were asked to predict the landing position of the shuttle based on what they observed. The findings showed that experts were more successful at predicting the landing positions than the novices. Researchers suggest this may be because the experts had developed an ability to pick up cues earlier from experience and prior knowledge.

Research conducted at the Australian Institute of Sport (AIS) examined concentration among AIS athletes and non-athletes aged 11 to 60 years (Tenenbaum, 2001), with a mean age of 23 years. Researchers were interested in examining how concentration levels varied by age, gender and skill level. Researchers found that:

- AIS athletes under the age of 17 were more focused and less likely to become distracted compared with non-athletes the same age
- external awareness increased consistently with increasing age
- concentration increases with age
- young athletes were more likely to make mistakes because they were externally distracted
- older athletes (24 years and over) were more likely to make mistakes because they were thinking too much, and became too narrowly focused.

Choking

choking
a situation where performance deteriorates because a heightened sense of pressure or importance is placed on an upcoming event or action

Choking can also cause concentration to falter. This occurs when athletes sense a build-up of pressure or there is a lot depending on the outcome of the next phase of play. Increased pressure often results in focus shifting to internal and narrow, and the ability to shift attention focus decreases. Impaired timing and coordination, fatigue, muscle tension, negative self-talk, decreased selective attention and poor judgement and decision-making usually accompany choking (see Figure 16.8).

Strategies for improving concentration are described in *Nelson Physical Education Studies for WA 3A, 3B*, Chapter 15.

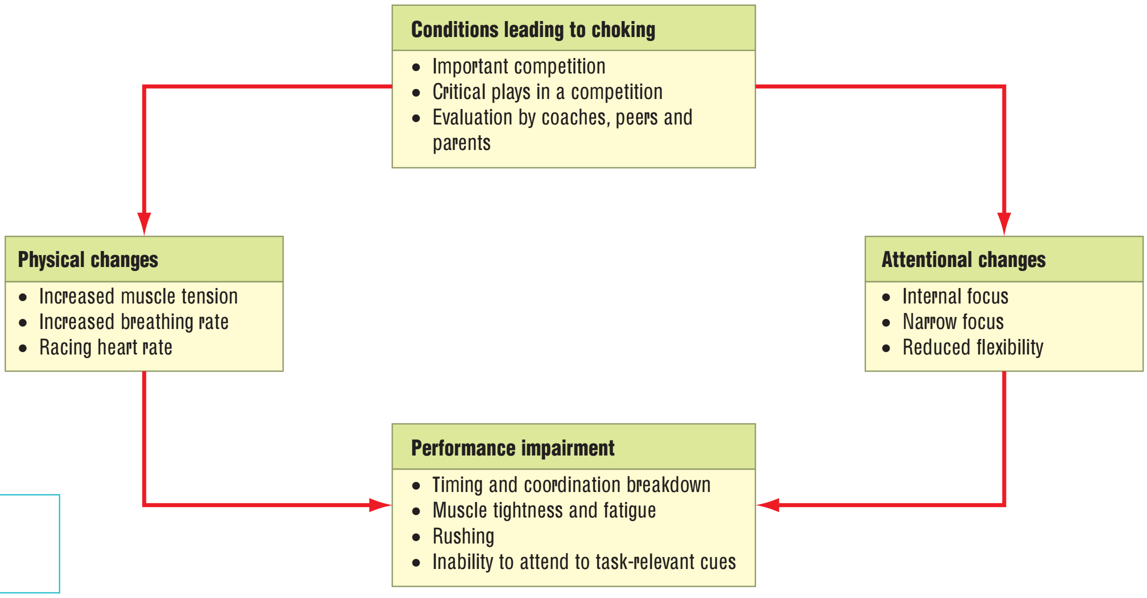

Figure 16.8 The choking process

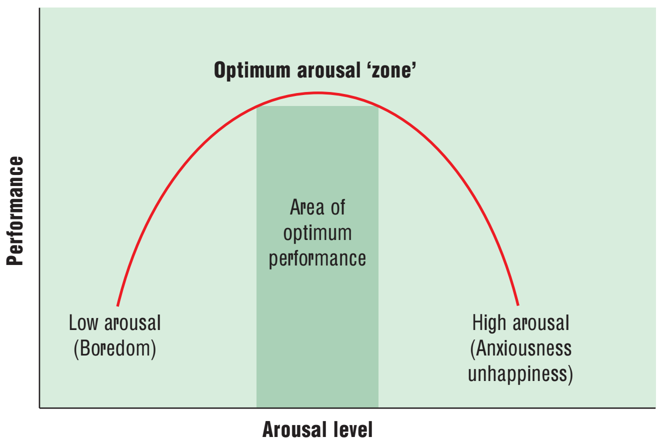

Figure 16.9 The relationship between arousal and performance – notice the optimum arousal zone

Arousal

Arousal is the amount of readiness or activation a person experiences when faced with a task. Athletes need an optimal level of arousal to experience success. The relationship between arousal and performance is seen in Figure 16.9. This is commonly referred to as the 'inverted U' hypothesis (or graph). (See also page 101.)

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As you can see, a zone of best performance exists at a moderate level of arousal. Keeping within this zone ensures sufficient arousal to give a high-quality performance, while not being over-stressed and off task. This zone is individualised and in a different place and different shape (heights and widths) for different people. Some people may operate most effectively at a level of arousal that would leave other people lacking motivation or interest. It is likely that someone who performs well in low-level competition might experience difficulties in high-level competition. Alternatively, someone who performs only moderately at a low level of competition might perform better under more pressure.

If the level of arousal is low, performance is likely to be poor. People show low levels of arousal when they lack motivation or are bored, tired or not directly involved in the action of a team game. Muscles feel heavy and lethargic, concentration drops, enthusiasm decreases and apathy rises. Conversely, if high levels of arousal are experienced, performance will also suffer and most likely not be optimal. This often happens to people who are tense, highly excited and/or anxious. Muscles become tense, movements jerky, coordination drops and mistakes increase. Under these conditions, the activity can become threatening and unpleasant and result in poorer performances.

Athletes must take responsibility for controlling their own arousal levels, particularly in a team situation. If some members are in their optimum zone, paying attention to a coach's motivating half-time talk may move them to a state of being over-aroused. Similarly, if some team members need to be relaxed, applying relaxation techniques to the entire team may move others to a state of demotivation.

demotivation
reversal from a state of being motivated and aroused

Activity type, skill level and arousal

Arousal level is influenced by different factors such as activity type and skill level. Different sports are likely to require different levels of arousal to optimise performance. Figure 16.10 shows arousal levels of athletes performing different tasks in different sports. Notice how the optimum level of arousal to kick a field goal in American football is considerably lower than the level of arousal required to perform a clean and jerk in weightlifting at an optimal level.

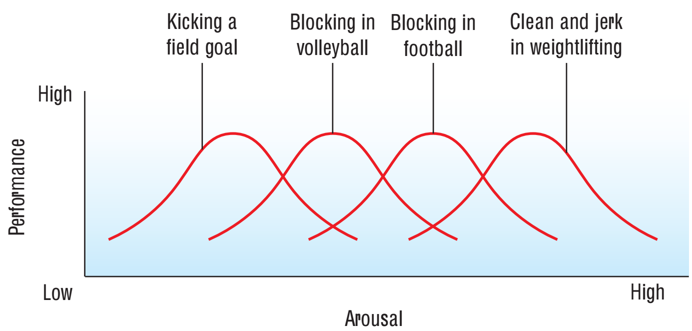

Figure 16.10 Optimal arousal levels required for various sports

In Figure 16.11, even within the same activity, rifle shooting, arousal levels vary significantly by skill level with the more advanced shooter being able to tolerate a much higher level of arousal than a beginner, who needs a much lower level of arousal to perform at their best.

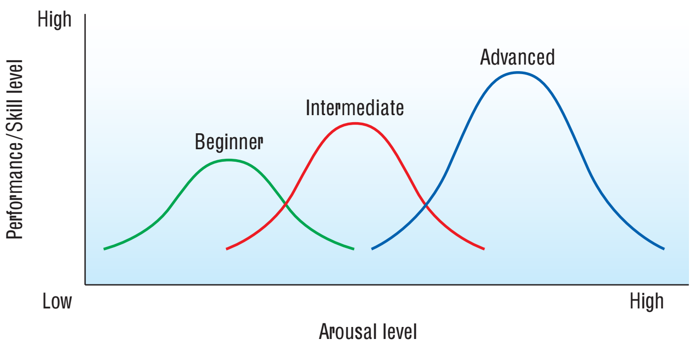

Figure 16.11 Application of the 'inverted-U hypothesis' to rifle shooters of differing skill levels

the zone
typically occurs during situations of optimal arousal and confidence – performance becomes autonomous, full of flow and unaffected by outside distractions

Arousal regulation

Athletes need to recognise the relationship between how they feel on the inside and their performance levels on the outside. They should think about how they felt when they were in the zone and performances were outstanding compared to feelings linked with poor performances. Arousal reduction and arousal promotion techniques are listed in Table 16.5. Each of these arousal reduction and arousal promotion techniques are described in more detail in *Nelson Physical Education Studies for WA 3A, 3B*, Chapter 15.

Table 16.5 Arousal reduction and arousal promotion techniques

Arousal reduction techniques	
Progressive muscle relaxation (PMR)	Progressively tensing and relaxing major muscle groups, usually working from head to toe, until all muscles are relaxed
Breath control	Breathing techniques which help athletes to relax and refocus while preparing for the next action or part of a match
Biofeedback	Receiving feedback regarding autonomous body functions such as heart rate, blood pressure and body temperature and using this information to bring about mental adaptation of them
Stress-inoculation training (SIT)	Athletes adapt, cope and effectively work while facing small amounts of stress and build up an immunity to it. Coping comes in the form of developing positive thoughts, mental images and self-confidence statements
Arousal promotion techniques	
Elevated breathing rate	Taking a few rapid breaths and focusing on the next task to be performed
Acting energetic	Acting in an energetic way, bouncing around, bumping into team-mates, or slapping each other
Positive self-talk and sounds	Upbeat and up-tempo music and positive words such as 'strong', 'go hard'; talk it up
Energising imagery	Imagining something uplifting, such as performing with excellent form
Pre-competition workout/ routine	Working through a set routine – e.g. stretches, drills, sprints, plays – to prepare physically and mentally

This chapter has covered a large amount of information relating to the fundamental concepts of sports psychology. For more information about specific strategies to develop these mental skills refer to *Nelson Physical Education Studies for WA 3A, 3B*, Chapters 15 to 17.

Evaluation and reassessing personal goals according to changing situations

Personal goals set for participation and performance in physical activity and sport should be regularly evaluated and reassessed according to changing situations. Many factors can influence goals, so not only is it important to regularly assess whether goals are being met; it is also essential to regularly evaluate whether the goals are appropriate and meaningful to the individual. An athlete's circumstance can change due to age, family commitments, injury, working roles, hours and responsibilities, skill level and so on.

When individuals start out in a new sport, they may simply set goals to learn the basic skills. As skills become more automatic, the goals may relate to learning tactics and rules.

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Later in the athletes' careers, they may set goals of achieving certain outcomes in relation to performances in competition (such as personal best times, throwing distances, podium finishes, scoring a certain number of goals). As athletes' skill levels improve, they have higher and higher expectations for themselves and these are reflected in the goals set. However, circumstances can change and lead to a change in opportunity to train or perform, and when this happens personal goals also need to be evaluated and reassessed.

For example, if an athlete becomes pregnant, there will be a period of time where she cannot train at the same intensity. Once the baby is born, she may not have much time or energy to play sport or continue to participate and compete at the same level.

As athletes get to a certain age, their performances drop due to deteriorating strength, power, speed, reaction time and eyesight. With increasing age, athletes need to regularly evaluate and reassess their goals so they remain realistic. At some point, they may need to consider whether they will be satisfied playing at a lower standard or in a lower grade or division. Otherwise, they may consider retiring from the sport and taking up other more recreational activities or playing another sport socially.

Retiring from a sport that an athlete has played most of their lives can be a big step, so often substituting that sport with another type of sport or activity can be beneficial.

KEEP IT REAL!

Psychological tests are used to identify an athlete's strengths and weaknesses, allowing sport psychologists to develop specific training in psychological skills. Figure 16.12 shows Iceberg profiles of successful and less successful athletes across a range of mental health predictors. (An Iceberg profile looks like an iceberg: all the negative traits such as depression, anger and tension, are below the surface and one positive trait – vigour – is above the surface. [Weinberg & Gould, 2007.]) The athletes were runners, wrestlers and rowers.

A successful athlete's Iceberg profile based on the Profile of Mood States (POMS) instrument shows vigour above the average (or mean) for the general population and tension, depression, anger, fatigue and confusion below the mean for the population. Research data collected using POMS has provided some support for the notion that athletes tend to have better mental health than non-athletes.

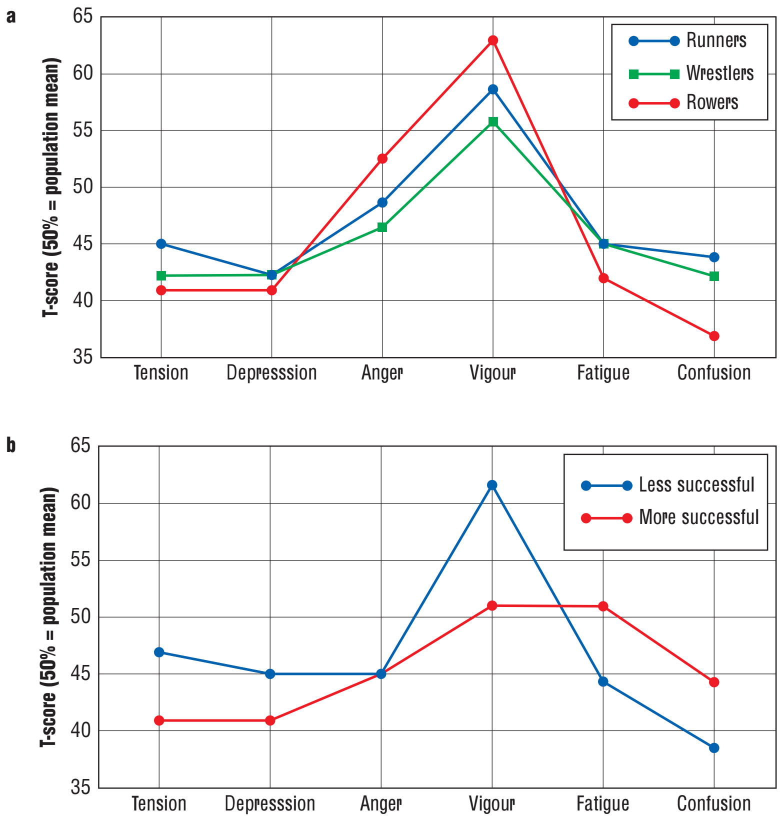

Figure 16.12 Psychological profiles of (a) athletes in three different sports (b) more and less successful elite athletes

TEST YOUR KNOWLEDGE

>> multiple choice

1 Motivating factors that come from within the individual, such as being satisfied with one's performance, are known as:

A imagery
B intrinsic motivation
C external motivation
D independent motivation.

2 What condition is often produced when the body encounters a threatening event?

A Stress
B Relaxation
C Tiredness
D Meditation

3 Which of the following types of attention involves responding well to predictable, slow changes in the environment?

A Narrow external
B Broad external
C Narrow internal
D Broad internal

>> short answer

4 Serena Williams had been sidelined for 6 months during the tennis season because of a chronic knee problem. She performed very well in her comeback from injury in the US Open in August 2006 and is now playing close to her best.

As a consequence of her injury, Serena has experienced a reduced confidence level. Explain two strategies that Serena could adopt to increase her confidence.

5 **a** Describe an example of an activity that requires sustained concentration.
b Identify three potential distractions to the concentration of an AFL footballer.
c Outline an effective strategy an AFL footballer could employ to aid concentration.

>> essay style

6 Imagine you are the sports psychologist providing advice to the Australian women's volleyball team prior to the World Championships. The lead hitter of the line-up is suffering from high levels of stress for the third month is a row. There is only 9 weeks to go before the World Championships. Explain four different stress-management strategies you would prescribe for the volleyball player to assist her to better manage her stress and produce her best performance.

7 Explain the association between arousal and performance and include specific sporting examples within your response. Describe several outcomes of arousal levels being too high and too low and how this may affect performance.

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Glossary

acceleration
how quickly an object can change velocity when an unbalanced force causes movement

adaptation
a long-term physiological change in response to training loads that allows the body to meet new demands

adenosine triphosphate (ATP)
a compound made up of adenosine and three phosphate molecules; energy released by its breakdown enables cellular function and muscular movement

aerobic capacity
the maximum amount of oxygen the body can take in, transport and use

aerobic glycolysis
the breaking down of glycogen during aerobic conditions (complete breakdown and no fatigue-producing by-products result)

aerobic training zone
considered to be 65–85% of an individual's maximum heart rate

agility
the ability to change body position quickly and accurately, and to maintain balance, while moving at speed

agonist (prime mover)
the muscle that instigates movement by contracting

all-or-none principle
when a muscle fibre receives a command from the brain, that muscle fibre either fires or doesn't fire

alveoli
tiny air sacs in the lungs where the gas/blood exchange occurs

anaerobic glycolysis
the breaking down of glycogen with insufficient oxygen, resulting in the production of lactic acid, lactate and hydrogen ions that all significantly contribute to fatigue

anatomy
the bodily structure of a plant or an animal or of any of its parts; the science of the shape and structure of organisms

anatomical position
a reference posture used in anatomical description in which the subject stands erect, with palms facing forwards and thumbs pointing away from the midline; allows descriptions of movements to be consistent

angle of projection
the angle at which an object is released into the air

angular motion
movement of an object or body parts around an axis

antagonist (muscle)
the muscle that relaxes to allow the agonist to contract

anterior–posterior (body)
forward–backward

anxiety
an emotional state characterised by negative feelings of nervousness, worry and apprehension

appendicular skeleton
the bones of the limbs and those connecting to the limbs, giving humans most movements; e.g. arms, legs, pelvic and shoulder girdles

arteriole
small blood vessel that carries blood to various parts of the body

arteriovenous oxygen difference (aVO_2 diff.)
difference in oxygen concentration when comparing that in the arterioles to that in the venules; an indirect measure of how much oxygen muscles are using

articular
of or relating to a joint or the structural components in a joint

ATP
see *adenosine triphosphate*

ATP–CP system
the first of the two anaerobic energy systems in which creatine phosphate (CP) is broken down to produce energy

atria
the two upper chambers of the heart (right and left atrium)

augmented feedback
any additional information gained about a movement or success of a movement

average acceleration
(final velocity – initial velocity) ÷ elapsed time

average (mean) speed
distance travelled ÷ time taken (does not take displacement into consideration)

axial skeleton
all the bones grouped together in the midline – the skull, vertebrae, ribs and sternum

balance
the ability of the body or an object to maintain stability or equilibrium when moving or stationary

behavioural
anything one does as a result of a specific situation

bicuspid (mitral) valve
valve in the heart with two cusps (points)

blood pressure
the pressure within the arteries that is caused by the pumping action of the heart

body composition
the various proportions of bone, muscle and adipose tissue in the body

bronchi
the two air passages connecting the trachea and the lungs

bronchioles
the small airways of the lung extending from the bronchi to the alveoli

capillaries
microscopic blood vessels with extremely thin walls

capillarisation
increase in the number of capillaries at the muscle, which increases the amount of blood supply to the muscle

carbohydrates
chemical compounds consisting of carbon, hydrogen and oxygen atoms; they are the body's preferred food fuel during exercise

carbohydrate loading
the practice of increasing carbohydrate stores within the muscles and body by increasing carbohydrate intake and tapering training in the days (up to 10) leading up to major competition

cardio-respiratory fitness
the efficiency at which the cardiac and respiratory systems work

cartilage
fibrous but flexible connective tissue, usually with no blood or nerve supply

cellular respiration
the different chemical reactions that take place in a cell to form ATP

choking
a situation where performance deteriorates because a heightened sense of pressure or importance is placed on an upcoming event or action

circuit training
a method of training for general conditioning in which athletes move from one exercise to another, usually in a series of different stations or pieces of equipment

circumduction
movement of a body part in a circular direction; the motion of the bone circumscribes a cone, the apex of which is in the cavity and the base of which is described by the distal end of the bone

coach
an individual involved in the direction, instruction and training of the operations of a sports team or of individual sportspeople

cognitive skill
the ability to think and decide is the desired outcome

collagen
the fibrous protein constituent of bone, cartilage, tendon and other connective tissue

compression force
force that pushes inwards

concentric contraction
when the muscle shortens and tension is developed

concurrent feedback
feedback given while a performance is occurring

consolidating
to maintain and strengthen an established skill

continuous training
long, slow distance training

contractibility
muscle cells can react to a stimulus by shortening, or decreasing their overall length

coordination
the ability of an individual to perform tasks accurately and smoothly

core strength/stability
having strength in those muscles that stabilise, align and move the trunk of the body. Major muscle groups here include lower back muscles and abdominal group

creatine phosphate (CP)
also referred to as phosphocreatine (PC) and is a compound that transfers phosphate and energy to ADP to generate ATP; a source of energy for muscle tissue

cue
a piece of information a performer receives from oneself or the environment

demonstration
to show, explain or provide an example

demotivation
reversal from a state of being motivated and aroused

deoxygenated blood
blood that is returned to the heart and carries little oxygen and a lot of the waste product from respiration (carbon dioxide)

detraining
stopping training causes the physiological adaptations that they have made to be reversed quickly

diastole
the relaxation of the atria and ventricles

diastolic blood pressure
pressure in the arteries when the heart relaxes and ventricles fill with blood

diffusion
oxygen is transported from the alveoli to the haemoglobin part of the red blood cells, across the alveolar–capillary barrier; carbon dioxide moves in the reverse manner diffusion gradients refer to the concentration of gases separated by a membrane; e.g. the concentration of oxygen in the lungs compared to that in surrounding pulmonary capillaries. Gases will move, or diffuse, from areas of high concentration to areas of low concentration and these are known as gradients

diffusion gradients
refer to the concentration of gases separated by a membrane; e.g. the concentration of oxygen in the lungs compared to that in surrounding pulmonary capillaries. Gases will move, or diffuse, from areas of high concentration to areas of low concentration and these are known as gradients

discovery method
learning through self-exploration and collaboration as opposed to through teacher direction

displacement
the difference between the initial position and the final position of an object

distal–proximal (body)
further away from the attachment point of a limb – closer to the attachment point of a limb

distributed practice
planned periods of work and rest in order to limit the effects of fatigue and boredom

duration
a measure of the length of each training session

dynamic balance
the ability to hold a moving position to execute an outcome

dynamic exercise
involves large muscle groups engaged in rhythmic, repeated movements; e.g. aerobic activities such as jogging, brisk walking, swimming, bicycling

eccentric contraction
when the muscle lengthens while developing tension

elasticity
the ability of cells, surfaces and objects to 'give' and then return to their original state or shape

energy system interplay
a situation where all three energy systems contribute to ATP production, with one system being the major ATP producer

energy system
any of the three metabolic systems responsible for the production of ATP

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environmental influences
outside forces that may cause an individual and/or team to change their tactics. These influences are not just to do with the weather, but include all influences that impact on performance

epiphyseal plates
growth plates located at the end of long bones

ergogenic
something that increases muscular work capacity; i.e. is performance-enhancing

excitability
the ability of a muscle fibre to respond rapidly to a stimulating agent

extendibility (extensibility)
the ability of a muscle to be stretched or extended without damage to the tissue

external information
information provided by the environment

extrinsic feedback
the feedback athletes receive from outside the performer, usually as sound or sight stimuli received from coaches, fellow performers or spectators through exteroceptors

fartlek
a Swedish word meaning speed-play

fatigue
mental and/or physical exhaustion that limits the body's ability to perform maximally

fats
components of foods containing fatty acids and glycerol; they are the body's preferred fuel at rest and during prolonged submaximal exercise

feedback
any information the performer receives (internal or external) on how the movement was completed

fixation muscle
steadies one body part to allow another to initiate its movement from a stable base

flexibility
a measure of the range of motion about a joint

force
mass × acceleration

frequency
the number of training sessions in a week or cycle

frontloading (feedback)
pointing out the key elements or teaching points prior to performing an activity

functional anatomy
the study of anatomy (bodily structure) in its relation to function (the intended purpose)

future-oriented thinking
thinking ahead of time about what you are going to do and what might happen

general motion
a combination of angular motion and linear motion; the most common form of motion in sport

global self-confidence
a disposition or personality trait; although someone can exhibit a great deal of global self-confidence, they may not achieve success at a specific sport or task

glycaemic index (GI)
a ranking of foods based on their immediate effect on blood glucose levels

glycogen sparing
a long-term adaptation resulting from aerobic training that allows fats to be used more readily and earlier during performances. This in turn results in less use of the lactic acid system and allows glycogen to be used much later in performances

glycolytic capacity
the ability to break down glycogen via key enzymes that facilitate glycolysis

goal-setting
a set of short-term plans aimed at achieving larger long-term outcomes

haemoglobin
oxygen-carrying pigment present in red blood cells

hitting the wall
when a person depletes their glycogen stores and primarily uses fat as an energy source

homeostasis
the maintenance of core body temperature within the normal healthy range

hyperplasia
increases in the number of muscle cells

hypertrophy
an increase in cell size that usually leads to an increase in tissue size as well

hyperventilation
the process of breathing more often and deeper than is necessary (also known as over-breathing)

hypoglycaemia
a condition created when blood glucose levels are significantly reduced, often during extended endurance activities, calling upon glycogen reserves in the liver

imagery
use of thoughts and images seen through the mind's eye

impulse
the application of force over a period of time

individuality
training programs that are specifically tailored for the individual

inertia
a measure of how difficult it is to move an object

infant
a child aged from 28 days to 18 months, although it may be based on developmental age rather than chronological age

insertion (muscles)
the point at which the muscle is attached to the moving bone

intensity
a measure of how hard each training session is

intermediate joint
a joint between the distal joint and the core of the body that may need to stabilise or isometrically contract to allow a correct movement in a specific activity

internal information (kinaesthetic or movement sense)
before and during the performance of a motor skill, the body itself gives

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the performer information about their relative position in space, and how much force to put into the movement, as well as the relationship of the limbs to each other

intrinsic feedback
the feedback athletes receive internally as a natural consequence of their performance; e.g. the kinaesthetic feedback arising from sensory receptors in muscles, tendons and joints, which provides performers with information about their movements

involuntary muscles
muscles that work without our conscious control

isokinetic contraction
a contraction in which the muscle shortens with varying tension while lifting a constant load, so that muscle strength remains even throughout the movement

isometric contraction
a minimal shortening of the muscle; tension on the muscle increases greatly, where muscles are pitted against an immovable object.

isometric exercise
see static exercise

isotonic contraction
when the muscle shortens and lengthens in response to a load, to produce movement

lactate threshold
the point at which lactic acid begins to accumulate (often expressed as occurring at 85% max HR or 70% VO_2 max); i.e. the point at which lactate production exceeds lactate removal

lactic acid (LA)
a by-product produced when muscles use sugar to get energy

learning
when there has been a relatively permanent change in performance as a result of training or skill practice

ligament
a tough band of connective tissue that connects various structures such as two bones

lipolysis
breakdown of fat for energy

long-term memory
an infinite memory store that can be accessed at a later date

maintenance
in a maintenance program, it is possible to decrease the frequency of training to hold the current fitness level but not strive for adaptations

massed practice
repetitive, continuous practice with little rest between successive efforts

medial–lateral (body)
near the midline – away from midline of body

mitochondria
cellular structures containing enzymes responsible for the production of energy under aerobic conditions

momentum
a measure of how much motion an object has

motivation
encouragement of an individual in order to improve performance

motor skill
an observable movement involving the muscles that is aimed at achieving a desired outcome

movement time
the time taken from initiating a movement to completing a movement

muscle endurance
the ability of a muscle or a group of muscles to sustain force production over an extended period of time

muscle fatigue
when a muscle contracts, it produces chemical waste products (carbon dioxide, lactic acid and acid phosphate) which make the muscle more irritable; continued contraction causes the muscle to cramp and refuse to move

muscular strength
force or tension that a muscle or muscle group can exert against a resistance in one maximal effort

nervous system
the control centre of the body; it stimulates movement

neural inhibition
the limiting of the motor neuron output, which has many causes, including fear of injury and low confidence; training is very important in decreasing neural inhibition

OBLA (onset of blood lactate)
the point where blood lactate concentration shows an increase equal to 4.0 mM, because the rate of lactate production exceeds the rate at which it can be oxidised (broken down); it accumulates at the muscle first and then moves into the bloodstream; sometimes confused with the lactate threshold, which is the point at which lactic acid begins to accumulate

origin (muscles)
the point at which the muscle joins the non-moving bone

osteocyte
a branched cell embedded in the matrix of bone tissue

osteoporosis
a medical condition where bone mass and strength is reduced, making the bones more susceptible to fracture

overlearning
repeated practise of skills – both physical and psychological – which sees them becoming automatic

oxygen deficit
period during exercise when the oxygen demand exceeds the body's ability to supply it. This typically occurs during the start of exercise or when exercise intensity increases until the body is able to adjust and supply more oxygen to meet this new demand

palmar–dorsal (body)
palm of hand – back of hand

peak bone mass
the formation of mineral deposits and compact bone that helps give maximum strength to a bone

perceived rate of exertion (PRE)
a commonly used method to monitor exercise intensity

performance
the externally measurable effort that we can easily observe

personal best
a performer's best recorded result or performance at a particular skill or activity

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phosphate
a form of phosphoric acid; calcium phosphate makes bones and teeth hard

phosphocreatine (PC)
also referred to as creatine phosphate (CP) and is a chemical fuel consisting of a bound phosphate and creatine molecule stored at the muscle site. It is split rapidly to rebuild ATP during explosive activities but has a limited capacity lasting approximately 10–12 seconds

pilates
a training method that concentrates on improving core strength, balance and flexibility

plantar–dorsal (body)
sole of foot – top of foot

plateau
commonly occurring when the body adjusts to new loads and maintenance of existing conditions/state prevails

platelets
cells that help from blood clots to stop bleeding; produced in bone marrow

plyometrics
the term used to describe explosive jump training

power
force × distance ÷ by time

precapillary sphincters
a band of smooth muscle that adjusts the blood flow into each capillary. It encircles each capillary branch at the point where it branches from the arteriole. Forceful contraction of the precapillary sphincter can close the branches off to blood flow

progressive overload
for the body to continue to improve fitness levels (obtain adaptation), the body needs to be overloaded over time

progressive part method (of practice)
where related parts or subroutines of a skill are practised before being added to another related part of the skill

protein
the fuel source used predominantly for growth and repair and as an energy source under extreme conditions; makes a negligible contribution to energy production during exercise and is mainly used for growth and repair

psychological skills training (PST)
rehearsal or practice of a variety of psychological techniques

pulmonary circulation
blood pumped to the lungs from the heart

pulmonary vein
carries blood to the left atrium (upper left chamber) of the heart

reaction time
the time taken to respond to a cue prior to actually initiating a response

red bone marrow
tissue found within the bones that creates red blood cells as well as small numbers of white blood cells

red blood cells
iron-rich cells that carry oxygen around the body

repetition maximum (RM)
the most weight an individual can lift a given number of times

resistance training
by providing a resistance to the muscle, we attempt to improve muscle strength and power

response time
reaction time + movement time; i.e. time taken from onset of cue to finished execution of movement

selective attention
the ability to only attend to relevant cues

short-term memory
'working memory', which has a limited time of around a minute for retrieval. Psychologist George Miller proposed that the human mind could only retain seven items plus or minus two depending on individual differences; this was called Miller's magic number

short-term sensory store
a snapshot of what you last looked at and observed, which is not highly detailed and is constantly being updated; it relies on selective attention to remember as much immediately relevant information as possible

signal detection
the process of identifying the cues gathered by the senses

sinoatrial node (pacemaker)
generates an electric signal that causes the heart to contract and pump blood

situation-specific self-confidence
believing you can succeed at a specific task. For example, the golfer who enjoys situation-specific self-confidence truly believes that they can sink a putt from four meters away when they need to par the hole

skill
the degree of efficiency in performing a given task in order to achieve a predetermined outcome

skill acquisition
the study of how a person acquires or develops skills

skinfold measurement
uses calipers to measure two layers of skin and two layers of subcutaneous fat; adding a number of sites together gives an overall picture of body fat

specificity
an athlete is attempting to make changes that are specific to the requirements of their sport

speed
the ability to move the body or a body part from one point to another in the shortest possible time

spirometer
measures vital capacity – the maximum amount of air you are able to breathe out after taking in a deep breath

static balance
a state of balance where a set position has to be maintained for a long period of time

static (isometric) exercise
a sustained contraction of a muscle group typically against an immovable resistance/weight – force is developed but no change in muscle length occurs

strategy
overall plan for achieving success

stressor
any stimulus or condition that causes physiological arousal beyond what is necessary to accomplish the activity

superficial–deep (body)
nearer to the surface – further away from the surface of the body

superior and inferior vena cava
where the veins from all of the body above (superior) and below (inferior) the heart empty into

superior–inferior (body)
upward–downward

synergistic muscle
controls intermediate joints, allowing the distal prime mover and antagonist to generate maximum force

synovial fluid
a transparent, protein-rich, sticky fluid that lubricates joints and nourishes the cartilage in a joint; also found in tendons, sheaths and bursae

systemic circulation
movement of blood from and to the heart

systole
the contraction of the atria and ventricles

systolic blood pressure
pressure on the arteries following contraction of ventricles as blood is pumped out of the heart to the aorta

tactics
the specific tools used to achieve a strategy

tendon
cord of thick strong fibres that connects muscle to bone

tensile force
force that pulls outwards

terminal feedback
feedback that is given at the completion of a movement

the law of diminishing returns
improvement rates will decrease over time even though the same change (overload) is added to a training program

the zone
typically occurs during situations of optimal arousal and confidence – performance becomes autonomous, full of flow and unaffected by outside distractions

training
the process of bringing a person to an agreed standard of proficiency by practice and instruction

trajectory
the flight path an object takes when released into the air

tricuspid valve
valve in the heart with three cusps (points)

variety
having various types of training sessions; athletes may participate in alternative types of exercises to keep them mentally fresh

vasoconstriction
the veins decrease in diameter and hence allow much reduced volumes of blood to flow through them

vasodilation
the veins increase in diameter and hence allow larger volumes of blood to flow to through them, to working muscles

vastus lateralis
a major quadriceps muscle on the outside of the thigh

velocity
the rate of positional change of an object

ventricles
the two lower chambers of the heart (right and left ventricle)

venules
the smallest veins adjoining the capillaries

vital capacity
the maximum amount of air you are able to breathe out after taking in a deep breath

VO_2 maximum (VO_2 max)
the maximal amount of oxygen that can be taken into the body and transported to and used up by the muscles during exercise

voluntary muscles
muscles that we can control to create movement

white blood cells
the body's defence system, fighting infection and building up the body's immunity

whole method (of practice)
where the whole skill is practised

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- 'Making it real' exposés of well-known Western Australian sportspeople
- End-of-chapter revision and sample exam questions
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