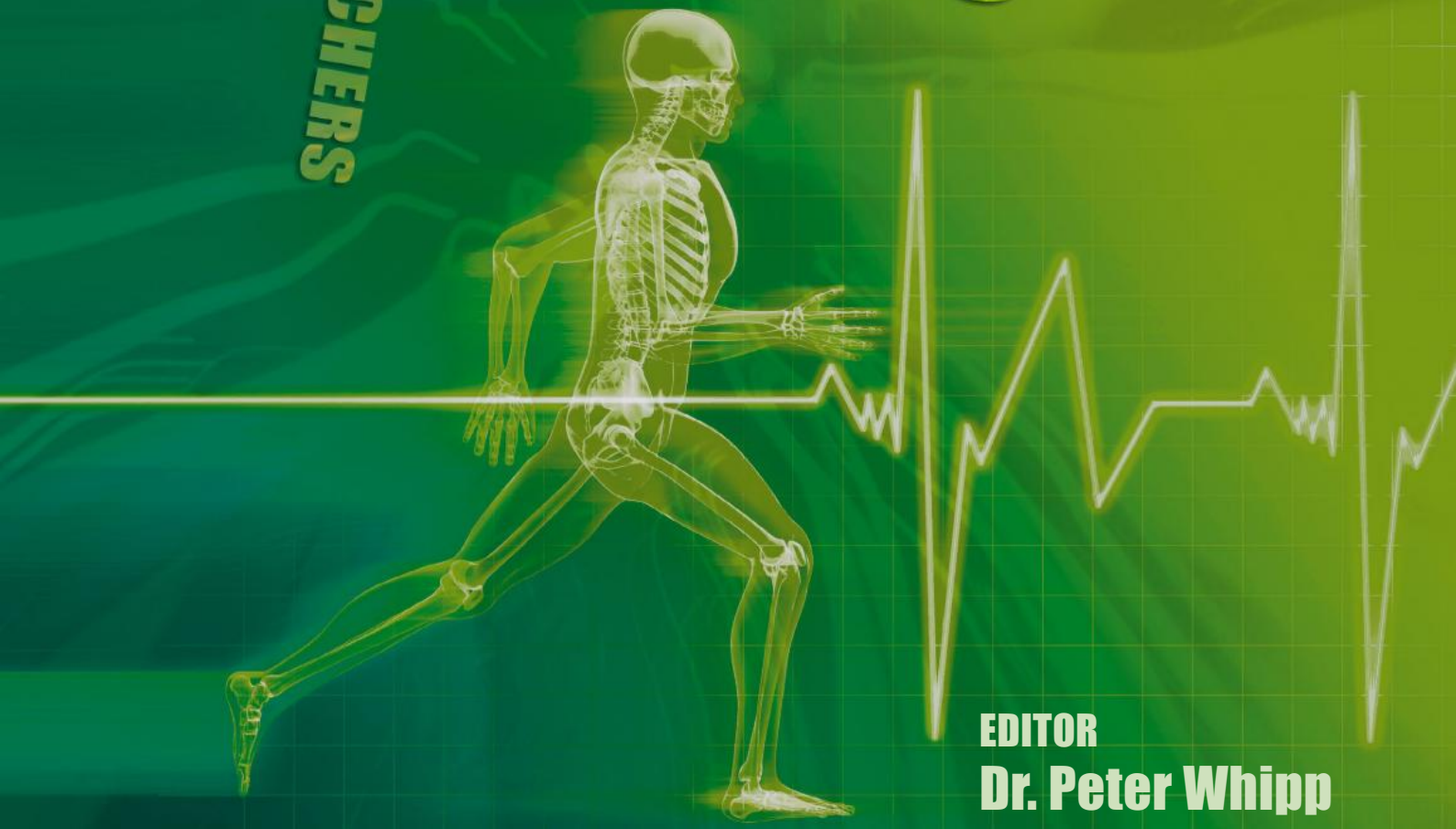
THE UNIVERSITY OF WESTERN AUSTRALIA

PHYSICAL EDUCATION STUDIES

A TEXTBOOK FOR TEACHERS

ATAR UNITS 1 AND 2



EDITOR
Dr. Peter Whipp

PHYSICAL EDUCATION STUDIES


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ATAR UNITS 1 and 2

A TEXTBOOK FOR TEACHERS

Associate Professor Peter Whipp
Professor Bruce Elliott
Dr Kym Guelfi
Dr James Dimmock
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THE UNIVERSITY OF WESTERN AUSTRALIA

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Authors' Profile

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Emeritus Professor Bruce Elliott (B.Ed; M.Ed; Ph.D) is one of the world's leading sport scientists. He is a fellow of the Australian Council for Physical Education, Health and Recreation; the American Association for Kinesiology and Physical Education; and the International Society of Sport Biomechanics. In 2000 he was selected by the IOC to administer the applied sport research projects at the Sydney Olympics and in 2003 he was awarded the Centenary Medal by the Australian Government for 'Service to Sport Research and Policy Development'. Although he has published over 200 refereed articles and fifty books/book chapters, his desire to promote the application of sport science – to meet the needs of teachers and students of PE – is the motivating factor in playing a role in this book.

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Dr James Dimmock (BSc (Hons); BCom; Ph.D) is a Senior Lecturer in sport and exercise psychology at the School of Sport Science, Exercise and Health, at The University of Western Australia. As well as teaching sport and exercise psychology, he also teaches units in sport, exercise and health management/ marketing at the School. Dr Dimmock is currently undertaking research on motivation in exercise, but has undertaken research in the past on topics such as spectator psychology, mental toughness, and 'choking' in sport. Dr Dimmock has also been involved in the presentation of PE Studies revision seminars to high school students

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Dr Grant Landers (BSc (Hons); Ph.D) is a lecturer and researcher in functional anatomy and exercise physiology at the School of Sport Science, Exercise and Health, at The University of Western Australia. His research interest relates to improving endurance performance and has represented Australia in adventure racing (2-4 days, non-stop, off road events). He is a successful triathlon coach and has contributed to coach education for the past 15 years. Dr Landers has previously worked for the National Heart Foundation in developing and delivering the Jump Rope for Heart program to schools.

Associate Professor Jacqueline Alderson (Ph.D) is a lecturer in biomechanics at The University of Western Australia. A fellow and current director of the International Society of Biomechanics in Sport, she is an active researcher and has published over 100 peer reviewed book chapters, journal papers and conference proceedings. She was a member of the IOC's medical commission biomechanics projects at the Sydney Olympics and from 1995-2014 served as biomechanics consultant to the International Cricket Council. She is a passionate advocate for the promotion of science in schools and serves as a biomechanics consultant and writer for the Australian and New Zealand Learning Federation as a biomechanics educator for the secondary teacher's enrichment program at The University of Western Australia (SPICE).

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Dr Peter Peeling (BSc (Hons); Ph.D) is a Senior Lecturer in exercise physiology at the School of Sport Science, Exercise and Health, at The University of Western Australia. Dr Peeling's primary research interest relates to applied sports physiology and nutrition, with a focus on enhancing human performance. Previously, he worked as an applied sports physiologist with the Australian Hockey team (The Kookaburras) leading into the 2008 Beijing Olympic Games, and also with the Western Australian Institute of Sport during the 4-year cycle to the 2012 London Olympic Games. During this time, Dr Peeling was involved in the daily training environment of many athletes competing at an International level, providing advice on aspects of training programming, recovery, nutrition and ergogenic aids.

Ms Monica Leslie (BSc) graduated from The University of Western Australia in 2014 with a double major in Psychological Science and Psychology in Society. After receiving a WACE Certificate of Distinction for 3A/3B PE Studies in 2011, Ms Leslie went on to continue her study of sport science through the School of Sport Science, Exercise and Health at UWA. She has been the recipient of numerous university awards, including the 2012 UWA Physical Education Students' Association Prize and the 2012 Convocation of UWA Graduates Prize for Human Movement. She is a regular presenter at high school PE Studies workshops and contributed to resources presented as part of the 2014 PE Studies Teachers' Conference at UWA. She is currently completing Honours research in the field of psychology, with a specific focus on elucidating the mechanisms of treatment action in anorexia nervosa.

Preface

Each chapter is preceded by a section that provides background information. These concepts will assist students to understand the ATAR Units 1 and 2 Physical Education Studies curriculum.

The authors acknowledge that content related to 'Developing physical skills, strategies and tactics' is best defined and delivered by the expert class teacher. Teachers are best placed to embed these concepts into the specific sports undertaken in the practical components of the course. However, when evaluating skill technique, the 'motion analysis procedural format' and 'video analysis' sections in the Biomechanics and Motor Control and Learning Chapters provides structured methods for a qualitative evaluation.

A similar approach is followed for each section of the ATAR Units 1 and 2 Physical Education Studies curriculum. Sections start with textbook-related learning outcome statements, followed by a dot-point box identifying the 'Content that follows' and the theory and application for each content area. Suggested class tasks and practical activities can be found within the sections of the text. A 'Key point summary' box is presented at the end of each section. Local and contemporary research is presented under the headings 'UWA research snapshot'.

Two practical investigations are included as Appendix B1 (ATAR Unit 1 content) and Appendix B2 (ATAR Unit 2 content). A format for report writing can be located at the end of each chapter (Appendix A), to assist students with their preparation of the practical investigation. Marking matrices are also included in Appendices B1 and B2. A test related to one of practical investigations offered in each chapter has also been prepared. Answers for both the practical investigation questions and the test questions are provided for teachers and these can be found in the *Physical Education Studies ATAR Units 1 and 2: A Textbook for Teachers.*

Revision questions (with answers) are included near the end of each chapter (Appendix C).

Two 'Personalised projects' are included in the textbook. These assessment tasks are framed by the principles of Bloom's taxonomy. The first project can be located at the end of Chapter 3, and a second project can be found at the end of Chapter 5. The first project requires students to display knowledge and understanding from Biomechanics, Functional Anatomy and Exercise Physiology (Chapter 3: Appendix D), while the second project focuses on 'Sport Psychology and Motor Learning and Coaching' (Chapter 5: Appendix D). Even if these tasks are not undertaken for assessment purposes, they are a valuable tool for revision.

A 'Glossary of key terms' appears on the final pages of each chapter (Appendix E).

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Features of this textbook

Domain-specific chapters: Colour-coded for each chapter

Chapter 1: Biomechanics
Prof Bruce Elliott, Dr Jacqueline Alderson and Dr Peter Whipp

Chapter 2: Functional Anatomy
Dr Grant Landers, Dr Peter Whipp and Dr Kym Guelfi

Chapter 3: Exercise Physiology
Dr Kym Guelfi and Dr Peter Whipp

Chapter 4: Sport Psychology
Dr James Dimmock, Dr Peter Whipp and Ms Monica Leslie

Chapter 5: Motor Learning and Coaching
Dr Brendan Lay and Dr Peter Whipp

Background information: Concepts that will assist students to understand the ATAR Units 1 and 2 Physical Education Studies curriculum.

ATAR Units 1 and 2 course specific content, with identification of content specific to Units 1 and 2.

Text learning outcomes: Statements that identify what students, on completion of engaging in class-related activities and studying the unit content, should be able to do. These are consistent with the needs of the course, as defined by the School Curriculum and Standards Authority and PES Course Syllabus of Western Australia.

Content that follows: Identifies the specific content that defines the section of work that follows within a chapter.

Key point summary: Statements that revise key content covered in each section of the chapter.

UWA research snapshot: Identifies recent research findings from experiments undertaken in the School of Sport Science, Exercise and Health.

Class task: A class-based task that facilitates students to access the concepts identified and requires no equipment.

Practical activity: A class-based or homework experiment that facilitates students to access the concepts identified. A list of the equipment required is provided.

Practical investigation: An in-depth, class-based experiment that facilitates students to

access the concepts identified. Each task is differentiated for ATAR Unit 1 or ATAR Unit 2 content. Questions, with allocated marks, are presented to access both the experimental data and to extend students through application of their learning to alternative movement and sporting contexts. A format for report writing and marking matrices are also included. A test related to one of practical investigations offered in each chapter has also been prepared. Answers for both the practical investigation questions and the test questions are provided for teachers and these can be located in the *Physical Education Studies ATAR Units 1 and 2: A Textbook for Teachers.* A list of the equipment required is provided.

Revision questions (with answers): Are included near the end of each chapter. Links to content-specific questions are identified in each chapter.

Personalised project: Two 'Personalised projects' are included in the textbook. These assessment tasks are framed by the principles of Bloom's taxonomy. These tasks require students to display knowledge and understanding from multiple content domains.

Glossary of key terms: Definitions of the words and concepts are provided.

PowerPoint slides: A PowerPoint slideshow that summarises all of the key concepts provides a valuable teaching and learning tool.

The Teachers' edition:
The teachers' edition of: *Physical Education Studies ATAR Units 1 and 2: A Textbook for Teachers;* and *Physical Education Studies ATAR Units 3 and 4: A Textbook for Teachers* contains answers to the practical investigation questions. The teachers' editions also contains test questions and answers that are offered as an in-class alternative to students completing a practical investigation report.

Updates and revised content
At the time of publication, many of the authors of this textbook are active researchers at the School of Sport Science, Exercise and Health at The University of Western Australia. They are constantly seeking new knowledge and to clarify our understanding through experimentation. When additional understanding of the content in this book is defined, it will be publicised through the UWA student revision seminars held on-campus each year, the teacher professional development seminars and the Physical Education Studies Teachers' Association (PESTA) website.

Things you should do in preparation for the theory examination
Whilst this book serves primarily as a tool for teaching and learning, ultimately it is important that students develop an awareness of how to best represent their learning outcomes. This will require written examination. The following are some considerations for responding to written questions.

- Set yourself a realistic study timetable– for all of your subjects.
- Confirm what content is examinable–use a summary page and list the key words or concepts (content) that you have covered.
    - Use the 'Key point summary' boxes that are embedded in each chapter as a guide to the important content and concepts. Consider copying the content in each summary box and placing it on your study wall.
    - Identify and clarify the content that

you do know and that which you need to further revise.

- Create summary notes. These should be all in the same format. Use **HEADINGS**, ***Sub-Headings*** and **dot-points**. Also use small graphs and diagrams to reinforce content. As part of your preparation try and visualise what is on the page of summary notes. Visualisation and mental imagery can be useful when trying to remember!
- Revise the content and use exam-style questions to reinforce how the content is applied as part of your revision.
- Maintain a personal exercise schedule.
- Consider a writing warm-up prior to going in to the written examination. Prepare to write with well formed legible handwriting.

What is the external examiner thinking?

- The course content being examined has come from the ATAR Units 3 and 4 PES Syllabus as defined by the School Curriculum and Standards Authority and PES Course Syllabus (http://www.scsa.wa.edu.au). The examiners will have used it to determine their choice of content to be examined.
- The examiners will have ensured that the questions require that you write a specific answer. They will know what information they are seeking in the answer. Therefore, you must answer the question – don't forget to revisit the question as you record your answer so that you stay on track.

What will the external marker do?

- The external marker will most likely not have written the question or the answer. They will be given the answer key and required to assign a mark for every time you make an appropriate point in your answer. Make it easy for them:
  - Record answers on the lines and within the space provided. This may need you to write with smaller letters than normal.
  - If you need additional space, try and fit it in under the lines provided.
  - Don't use faint pencil; a pen is far easier for the marker to read.
  - If you wish to cross something out, keep it as neat as possible and direct the marker with arrows or words to where your answer is located.

Things you should do in the examination

Use the reading time to:

- Affirm yourself and build self-confidence by reading to identify what you do know–not what you don't know.
- Decide what optional essay questions you will answer.
- If you need to write down acronyms of content cue words, do this as soon as the writing time begins.

Answering questions:

- Write an answer that, at minimum, matches the marks on offer. Generally, there is one mark on offer for each content area or point covered in your answer. For example, in an extended answer worth fifteen marks that requires five areas to be covered, you could be expected to record three different pieces of information under each area.
- Definitions: You can choose to write the word to start the answer but don't use the word you are defining in your answer.
- List: Normally just a dot-point will suffice. List is often accompanied by the word 'explain'. In that case you need to give more than a dot-point.

- Identify: Avoid just a list here. A sentence is required rather than just a one- or two-word dot-point.
- Suggest: There is generally more than one answer to this question. Each suggestion will need a definition and explanation.
- Explain: Often needs an application to a specific example. You should identify how the suggestion is useful or applied to the specific question or a problem.
- Describe: Similar to 'explain'.
- Discuss: With each point that you raise, you need to define, explain and justify your response. A discussion brings together facts and considers or examines by providing a comment or argument.
- Re-read every answer you have given. Consider using a highlighter–when you have finished answering all of the questions on the paper to reinforce your key points or words in your answer.
- The question: Save space and time by not writing the question in your answer. For example:

Q2. Identify and describe three immediate physiological changes that occur with exercise. (6 marks)

Don't repeat the question

Poor answer: For example,

'*Three immediate physiological changes that occur with exercise* are heart rate goes up, amount per heart beat increases and more blood is pumped.'

These physiological changes recorded in the poor answer above are described with general language. Use language that reflects that you have studied the topic and have an understanding. Also, be specific or accurate. If you know the figures or capacities, then put them in.

Good answer: For example,

1. An increase in heart rate. Both an anticipatory rise in heart rate that occurs when you know you are about to start exercise and an increase in heart rate that is in direct proportion to the increase in the exercise workload to a maximum of 220-age.
2. An increase in stroke volume. An increase in the volume of blood pumped per beat as result of greater venous return and an increase in the heart's force of contraction. From 70 ml at rest to a maximum of approximately 110 ml for a non-endurance trained person.
3. An increase in cardiac output. Increases in heart rate and stroke volume result in an increase in the volume of blood pumped by the heart per minute to a maximum of approximately 22 litres for a non-endurance trained person.



Biomechanics

Dr Bruce Elliott (Emeritus Professor), Dr Jacqueline Alderson (Associate Professor)
and Dr Peter Whipp (Associate Professor)

BACKGROUND INFORMATION

What is Biomechanics?

Simply put, biomechanics is 'a study of movement using applied physics (the mechanics section) and anatomy'. Typically it is considered a quantitative field (based on measuring and reporting in numbers) of study within the discipline of sport and exercise science. However, it does not always have to be based on ***numbers*** (***quantitative***), as a biomechanical approach to analysis may be used to evaluate movement without using objective measures. This would be a ***qualitative*** approach to biomechanical assessment and is what coaches do most of the time.

Coaches observe a player, make judgements and suggest modifications to improve performance. This qualitative approach to analyse sporting movement is the basis of Physical Education.

Remember, the analysis method in biomechanics is the same irrespective of the quantitative (objective measures used as the basis for movement evaluation and subsequent intervention to improve performance) or qualitative method (movement evaluation and subsequent intervention based on mechanical considerations that are considered but NOT measured).

The Role of Biomechanics

Text outcomes:
The role of biomechanics

- *Show an understanding of the role that biomechanics plays in aspects of everyday movements.*
- *Explain how biomechanics may be used to improve performance and/or reduce the likelihood of injury.*

Biomechanics plays an important role in many aspects of Australian human endeavour and can be related specifically to three primary areas: sport (Figure 1.1), clinical application and ergonomics (biomechanics in work and everyday life).

Sport biomechanics

The focus in this area may be on the techniques required to kick straight in AFL or successfully shoot a goal in netball. Biomechanics provides a framework for the evaluation and potential modification of technique, in an endeavour to improve performance (kick further or straighter or to shoot more accurately). Roger Federer

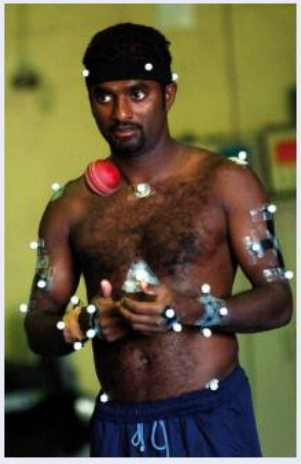


Figure 1.1: *Infra-red cameras track reflective markers in biomechanical analysis of bowling action at The University of Western Australia (Picture courtesy of Mr Tom Rovis-Hermann)*

UWA research snapshot: *Reducing knee injury during sidestepping and landing*

Did you know that approximately 60% of anterior cruciate ligament (ACL) injuries sustained in sport, athletes do to themselves? That is, the injury does not involve contact with another player. The player actually moves in a way that creates high loading at the knee, causing the ligament to rupture. Researchers from the School of Sport Science, Exercise and Health at The University of Western Australia confirmed that it is important to keep your landing or take-off leg relatively close to the vertical line of the body's centre of gravity, if you want to reduce the likelihood of a knee injury.



Figure 1.3: *Image of a player performing a sidestep (a), computer graphic representation of a similar action (b) and computer reconstruction of a footballer landing after catching a ball (c)*

(Figure 1.2), one of the world's leading tennis players, continually works on technique to improve his performance. His ability to consistently hit the ball with great power and precision, in a variety of strokes, is the basis of his game.

Figure 1.3a shows a footballer performing a sidestep, wearing reflective markers for motion analysis and equipment to record muscle activity. Figures 1.3b and 1.3c represent, using biomechanical computer software, sidestepping and landing tasks, respectively. The large arrow in these figures represents the force applied by the ground back to the player at contact with the ground (Newton's 3rd law of motion – This force is greater than three times the player's body weight).



Figure 1.2: *A professional tennis player near impact in the tennis serve (picture published with the permission of the International Tennis Federation)*

Clinical biomechanics

Here the focus may be on the walking pattern of a young child with cerebral palsy, or an elderly person who has had a hip replacement. Again the biomechanist assists the clinician (surgeon, doctor, physiotherapist and exercise rehabilitation specialist) to improve performance by modifying movement technique. Clinically, biomechanics is used to measure impairment and then, through intervention, either tries to make the movement more efficient, or reduce the likelihood of injury. In Figure 1.4 an individual with a lower limb burn is prepared for a gait (walking) assessment, to determine the effectiveness of a clinical intervention. Other clinical studies have focused on such topics as the role of exercise in the prevention of osteoarthritis and improving the outcomes for people with neuromuscular disorders, such as Parkinson's disease.



Figure 1.4: *An individual with lower limb burns prepared for a 3D gait analysis*

During work or everyday life (ergonomics)

This includes such interests as: the 'load' on the back, such as when a mother lifts a child or a labourer lifts a heavy weight or when holding a particular posture for an extended period. Examples of research in this field include topics as diversified as: evaluating load



Figure 1.5: *Load on the body being assessed during wheelbarrow (a) preparation for lift, the lift (b) and walking with the wheelbarrow (c)*

UWA research snapshot: *Loading during ballet lifts and acrobatics*

Researchers from the School of Sport Science, Exercise and Health at The University of Western Australia investigated loading to the lower back during ballet dancing, both from technique and floor design perspectives. This work parallels studies completed with the acrobats from Cirque du Soleil, where the rate of lower limb injuries was high because of the variability in hardness across the floor, due to the placement of support beams. Once the floor was made a constant hardness the lower limb injury rate dropped drastically– dancers knew what to expect and could prepare the body for the floor impact.



Figure 1.6: *Load on the back being assessed during sheep shearing*

on the body when lifting and walking with a wheelbarrow (Figures 1.5a, b and c) or loading on the back when shearing a sheep (Figure 1.6). Any activities performed that involve lifting, carrying or moving will involve biomechanics — even gardening involves an appreciation of biomechanical principles.

Two features are commonly associated with all the above areas. The exercise scientist, coach, teacher and student completing a Physical Education course all look to: improve performance and/or reduce the likelihood of injury, irrespective of whether the issue being discussed involves hitting a ball, jumping in athletics, throwing a frisbee or lifting a heavy load. The analysis system discussed below is aimed at permitting the evaluation of all forms of movement, so that intervention strategies may be introduced that will either improve performance or permit the activity to occur in an injury-free environment. An understanding of the mechanics of movement (biomechanics) is critical to both of these processes. In netball, the teacher may emphasise the importance of wrist flexion in improving shooting performance, while also stressing the need to land, following a catch, with your foot 'under your midline and not to the side of the body', to reduce the likelihood of a knee injury (Figures 1.7a and b).



Figure 1.7: *Netballer landing from a jump with (a) her foot under her body (safe for the knee) and (b) with leg out wide (unsafe for the knee)*

Class task: *Identifying important performance indicators*

In small groups, identify two examples where biomechanics may play a part in a sporting activity to improve performance. Provide one example from a clinical situation and one example in the workplace.

Practical activity: *Identifying important performance indicators*

In small groups, select a sporting activity and identify one factor in the movement that is important in:

- successful performance of the skill
- reducing the likelihood of injury during performance of that skill.

Video one of your group members performing this skill, making sure that the above two features of performance are recorded. You may need to record these features separately, as you will want to place the camera perpendicular (at right angles) to the movement of interest. Review these findings with your teacher and the class.

Equipment:

- Video camera and playback monitor (ensure camera has a 'sport' setting or the ability to reduce the exposure time). Ensure you manually focus the camera.
- Various sporting equipment as identified by the class. The teacher may wish to limit the scope of the sports chosen by the group.

There are a number of steps in the application of biomechanics to either improve performance or reduce the likelihood of injury. Firstly, as stated above, a student needs to at least have some understanding of the movement characteristics of the skill. Secondly, you must be able to observe movement from an individual segment perspective and this requires a systematic approach to evaluating the skill. This chapter introduces selected mechanical factors, which includes discussion of an analysis system. The first step in gaining an appreciation of movement from a biomechanical perspective requires a student to identify the differences between linear and angular motion and how these two types of motion link to form general motion that we see in everyday life.

Motion Analysis

To successfully analyse and then modify a skill typically requires a five-step process that includes preparation, observation, evaluation, intervention and re-observation (Figure 1.8).



Figure 1.8: *Analysis procedural format*

Text outcomes: *Qualitative motion analysis*

- *Explain the difference between qualitative and quantitative motion analysis.*
- *Create a 'check list' of technical (mechanical) factors used to identify errors in performance for all phases of movement (preparation, action and follow-through).*
- *Explain how the five-step or stage process of motion analysis (preparation, observation, evaluation, intervention and re-observation) is used to improve performance or reduce the potential for injury.*



Figure 1.9: *Various phases of the tennis serve from: (a) preparation, (b) backswing, (c) forward swing and (d) follow through (Pictures published with the permission of the International Tennis Federation)*

1. Preparation

In this phase it is important to have some understanding of the biomechanics of the movement of interest. Having created this list of variables you must then: identify the key variables involved in the skill that, if changed, will truly improve performance or reduce the likelihood of injury. For example, in a kick for distance, one mechanical variable important for success would be flexion of the knee joint during the backswing. In developing this list of important variables, always do so for each of the phases of the movement. For instance, in the tennis serve, consider the following phases:

Stroke preparation phase (Figure 1.9a)

- Position of the feet.
- Rotation of the trunk.

Backswing phase (Figure 1.19b):

- Rotation of the hips and trunk.
- Drive from the legs.

Forward swing to impact phase (Figure 1.9c):

- Is the body off the ground?
- Height of impact.

Follow-through phase (Figure 1.9d):

- Movement into the court.
- Did the player land on the front or back foot?

2. Observation

In this phase, you must observe the key mechanical variables in the skill of interest. Considerations should be given to:

- ***At what stage of performance*** should this observation occur? Will it be the start of training or a match or after a period where fatigue may be a factor?
- ***What is the level of performance*** during a lesson or in a match situation when performance is influenced by factors such as nerves and audience expectation?

Different mechanical features should be observed from different viewpoints (for example, side or back). As shown in Figures 1.9a to 1.9d, the tennis serve is best observed from different viewing positions. For example, the lean of the trunk to the side would best be assessed from behind, whereas the distance into the court at impact would be viewed best from the side.

3. Evaluation or Diagnosis

In this phase, you compare what is observed, to what you think should be ideal for the performer being analysed, based on their age and skill level. This observation would be based on some quantitative assessment, namely the angle of the trunk or distance between impact and the baseline. In assessing the key variables you must also:

- Assess the strengths & weaknesses in the performance.
- Prioritise weaknesses, so that they may be addressed in a systematic manner.

In looking at the knee flexion angle in kicking, as discussed earlier, you would compare what you see, with the ***ideal*** knee angle in kicking for distance. Remember, this angle may change with age or level of development in the kick. Young children may be encouraged to show a small level of flexion, while adolescents would show an intermediate level and finally a skilled performer may show full flexion. In the tennis serve example (Figures 1.9 a–1.9d) the level of knee flexion during the preparatory phase may be small for a beginner (approximately 20°) and large (approximately 80°) for an advanced player.

4. Intervention or Remediation

This is the most difficult step in this process, where having decided what to change, you then go about trying to modify the technique, either to improve performance or reduce the likelihood of injury. You must select the appropriate intervention(s). How are you going to change the variable of interest? If you use a series of interventions to improve the swim turn, you may do this from a number of different perspectives (Figure 1.10):

- ***Technical***: The performer may need to modify his turn technique to improve performance. He may not be tucking sufficiently to permit an efficient body rotation (Compare Figures 1.10a and b).
- ***Physical***: His push from the wall may be weak and more physical training may be needed to improve this aspect of the turn.
- ***Psychological***: He may fear hitting the wall in the turn and therefore you may need to overcome this fear before being able to develop an effective tumble turn.

This process obviously requires a fifth step, where the modified performance is ***5. re-observed*** to check if the required changes have actually been made. While this approach has been qualitative in nature, you may wish to use simple quantitative measures, such as time (stopwatch) or distance (metres from a tape) to assist in assessing the performance outcome. Video analysis may also be used to assist performance assessment, as you can view the performance ***frame by frame*** and repeatedly. Some tips on video photography may assist in this process and include:

- Use a tripod where possible to keep the camera level and steady.



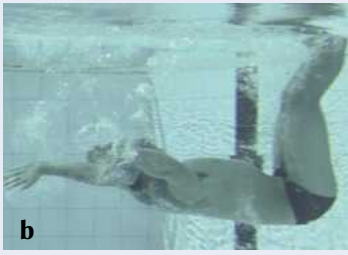


Figure 1.10: *Two aspects of the freestyle tumble turn with (a) a good tuck and (b) a poor tuck.*

- Where possible use the sport exposure setting in the video menu. This will reduce blur in the picture, particularly when recording fast movements.
- Always film at right angles (90° side-on) to the performance, or to the variable you are trying to view.
- Make sure the image is as large as possible (when focusing, zoom in and focus and then zoom out to establish the area needed in the analysis).

Practical activity: *Qualitative analysis of throwing a dart*

- Analyse the upper limb technique used in dart throwing with the dominant and non-dominant hands. As a class, compile the list of key biomechanical variables (segment movements, angles and so on) associated with movement at the elbow and wrist joints in dart throwing. Then decide on the position an observer would stand to assess the above variables. Carry out an analysis with the intention of identifying variables that may need modification to improve performance.

Equipment:

- Dart board and darts.
- Whiteboard and pens.

Practical activity: *Qualitative analysis using video playback*

In small groups, select a sporting skill of your choosing. In this skill:

- Select two key performance variables involved in each of the backswing, forward swing and follow-through phases of the skill.
- Decide which ideal movement characteristics are related to each of these variables (for example, balance, range of motion, speed of movement, sequencing of movement).
- Video a student from your group performing this skill, from as many views as is necessary to record the selected variables.
- Using slow motion playback, review the skill and compare the movements of your subject against your ***ideal movement characteristics***.
- Make recommendations for modifications for improved performance
- If time allows, you could attempt to modify the performance and then re-video to see if you have been able to successfully improve performance. This may be decided objectively by an increased kicking distance or number of goals scored, or qualitatively, by assessing the movement to be more fluent.

Equipment:

- Video camera and playback monitor.
- Various sporting equipment.

Biomechanics: ATAR Units 1 and 2

A similar approach is followed for each section, starting with textbook-related learning outcome statements, followed by a dot-point box identifying the 'Content that follows' and the theory and application for each content area. Suggested class tasks and practical activities are embedded within the sections of the text. A 'Key point summary' box is presented at the end of each section.

Two practical investigations are included in this chapter. They are identified as Appendix B1 (Unit 1 content: The principles of optimal projection) and B2 (Unit 2 content: Newton's laws of motion). A format for report writing can be located at the end of this chapter (Appendix A) to assist students with their preparation of the practical investigation. Marking matrices are also included in Appendices B1 and 2. Answers are provided for teachers only.

Revision questions (with answers) are included near the end of each chapter (Appendix C). A 'Glossary of key terms' appears in the final pages of this chapter (Appendix E).

At the end of the chapter titled Exercise Physiology is a 'Personalised project', which requires students to apply knowledge and understanding from Biomechanics, Functional Anatomy and Exercise Physiology (Appendix D). Even if this task is not undertaken for assessment purposes, it provides a valuable tool for revision.

Linear and Angular Motion

Text outcomes:
***Linear and angular motion* (Unit 1)**

- *Define and show an understanding of biomechanical principles relating to:*
- *Linear motion*
- *Rectilinear and curvilinear motion*
- *Angular motion*
- *General motion.*

There are two ways to classify the human body as it moves during a sporting activity. The first is to consider the path traced by either the body as a whole (using the hip to represent the entire body's centre of mass) or the end of a segment (using a point, such as the elbow or knee — they represent the endpoints of the upper arm and thigh, respectively). That is, you consider the movement of the hip during cricket fast bowling from the start of the run-up to ball release (Figure 1.11a) or the path tracked by the ankle (the end of the leg) during a kick (backswing position through impact to the completion of the follow-through, Figure 1.12). These are examples of **linear motion**.

The second method is to look at how a segment moves. Consider how the leg rotates during a kick discussed above, or the hand flexes at the wrist during a basketball or netball

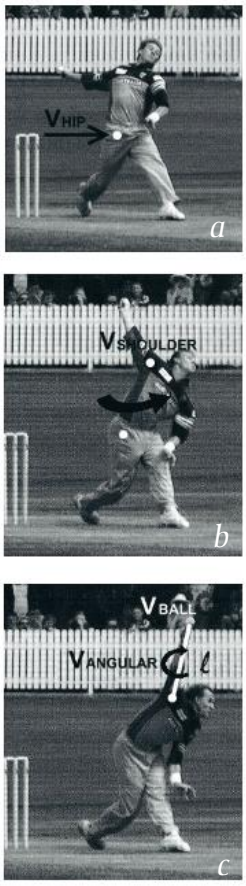


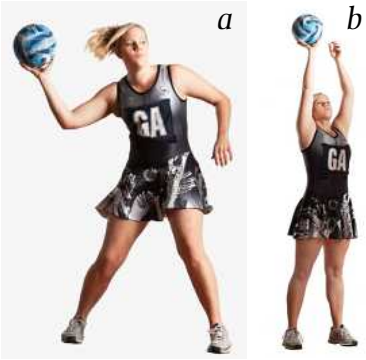
Figure 1.11: *A fast bowler during (a) run-up and (b and c) delivery, showing linear and angular motion*

shot for goal. These are examples of **angular motion**. In Figures 1.11b and c the angular motion of various segments produces the linear motion of the ball at release in cricket fast bowling. The linear motion of the ball at release is therefore a combination of:

The linear motion of the hip (V_{hip})
Figure 1.11a)
(the higher the speed of run-up, measured by the speed of the hip at ball release, the higher the speed of the ball, all other things being equal — compare the approaches of a spin and fast bowler)
+
The angular motion of the trunk ($V_{shoulder}$)
(Figure 1.11b)
(the rotation of the trunk, when added to the linear speed of the hip (above) will produce the linear speed of the bowling-shoulder at release)
+
The angular motion of the upper limb (V_{ball})
(Figure 1.11c)
(the movements above are then increased through a rapid rotation of the upper limb to produce the linear motion of the hand/ball at release. The length of the upper limb also plays a role in this process if you wish to actually calculate the speed of the hand at release)

Linear motion

This describes motion along a line (trajectory or path) that is either: rectilinear (straight line) or curvilinear (curved trajectory). Such straight-line movements may be represented by: movement of the body as a whole (eg. hip) or segment endpoint (eg. top of head), as discussed above. Compare the movement of a ball in a netball pass (Figure 1.13a) and a shot for goal (Figure 1.13b). While both of these may be defined as linear motion, the pass is more rectilinear as it generally travels flatter and in a straight line. The shot is more curvilinear as it follows a curved path to go through the goal. In a 400 m race, a runner is performing linear motion on the straight and curvilinear motion when running the bend. Both of these forms of motion are measured in units of length (metres, centimetres).



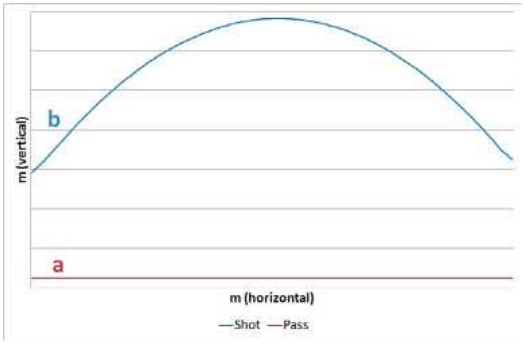


Figure 1.13: *Examples of linear motion where both rectilinear (line a: netball pass) and curvilinear (line b: netball goal shot) motion occur for the ball during a netball game*

Angular motion

This is rotary (circular) motion and the best way to think about this from a human motion perspective is to consider the movement of body segments or implements that are swung in a full or part circle during a sporting action (for example, stick in hockey, club in golf or racquet in tennis). This would be the rotation of the upper limb (arm) in cricket bowling or in softball pitching. This form of motion may be measured in varying units.



Figure 1.12: *The ankle joint during a football kick is an example of linear motion*

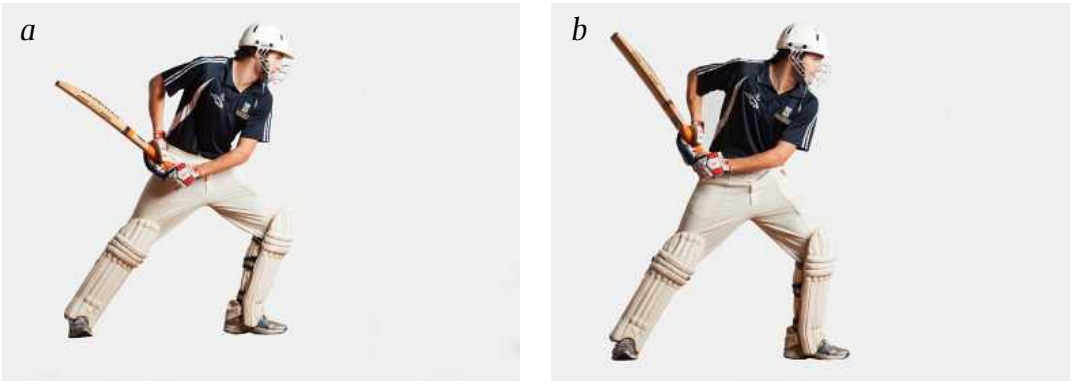


Figure 1.14: *Cricket strokes with (a) reduced and (b) large ranges of bat rotation*

When batting in cricket, the rotation of the bat is a form of angular motion, typically measured in degrees. In Figure 1.14, compare the rotation of the bat in a defensive stroke (Figure 1.14a) and an aggressive drive (Figure 1.14b). From the backswing position to release, the bat may rotate through approximately 140° in the defensive shot and 160° in the aggressive stroke. Although you are not required to measure this angle within this section of the course, you should be able to evaluate the general amount of movement about a joint or implement and the impact this may have on the performance.

General motion

This is where angular motion of a number of body segments produces linear motion of the body — collectively referred to as general motion. Consider the general motion of a cyclist, where the angular motion of the lower limbs apply force to the pedals, causing circular motion that typically drives the total body (the hip or the centre of gravity as discussed later) in a straight or linear path (Figure 1.15). Similarly, during sprinting the legs and arms operate with angular motion to drive the body forward, down the track along a linear path. Together, linear and angular motions combine to create general motion, which is typically the type of motion we observe in sport.



Figure 1.15: *Cyclist, showing how angular motion of the lower limbs drives the linear motion of the body's centre of mass forwards*

Class task: *Throwing it faster*

How do you throw a ball at a higher speed? In this discussion, consider the value of the run-up (movement of the throwing-shoulder forwards: linear motion) and also the rotation of the upper limb segments (angular motion). Discuss how many upper limb segments are involved in the movement.

Equipment:

- Whiteboard and marking pens.

Practical activity: *Motion analysis*

Video a runner, from a side-view, sprinting along a 100 m track. Use this video to plot the hip, knee and ankle motion during a running cycle. To do this, attach paper to the playback screen of your TV and advance the runner frame by frame, marking the appropriate positions for each frame. Discuss the types of movement of these markers and how they differ.

Equipment:

- Video camera and playback monitor.
- Transparent paper and marker pen.

Practical activity: *Improving performance*

Watching a cyclist on a stationary bike, identify technical or positional changes that the rider could use to increase his linear speed, when riding on the road.

Equipment:

- Stationary bike.

Text outcomes:
Linear kinematics (Unit 1)

- *Define and apply the following during linear motion: displacement, velocity and acceleration.*
- *Identify the differences between displacement and distance, speed and velocity, and instantaneous and mean velocity measures.*
- *Define and understand the role of release velocity and the angle and height of release during projectile motion for a range of sporting activities.*

Linear Kinematics

Linear kinematics is the term used to describe motion along a line (trajectory or path), which may be either rectilinear (a straight line) or curvilinear (a curved line; often referred to as parabolic motion) as previously discussed in the earlier section.

Content that follows:
Linear kinematics (Unit 1)

- *Displacement/distance*
- *Velocity/speed*
- *Acceleration*

Displacement (distance)

Displacement is the change in overall position of a person measured in the unit of metres (m). It refers to the absolute difference between your start and finish positions and should not be confused with the term distance, which refers to how far you have travelled from your start to finish positions. For example, a runner who completes the 100 m sprint (Figure 1.15a) will have a displacement of 100 m (ignoring the section after the finish line where he/she is slowing down) and will also have covered a distance of 100 m. Whereas the 400 m sprinter covers 400 m in distance but effectively has 0m displacement at the end of the race — this is how far the runner is ***out of place*** from the start to the completion of the race.

Velocity (speed)

This is distance divided by time, measured in metres per second (m/s or m s^{-1}), which simply stated, is how quickly you cover a given distance. We use distance here and not displacement because if you run a 400 m race as stated above, to obtain your average velocity for the race you would divide the distance covered (400 m) by the time taken; whereas if one used displacement one would divide 0 m by the time taken, producing a misleading answer of 0 m/s.

Velocity is simply speed with direction. Consider the 100 m final at the Beijing Olympics, won by Usain Bolt from Jamaica (9.69 seconds; World and Olympic records). His displacement and distance travelled during the race was 100 m (Figure 1.16a). From this curve it could be calculated that:

- His peak (maximum) speed of 12.2 m/s was recorded at about the 70 m mark of the race (Figure 1.16b). This would be his ***instantaneous*** speed at this mark. Notice how he is able to maintain this peak speed from approximately the 60 – 80 m marks. The ***average*** speed for the race would be 10.3 m/s (100 m/ 9.69 s). Remember, this would be less than the peak value of 12.2 m/s, primarily because of the time taken in the start, the slowest part of the race.

Acceleration

This is calculated as velocity divided by time (m/s/s or m s^{-2}). Again, in simple terms, it can be thought of as how quickly we are changing our velocity. For example, when a car takes off from a red light the car's velocity increases markedly, which is why we say the car is accelerating. If the car's speed then reaches 60 km/hr and stays there for 5 km, then the car is still moving but it has zero acceleration, because the speed is constant (we refer to speed here because for the car to have velocity we need to say what direction it is travelling). When the driver sees a stop sign and begins to break, the car reduces its speed and, therefore, is decelerating.

Figure 1.16C shows:

- Bolt's peak acceleration is recorded very early in the race (20 m) where the greatest rate of change in speed was occurring.
- Even though the acceleration curve appears to go downwards after the 20 m mark, Bolt is still accelerating until the 70 m mark of the race. We can say this because the acceleration remains positive for this period of time. He is still accelerating but just at a lesser rate than that observed in the first 20 m. From the 70 – 80 m mark (approximately the 60 – 80 m marks mentioned above) Bolt maintained a constant speed of 12.2 m s^{-1} and, therefore, an acceleration value of 0 m s^{-2} is observed. From this point Bolt slows down in speed from 12.2 to 11.1 m s^{-1}, indicating that he is decelerating.

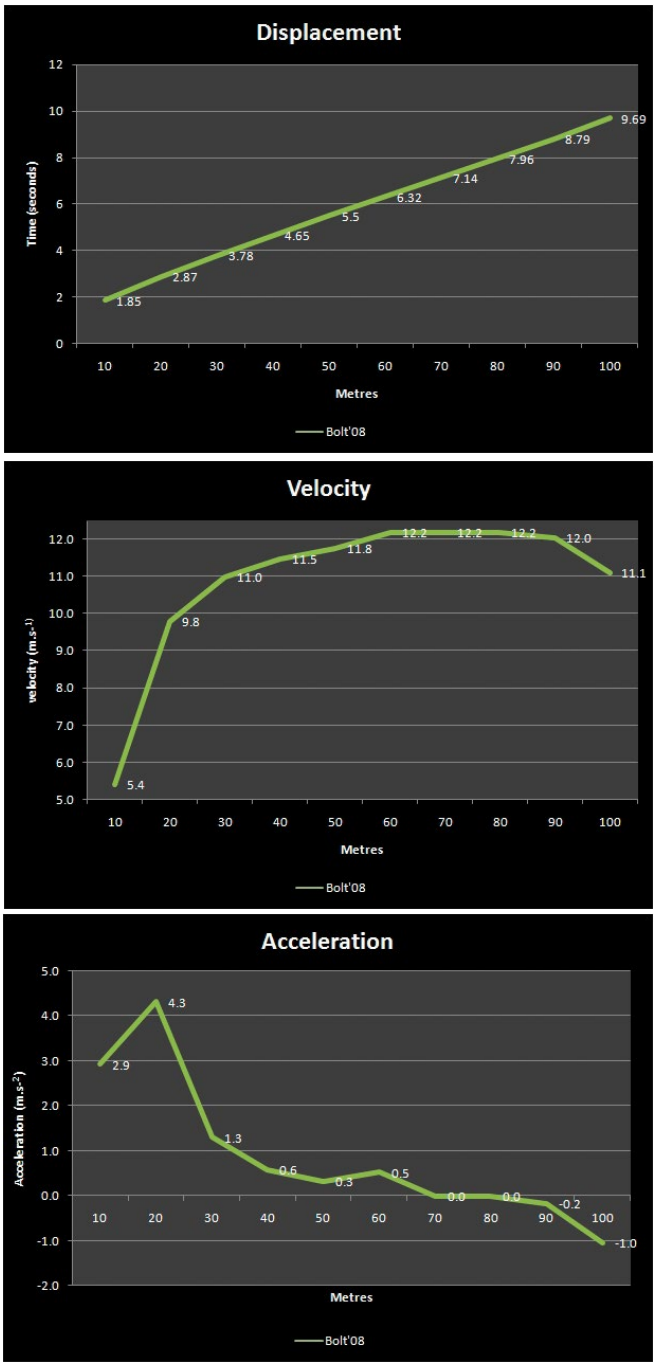


Figure 1.16: *(a) Displacement, (b) speed and (c) acceleration curves for Usain Bolt's World Record 100 m sprint at the Beijing Olympics*

Key point summary:

- When running on a treadmill, although you are covering a distance, your displacement is zero because you have not gone anywhere. If the speed of the treadmill belt is not increased you will run at a constant velocity and your acceleration will be zero.

Revision questions:
Test yourself on revision questions 1–3 located at the end of this chapter.

Practical activity: *Calculating average speed*

Ask one class member to walk the length of a room. As the person walks, the class records the time it takes to pass a number of equally spaced points (use markers) between these two endpoints.

Ask the walker to change their speed for another trial. The class should then plot displacement of the walker and calculate average speed over the different trials. Compare this with a 100 m sprint time where times are recorded every 10 m.

Equipment:

- Clock or stopwatch.
- Markers.
- Measuring tape.

Content that follows:
Projectile motion (Unit 1)

- *Horizontal component*
- *Vertical component*
- *Gravity*
- *Velocity, angle, and height of release*

Projectile Motion

Projectile motion refers to motion of objects in sports such as baseball, basketball, golf, tennis and volleyball and the motion of the whole body in events like the high jump, long jump and aerial activities. An object, which is thrown vertically upwards or thrown upwards at an angle to the horizontal, is a projectile. A projectile is, therefore, any object, which, once projected or dropped, continues in motion by its own mass and is influenced only by the downward force of gravity (remember we are ignoring air resistance). The following factors are integral to an understanding of projectile motion:

The force of gravity results in constant vertical acceleration (dropping object) or deceleration (object moving upwards).

Key point summary:

- Gravity does NOT influence horizontal motion; it only applies vertically and affects all objects at a constant rate of 9.8 m s^{-2}.
- Two objects of a similar surface area and shape, such as a shot put and a softball, although of two different masses, when dropped from a height of 10 m, would both hit the ground at a similar time.

Gravity is 9.8 m s^{-2} (sea level) though this level reduces to 1.6 m s^{-2} on the moon. This means that an object dropped from a height would accelerate towards the earth at 9.8 m s^{-2} and accelerate toward the surface of the moon at 1.6 m s^{-2}.

There are three factors, other than gravity, that have an influence on projectile motion.

Velocity of release

How fast was the ball thrown or how fast were you travelling, when you jumped into the air? A higher release or take-off velocity will increase either the horizontal displacement, if the projection angle is less than 45° or increase the vertical displacement (height) if the angle is greater than 45°. If the angle of release or take-off is constant, then a higher velocity will produce a better result (Figure 1.17a).

Angle of release (projection angle)

This refers to the angle that the projectile is thrown. As can be seen in Figure 1.17, the projection angle and horizontal and vertical velocities are clearly linked. If you want to jump vertically you would approach with an optimal and not maximum velocity and jump with a higher (more vertical) take-off angle. Examples of actions or skills that require higher angles of release are the high jump, or when you attempt to dunk a basketball or jump vertically to spike in volleyball. Alternatively if you want to jump or throw for maximum distance you would use an angle close to the optimal mathematical angle of 45° (Figure 1.17b). In reality, though, the long-jumper is just not physically strong enough to retain sufficient horizontal velocity and at the same time achieve the 45° angle — hence the lower ~20° angle. The long-jumper trades off the optimal take-off to maintain near maximum velocity.

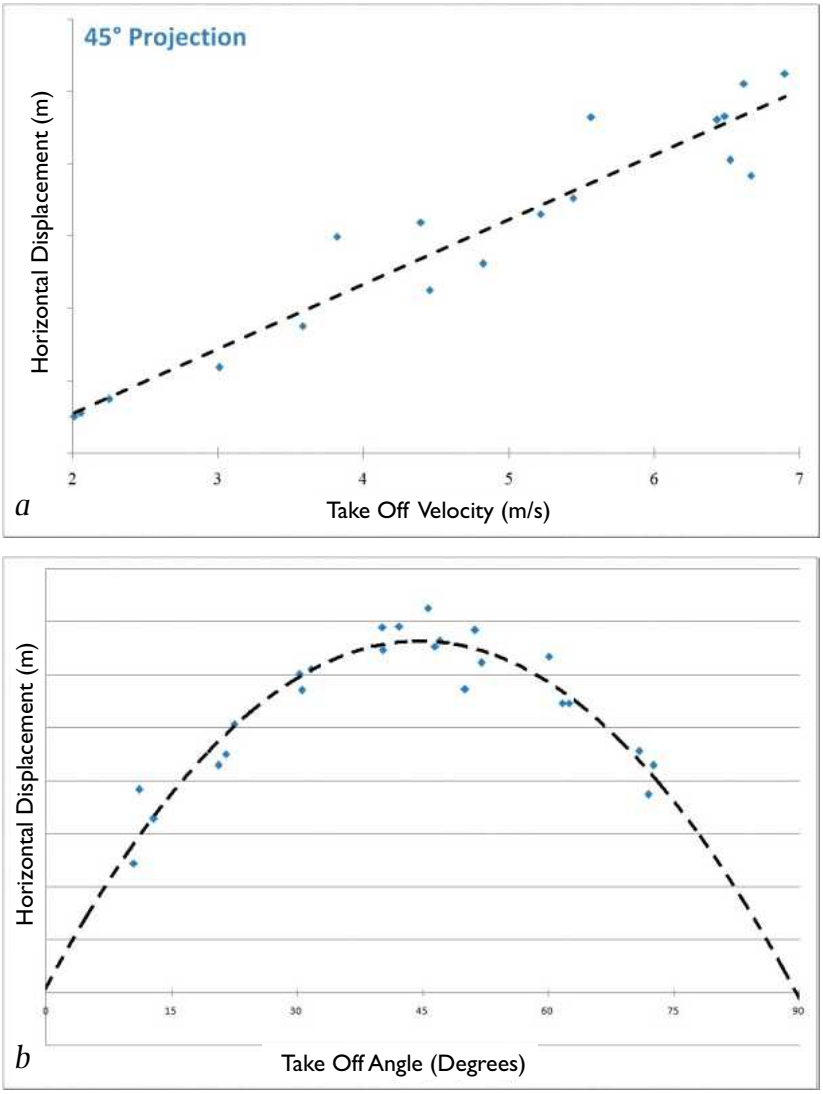


Figure 1.17: *Take-off velocities and projection angles where (a) represents increased displacement for increased velocity, when the take-off angle is constant. Where (b) represents the parabolic displacement profile for varying take-off angles, when take-off velocity is held constant, you can observe the optimal take-off angle is approximately 45°.*

Class task: *Angle of release and velocity trade-off*

Imagine if you could maintain Usain Bolt's maximum velocity of ~12 m s^{-1} and take off at an angle of 45°—you would jump an amazing distance. The current World record is approximately 9 m, yet if you could run at 12 m s^{-1} and take off at the optimal 45° you would jump approximately 14.7 m.

Discuss other examples in sport where a trade-off exists between run-up velocity and angle of take-off.

Height of release

What height was the projectile (person or implement) released from, compared with the height of the landing or target (for example, basketball ring)? The height of release is not as critical a factor as velocity and angle of release, when the point of release (in a throw) or take-off (in a jump), is approximately at the same height as the landing. However, it is a major issue if there is a large difference between the take-off and landing positions. Typically if the landing height is greater than the take-off height (for example, a basketball shot) then the projection angle is greater than 45°. Conversely, if the landing height is less than the take-off height (for example, in shot put) the angle will be less than 45°.

Key point summary:

There are three features in projectile motion (projection velocity, angle and height of take-off), however, the key concepts are:

- Take-off velocity is optimal for each individual sport.
- Horizontal velocity is lower in vertically-oriented sports (spike in volleyball) and higher for horizontally oriented activities (long jump).
- The angle of release is also critical for success in most examples of projectile motion and should be matched with the requirement of the activity. The angle of projection is lower for a golf 3-iron versus a 9-iron, as the 9-iron is designed to produce height and the 3-iron is designed for gaining distance (length).
- When the release height is greater than the landing point, the optimal projection angle (release angle) is generally lower than 45°.
- Optimal projection angle (release angle) is generally greater than 45° when the landing point (or target in basketball) is higher than the release height.

Practical activity: *Manipulating the three features of a projectile*

- Shoot an elastic band using different launch angles to evaluate distance travelled. How does the angle of release influence distance?
- If you use different strength/width bands does this influence distance travelled for the same angle?

Equipment:

- Elastic bands (select bands of varying thickness to show the influence of velocity at a given trajectory).

Practical activity: *Determining the optimal angle of release*

Evaluate the role of the angle of release on horizontal displacement.

Working in pairs, ask your partner to throw a shuttlecock at a 45° angle at maximum velocity, such that you are able to catch the shuttle at a similar height to the release height.

- Draw and label the flight path/trajectory of a 45° angle of release on a piece of graph paper.

Determine the optimal angle of release for the shuttlecock.

- Throw above an angle of 45° then draw and discuss the shape of the flight path.
- Throw below an angle of 45° then draw and discuss the shape of the flight path.
- What impact does an *increase* in the angle of release have on:
    a) The horizontal displacement of the shuttle?
    b) The vertical displacement of the shuttle?

Equipment:

- Shuttlecock.
- Graph paper.
- Large protractor.

Practical investigation

Evaluate the role the angle of release, height of release and velocity of release has on the horizontal distance a projectile travels.

See Appendix B1 for a practical investigation, along with questions and report writing format recommendations.

Revision questions:

Test yourself on revision questions 4–8 located at the end of this chapter.

Angular Kinematics

While each of the key linear kinematic variables — displacement (distance) velocity and acceleration — has an angular equivalent in this text, we will only deal with angular distance and velocity (Table 1.1). Angular motion refers to the rotation of a whole body or segment (for example, forearm or leg), or an implement, such as a bat, stick or club.

Text outcomes:
Angular kinematics (Unit 1)

- *Understand the difference between linear and angular motion.*
- *Understand how angular motion influences movement in sport.*
- *Identify how linear and angular motions combine in sport.*

Content that follows:
Angular kinematics (Unit 1)

- *Angular distance*
- *Angular velocity*

Angular distance

How far does a body segment or implement rotate from its start position (degrees°)?

A gymnast on the high bar will rotate through an angular distance in much the same way as a hockey player rotates their stick through an angular distance to generate velocity of the stick-head for ball impact (Figure 1.18). If you are only concerned with measuring the rotation of the stick, then this may be measured in degrees. In Figure 1.18, the stick moves through approximately 110°

Table 1.1: *Units for linear and angular motion*

Variable	Linear motion—units	Angular motion—units
Distance	m	Degrees (°)
Velocity	m/s; m s^{-1}	Degrees/s; deg s^{-1}

from the backswing position to impact. To increase this range of angular motion, the stick would need to be taken back further in the backswing, thus allowing for an increased distance over which the stick may ***build velocity*** for impact.

Angular velocity

How quickly does a body segment or implement rotate (°/s; deg s^{-1})?

As with linear velocity, angular velocity is calculated by dividing the angular distance an implement travels (for example, the stick, which is measured in degrees) by the time taken for this rotation to occur (seconds). The term angular velocity is represented by the symbol omega (ω) and as an equation is expressed as:

Angular velocity = angular distance divided by time or $\omega = \theta/time$

However, to fully understand angular motion it is necessary to appreciate how angular and linear motions interact (this concept is further explored in the section on segment coordination or segment interaction). In building stick speed in hockey, club speed in golf or hand speed in bowling (cricket and tenpin), other movements of the body must also be taken into account. For example, the cricket fast bowler or tenpin bowler uses the linear velocity of the whole body (run-up), combined with rotation of the trunk, upper limb and hand to ***build*** the linear release velocity of the ball (Figure 1.11).

Therefore, when we want to calculate the linear speed of an endpoint, such as the hand or the foot we need to consider the:

- Forward movement of the total body, which is assessed from the forwards movement of the hitting-shoulder in throwing and bowling activities or the hip in kicking activities (Figure 1.19).
- Rotational velocity of the upper (throwing) or lower (kicking) limb multiplied by the length of the limb

Figure 1.18: *Hockey player hitting a powerful pass (a) showing backswing and (b) impact positions (Desmond Abbott: The first male Australian Aboriginal to win an Olympic hockey medal)*



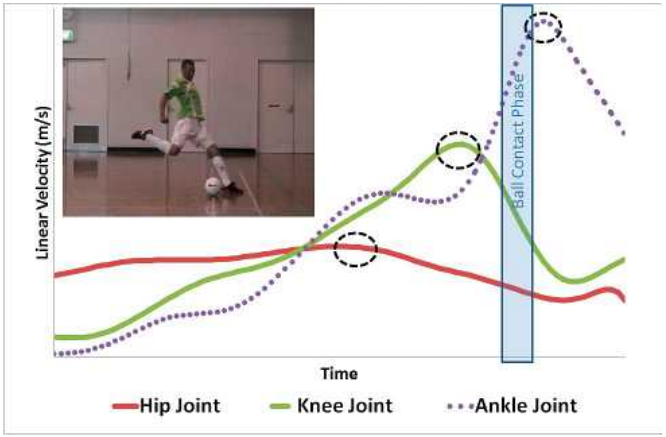


Figure 1.19: *Building foot speed in a kick for distance*

Key point summary:

There are four things to consider when building the speed of the hand or the foot, in linking linear and angular motion:

- How fast is the body moving forwards at the time of impact or release (run-up velocity)?
- How quickly do you rotate the segment(s) involved in the movement, remembering that you may need to consider more than one segment?
- The number of body parts that contribute.
- What is the length of the segment? In the kicking example in Figure 1.19, the linear velocity of the ankle/instep compared with the knee would be calculated using the distance (length) between the knee joint (the point of rotation) and the instep of the foot.

Practical activity: *Observing linear motion*

Use a tape to mark lines on a long pole at different lengths. Swing the pole by your side in full circles and observe how points at different lengths along the pole are travelling at different linear velocities – even for the same rotation rate (angular velocity) of the pole.

Equipment:

- Pole.

Practical activity: *Observing linear and angular motion*

Watch a video of a person hammering a nail. In your group, discuss how the person provides velocity to the head of the hammer. In this movement, where is the angular rotation and where is the linear movement? If the handle of the hammer were longer would the head of the hammer move faster?

Equipment:

- Hammer.
- Video camera and playback monitor.

Revision questions:

Test yourself on revision questions 9–11 located at the end of this chapter.

Text outcomes:
Linear kinetics (Unit 2)

- *Define the centre of gravity and explain how this concept may be used to assess sporting performance.*
- *Define and apply the principles of balance during static and dynamic activities.*

Content that follows:
Linear kinetics (Unit 2)

- *Body weight*
- *Centre of gravity and line of gravity*
- *Static balance*
- *Dynamic balance*
- *Base of support*

Linear Kinetics

Body weight

Your body weight is a product of your mass (the amount of matter that makes up an object measured in kgs, which varies minimally over different positions on the earth) and your acceleration due to gravity (9.8 m s^{-2}).

Class task: ***The impact of gravity***

Determine the value of gravity on the earth and on the moon. What would be your weight on the moon compared with that on the earth?

Centre of gravity

Gravity acts on the body in a vertically downward direction towards the centre of the earth, through a point called the body's centre of gravity (C of G) or the centre of mass. While gravity acts downwards on every segment of the body, there is one point that can represent all others and that is the C of G. It is an imaginary point, which may lie inside or outside of the body, about which all of the body's mass is equally distributed. When viewing an individual from the side, we typically select the hip joint to represent the C of G of the body during many athletic movements. However, the C of G is a point that may change, based on the relative positions of all body segments.

For example, consider the doughnut depicted in Figure 1.20a. The point whereby all of the doughnut's mass particles are equally distributed is a point found in the middle of the hole of the doughnut. That is the C of G is actually located within the inner hole and not within the doughnut itself. In a similar manner, an athlete may alter the position of different body segments to change the position of the total body's C of G required for a particular activity. In Figure 1.20b, the high-jumper tries to have the C of G pass under or very close to the bar. The jumper does this by performing what is commonly called a 'Fosbury flop' that positions various parts of the body below the bar (arms, head and legs), while at the same time other parts are above the bar (trunk). That is you do not need to raise your C of G as high using this technique to record a successful jump.

Given the importance of the C of G during movement and the fact that it can move around and the vertical line from the C of G to the ground (line of gravity), can even fall outside the boundaries of the body, it logically plays a critical role in the maintenance of balance.

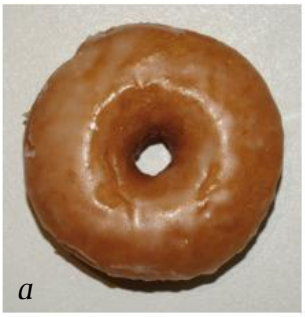




Figure 1.20: *Estimated C of G in (a) a doughnut and (b) a high-jumper.* *Picture published with permission of Western Australian Institute of Sport.*

Key point summary:

- The centre of gravity (C of G) represents the weight centre of the body and is determined by the positioning of all the parts of the body.
- The C of G may lie outside the body itself.

Class task: *Determining the centre of gravity*

In small groups, discuss where the position of the C of G would be for the following figures and what implications this may have on the performance of a hockey player (Figure 1.21a), a long-jumper (Figure 1.21b) and a giraffe (Figure 1.21c).



Figure 1.21: *Various C of G locations in (a) a hockey player, (b) a long-jumper and (c) a giraffe*

Balance

To understand the concept of balance in static (for example, archery) and dynamic (for example, movement about a tennis court) activities, we must consider three factors.

1. Mass

The mass of an object will play a role in determining its balance and how easily it can be moved. In some sporting skills, such as wrestling and tug of war, the object of the game is to resist movement known as static balance. In these cases the performer with the greatest mass has a distinct advantage over a lighter opponent (Figure 1.22). Obviously in dynamic balance lighter athletes will have an advantage, as they do not have to apply a great deal of force to produce acceleration (F = ma).

2. Area of the base of support (Figure 1.23)

Generally the larger the area or base of support (most commonly provided by the feet) the more stable the body is; however, you must look at the position of the C of G in various directions to truly appreciate balance:



Figure 1.22: *A sumo wrestler with a substantial mass is almost impossible to move by a lightweight opponent*

- Side-to-side: The feet are typically positioned shoulder-width apart to create a stable base for performance. If your feet are very close together, your base of support is small and the line of your C of G may fall near or outside the boundaries, thereby creating a situation where it is very easy to topple you over, or very difficult for you to accelerate in a given direction, thus creating an unstable base.
- Front-to-back: Typically we align our feet with the intended direction we wish to travel in or in-line with the direction of an expected external impact (for example, someone tackling you). In a sprint start, the feet are positioned forwards and back, so you can drive to the finish line. In rugby, if possible, the feet are positioned such that you can better withstand the force of a tackle. However, when we are unsure of the direction of travel, our feet are generally aligned, as in Figure 1.23, as this offers the best option to accelerate in varying directions.

3. Position of the C of G with reference to this base of support

A more stable position is achieved when the line of gravity falls in the middle of the base of support:

- Side-to-side. Typically you orientate your C of G so that it is central to the base of support for stability. Athletes, who want to move quickly in a given direction often position their C of G near an edge of the base-of-support to create an ***unstable situation***. Think of the start in swimming or sprinting in athletics (Figures 1.24a and b) and consider where the C of G is, compared with the tennis player in Figure 1.23.
- Vertical. Typically an athlete lowers their C of G to improve balance, as situations where the lower limbs are fully extended (straight) are not common in sport or general movement. Why is the person who is walking on stilts so susceptible to a fall (Figure 1.24c)?
- Front-to-back. How many times have you been told to place your 'weight on your toes', so that you are ready to move quickly as in Figure 1.23? This moves your C of G to the front edge of the base of support and places your bodyweight in a position that means you are ready to move quickly.



Figure 1.23: *Tennis player with her C of G positioned central to her base-of-support, with her weight on her toes*







Figure 1.24: *Sporting pictures showing: (a) position of the C of G in the swimming start, (b) sprint start and (c) person on stilts.*

With an understanding of the position of the C of G relative to the base of support, it is then easy to see how an athlete or in fact someone working in the garden can maintain static balance (sprint start, archery, pistol shooting, bending over to remove a weed in the garden) or have dynamic balance during sporting activities (sidestep to avoid an opponent, quick movement to block a shot in basketball or intercept a pass in netball).

Key point summary:

- When you want to be very stable (static balance), position your C of G such that it is central to your base of support.
- When you are required to continually move, such as in football or soccer, you need to be able to position your C of G so that it is close to the edge of your base of support and generally lower than in the static situation.

Class task: *Maintaining balance*

As a class, discuss why a sumo wrestler gets down low with legs far apart.

Revision questions:

Test yourself on revision questions 12–18 located at the end of this chapter.

Newton's Laws

Text outcomes: *Newton's laws (Unit 2)*

- *Define and apply Newton's three Laws of Motion.*

Content that follows: *Newton's laws (Unit 2)*

- *Newton's 1st Law—the law of inertia*
- *Newton's 2nd Law—the law of acceleration*
- *Newton's 3rd Law—the law of action-reaction*

Newton's Laws

Each of Newton's three ***Laws of Motion*** is discussed separately, followed by practical activities and a practical investigation applicable to each of the three laws.

Newton's 1st Law — The law of inertia

A body continues in its state of rest or uniform motion in a straight line, unless it is compelled to change that state, by a force.

This law may be considered from two perspectives, firstly in the ***creation of motion***.

- Consider a golf ball sitting on the tee (Figure 1.25a). The ball will remain on the tee until the club-head (or the wind) applies a force to change the ball's state of rest (it is not moving), causing it to leave the tee.
- The golfer must apply internal forces through the muscles of the body (Figures 1.25a –1.25b) to cause the club to move from the set to the backswing positions.
- The second part to this law deals with ***changing*** the state of an object.
- In golf the ball would retain a constant velocity after impact if external forces, such as gravity and air resistance, were not apparent. That is, gravity applies a downward force on the ball, while air resistance reduces the velocity of the ball as it moves through the air horizontally. Spin on the ball also creates another force when considered in combination with air resistance.

Newton's 2nd Law — The law of acceleration

The second law of Newton can also be considered from two perspectives. The first is ***force production***.

An athlete undertakes a 'weight training' program to increase the cross-sectional area of a muscle(s) (Figure 1.26 shows the development of Rafael Nadal's dominant, left arm), which then enables more force to be produced, in turn permitting the forearm (made up from bones) either to rotate more quickly or to rotate against a greater load. That is, an increased biceps force can either permit the forearm to flex more quickly in a tennis forehand drive (higher speed of the hand and racquet) or enable more weight to be lifted in a biceps curl exercise. This is the ***force production*** aspect of Newton's 2nd Law:

$$F = ma$$

F = applied force - measured in Newtons

m = mass - kilograms

a = acceleration - m/s/s or m s^{-2}

More force will therefore produce a greater acceleration, if mass is held constant. If you want to throw a greater distance you need to apply more force in the muscles of the lower limbs, trunk and upper limb, so that the upper limb segments rotate at a higher rate — the movement sequence needs to be well-coordinated as well, to achieve maximum velocity.

Alternatively, if you increase the mass of the object to which the force is applied (curl 50 kg rather than 20 kg), then, if the same force is applied, the acceleration of the upwards movement would be less for the heavier mass (50 kg). By increasing the load to be lifted, the athlete will eventually reach their limit and will not be able to accelerate the bar upwards, or indeed move the weight at all.



Figure 1.25: *Sequence of shots for golfer hitting a ball (Figures included with permission of Athletic Edge, Scotch Plains, NJ, USA)*



Figure 1.26: *A specific training program (both in the gymnasium and on the court) has caused the development of Rafael Nadal's dominant left upper limb (picture courtesy of Getty Images)*

Practical activity: *Impact of varying the mass of the ball*

Throw for distance with different weighted balls (tennis ball to shot put). Who in the class threw the shot put the furthest (with the greatest acceleration)? Why do you think they are able to do this?

Equipment:

- Balls of varying weights: tennis ball to shot put.

If we continue the golf example, it is evident that to increase the acceleration of the ball (the mass of the ball is constant) then the force applied to the ball must increase. Greater force will equal greater acceleration of the ball from its stationary position on the tee and thus higher ball velocity. If you want to throw a ball further in cricket or baseball then you apply more force to the ball via the hand (more acceleration if the mass of the ball is held constant).

The second application of Newton's 2nd law deals with ***force absorption***. To understand this conceptually, and not from a mathematical perspective, still requires you to understand that:

a = change in velocity/time $(V_2 - V_1)/t$

That is, $F = ma$ becomes $F = m\ (V_2 - V_1)/t$
V_2 = velocity at the end of a movement
V_1 = velocity at the start of a movement
t = time from V_1 to V_2

So force is now involved with stopping movement (for example, the mass and velocity of the person) over a time period. The application of force over time (Ft) is termed impulse. Consider the following examples:

High Jump

When performing the high jump it is better to land in a foam pit, compared with landing on a concrete surface. Even though you are landing with the same force (your mass and the acceleration of gravity is constant) the time (t) taken to absorb the force (F) of your body hitting the foam, compared with concrete, is greater for the softer foam surface. That is, more time is available to absorb the force with the foam compared with concrete. This results in the same

amount of total force over time but less peak force (that is to say, stopping the force is spread out over a longer period of time in the foam).

Long Jump

Similar to the high-jumper, the long-jumper prefers to land in a sandpit, compared with a grass surface, so the force experienced at impact is spread out over a longer time period.

Gymnast

The gymnast, who is learning new tricks, also uses a foam pit, as opposed to the hard gymnasium floor.

Cricket bowling

A fast bowler flexes the front knee to increase the time the force is absorbed, as they 'slam' their front foot into the pitch during the delivery stride. This results in less peak force.

Baseball

The glove used in baseball has a pocket, which increases the time taken to stop the ball; without a glove you 'give' with the catch. That is, you bend your elbow and move your hand backwards in the direction of the ball, to similarly increase the time taken to stop the ball.

Car racing

Today, selected sections of a car are built so that they have zones that 'crumple' on impact, thus increasing the time over which force is applied to the car. This lessens the likelihood of injury to the driver and passengers.

Practical activity: *Force absorption*

In groups, drop an egg from about 50 cm into a tray with soft foam. Then take the foam away and drop an egg into a tray with a hard bottom. Discuss any observed differences.

In groups, get one person to throw a tennis ball in the air and try to catch it on a racquet without it bouncing. In the group, discuss the features of the most successful technique.

Equipment:

- Tennis balls.
- Tennis racquets.
- Tray with soft foam.
- Eggs.

Class task: *Catching a cricket ball*

Let's look at the practical example of catching a cricket ball (mass = 0.14 kg) and consider the change in force needed to stop a ball (V_2 = 0) travelling at 30 m/s (V_1) over 0.002 s (suddenly) and over 0.01 s (less suddenly).

For the very short time period: $F = m (V_2 – V_1)/t$

$F = 0.14 (0 - 30)/0.002$

$F = 2{,}100$ Newtons

(Sign is related to change in direction for the ball)

(2,100 Newtons is equivalent to approximately 3 times a 70 kg student's body weight)

For the very long time period: $F = m (V_2 – V_1)/t$

$F = 0.14 (0 - 30)/0.01$

$F = 420$ Newtons, which is equivalent to approximately 0.6 times the student's body weight)

Discuss the application of force absorption in a range of sports.

Newton's 3rd Law — The law of action-reaction

To every action there is an equal and opposite reaction

$$F_{2\text{-}1} = F_{1\text{-}2}$$

When striking a golf ball, it is the force applied to the ball by the club ($F_{2\text{-}1}$) that causes it to fly into the air. The ball applies an equivalent force back against the club ($F_{1\text{-}2}$), which assists to slow the club after impact. That is:

The forces of the club on the ball ($F_{2\text{-}1}$) is equivalent to the force applied by the ball on the club ($F_{1\text{-}2}$)

While movement is obviously a positive outcome of this law, we forget that ***overuse injuries*** are also often an outcome of this law. The number of times a force is absorbed by the body must be considered with reference to the likelihood of injury. The higher the number of repetitions, the more likely an overuse injury will occur, particularly if the forces are high, as often occurs in sport. As a very general idea the peak vertical force in body weights (BW — equivalent to the weight of your body) recorded for various activities is:

- Walking ~ 1.2 BW — this is one reason why walking is such a great activity for the elderly (the force applied to the support leg is only marginally more than their body weight).
- Jogging ~ 2.0 BW
- Sprinting ~ 3.0 BW — the force is far greater than in walking. You absorb approximately three times as much force by the support leg when you sprint compared with walking.
- Landing from a height (landing after a netball/football catch) ~ 5.0 BW
- Jumping (high jump and long jump take-off) ~ 8 BW — this is why jumpers often sustain injuries because the forces absorbed by the support leg are huge.
- Landing from extreme heights ≥ 8 BW

The force the ground applies back to the body following an impact is very great for many activities (imagine 10 times your body weight — this would be approximately half the weight of a small car). While we need vertical forces (upwards) and horizontal forces (backwards–forwards) to create motion, the reaction to these forces must be absorbed by the body, starting at the lower limb. Additionally, if one wishes to reduce the potential for overuse injury in high force activities, such as jumping, the number of repetitions must be controlled. However, it should also be noted that force is not always a negative. Force is required to maintain bone density, with bone density loss one of the biggest problems NASA is trying to solve when astronauts are in space for extended periods of time.

Key point summary:

- Newton 1: A body remains in its state of motion unless acted on by an external force.
- Newton 2: Force equals the mass multiplied by the acceleration.
- Where you are stopping the momentum of an object (mass multiplied by velocity) it is important to do so over as long a time period as is practical. That is: $F = (m V_2 - m V_1)/t$ or $F = m (V_2 - V_1)/t$
- Any increase in time will reduce the value of the peak force required to stop the motion, as Ft (referred to as impulse) will be constant.
- Newton 3: Every action has an equal and opposite reaction.

UWA research snapshot: *Sand walking for the elderly*

Researchers from the School of Sport Science, Exercise and Health at The University of Western Australia confirmed that sand walking has excellent outcomes for the elderly, as it:

- increases cardiovascular demand while not increasing the impact force experienced by the body
- improves balance – the irregular surface is very good at improving mechanisms that assist in balance and reducing the risk of falls, which is a large problem in elderly populations.

Practical activity: *Observing Newton's 3rd law of motion*

- Working in pairs, drop a tennis ball onto the floor and record how high it bounces. Now throw the ball more forcefully onto the floor and record its bounce height. Why does the ball thrown onto the floor bounce higher?
- Have members of the class jump into the air and, while in the air, rapidly rotate the arms forwards and downwards (such as a volleyball spike). What happens to the legs? Why?

Equipment:

- Tennis ball.

Practical investigation

Evaluate the role of key movement principles in velocity development of the tennis or volleyball serve and catching a ball.

See Appendix B2 for a Practical Investigation, along with questions and report writing format recommendations.

Revision questions:

Test yourself on revision questions 19–26 located at the end of this chapter.

Coordination of Movement

Text outcomes: *Coordination of linear motion (Unit 2)*

- *Define and apply the concept of summation or coordination to activities requiring accuracy compared with those where maximising velocity is of primary concern.*

Content that follows: *Coordination of linear motion (Unit 2)*

- *Optimal velocity: Simultaneous summation*
- *Maximum velocity: Sequential summation*

This section deals with the interaction of the various segments of the body. There are primarily two approaches to how an athlete coordinates the various segments of the body in movement (for example, in throwing, hitting and kicking), in an endeavour to achieve a desired end result (for example, maximum velocity of the hand or foot at impact or release or an accurate shot). These are the accuracy approach and the maximum velocity approach.

Accuracy approach: Simultaneous movement

In sporting activities where performance requires a great deal of accuracy and distance is not a problem, such as in a netball shot for goal, a shot to sink the black in snooker or to score a bullseye in darts, the sequencing of segments is added ***simultaneously***. Figure 1.27a shows the shoulder, elbow and wrist linear velocities reaching maximum levels simultaneously. While this produces a lesser velocity of the hand or foot, than would occur with the velocity-based approach, a more controlled velocity of the endpoint is produced. Some velocity is traded for accuracy (velocity–accuracy trade-off).

In this netball goal shot (Figure 1.27a) the extension of the forearm at the elbow and the flexion of the hand at the wrist are summed simultaneously to produce a ***controlled*** velocity at the fingers. In basketball and sometimes, when shooting goals in netball, knee extension may also be used to create vertical motion and this also should occur simultaneously with the actions above.

Maximum velocity approach: Sequential movement

In sporting activities where a high velocity is required at release (a long-distance throw, even with some consideration for accuracy, such as throwing a cricket ball from the outfield to hit the wickets) or at impact (a kick for distance) the coordination of segments follows a proximal (larger/slower body parts, such as hips) to distal flow (smaller or faster body parts, such as ankle or foot), with each segment adding velocity to the previous, when that segment has achieved its maximum velocity (Figure 1.27b). This is a staircase approach. By summating at this point of maximum velocity of the preceding joint (segment endpoint) an optimal velocity is achieved at the most distal endpoint. It is easiest to assess this ***summation*** by tracking the linear velocities of the more proximal to more distal segment endpoints (for example, the hip, the knee and finally the ankle). Figure 1.27b shows how in a soccer kick the hip joint reaches its peak linear velocity first and is then

sequentially followed by the knee and finally the ankle reaches maximum linear velocity for impact.

The concept of ***summation of velocity*** is represented in Figures 1.27b, and 1.27c. When kicking, players often approach with a curved run-up to enable more hip rotation to be used in the building foot velocity for impact. Remember, this also makes it easier to impact the ball with the instep of the foot — a more solid base for the kick.

In a throw, the sequence to develop this optimal velocity at the hand typically starts with the legs and trunk, creating linear velocity of the ***throwing-shoulder***, while in a kick it starts with the forward movement of the body, creating linear velocity of the ***kicking hip*** (Figures 1.12 and 1.19). So in a kick for distance the sequence reviewed would typically start by measuring the velocity of the kicking hip (Table 1.2). This assesses the contribution of the run-up and trunk rotation to the final velocity of the ankle. That is, if you kick a ball with no run-up and no trunk rotation then the velocity of the kicking foot (at the instep) will be reduced by the loss of these movements, providing all other factors remain the same - this is why footballers typically use a curved run-up when kicking for distance in AFL or for goal in soccer.

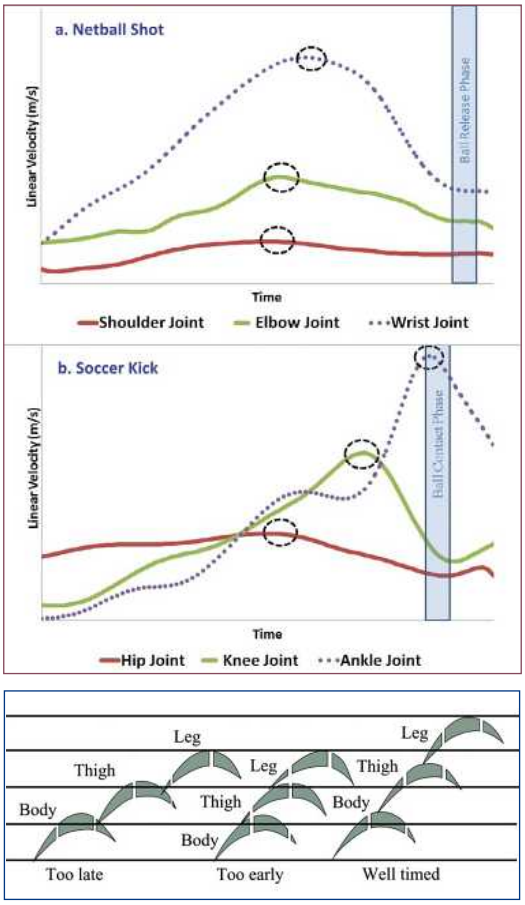


Figure 1.27: *Sporting activities showing (a) accuracy-based sequence in netball shooting, (b) velocity-based sequence for kicking and (c) a graphic of various velocity-based sequences*

Table 1.2: *Velocity-based coordination sequence during a kick for distance*			**Desired result** ***Maximum velocity of the ankle — the instep***
Segment contributing to the movement	Segment end point (linear velocity m/s)	Contribution to the final ankle velocity	
Trunk	Hip	Run-up and trunk rotation	
Thigh	Knee	Thigh flexion at the hip	
Leg	Ankle	Leg extension at the knee	

Practical activity: *Throwing for accuracy versus velocity*

Show how ball velocity in a netball pass or an AFL hand pass can be increased by moving forwards with the body, compared with standing still when you pass.

Discuss the differences in the accuracy versus velocity trade-off in the two- and three-point shots in basketball.

Ask a volunteer to demonstrate how they would throw a ball to hit a small target one metre away on the ground. Then ask the volunteer to demonstrate how they would throw to get the ball as far as possible. Discuss the different strategies.

Equipment:

- Netball or football.
- Basketball.
- Tennis ball.

Practical activity: *Evaluating the contribution of linear motion*

In small groups, select a skill where the movements are relatively linear (for example, kicking, shooting for goal in netball or basketball, bowling or long jump). Video the desired movement and, using slow motion playback facilities, track the path of the desired segment endpoints. Report if the various segments involved in the activity are summated using the maximum velocity or accuracy approach.

Equipment:

- Sports equipment.
- Video camera.
- Payback facilities.

Key point summary:

- If maximum velocity is required then segments should be added sequentially, when the previous segment has reached its maximum speed. The concept of summation of velocity involves the following principles:
  - ◊ Incorporate as many body parts as possible moving through their maximum range of motion.

Key point summary (continued):

- ◊ Develop the force over the longest period of time possible.
- ◊ Sequential movement of the largest and strongest body parts first.
- ◊ Sequentially stabilise each segment so that the next one accelerates around a stable base.
- ◊ Follow through to ensure no deceleration before release.
- ◊ Ensure all forces are directed towards the target. Step to the target and follow through to the target.

- If accuracy is the key to success then movement of these segments should be simultaneous.

Revision questions:

Test yourself on revision questions 27–32 located at the end of this chapter.

Appendix A: Writing the practical investigation report

Writing a report

If you are required to write a report as part of your practical investigation, you may choose to use the following format:

Title: Title of the practical investigation.

Aim: State what you hope to achieve in the experiments (~30–50 words).

Introduction: Define and discuss the sport science principles being investigated (~200 words).

Hypotheses: Identify the expected results or anticipated outcomes (statements).

Method: Identify the steps taken to complete the experiments (~100 words).

Results: Present the data and findings in the appropriate format (for example, graphs, diagrams and tables).

Response to the questions: Write the questions out and respond.

Discussion: Provide a detailed discussion of the results. Apply the sport science principles under investigation to other sporting contexts *(~400 words)*.

Conclusion: Summarise the discoveries made. Make links to each hypothesis and include limitations of the experiment (~100 words).

Appendix B1

Practical Investigation and Report: Biomechanics
The principle of optimal projection

Weighting: Unit 1

Type: Investigation

Content:

- Define and apply projectile motion to a selected sport in relation to the:
  - ◊ principle of optimal projection
  - ◊ parabolic (curvilinear) trajectory
  - ◊ release of projectiles—angle, velocity and height.

Total marks = /30

Task outline

When completing the experiment outlined below, you are to observe and determine the effects of the following factors on the distance that a projectile will travel.

- The angle at release or take-off.
- The height at release or take-off.
- The velocity at release or take-off.

Experiment: Task one

Note: When completing the following tasks, remember to conserve water. Get a friend to manoeuvre a bucket at the landing point to catch water and use it wisely (or alternatively complete the task on grass).

Condition A: Using a hose, direct a stream of water from ground level to cover the greatest distance.

Condition B: Repeat A, but hold the nozzle of the hose at hip height.

Condition C: Repeat B, keeping the angle of projection the same and increase the velocity of the stream of water.

Equipment

- Garden hose.
- Brick wall to run the water stream against and measure.
- Tape measure.
- Protractor.

Questions: Task one

In presenting your findings respond to the following:

a. Identify what is the optimal angle of release for Condition A (1 mark).
   (i) Include a diagram of the optimal water stream pathway or trajectory (0 mark).
   (ii) Describe the shape of this water stream pathway or trajectory (0 mark).
b. Identify what the optimal angle of release is for Condition B (1 mark).
c. Compare the angle of release in Condition A to Condition B (1 mark).
d. What factors influence the angle of release in Condition B? (1 mark)
e. Describe and use a diagram to identify the pathway followed by the water stream in Condition C (1 mark).

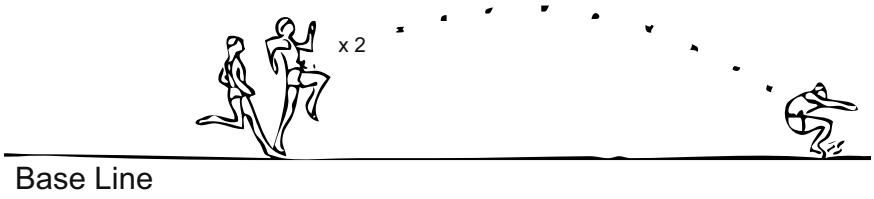


Figure 1.28: *A long jump*

f. What observations can be made relating to the difference in pathways in Condition B and C? You may wish to support your response with a diagram (1 mark).
g. Of the factors that determine the distance a projectile travels, which is the most important in achieving the greatest distance? (1 mark)

Questions: Task two

Study the diagram (Figure 1.28) of the long-jumper and answer the following questions.

a. Describe the pathway of the long-jumper (1 mark).
b. What is the angle of take-off? (1 mark)
c. What factors investigated in task one would cause a reduction in a take-off angle from 45°? (1 mark)
d. What aspect of a long-jumper's technique would account for the angle of take-off? (1 mark)
e. What is the most important factor at take-off in achieving the maximum distance in long jump? (1 mark)
f. Identify and briefly explain, using a sporting example, where the optimal angle of release would be greater than 45° (1 mark).
g. Explain, using the example of tennis, how the angle of release is changed to match the different shot requirements within the game performance (2 marks).

Task: The principle of optimal projection: 30 marks

Components and Performance Standards	Marks
Hypotheses (2 marks)	
Provides simple statements of the expected results or outcomes in relation to the factors associated with projectile motion.	**1 mark**
Provides clear statements of the expected results or outcomes in relation to the angle, height and velocity of release of a projectile travelling for maximum distance.	**2 marks**
Introduction (3 marks)	
Identifies and defines the variables associated with projectile motion.	**1 mark**
Shows an understanding of the principles that govern the behaviour of projectiles and the factors affecting projectile motion.	**2 marks**
Shows a comprehensive understanding of the principles that govern the behaviour of projectiles (trajectory, horizontal motion/velocity and vertical motion/velocity) and the factors affecting projectile motion (velocity, angle and height of release).	**3 marks**
Results (2 marks)	
Satisfactory presentation of data.	**1 mark**
Accurate and relevant presentation of data.	**2 marks**
Response to Questions (15 marks)	
Task one: 1 mark for each correct answer to questions a–g (7 marks).	
Task two: 1 mark for each correct answer to questions a–f (6 marks). Question g (2 marks).	
Discussion (6 marks)	
Shows little comprehension of the variables associated with the activities undertaken.	**1 mark**
Limited discussion of the results found and few links made to the variables associated with the activities undertaken.	**2 marks**
Uses other sporting contexts to discuss the results found and identifies some of the variables associated with projectile motion.	**3 marks**
Uses other sporting contexts to discuss the results found and identifies and defines most of the variables associated with projectile motion.	**4 marks**
Uses other sporting contexts to show an understanding of the results found and discusses these in reference to the principles that govern the behaviour of projectiles and the factors affecting projectile motion.	**5 marks**
Uses other sporting contexts to show a comprehensive understanding of the results found and discusses these in application to the principles that govern the behaviour of projectiles (trajectory, horizontal motion/velocity and vertical motion/velocity) and the factors affecting projectile motion (velocity of release, angle of release and height of release).	**6 marks**
Conclusion (2 marks)	
Summarises some of the factors associated with projectile motion in relation to the hypotheses.	**1 mark**
Fully summarises the impact of the angle, height and velocity of release in relation to the hypotheses. Limitations discussed.	**2 marks**
Comment:	**Total** **/30**

Appendix B1.1 – Answers

Practical Investigation and Report: Biomechanics
The principle of optimal projection

Answers: Task One

a. Identify what is the optimal angle of release for Condition A. (1 mark)
Answer: 45°

b. (i) Include a diagram of the optimal water stream pathway or trajectory. (0 mark)
(ii) Describe the shape of this water stream pathway or trajectory. (0 mark)
Answer: Curvilinear or parabolic

c. Identify what the optimal angle of release is for Condition B. (1 mark)
Answer: Approx 35°

d. Compare the angle of release in Condition A to Condition B. (1 mark)
Answer: B is 10° less than A

e. What factors influence the angle of release in Condition B? (1 mark)
Answer: Height of release: The release point and landing point are different. The greater the height of release, the lower the optimal angle of projection.

f. Describe and use a diagram to identify the pathway followed by the water stream in Condition C. (1 mark)
Answer: Diagram/explanation should indicate that Condition C covers a greater distance**.**

g. What observations can be made relating to the difference in pathways in Condition B and C?
You may wish to support your response with a diagram. (1 mark)
Answer: The greater the velocity the greater the distance covered.

h. Of the factors that determine the distance a projectile travels, which is the most important in achieving the greatest distance? (1 mark)
Answer: Velocity of release

Answers: Task Two

a. Describe the pathway of the long jumper.
Answer: Parabolic/curvilinear

b. What is the angle of take off?
Answer: Approximately 20°

c. What factors investigated in Task One would cause a reduction in a take-off angle of 45°?
Answer: Velocity of the run up

d. What aspect of the long jumpers' technique would account for the angle of take off?
Answer: Velocity, as the jumper would be unable to project him/herself at a 45° angle. That is, he/she would need to slow down in order to jump up.

e. What is the most important factor at take off in achieving maximum distance in long jump?
Answer: Velocity at take off

f. Identify and briefly explain using a sporting example, where the optimal angle of release would be greater than 45°.
Answer: A basketball shot for goal from close to the basket requires an angle greater than 45° such that the flight path will see the ball enter the basket. This means that the vertical component of the ball in flight is greater than the horizontal to achieve this angle.

g. Explain, using the example of tennis, how the angle of release is changed to match the different shot requirements within the game performance. (2 marks)
Answer: A variety of shots and the needs of each shot should be discussed. For example, the lob requires the ball to travel over the players head; therefore a relatively high angle of release is appropriate. A ground-stroke is used to manoeuvre the opponent and force errors; therefore a relatively low angle of release is appropriate. When compared to the lob and a ground-stroke, the front court smash (hit in close proximity to the net) has the highest point of release and it requires the player hit it down into court quickly; therefore it necessitates the lowest angle of release.

Appendix B1.2

Practical Investigation Preparation: Biomechanics
The principle of optimal projection

Unit 1

Type: Investigation

Outcome 3: Knowledge and understanding of movement and conditioning concepts for physical activity.

Content:

- Define and apply projectile motion to a selected sport in relation to the:
  - ◊ principle of optimal projection
  - ◊ parabolic (curvilinear) trajectory
  - ◊ release of projectiles—angle, velocity and height.

Task outline

You are required to complete the experiment outlined. It is important that you accurately record all results.

When completing the experiment you are to observe and determine the effects of the following factors on the distance that a projectile will travel.

- The angle at release or take-off.
- The height at release or take-off.
- The velocity at release or take-off.

Once the experiment is completed you need to:

1. Compose an accurate and relevant presentation of the results. (Bring with you and submit at the completion of the In-Class Assessment Task.)
2. Answer all of the questions outlined in Task 1 and Task 2. Some of these questions, along with additional questions will appear in the In-Class Assessment Task.
3. Develop a comprehensive understanding of the principles that govern the behaviour of projectiles (trajectory, horizontal motion/velocity and vertical motion/velocity) and the factors affecting projectile motion (velocity, angle and height of release).
4. Through research, use other sporting contexts to show a comprehensive understanding of the results found and discuss these in application to the principles that govern the behaviour of projectiles (trajectory, horizontal motion/velocity and vertical motion/velocity) and the factors affecting projectile motion (velocity of release, angle of release and height of release).
5. Discuss the limitations of this experiment.

Experiment: Task one

Note: In completing the following tasks remember to conserve water. Get a friend to manoeuvre a bucket at the landing point to catch water and use it wisely (or alternatively complete the task on grass).

Condition A: Using a hose, direct a stream of

water from ground level, to cover the greatest distance.
Condition B: Repeat A, but hold the nozzle of the hose at hip height.
Condition C: Repeat B, keeping the angle of projection the same and increase the velocity of the stream of water.

Equipment

- Garden hose.
- Brick wall to run the water stream against and measure.
- Tape measure.
- Protractor.

Questions: Task one:

a. Identify what is the optimal angle of release for Condition A.
   (i) Include a diagram of the optimal water stream pathway or trajectory.
   (ii) Describe the shape of this water stream pathway or trajectory.
b. Identify what the optimal angle of release is for Condition B.
c. Compare the angle of release in Condition A to Condition B.
d. What factors influence the angle of release in Condition B?
e. Describe and use a diagram to identify the pathway followed by the water stream in Condition C.
f. What observations can be made relating to the difference in pathways in Condition B and C?
g. You may wish to support your response with a diagram.
h. Of the factors that determine the distance a projectile travels, which is the most important in achieving the greatest distance?

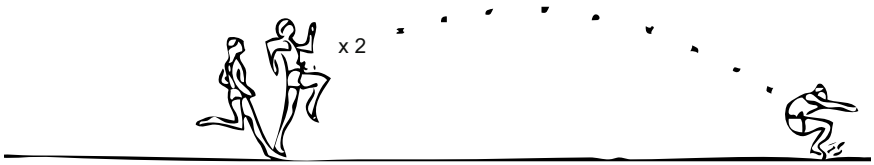


Figure 1.27: *A long jump*

Questions: Task two

Study the diagram (Figure 1.27) of the long-jumper and answer the following questions.

a. Describe the pathway of the long-jumper.
b. What is the angle of take-off?
c. What factors investigated in task one would cause a reduction in a take-off angle from 45°?
d. What aspect of a long-jumper's technique would account for the angle of take-off?
e. What is the most important factor at take-off in achieving the maximum distance in long jump?
f. Identify and briefly explain, using a sporting example, where the optimal angle of release would be greater than 45°.
g. Explain, using the example of tennis, how the angle of release is changed to match the different shot requirements within the game performance.

Appendix B1.3

Practical Investigation Assessment Task: Biomechanics
The principle of optimal projection

Name: _____

Unit 1

Type: Investigation

Outcome 3: Knowledge and understanding of movement and conditioning concepts for physical activity.

Content: Define and apply projectile motion to a selected sport in relation to the principle of optimal projection.



Total: _____ / 40 marks

Having completed the Projectile Motion experiment you are required to address the questions outlined.

The three conditions that were observed and measured included:

- **Condition A:** Using a hose, direct a stream of water from ground level, to cover the greatest distance.
- **Condition B:** Repeat A, but hold the nozzle of the hose at hip height.
- **Condition C:** Repeat B, keeping the angle of projection the same and increase the velocity of the stream of water.

Section One – Results

1. Draw a diagram identifying the optimal angle of release and water stream pathway/trajectory for Condition A.
   (2 marks)

2. Identify the optimal angle of release for Condition B.

_____

(1 mark)

3. What factor determines the angle of release in Condition B?

_____

(1 mark)

4. Describe and justify the difference in pathways between Condition B and C? Draw a diagram to support your response.
Explanation

_____

_____

_____

_____

_____

(2 marks)

Diagram

(2 marks)

5. Of the factors that determine the distance a projectile will travel, which is the most important in achieving the greatest distance?

_____

(1 mark)

6. Outline three limitations of the experiment and how they may be overcome. You may wish to include any potential limitations that may not have been observed.

_____

_____

_____

_____

_____

(3 marks)

7. Presentation of results (teacher to indicate).
   - Accurate and relevant presentation of data. (2 marks)
     OR
   - Satisfactory presentation of data. (1 mark)

Section Two – Application

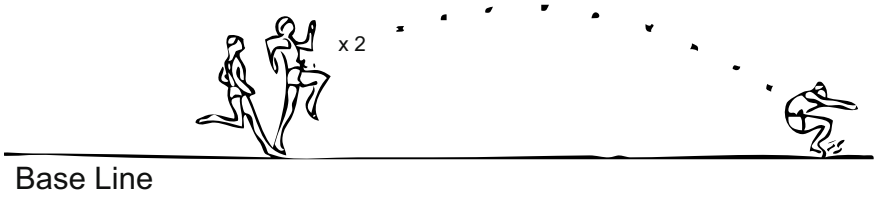


Figure: *A long jump*

Study the diagram (above) of the long-jumper and answer the following questions.

What is the approximate angle of take-off?

8. _____

(1 mark)

9. What factor investigated in task one would cause a reduction in a take-off angle from 45°? Justify your response.

_____

_____

_____

_____

_____

(2 marks)

10. Identify and briefly explain, using a sporting example, where the optimal angle of release would be greater than 45°.

_____

_____

(2 marks)

11. Explain, using the example of tennis, how the angle of release is changed to match the different shot requirements within the game performance.

_____

_____

_____

_____

_____

(4 marks)

Section Three – Extension

12. When throwing a javelin for maximum distance, what two factors, will determine the balls path once it has been released.

_____

(2 marks)

13. If an individual threw a javelin into a strong headwind, what factor could be adjusted to maximise distance?
    i. Factor:_____
    ii. How would this factor be adjusted?

    _____

    (1 mark)

14. Explain what the vertical and horizontal components are of a projectile. Include a definition of each.

    _____

    _____

    _____

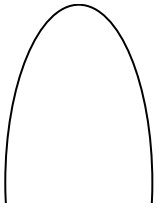
    _____

    _____

    (2 marks)

Diagram A and B represent two different trajectories. One with an angle of above 60° (A) and one below 20° (B).

A



B



15. Describe each trajectory (diagram A and B above) in terms of its vertical and horizontal components. In doing so give an example of where they may be used in a sporting context.

    _____

    _____

    _____

    _____

    (6 marks)

16. Use a sporting example not already used in this assessment show your understanding of the factors affecting projectile motion.

_____

_____

_____

_____

(6 marks)

Teachers – maintain the security of these documents. Do not provide them to students.

Appendix B1.4

Practical Investigation Marking Key: Biomechanics
The principle of optimal projection

Unit 1

Type: Investigation

Outcome 3: Knowledge and understanding of movement and conditioning concepts for physical activity.

Content: Define and apply projectile motion to a selected sport in relation to the principle of optimal projection.



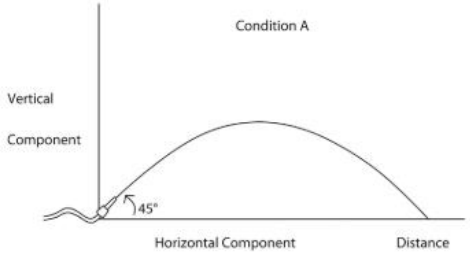
The three conditions that were observed and measured included:

- **Condition A**: Using a hose, direct a stream of water from ground level, to cover the greatest distance.
- **Condition B**: Repeat A, but hold the nozzle of the hose at hip height.
- **Condition C**: Repeat B, keeping the angle of projection the same and increase the velocity of the stream of water.

Section One – Results

1. Draw a diagram identifying the optimal angle of release and water stream pathway/ trajectory for Condition A.

   - **Angle = 45°**



(2 marks)

2. Identify the optimal angle of release for Condition B.
   - **See class results.**

   (1 mark)

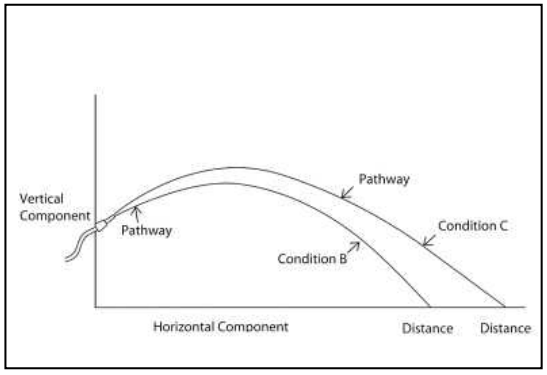
3. What factor determines the angle of release in Condition B?
   - **Height of release.**

   (1 mark)

4. Describe and justify the difference in pathways between Condition B and C? Draw a diagram to support your response
   Explanation
   - **Pathway C covers a greater distance compared to Pathway C.**
   - **May include distance.**
   - **This is a result of an increase in velocity.**
   - **The greater the velocity the greater the distance covered.**

   (2 marks)

Diagram



(2 marks)

5. Of the factors that determine the distance a projectile will travel, which is the most important in achieving the greatest distance?
   - **Velocity of release.**

   (1 mark)

6. Outline three limitations of the experiment and how they may be overcome. You may wish to include any potential limitations that may not have been observed.
   - **Wind or air resistance.**
   - **Inaccurate measurement of the angle.**
   - **Inaccurate measurement of the water velocity.**
   - **Experiment is only conducted once i.e. validity.**
   - **Difficulty in determining an accurate distance.**

   (3 marks)

7. Presentation of results (teacher to indicate).
   - Accurate and relevant presentation of data.

     (2 marks)

   OR
   - Satisfactory presentation of data.

     (1 mark)

Section Two – Application

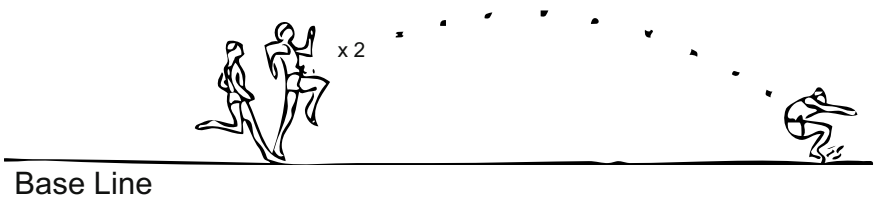


Figure: A long jumper

Study the diagram (above) of the long-jumper and answer the following questions.

8. What is the approximate angle of take-off?
   - **Approximately 20º-22º**

   (1 mark)

9. What factor investigated in task one would cause a reduction in a take-off angle from 45°? Justify your response.
   - **Velocity of release/take-off.**
   - **As the jumper would be unable to project him/herself at a 45° angle**
   - **That is, he/she would need to slow down in order to jump up.**

   (2 marks)

10. Identify and briefly explain, using a sporting example, where the optimal angle of release would be greater than 45°.
    - **A basketball shot for goal from close to the basket requires an angle greater than 45° such that the flight path will see the ball enter the basket.**
    - **The landing point is above/greater than the release point.**
    - **This means that the vertical component of the ball in flight is greater than the horizontal to achieve this angle.**

    (2 marks)

11. Explain, using the example of tennis, how the angle of release is changed to match the different shot requirements within the game performance.
    - **The lob requires the ball to travel over the players head; therefore, a relatively high angle of release is appropriate.** (2 marks)

    and/or
    - **A ground-stroke is used to manoeuvre the opponent and force errors; therefore, a relatively low angle of release is appropriate.**

    (2 marks)

    and/or
    - **The front court smash (hit in close proximity to the net) has the highest point of release and it requires the player hit it down into court quickly; therefore, it necessitates the lowest angle of release.** (2 marks)

    (4 marks)

Section Three – Extension

12. When throwing a javelin for maximum distance, what two factors, will determine the balls path once it has been released.
    - **Gravity.**
    - **Air Resistance.**

    (2 marks)

13. If an individual threw a javelin into a strong headwind, what factor could be adjusted to maximise distance?
    i. Factor: **Angle of release**.
    ii. How would this factor be adjusted? **It should be reduced.**
    (1 mark)

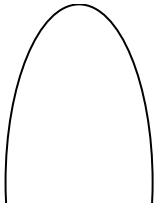
14. Explain what the vertical and horizontal components are of a projectile. Include a definition of each.
    Horizontal Component
    - **Is parallel to the ground.**
    - **No influence in raising the projectile into the air**
    - **Horizontal Velocity: the distance and the rate of movement at which the body/projectile is going out/across.**
    - **Projectiles maintain the same horizontal velocity throughout its flight as there is nothing which tends to change the rate at which it is moving horizontally (ignoring air resistance) i.e. it remains constant.**

    Vertical Component
    - **Vertical Velocity: is imparted on the body at the time of release/take-off and is responsible for the lifting of the body into the air.**
    - **Vertical Velocity: The rate of movement of which the body is going that the projectile reaches including the time in flight to reach the apex and the time it takes to return to the landing.**

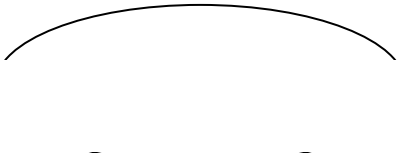
    (2 marks)

Diagram A and B represent two different trajectories. One with an angle of above 60° (A) and one below 20° (B).

A



B



15. Describe each trajectory (diagram A and B above) in terms of its vertical and horizontal components. In doing so give an example of where they may be used in a sporting context.
    A
    - **Large vertical component and small horizontal component.**
    - **Projectile will spend much time in the air.**
    - **Badminton or Tennis lob.**

    B
    - **Large horizontal component and small vertical component.**
    - **Projectile will spend little time in the air.**
    - **Baseball throw to first base to get a runner out or throwing a cricket ball at the stumps.**

    (6 marks)

16. Use a sporting example not already used in this assessment show your understanding of the factors affecting projectile motion.
Velocity
- **Velocity at release/take-off has the greatest influence. It will determine height (vertical component) and length (horizontal component) of the trajectory (when all other factors are constant).**

Height and Angle
The angle of release is determined by the height of release. For example:
- **The projectile is released and lands at the same level.** The optimum angle of release is 45° e.g. Golf.
- **The projectile is released from a higher position than the landing point.** The optimum angle of release is less than 45° e.g. Shot put. If the projectile is released from above the landing point you need to decrease the release angle.
- **The projectile is released from a lower position than the landing point.** The optimum angle of release is greater than 45° e.g. Basketball. If the projectile is released from below the landing point you need to increase the release angle.

Angle (assuming the release point and landing point are the same)
(6 marks)

Appendix B2

Practical Investigation and Report: Biomechanics
Newton's laws of motion

Weighting: Unit 2

Type: Investigation

Content:

- Define and apply Newton's 1st, 2nd and 3rd laws of motion

Total marks = /30

Task outline

By completing this experiment outlined below you will observe and evaluate the role of the key movement principles in velocity development of the tennis serve, catching water balloon and a volleyball block or spike.

Experiment: Task one

- In pairs you will be required to examine the effects of the following (groups of) activities.
- Complete the table.

Activity	What movement principle(s) was (were) affected? (1 mark for each answer)	How? (1 mark for each answer)
1. Serve with no knee flexion or extension.		
2. Serve with no follow-through.		
3. a) Serve front on. b) Serve with a variety of ball toss locations.		
4. a) Serve with racquets of different length. b) Serve with racquets with varying weights attached (or of different mass).		
5. a) Throw a water balloon over 2–8 m such that it can be caught. b) Throw the water balloon over the greatest distance that it can be caught without breaking.		
6. Perform a volleyball block.		

Equipment

- Four tennis racquets.
- One child's racquet.
- One weighted racquet.
- Eight + tennis balls.
- Two volleyballs.
- One chair.
- Thirty water balloons.

Task two

Study the diagram of the volleyball player performing a spike (Figure 1.29) and answer the following questions concerning the actions observed.

Questions:

During the flight stage of a volleyball spike, the player's body extends (Figure 1.29b) and then in diagram c it is seen to flex at the hip.

a. State and define which of Newton's laws of motion best describes the body's action represented in Figure 1.29b and c (1 mark).
b. Using one of Newton's laws of motion to assist, explain how the player can attain greater acceleration of the ball (1 mark).
c. Which of Newton's laws of motion best describes the change of direction of the ball after impact? (1 mark)

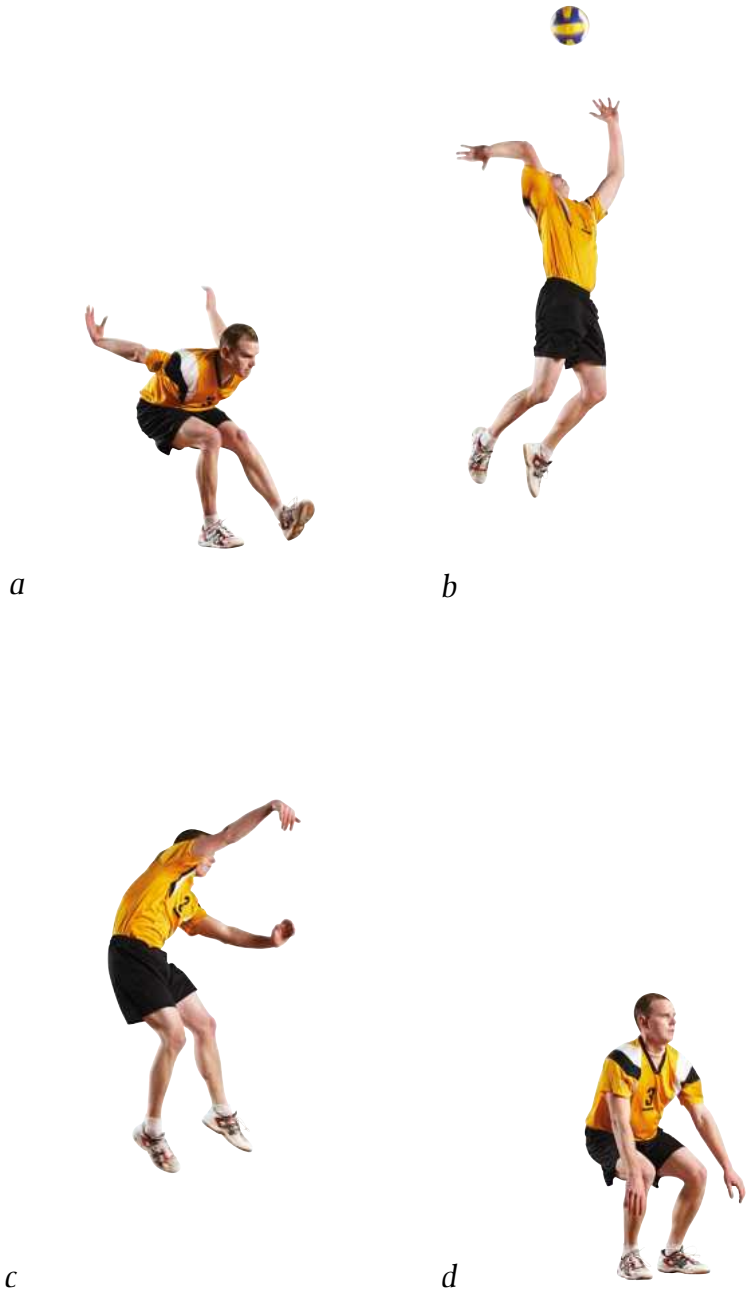


Figure 1.29: *A volleyball spike*

Task: Newton's laws of motion: 30 marks

Components and Performance Standards	Marks
Hypotheses (2 marks)	
Provides simple statements of the expected results or anticipated outcomes in relation to most of the principles associated with Newton's laws of motion.	**1 mark**
Provides clear statements of the expected results or anticipated outcomes of Newton's laws in relation to velocity development of the tennis serve, catching a water balloon and performing a volleyball spike.	**2 marks**
Introduction (3 marks)	
Identifies and defines Newton's laws.	**1 mark**
Shows an understanding of Newton's laws and the principles that govern the behaviour of bodies in motion.	**2 marks**
Shows a comprehensive understanding of Newton's laws and application of the principles that govern the behaviour of bodies in motion.	**3 marks**
Results (2 marks)	
Satisfactory presentation of data.	**1 mark**
Accurate and relevant presentation of data.	**2 marks**
Response to Questions (15 marks)	
Task one: *2 marks for each correct answer to questions 1–6 (1 mark for identifying the correct principle and 1 mark for explaining how the principle applies to the task) (12 marks).*	
Task two: *1 mark for the correct answer to questions a–c (3 marks).*	
Discussion (6 marks)	
Shows little comprehension of the variables associated with the activities undertaken.	**1 mark**
Limited discussion of the results found and few links made to the variables associated with bodies in motion (Newton's laws of motion) and a few of the factors affecting the activities addressed.	**2 marks**
Uses other sporting contexts to discuss the results found and identifies some of the variables associated with the behaviour of bodies in motion (Newton's laws of motion) and some of the factors affecting the activities undertaken.	**3 marks**
Uses other sporting contexts to discuss the results found and identifies and defines variables associated with the behaviour of bodies in motion (Newton's laws of motion) and most of the factors affecting the activities undertaken.	**4 marks**
Uses other sporting contexts to show an understanding of the results found and discusses these in reference to the principles that govern the behaviour of bodies in motion (Newton's laws of motion) and the factors affecting velocity development of a tennis serve, the absorption of force whilst catching a water balloon and principles of momentum as they apply to performing a volleyball spike.	**5 marks**
Uses other sporting contexts to show a comprehensive understanding of the results found and discusses these in application to the principles that govern the behaviour of bodies in motion (Newton's laws of motion) and the factors affecting velocity development of a tennis serve, the absorption of force whilst catching a water balloon and principles of momentum as they apply to performing a volleyball spike.	**6 marks**
Conclusion (2 marks)	
Summarises some of the factors associated with Newton's laws of motion in relation to the hypotheses.	**1 mark**
Fully summarises Newton's laws of motion in relation to the hypotheses. Limitations discussed.	**2 marks**
Comment:	**Total** **/30**

Appendix B2.1 – Answers

Practical Investigation and Report: Biomechanics
Newton's laws of motion

Answers: Task One

Activity	What movement principle(s) was (were) affected? (1 mark for each answer)	How? (1 mark for each answer)
1. Serve with no knee flexion or extension.	Newton's 2nd Law: F = ma	Can't accelerate the racquet or produce as much velocity because less force can be produced. Mass of the ball, racquet and body are the same.
2. Serve with no follow through.	Newton's 2nd Law: F = ma	Player will begin to decelerate before impact therefore reducing impact velocity.
3. a) Serve front on. b) Serve with a variety of ball toss locations.	Newton's 2nd Law: F = ma	a) Lacks body rotation - can't generate the force over the same time – less time to build velocity. b) Limits rotation and ability to apply force in certain situations.
4. a) Serve with racquets of different length. b) Serve with racquets with varying weights attached (or of different mass).	Newtons' 1st Law: Inertia Newton's' 2nd Law: F=ma	A longer bat is more advantageous - it has higher velocity at its distal end than a shorter bat - providing they are swung with the same rotational velocity. However, the heavier longer racquets are more difficult to swing. b) Heavier bats will have more momentum for the same swing velocity (and impact location). However, a heavier racquet may be harder to swing and may result in a reduced bat velocity. There is an ideal bat weight for each individual.

Activity	What movement principle(s) was (were) affected? (1 mark for each answer)	How? (1 mark for each answer)
5. a) Throw the water balloon over 2-8 m such that it can be caught. b) Throw the water balloon over the greatest distance that it can be caught without it breaking.	Newton's 2nd Law: Impulse/Force Absorption	a) Increase the time over which force is absorbed. Decreasing the time over which the force is absorbed will increase risk of injury. While change in momentum remains the same - impulse is spread over longer time. b) Catcher has applied an opposing force over a longer period of time - absorbing the momentum of the water balloon.
6. Perform a volleyball block	Newton's 3rd Law: Action Reaction	As the hands move forwards and down to reach over the net, the feet also move forward and up.

Answers: Task Two

a. State and define which of Newton's laws of motion best describes the body's action represented in Figure 1.28 b and c (1 mark).
Answer: Newton's 3rd Law: For every action there is an equal and opposite reaction. In diagram 3 the arms are moving down and legs moving up.

b. Using one of Newton's laws of motion to assist, explain how the player can attain greater acceleration of the ball (1 mark).
Answer: Newton's 2nd Law: F=Ma. The greater the force the ball is struck, the greater will be the acceleration after impact (all other things being equal).

c. Which of Newton's laws of motion best describes the change of direction of the ball after impact? (1 mark)
Answer: Newton 1st law - law of inertia. The ball will remain in uniform motion, unless acted on by an external force. In the case of the volleyball spike, the player changes the balls direction with a force imparted by his hand.

Appendix C (I)

Revision questions

1. Whilst running a 400 m running race around a traditional athletics track, at different times your whole body displays curvilinear and rectilinear motion. Identify the different times when this happens.
2. Displacement and distance are measured in metres. What is linear velocity is measured in?
3. Whilst competing in a 50 m breaststroke race, your acceleration is greatest before you enter the water and often lowest just prior to touching the wall. Explain how this is so.
4. Angle of release is one variable that influences a projectile's motion. Name the two other factors.
5. Whilst standing on top of a three-story building you are asked to throw a cricket ball that will land on the ground, to achieve maximum distance. Compared to when you perform this task whilst standing on the ground and the ball lands on the ground, you will achieve the best result from the rooftop by
   a. throwing the ball with less horizontal component and less release velocity.
   b. releasing the ball with a lower angle of release.
   c. releasing the ball at an angle of 45 degrees.
   d. releasing the ball with a higher angle of release.
6. Why does a high-jumper run up at less than maximum velocity?
7. Some elite basketballers can dunk the ball with a take-off from the free-throw line. Do you think their optimal run-up velocity would be higher or lower for this dunk than that used in a volleyball spike?
8. Why would a long-jumper choose not to slow down to such an extent that they can maximise their take-off (projection angle) to 45°?
9. A cricket fast bowler tries to maximise the angular velocity of their arm (upper limb). They also try and use the linear velocity of the body (C of G) to contribute to the velocity of the ball. How do they do this?
10. Immediately before a soccer player kicks the ball, which part of their leg has the greatest linear velocity?
    a. Hip
    b. Knee
    c. Foot
    d. Thigh
11. Whilst learning to serve in tennis, the player is often told to imagine they are 'reaching for the sky' at impact. Using the principles of angular motion, explain why the player might benefit from executing this instruction.
12. If a surgeon said to you, 'I think you will be healed by removing your centre of gravity', why might you be sceptical of this recommendation?
13. If you were to hold a 10 kilogram weight above you head, your centre of gravity, when compared to not holding the weight, would
    a. rise.
    b. stay the same.
    c. lower.
    d. allow you to be more stable when impacted by an external force.
14. A gymnast claims that they can place their centre of gravity outside their body. Describe in principle how they will need to position themselves to accomplish this?

15. What defines the area described as the base of support?
16. In crouching down to improve your balance, what have you done with the vertical component of your centre of gravity?
17. You want a rugby player, who is facing an oncoming player running with the ball, to move their line of gravity closer to the front edge of the base of support. How would the player actually achieve this? What is the justification for asking for this to be done?
18. Sports performers who display the greatest levels of dynamic stability are often relatively short in stature. Using the concept of the centre of gravity, explain why this is so.
19. When throwing a softball from the outfield to home plate, what factors will reduce the vertical and the horizontal components of the ball's flight path?
20. What is the relationship between the force applied to an object and the resultant acceleration?
21. Force absorption is explained by an application of which of Newton's Laws of Motion?
22. What two factors are important in the absorption of the force of a ball when trying to stop or catch it?
23. Using Newton's 3rd Law of Motion, explain why the risk of injury might be increased by jogging with a backpack full of sand.
24. If Newton's 3rd Law says that when we land from jumping off the garage roof there is an equal and opposite force on the body and the ground, why doesn't the earth move?
25. Using Newton's 3rd Law of Motion, explain why people might choose to walk in a swimming pool.
26. When you jump into the air and throw your arms up and backward, Newton' 3rd Law of motion says that your
    a. arms will experience an opposite reaction.
    b. feet will lift forward toward your face.
    c. body will absorb the reaction and nothing will happen.
    d. feet will move backward in an equal and opposite reaction.
27. Simultaneous body actions are generally used when the athlete desires distance or accuracy?
28. Sequential body movement
    a. is best used when accuracy is desired.
    b. assists to develop optimum swing velocity when swinging a baseball bat.
    c. prevents momentum of one body part to be transferred to another.
    d. never occurs in sport.
29. A run-up serves to maximise the distance a kicked AFL football travels. Explain how this occurs.
30. If linear velocity is important to the distance a ball travels, why would you not use a run-up for a shot in basketball from the free-throw line?
31. If linear velocity is important to the distance a ball travels, why would you not use a run-up for a golf drive?
32. Why might a small girl ignore the principles of simultaneous force development and adopt a sequential velocity development when making a basketball shot from the three-point line? What technical or action differences might she adopt with this shot?

Appendix C (II)

Revision answers

1. On a 400 m track, you are performing linear motion on the straight and curvilinear motion when running the bend.
2. Metres per second (m/s or m s^{-1})
3. Your velocity on the block is zero and then after the beeper goes off your change of velocity (acceleration) from the push off the stable base (the block) is high and your movement through the air is relatively unimpeded, as it has not yet encountered water resistance. As you approach the wall you are fatiguing and potentially decelerating (velocity is reducing) or slowing down.
4. Velocity of release and height of release relative to the height of the landing.
5. b. Releasing the ball with a lower angle of release.
6. A high jump requires a significant vertical velocity and little horizontal velocity. The athlete lacks the strength to execute the jump with the required optimal angle of take-off with a maximal run-up velocity.
7. The dunk from this position requires greater horizontal velocity and therefore the optimal run-up velocity for the dunk would be greater. The volleyball spike requires maximum vertical displacement and if the player has too much horizontal movement they may hit the net (rule infraction).
8. To jump at an angle of 45° would demand a significant sacrifice to the run-up horizontal velocity and therefore compromise the jump. In the long jump the horizontal component (run-up velocity) is more important to maintain than is the angle of take-off (angle of release).
9. They use a relatively high velocity run-up.
10. c. Foot
11. The greater the velocity at the distal end (impact position), the greater the linear velocity of the impact point and the resultant post-impact ball velocity.
12. Your centre of gravity is an imaginary point about which the body's mass is equally distributed. It is not fixed within one location in the body.
13. a. Rise
14. Two methods could apply. Firstly, they could bend (flex or extend) at the hip so that they drape in a pike or hyperextended position. The second method would see them place their line of gravity (significant amount of body such as their legs, arms and/or upper trunk) outside of their base of support, but they will not be able to maintain this position and this will render them unstable.
15. The area identified by the points of contact with the ground and the area between these contact points.
16. You have lowered the centre of gravity and most probably improved your stability.
17. Stand astride and align the feet, so that you can lean towards the oncoming player. This will allow you to remain more stable when absorbing the oncoming force, with less opportunity to have your line of gravity forced outside the base of support. It will also allow more time to absorb the force before reaching the critical point where the line of gravity moves outside the back foot and you become unstable and fall backwards.
18. For example, basketball players, when comparing a guard to a centre. The guard, who is shorter, has a relatively low centre of gravity and therefore is more stable during quick movements.

19. Vertical – Gravity
    Horizontal – Air resistance
20. F = ma. Providing the mass remains constant, a direct relationship exists between the force applied and the resultant acceleration.
21. Newton's 2nd Law F = m (V2 – V1)/t.
22. The velocity of the ball and the time over which the force is absorbed.
23. For every action there is an equal and opposite reaction. The impact of force on the ground and, therefore, the resultant force on the body will be increased when carrying the backpack full of sand (greater mass).
24. The earth has so much mass that such a relatively small force (of you landing) has no influence on the subsequent movement of the earth.
25. With the aid of buoyancy the body is lighter in water and therefore the impact velocity of you touching the pool floor with each step is lessened. you can get whole-body exercise without the same resultant impact forces.
26. d. Feet will move backward in an equal and opposite reaction.
27. Accuracy.
28. b. Assists to develop optimum swing velocity when swinging a baseball bat.
29. The run-up means that the ball is already moving forwards. It already has linear velocity and this is added to the velocity created through rotation of your leg.
30. The action requires optimal accuracy and repeatability of action. When a relatively small displacement is required and accuracy is essential, the performer will employ a simultaneous velocity summation. A run-up would serve to add linear velocity to the ball and potentially contribute to its displacement. However, this additional element would reduce the chance of repeatability and therefore decrease their chances of regularly being successful.
31. Whilst maximum distance is the main objective, the golfer is also seeking accuracy through repeatability of action. However, unlike the free-throw shot in basketball, the golfer uses rotation and the large body muscles (legs, trunk and shoulders) to accelerate the club to optimal velocity and accuracy at impact. Therefore the golfer employs a sequential development of velocity. A run-up (Happy Gilmore) may in theory serve to increase club head velocity at impact and ball distance, providing you could stop at the ball, stabilise the body and pivot about the front leg, but it would make the goal of repeatability very difficult.
32. She may be unable to generate sufficient force and subsequent ball velocity through traditional accuracy-based actions (simultaneous) to reach the basket. She would align her stance to the basket (straddle her legs) and rotate herself (hips and shoulders) side-on to the basket. In doing so, she would allow her body mass to be positioned more on her back foot. She in now ready to initiate a throwing action that sees her transfer her weight to a stabilised front leg, pivot about the front leg with hip and trunk rotations and finally shoulder rotation. These rotations and subsequent stabilisations of body parts realise a sequential development of the velocities and, therefore, at the time of release the arms and hands extend and accelerate quickly and are travelling with greater velocity. She imparts greater velocity to the ball and this potentially increases her chances of making the ball reach the basket. She may also employ a run-up to generate linear ball velocity before release. All of the above bring about a potentially greater ball release velocity, but potentially compromise repeatability and, therefore, accuracy.

Appendix E

Glossary of key terms

Acceleration: A measure of how quickly an object is changing its velocity. This is calculated as velocity divided by time and is recorded as m/s/s or m s^{-2}.

Angular distance: How far a body segment or implement rotates from its start position and is measured in degrees (°).

Angular motion: Rotary or circular motion.

Angular velocity: How quickly a body segment or implement is rotating and is measured in degrees per second (°/s; deg s^{-1}).

Area of the base of support: Includes the points of contact with the supporting surface (such as feet on the floor), including the area between these contact points.

Centre of gravity: An imaginary point, which may lie inside or outside the body, about which all of the body's mass is equally distributed.

Curvilinear motion: Motion in a curved trajectory.

Displacement: The absolute difference between your start and finish positions and is measured in the unit of metres (m).

Distance: How far you have travelled from your start to finish positions and this is measured in the unit of metres (m).

General motion: This is where angular motion of a number of body segments produces linear motion of the body–collectively referred to as general motion.

Linear motion: Motion along a line (trajectory or path).

Mass: The amount of matter that makes up an object.

Momentum: Is a product of the mass of the object and its velocity.

Qualitative analysis: Movement evaluation and subsequent intervention based on mechanical considerations that are considered but NOT measured.

Quantitative analysis: Objective measures used as the basis for movement evaluation and subsequent intervention to improve performance.

Rectilinear motion: Motion in a straight line.

Velocity (speed): A measure in time of how quickly an object is covering a given distance and is measured in metres per second (m/s or m s^{-1}).



Functional Anatomy

Grant Landers (Assistant Professor), Dr Peter Whipp (Associate Professor)
and Dr Kym Guelfi (Senior Lecturer)

BACKGROUND INFORMATION

What is Anatomy?

Our anatomy plays a role in how we interact with the environment we live in. Functionally, how we are structured can be advantageous in many circumstances, yet in others, it may limit our ability to complete certain tasks. Flexibility is advantageous in some sports such as gymnastics (Figure 2.1a), where points are awarded for achieving certain positions. In contrast, consider the shoulders of athletes involved in contact sports. How often do you see AFL players with their shoulders taped (Figure 2.1b) to restrict movement in this joint and prevent injury? Being tall can be advantageous in sports such as basketball (Figure 2.1c) and volleyball, but may hinder athletes' successful performance in diving or horse racing (Figure 2.1d).

Text outcomes:
Functional anatomy

- *Identify the three body types (somatotypes) and indicate their suitability to specific sports.*

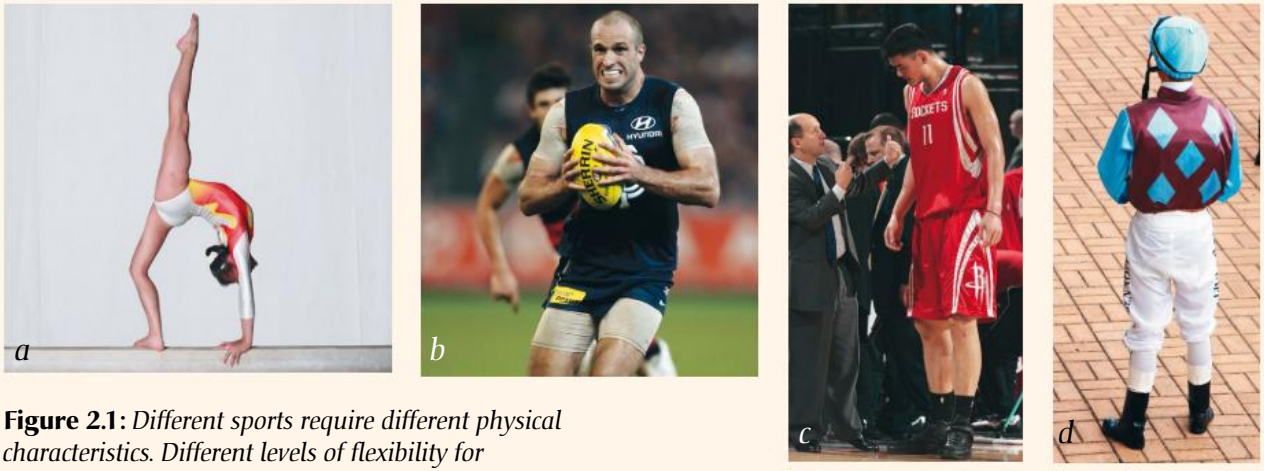


Figure 2.1: *Different sports require different physical characteristics. Different levels of flexibility for gymnasts (a) and footballers (b) Basketballers (c) are taller than jockeys (d)*

Somatotypes

In most instances we consider anatomy to relate to the bones, muscles and organs of the body and generally look at each of these components in isolation. However, it is how these components interact which determines how the body will function. The final shape of the body, or ***somatotype***, is a result of the many components within the human anatomy. This somatotype is broken into three major categories (Figure 2.2): ***endomorphy (a)*** is related to adiposity or body fat, ***mesomorphy (b)*** gives an indication of the robustness of the body characterised by the muscularity of an individual, and ***ectomorphy (c)*** highlights the linearity.

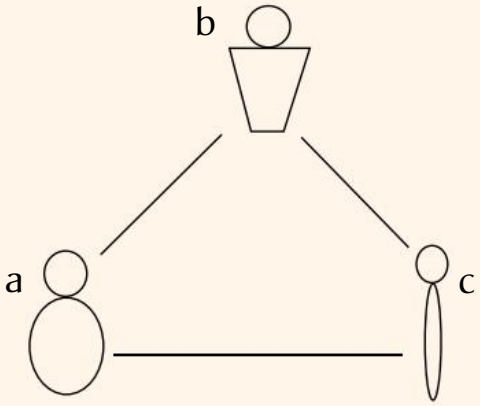


Figure 2.2: *Somatotypes: emdomorph (a), mesomorph (b) and ectomorph (c)*

An individual may show characteristics in one or two of the somatotype categories but not all three. Someone who is an endomorph is typically overweight or obese; they have large amounts of body fat and, generally, are not seen in high-level sporting events (Figure 2.3a). Most athletes have a high degree of mesomorphy as this relates to the large muscle sizes and greater supporting bone structure. A bodybuilder would represent the ideal mesomorph (Figure 2.3b). Finally, the ectomorph is very linear. This means they are quite tall compared to their body weight. High jumpers, many basketballers and distance runners (Figure 2.3c) show high degrees of ectomorphy. Athletes competing in contact sports such as sumo, wrestling and rugby may be classified as endo-mesomorphs while ecto-mesomorphs may be seen in triathletes.

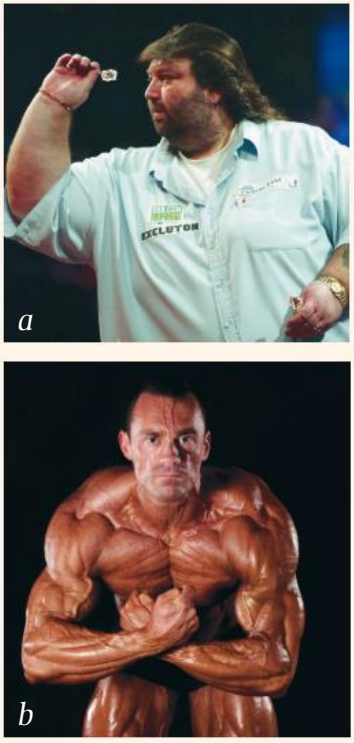


Figure 2.3: *Somatotypes of athletes. Endomorphic darts player (a), mesomorphic bodybuilder (b) and ectomorphic runner (c)*

The Skeleton

Text outcomes:
Functional anatomy

- *Explain the major functions of bones.*
- *Identify the bone classifications.*
- *Understand the structure of a long bone.*
- *Understand the anatomical planes.*

It can take over twenty years for all the bones in your body to fully mature and become completely calcified. At birth, the human skeleton is a mixture of cartilage, fibrous tissue and calcified bone. Eventually, all 206 bones in the body, from the smallest three bones in the middle ear, to the largest bone of the femur, become fully calcified (hardened).

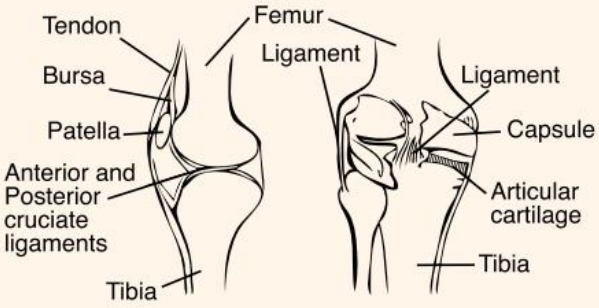
Skeletal function

The human skeleton is called an endoskeleton because the skeleton is found beneath the skin, unlike the exoskeleton of insects and crustaceans, which is on the outside. As with most vertebrates in the animal kingdom, the human skeletal and muscular systems have similar functions. The skeletal system ***supports*** the body's structure, ***protects*** the internal organs, is an area of ***red blood cell development*** and ***storage of nutrients,*** and is the ***framework from which movement is derived.***

Support

The skeletal system provides a framework to connect the soft tissue. It is the rigid structure to which most of the body's skeletal muscles can attach.

Ligaments are the 'sticky tape' that hold the bones together. Wherever two or more bones join they are held in place by ligaments. These are fibrous connective tissue similar to the tendons that join muscle to bone. They are not very flexible, but do allow small amounts of movement between bones.



a medial view *b posterior view*

Figure 2.4: *Ligaments of the knee help hold the joint together*

Protection

The skeletal structure and protective functions do not differ greatly between animals; the skull protects the brain and the ribs protect the heart and lungs. However, the protective nature is somewhat less for those animals that walk on two legs (bipedal), where the neck and abdomen are exposed, compared to those that move on four legs (Figure 2.5).



Figure 2.5: *The skeletal structure offers less protection to humans (a) than quadrupedal animals (b) because they stand upright, exposing internal organs*

It must be noted that, although internal organs are not as protected, the slight differences in skeletal and muscular structures that allow people to walk on two legs has other advantages. These variations in structure offer a host of animals various physical advantages, such as the long neck of the giraffe (Figure 2.6a), the streamlined dolphin (Figure 2.6b) or the long tail of the kangaroo (Figure 2.6c).

Class task:

Anatomical advantages

In small groups, identify three other animals whose specific physical or anatomical characteristics give it an advantage.

Red blood cell production

Red blood cells are vital for the transportation of nutrients and waste products around the body. As red blood cells have a lifespan of 100–120 days they need to be replaced constantly. This production occurs in bones, which contain red bone marrow. Small canals in the bone allow these new red blood cells to travel from the marrow on the inside of the bone to the capillaries that sit close to the outside of the bone. Prior to birth, red bone marrow is found in most bones.

Storage

Bones are a storage area for major elements including calcium, phosphorus, sodium, potassium and magnesium. It is the high mineral content of bones that enables their structure to remain unchanged hundreds of years after death.

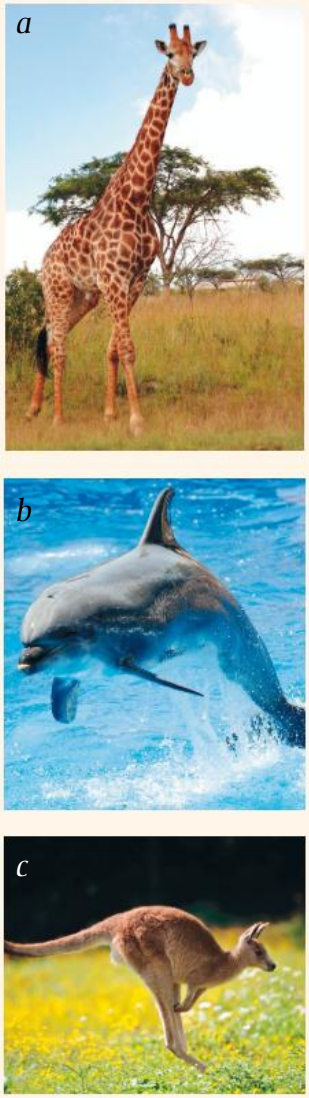


Figure 2.6: *Advantageous physical characteristics in the animal world: giraffe (a), dolphin (b) and kangaroo (c)*

Framework for movement

Body movement is the result of muscles contracting against the rigid skeletal structure. These muscular contractions may also assist in maintaining posture and the stability of joints. A muscle must cross a joint formed by two or more bones in order to create movement. The type of movement permitted is dependant on the:

- structure of these bones
- placement of ligaments
- attachment points of the muscles (called the origin and insertion)
- muscle flexibility
- size of the bone.

The ***origin and insertion*** points of muscles relate to where the muscle attaches to the bone. Generally the muscle's ***origin*** is attached to the more stable bone, whereas the ***insertion*** of the muscle attaches to the bone which moves when the muscle contracts (Figure 2.7).

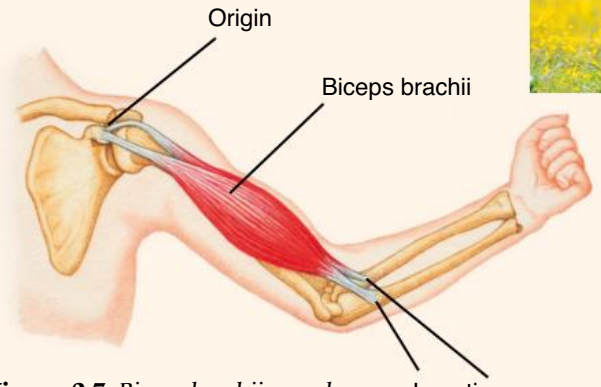


Figure 2.7*: Biceps brachii muscle, the origin on the scapula and insertion on the radius and ulna*

As we discuss in this chapter, with each movement, such as pulling your heel up to your backside in readiness to kick a ball (flexion, Figure 2.8a), there is a reciprocal or opposite action. In our example of preparing to kick the ball, ***the reciprocal or opposite action*** is swinging the foot down to actually kick the ball (extension, Figure 2.8b).



a



b

Figure 2.8: *Flexing the leg in readiness to kick (a) and extending the leg to kick the ball (b)*

Skeletal structure

The structure of the bones determines its function. As described above, there are five main functions of bone. Bones have a hard outer layer of compact bone, which surrounds the internal spongy bone. This spongy bone reduces the weight of the bone while giving strength to the bone in numerous directions.

Bone types

Bones come in four main types. ***Flat bones***, such as those found in the ribs, sternum and skull, typically take the role of protecting internal organs. Bones are very soft at birth and, in the case of flat bones, have not yet fused together. This malleability allows the head of the baby, which is usually 30–40 cm in circumference, to be safely squeezed through the mother's 30–35 cm pelvis during childbirth (Figure 2.9a).

Long bones are longer than they are wide, being characterised as having a long axis (shaft) with spongy bone on the ends. Examples of long bones include those in the limbs such as the femur (Figure 2.9b) and humerus. It is the long bones in the lower limb that have the greatest impact on your height, as they continue to lengthen until you reach your late teens or early twenties.

Short bones do not have a long axis and are found in the wrist (carpals, Figure 2.9c) and feet (tarsals). Many of the short bones of the wrist do not begin ossification (hardening) until early childhood or even into the teens.

Finally, ***irregular bones*** are those of various shapes and sizes, which do not fit into one of the above categories. Such bones have very specific functions and examples include the vertebra and pelvis (Figure 2.9d).

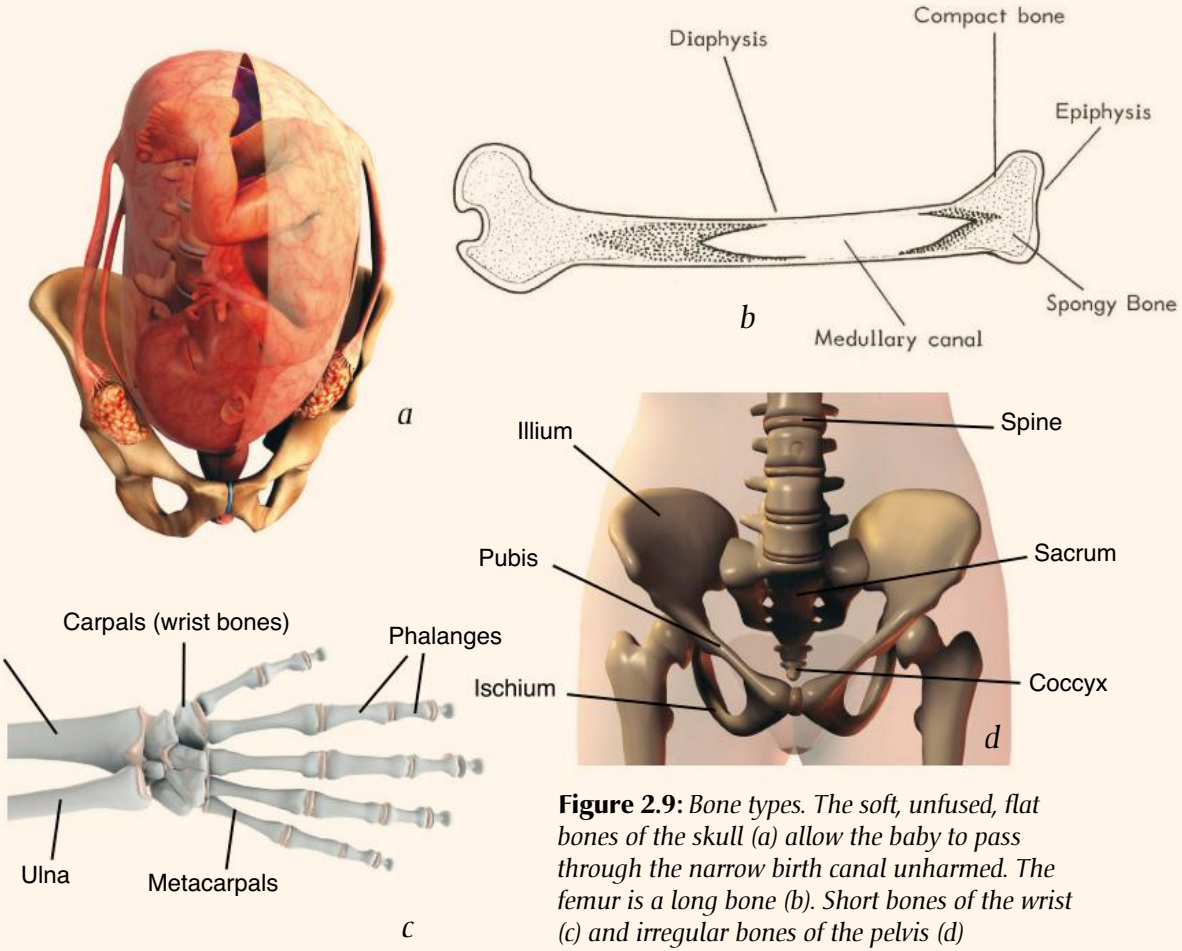


Figure 2.9: *Bone types. The soft, unfused, flat bones of the skull (a) allow the baby to pass through the narrow birth canal unharmed. The femur is a long bone (b). Short bones of the wrist (c) and irregular bones of the pelvis (d)*

Movement

The joints between bones allow movement. The range of motion (ROM) of these joints may be reduced or enhanced by a number of factors, these include the:

- structure of the bone
- type of joint it forms
- muscle attachment points
- muscle size
- flexibility.

Minmal bone and soft tissue can allow greater ROM (Figure 2.10). However, an increase in the size of the bony tissue or larger amounts of soft tissue, either muscle or adipose tissue, means during a movement these anatomical structures may limit the ROM by forming a physical barrier. If a muscle is too tight, movement will be restricted and if the muscle is too weak to move a segment, a full ROM will not be obtained.

For example, for most people it is impossible to get your wrist to touch your shoulder on the same limb. From a skeletal perspective, your forearm bones (ulna and radius) are usually shorter than the arm bone (humerus) and thus can't physically reach the distance. In a muscular individual, the soft tissue of the biceps muscle at the front of the arm may be too large and prevent the wrist from coming too close

to the shoulder. In an individual with a large amount of body fat, this can have a similar effect to that of a large biceps muscle (Figure 2.11a). In both of these cases, if a physical force is applied to the forearm to push the bones closer together, some of this soft tissue can be squeezed and displaced. In some instances, the muscle at the back of the arm (triceps) prevents the movement from continuing, as it is too inflexible. As you try and bring your wrist to your shoulder, triceps muscle tightens, just as an elastic band becomes tight as it reaches its limit (Figure 2.11b).





Figure 2.10: *Minimal bone allowing hyperextension of the elbow*



Figure 2.11: *Arm flexion is reduced by large biceps muscles (a) and increased by smaller biceps (b)*

Practical activity: *Discovering limitations to movement*

Lie face down on the floor. Without any assistance, attempt to touch your right buttock with your right heel. What is preventing the contact?

Now, using your hands, pull your right foot towards your buttock. Does contact occur? What was preventing the contact?

Equipment:

- None.

The anatomical position and planes

The anatomical position (Figure 2.12) is used as a reference point when describing movements of the body. In most cases, ***flexion*** refers to a decrease in angle (Figure 2.8a) while ***extension*** creates an increase in joint angle (Figure 2.8b) and occurs in the sagittal plane. ***Abduction*** refers to moving a segment away from the midline of the body and occurs in the frontal plane. This movement is highlighted in Leonardo Da Vinci's Vitruvius Man, where the arms and legs are abducted (Figure 2.13). The reciprocal movement to return these limbs to the midline is called ***adduction***. Other more complex movements are described later in this chapter.

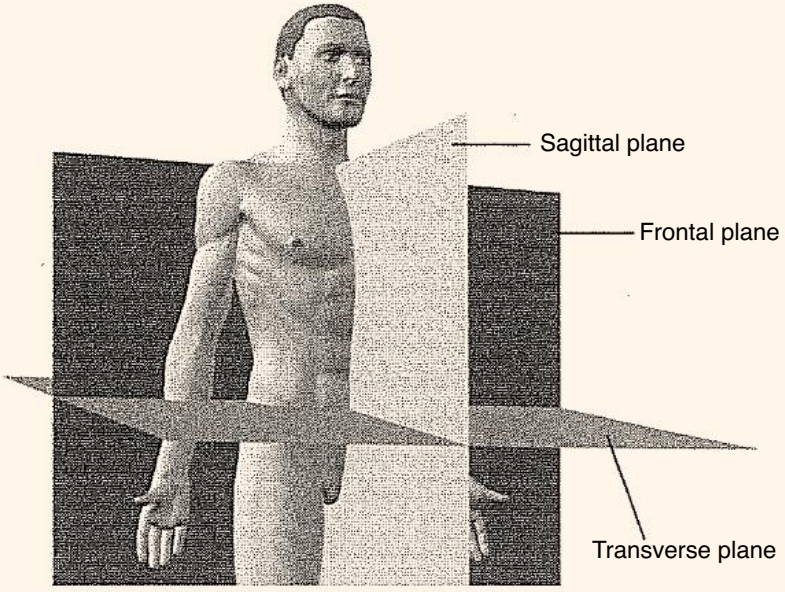


Figure 2.12: *The anatomical position and reference planes of the body*

Text outcomes:
Functional anatomy

- *Explain the types of muscles.*
- *Understand the structure of skeletal muscle.*
- *Understand how reflexes work.*
- *Identify the different muscle fibre types.*

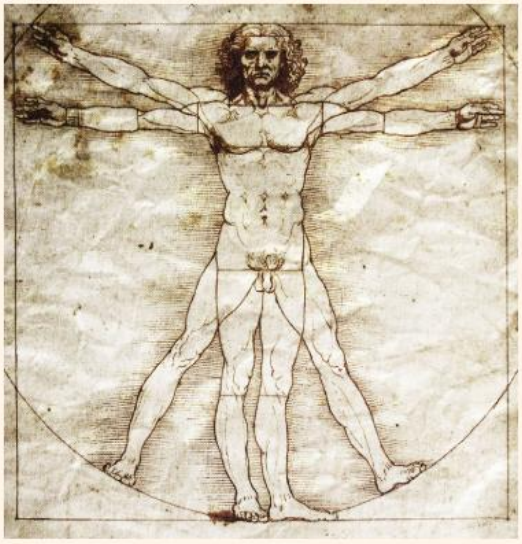


Figure 2.13: *Da Vinci's Vitruvius Man, showing abduction of the arms and legs*

Muscles

Muscle types

There are three types of muscle tissue in our body. Two of these, the cardiac and smooth muscles, contract involuntarily, that is, they work without you having to think about what is happening. ***Cardiac muscle*** relates specifically to the muscles of the heart (Figure 2.14a). When the heart contracts, blood is squeezed throughout the body. Consider how little sleep you might get if you had to constantly remind your heart to beat, to supply blood to your body. When we measure

heart rate we are determining the frequency that the cardiac muscle contracts. During exercise and in times of stress, heart rate will increase; whereas, when at rest and the body's demand for energy is reduced, heart rate will be at its lowest (see Exercise Physiology). The digestive system and blood vessels transport various energy and waste products throughout the body with the help of ***smooth muscle*** (Figure 2.14b). When we are cold, the smooth muscles in the blood vessels of the body's extremities contract (***vasoconstriction***) to reduce blood to these regions, thus conserving heat. Conversely, in a hot environment these smooth muscles relax (***vasodilation***) and blood flow is increased to the skin to cool the body.

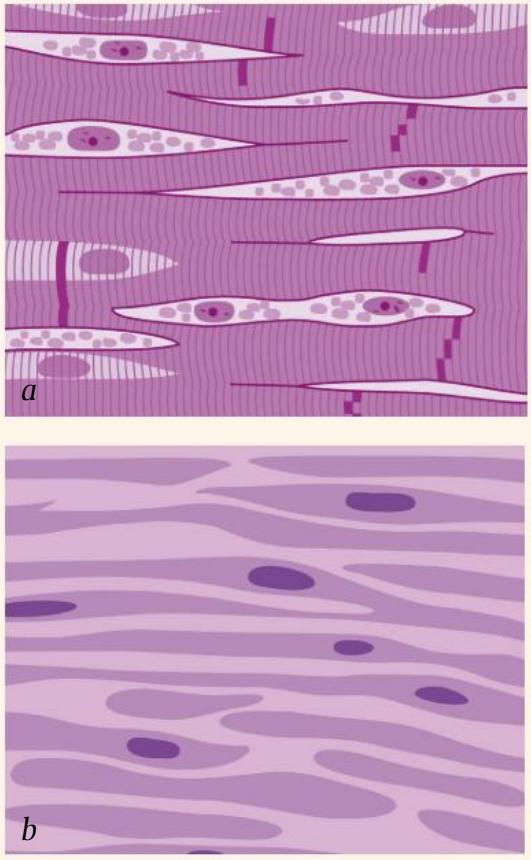


Figure 2.14: *Cardiac muscle (a) and smooth muscle (b)*

Skeletal muscles are muscles that are connected to bones (skeleton) via tendons and cause movement when contracted (Figure 2.15). It is important to realise that muscles only pull, they do not push. The contraction of skeletal muscle is voluntary, which allows us to manipulate objects, move around the room and balance on one leg. That is, you must first 'think' about what you want to do, then the brain sends a message to the muscles to either contract or relax to allow the movement to occur.

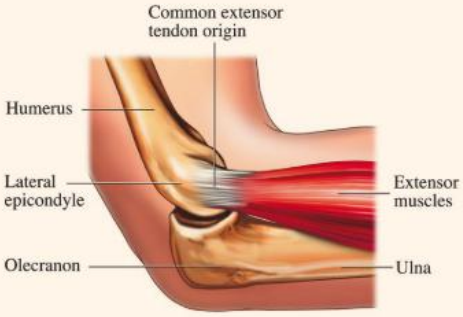


Figure 2.15: *Skeletal muscle, attached to bone via tendons*

Skeletal muscle structure

Skeletal muscle is made up of long muscle fibres all bundled together, similar in appearance to a large group of electrical cables. A number of these bundles of muscle fibres contribute to creating the muscle belly (Figure 2.16). When you cook a piece of meat, it may be possible to separate out groups of muscle fibres in a particular muscle belly (for example, chicken breast). In meat from larger animals (for example, steak) it may be possible to determine different groups of muscles that are each surrounded by thin layers of connective tissue. It is these long muscle fibres where contraction occurs and movement is generated.

Information must be sent from the brain down the spinal cord, then to the target muscle for

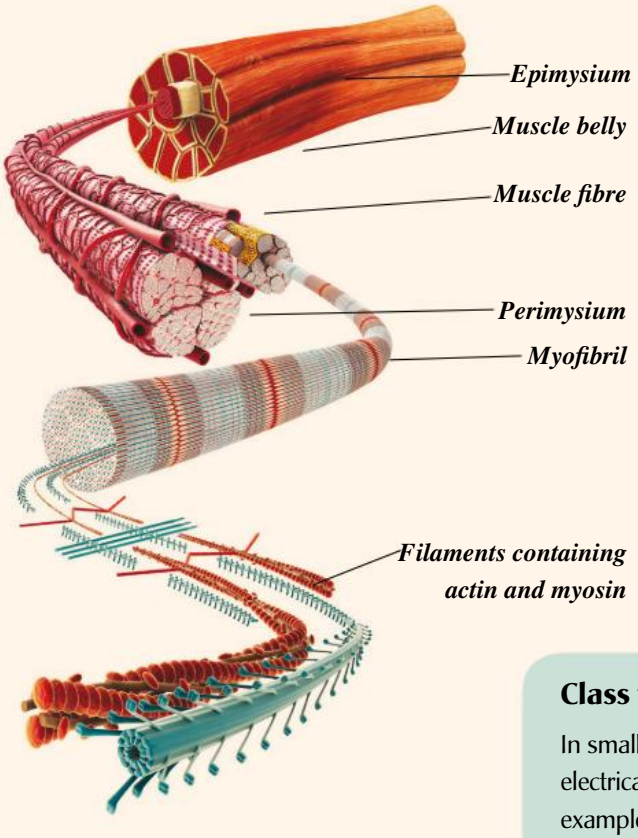


Figure 2.16: *The structure of a skeletal muscle*

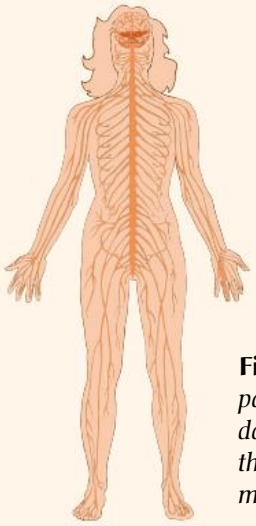


Figure 2.17: *Basic neural pathway from the brain down the spinal cord, then to a muscle to derive movement*

Class task: *Electrical impulses*

In small groups, discuss the use of electrical impulses in the following examples: A defibrillator, taser gun and a muscle-stimulation, rehabilitation machine.

muscle contraction in order for movement to occur (Figure 2.17). This information is sent via an electrical impulse with the nerves acting as a conductor. These nerves act in the same manner as an electrical cable, like the power cord for a toaster. Hence, it is not advisable to put your fingers in a power point!

Many of our daily movements are conducted somewhat automatically, as we have stored specific movement patterns in our brains after countless repetitions. Consider how many times you have brushed your teeth, drunk from a cup or walked around the room. After repeating these tasks, you have developed an automated response to conduct these movements efficiently. If you have ever watched a child learn to walk (Figure 2.18a) you would have noticed the inefficiency in their action and that if they are distracted, they tend to fall. As we grow and learn new skills (such as how to kick a ball or ride a bike) we are required to again think about our every action and ask our muscle to contract in a specific way. Again, after countless attempts, these movements become more automated such that the athlete can then apply this in a competitive situation (Figure 2.18b).





Figure 2.18: *Developing movement patterns in a toddler walking (a) and applying automated movement to competitive situations (b)*

Reflex actions

However, in order to protect the body from harm, the body has developed some reflex actions. Reflexes do not require input from the brain for skeletal muscles to contract and thus ensure movements occur in a timely manner. Some examples of this are if you were to step on something sharp, touch something hot or a muscle is stretched too quickly, the body part is withdrawn microseconds before the pain is registered consciously.

In this last example, muscle receptors detect a rapid increase in muscle length and send information to the spinal cord. If you were to wait for this information to be sent to the brain (central nervous system, CNS) to be processed and a response to return to prevent this from happening, damage would have already occurred. Thus, when this sensory information reaches the spinal cord, as well as sending the information to the CNS, motor signals are sent straight back to the stretched muscle to contract and prevent further damage.

The term 'knee jerk reaction' relates to making a quick movement without any thought, or without using your brain. It has origins from the patella tendon reflex test (Figure 2.19), where the patella tendon is stretched via a sharp tap below the patella, the information is processed in the spinal cord and the leg extends rapidly before the brain has time to determine that there is no danger to the muscles.

Practical activity: *Initiating a reflex action*

Work in pairs. Sit on the desk with legs hanging over the edge. Ensure that the subject relaxes the leg muscles. Have a partner tap the tendon with a side edge of a wooden ruler just below the patella (kneecap). Observe the 'knee jerk reaction'. If a ruler is not available then use a small karate chop with your hand.

Equipment:

- Desk.
- Wooden ruler.

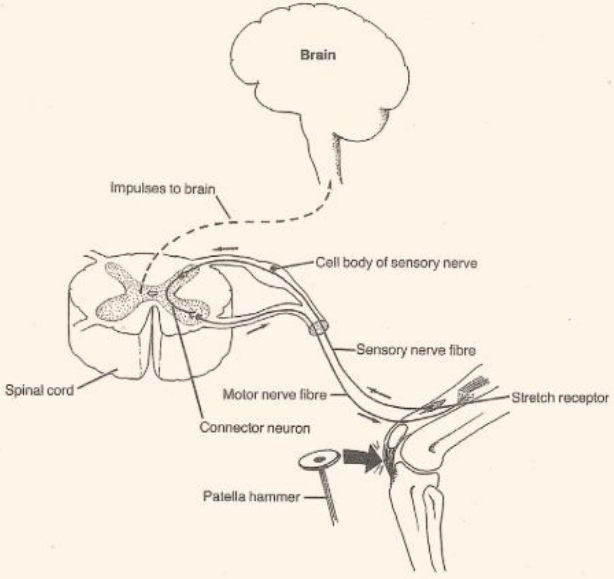


Figure 2.19: *Representation of the patella tendon reflex*

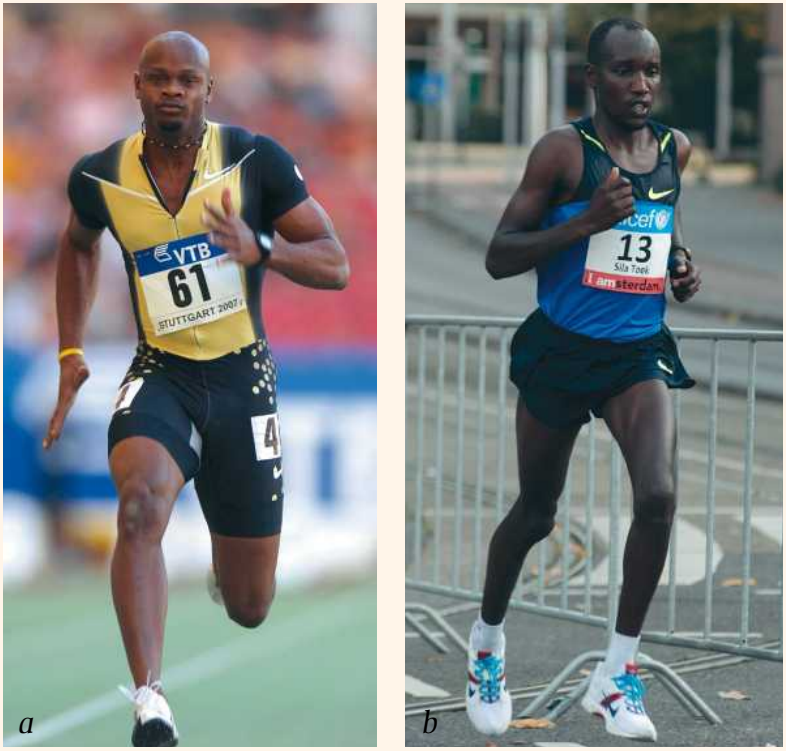


Figure 2.20: *Fast-twitch muscle fibres are more prevalent in sprinters (a), whereas endurance runners have more slow-twitch fibres (b)*

Muscle fibre types

Skeletal muscle comprises the contractile component, which is made up of muscle fibres. These fibres can be either fast- or slow-twitch. ***Fast-twitch fibres*** (Type II) are those linked to muscles involved in quicker, more explosive movements. Sprinters have a higher percentage of fast-twitch muscle fibres (Figure 2.20a) compared to the normal population, which gives them a greater advantage in their sport. Muscles of the eye are made up primarily of fast-twitch muscle fibres.

Slow-twitch muscle fibres (Type I) are found in muscles related to posture. They are more fatigue resistant and, as a result, athletes involved in endurance events typically have a higher percentage of slow-twitch muscle fibres (Figure 2.20b).

The muscle fibres may also be known as white or red, based on their visual appearance. Fast-twitch fibres are typically white in colour as they have less blood supply, because they do not require oxygen to produce energy compared to the redder, slow-twitch muscle fibres. Compare the colour of the meat of a chicken to that of a cow. The chicken flesh is much whiter. Chickens make much more rapid movements than the cow, which maintains a consistent posture for prolonged periods. The chicken has greater amounts of fast-twitch muscle fibres, compared to the slow-twitch muscle fibres of the cow. Please see the following chapter (Exercise Physiology) for more information about muscle fibre types, their characteristics and the impact of training.

Functional Anatomy: ATAR Units 1 and 2

A similar approach is followed for each section of the ATAR Unit 1 and Unit 2 curriculum. This starts with textbook-related learning outcome statements, followed by a summary box 'Content that follows' and the theory and application for each content area. Suggested class tasks and practical activities are embedded within the sections of the text. A key point summary is presented at the end of each section.

One practical investigation relevant to this section is included at the end of the Exercise Physiology chapter that follows (Appendix B2: The Functional Anatomy of Hip Flexion or Extension and the Fitness Components of Speed, Agility and Flexibility). A format for report writing can be located at the end of the Exercise Physiology chapter as Appendix A, to assist students with their preparation for a practical investigation. A marking matrix is also included in Appendix B2.

Revision and examination style questions (with answers) are also included at the end of this chapter (Appendix C).

This chapter relates to the understanding of the structure and function of skeletal and muscular systems, and the circulatory and respiratory systems.

This section is introduced with labelled diagrams of the skeleton and musculature of the body. This is followed by content related to the structure and function of the circulatory and respiratory systems. The chapter concludes with a table summarising the attachment site and action of the important muscles. Specific sporting actions are analysed to highlight the important functional anatomy content. These are:

1. Doing a crossover dribble in field hockey.
2. Performing a biceps curl.
3. Swinging a softball bat (trunk action) or doing a sit-up to highlight gliding actions.
4. Kicking a football.
5. Doing the splits and pitching a softball.
6. Performing a breaststroke leg kick.

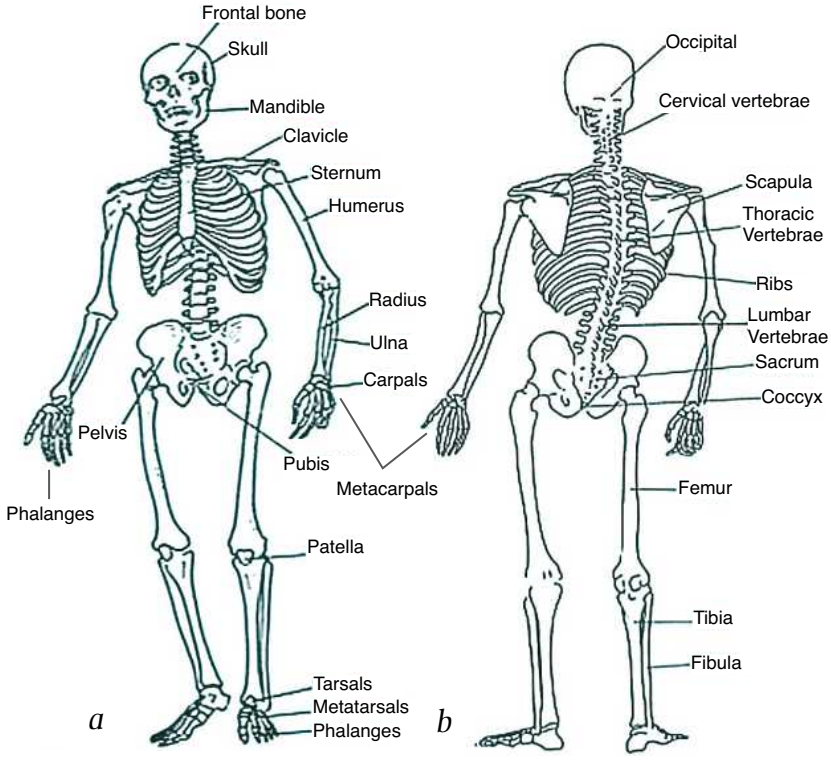


Figure 2.21: *The human skeleton: anterior (a) and posterior view (b)*

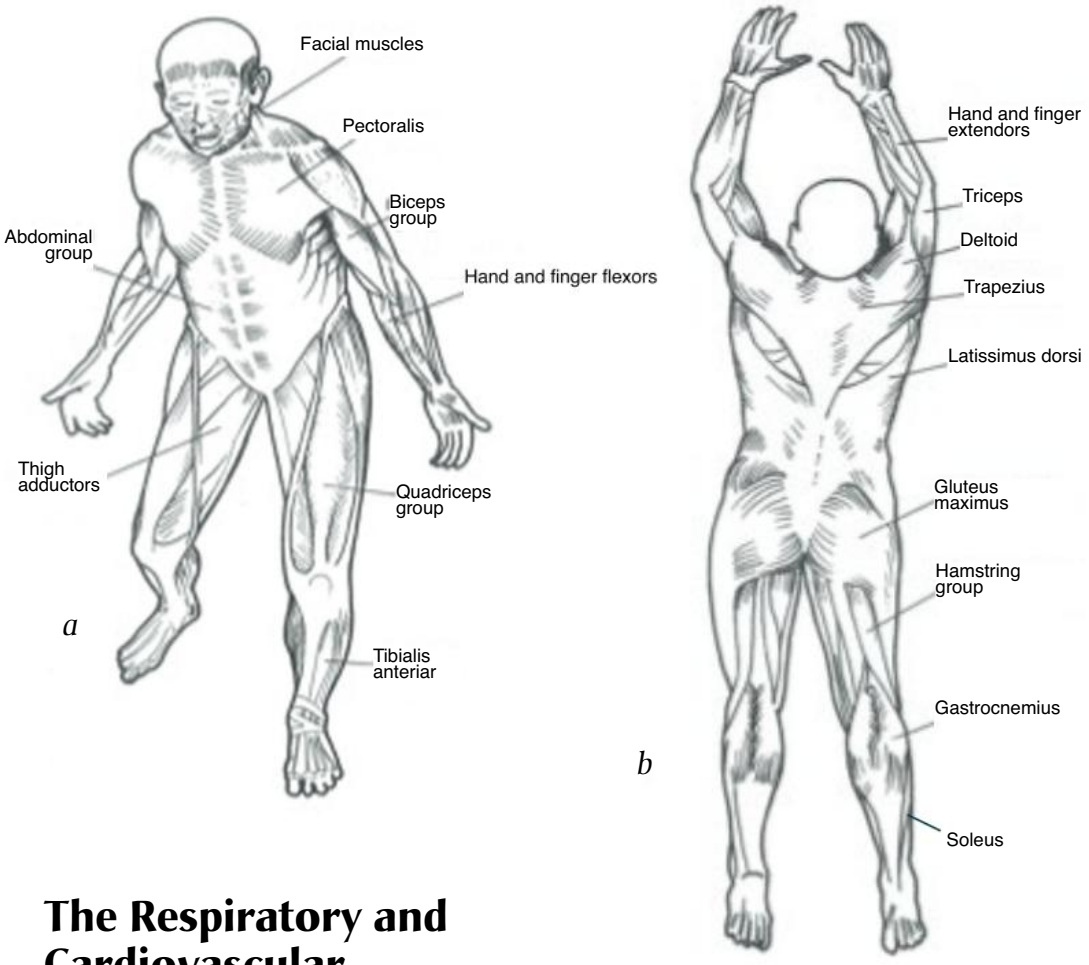


Figure 2.22: *The human muscular system: anterior (a) and posterior (b)*

The Respiratory and Cardiovascular

Text outcomes:
Functional anatomy (Unit 1)

- *Describe the structure and function of the respiratory system.*
- *Describe the structure and function of the circulatory system.*

Systems

Fundamental to the aerobic energy system is the amount of oxygen consumed by the body, since adequate ATP production via the aerobic system can only be achieved in the presence of enough oxygen. The ***volume of oxygen consumed*** by the body at any one time is often abbreviated as $\dot{V}O_2$. The $\dot{V}O_2$ is determined by the integrated workings of the respiratory system, together with the cardiovascular (circulatory) system. The respiratory system brings oxygen from our external surroundings into the lungs where it can be moved into the bloodstream to be transported by the cardiovascular system to the working muscles. For this reason, we will now focus on the respiratory and cardiovascular systems, which play a vital role in the function of this energy pathway (Figure 2.23).

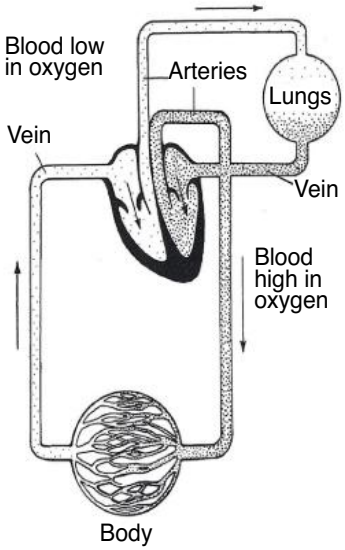


Figure 2.23: *The respiratory and circulatory systems work together to provide oxygen to working muscles*

Respiratory System

Content that follows:
The respiratory system (Unit 1)

- *Pulmonary ventilation*
- *Trachea, bronchi, bronchioles, and alveoli*
- *Mechanics of breathing*
- *Minute ventilation*
- *Tidal volume and breathing rate*
- *Gas exchange in the lungs*

In order to provide adequate oxygen to support the aerobic energy system, the respiratory system must first transport oxygen from our external surroundings to the lungs.

This is achieved through a process called ***pulmonary ventilation***. Several anatomical structures are involved in this process. First, air must enter through the mouth or nose, and then travel through the ***trachea*** (a narrow tube) to the lungs. At the level of the lungs, the trachea branches into tubes of progressively smaller diameter, called ***bronchi*** and ***bronchioles,*** respectively. These bronchioles continue to branch until reaching the ***alveoli*** located at the end of the respiratory tract. The alveoli are thin-walled, air-filled sacs. There are 300-500 million alveoli in the human lungs which creates a massive surface equivalent to the size of a tennis court area for gasses to move in and out of the bloodstream. It is here that gases

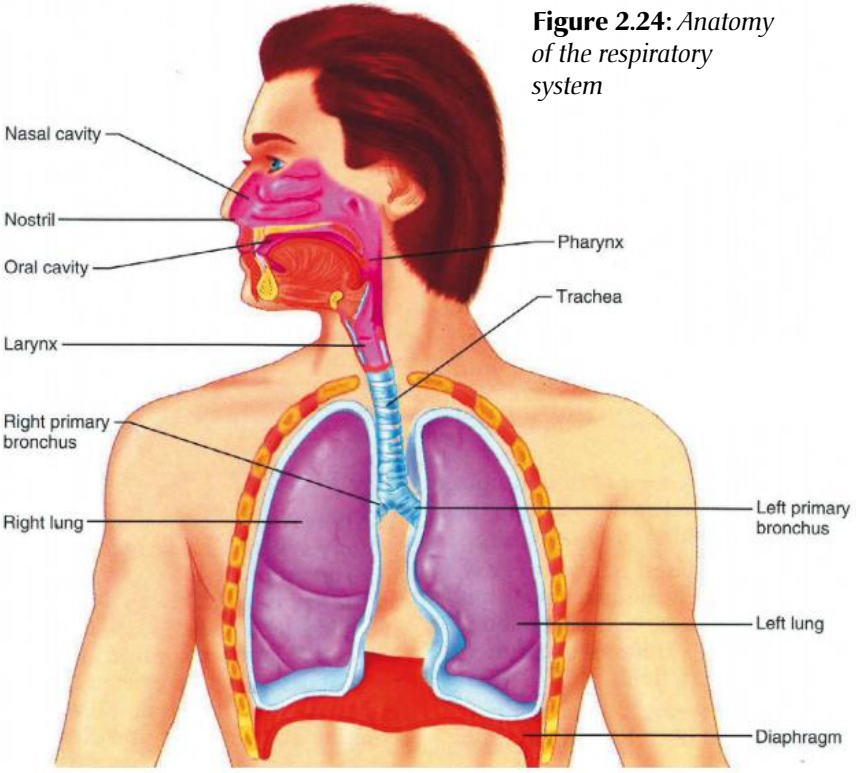


Figure 2.24: *Anatomy of the respiratory system*

move in and out of the bloodstream across the thin wall of the alveoli. A dense network of capillaries (tiny blood vessels) surrounds each alveolus to assist in this process (Figure 2.24). I like to think of alveoli as a marina (Figure 2.25), if we had just 1 jetty along the shore only a couple of boats could dock. Having multiple jetties allows for greater number of boats (and people) to come and go. The transfer of gases between the alveoli and bloodstream is called ***gas exchange***.

Mechanics of breathing

It is important to note that air doesn't simply enter the respiratory system from the external environment and travel to the alveoli on its own accord. Instead, complex processes resultsin the inspiration of air. A muscle called the ***diaphragm*** plays an important role in this action. The diaphragm is a dome-shaped sheet of muscle that separates the thoracic cavity, containing the lungs and heart, from the abdominal cavity below.

Inspiration (Figure 2.26) of air occurs when the diaphragm contracts and moves downwards towards the abdominal cavity (the dome flattens). The action of the diaphragm moving down causes increased space for the lungs to expand, resulting in a lowering of air pressure within the lungs. When the air pressure in the lungs is lower than that of the external environment, air rushes in. The reason for this is that gases naturally move along a pressure gradient from areas of higher pressure to areas of lower pressure to equalise any differences. On the other hand, expiration is predominantly a passive process, with air being forced to leave the lungs as the diaphragm relaxes and rises back towards the thorax, causing the previously expanded lungs to recoil. The decrease in lung space results in an air pressure in the lungs that is now higher than the external environment. This causes air to move out of the lungs back into the surrounding environment.



Figure 2.25: *A marina is used to represent the structure of alveoli in the lungs*

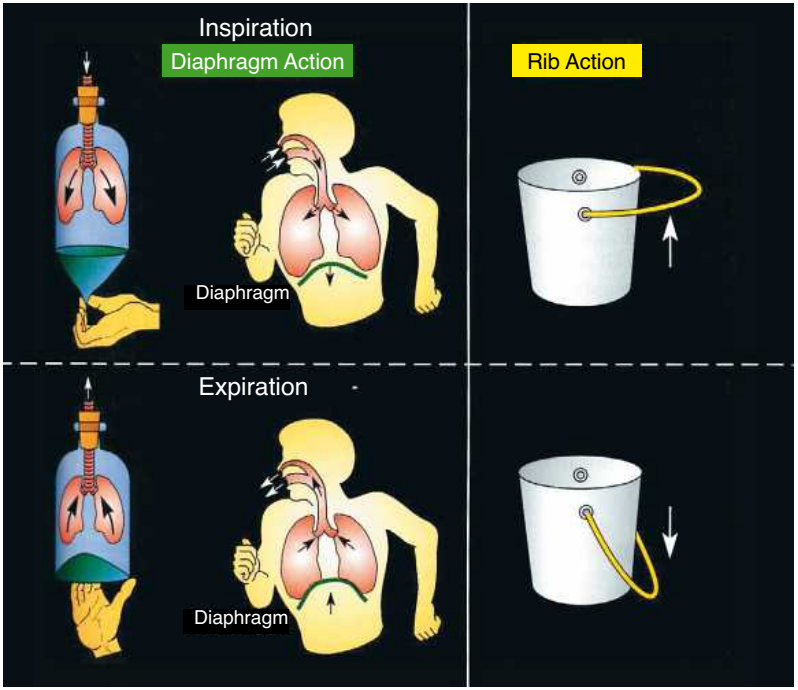


Figure 2.26: *Mechanics of breathing*

Minute ventilation

Minute ventilation represents the amount of air in litres that is inspired each minute. The minute ventilation at any one time is dependent upon the amount of air inspired with each breath, together with the frequency of breaths each minute. The amount of air moved during one cycle of inspiration is referred to as ***tidal volume***. Resting tidal volume is typically about 500 mL of air. The frequency of breaths per minute (***breathing rate***) is typically around twelve, although this can vary from ten to twenty-five. Based on these figures, we can calculate that the minute ventilation at rest is equivalent to about 6 L of air (that is 500 mL per breath x 12 breaths per minute = 6 L per minute).

Gas exchange in the lungs

The process of inspiration brings air from the external environment to the alveoli. However, it is important to note that the air we breathe consists of a mixture of gases, not oxygen alone. The composition of the air we breathe is fairly constant and consists of 20.93% oxygen, 79.04% nitrogen and 0.03% carbon dioxide. Despite inspiring this mixture of gases, it is only oxygen that we need to transport from the level of the alveoli across the thin-walled membrane into the bloodstream. The transfer of oxygen from the alveoli into the surrounding network of capillaries occurs via a process called ***gas exchange***. Gas exchange occurs by ***passive diffusion***. In passive diffusion, a particular gas will naturally move from an area of higher concentration to an area of lower concentration in order to attempt to reach equilibrium (an equal concentration in both areas). In other words, gases naturally spread out evenly in the environment. In this way, oxygen from the air we breathe in moves passively (without assistance) from the alveoli through the thin-walled membrane into the blood, since the concentration of oxygen is lower in the surrounding capillaries. At the same time, carbon dioxide (a waste product of the aerobic energy system) is removed from the body by diffusing from the bloodstream into the alveoli, where the concentration of carbon dioxide is lower (in the opposite

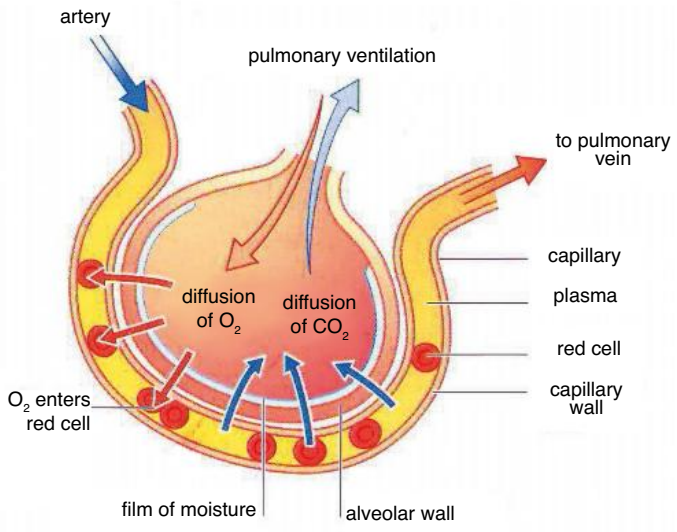


Figure 2.27: *Gas exchange at the alveoli via passive diffusion*

Class task: *What is your resting breathing rate?*

Check your own resting breathing rate by counting how many breaths you take over the next minute. From this, estimate your minute ventilation assuming that you have a tidal volume of 500 mL.

direction to oxygen diffusion). This allows for carbon dioxide to be expelled from the body during expiration (Figure 2.27).

Key point summary:

- The respiratory system transports oxygen from our external surroundings into the lungs to the site of gas exchange (the alveoli).
- The amount of air we inspire (minute ventilation) is determined by the amount of air inspired with each breath (tidal volume) and the frequency of breaths each minute.
- At the alveoli, passive diffusion occurs where oxygen moves from the alveoli (high concentration) into the bloodstream (low concentration), while carbon dioxide moves from the blood (high concentration) into the alveoli (low concentration) to be expelled from the body upon expiration.

Revision questions:

Test yourself on revision questions 1–4 located at the end of this chapter.

Cardiovascular System

Although it is the role of the respiratory system to transport oxygen inside the body to the lungs, this is of no use unless the oxygen can be transported to the level of the working muscle. This is the role of the ***cardiovascular system***. The cardiovascular system consists of several anatomical structures that work together to transport oxygen around the body. These include a pump (the heart) and a series of pipes (arteries, capillaries and veins) (Figure 2.28).

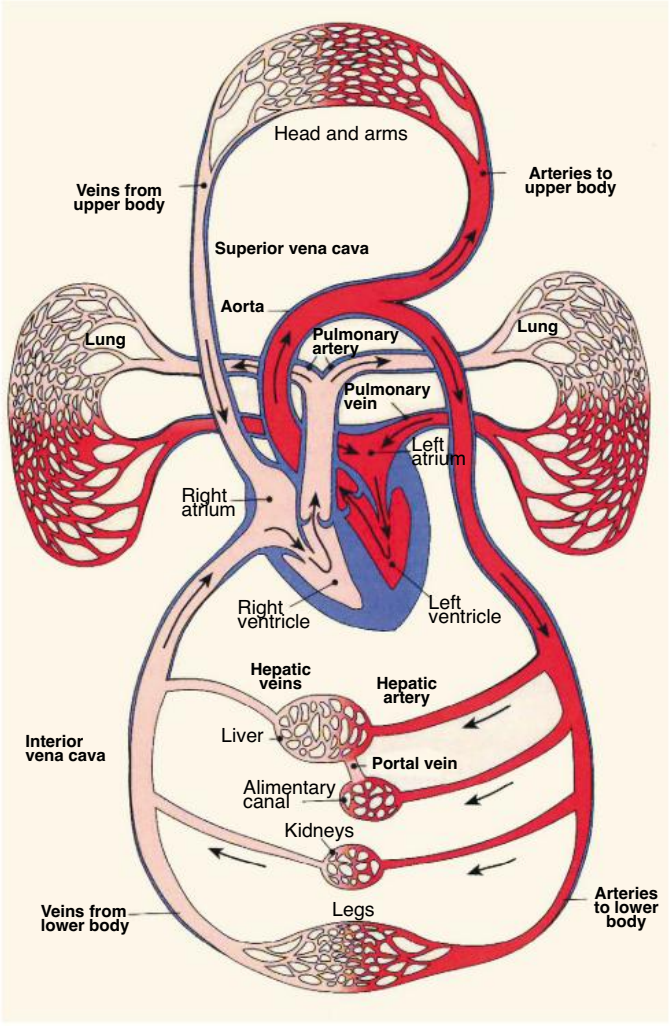


Figure 2.28: *Components of the cardiovascular system*

Content that follows:
The cardiovascular system (Unit 1)

- *Heart: Atria and ventricles*
- *Pulmonary and systemic circulation*
- *Heart rate*
- *Stroke volume*
- *Cardiac output*
- *Blood vessels: arteries, capillaries, and veins*
- *Blood: Volume, plasma, and haematocrit*
- *Blood pressure: Systolic and diastolic*
- *Blood distribution*
- *Oxygen transport: Haemoglobin*
- *Oxygen exchange at the tissues: Arteriovenous oxygen difference*
- *Oxygen consumption*

Heart

The ***heart*** is central to the cardiovascular system. This organ is located in the thoracic cavity between the lungs and is divided into four chambers. The top two chambers are called ***atria*** and receive blood from circulation, whereas the bottom two ***ventricles*** are much larger and are responsible for pumping blood out again into circulation (Figure 2.29).

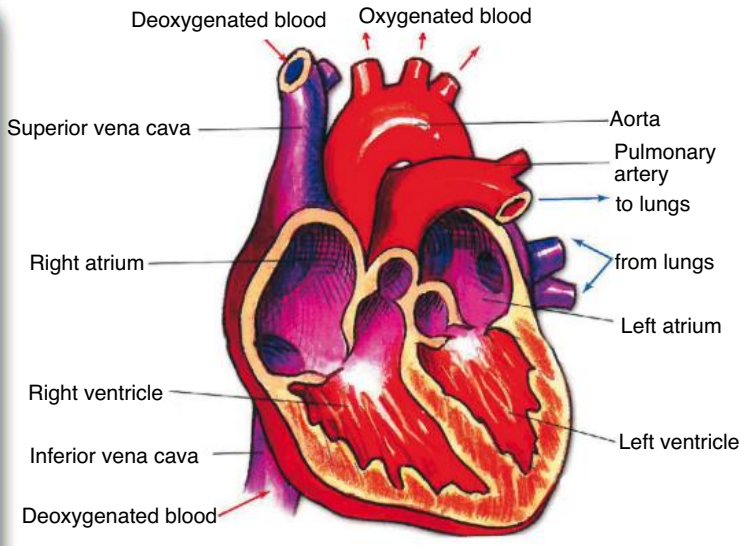


Figure 2.29: *Basic anatomy of the heart*

Pulmonary and systemic circulation

Although we think of the heart as a single pump that drives blood throughout the circulatory system, it actually consists of two separate pumps, which serve different pathways of circulation. These are ***pulmonary circulation*** (circulation of blood between the heart and lungs) and ***systemic circulation*** (circulation of blood between the heart and body tissues). Pulmonary circulation begins with blood received into the right atrium from the body tissues via the ***vena cava*** (a large vein). This blood is relatively low in oxygen and high in carbon dioxide. The reason for this is that the body tissues have already extracted the oxygen needed by the aerobic energy system and must remove carbon dioxide. This blood is then pumped from the right atrium into the right ventricle below, and from there it is pumped to the lungs via the ***pulmonary arteries*** for gas exchange, where the excess carbon dioxide is expelled from the body via expiration and fresh oxygen is collected at the alveoli. This newly oxygenated blood is then transported from the lungs back to the left side of the heart in the

pulmonary veins, where it enters the left atrium, followed by the ventricle below to be pumped into systemic circulation via the ***aorta*** (the main artery connected to the heart) around the rest of the body. It should, therefore, come as no surprise that the left ventricle has a much thicker muscular wall than the right ventricle, since the blood pumped into systemic circulation has a lot further to travel (around the whole body) than that in pulmonary circulation (from the heart to the lungs and back).

Heart rate

At rest, the heart beats around seventy times per minute. However, this can vary considerably depending on the individual. In particular, aerobically trained athletes may have a resting ***heart rate*** as low as forty beats per minute (bpm).

Practical activity: *What is your resting heart rate?*

Check your own pulse rate at the radial artery. To do this, palpate with your index and middle finger in line with the base of the thumb. Count how many beats you feel in thirty seconds and multiply by two to determine beats per minute. Keep in mind that a variety of factors can affect heart rate such as anxiety, caffeine or prior exercise. Therefore, the best measure of resting heart rate is taken first thing in the morning after waking up, before you get out of bed.

Equipment:

- Stopwatch or clock.

Stroke volume and cardiac output

The fact that athletes have such a low resting heart rate may cause you to wonder how they manage to get enough blood around the body. The answer to this relates to the volume of blood pumped with each beat of the heart (***stroke volume***). The average stroke volume at rest is approximately 70 mL per beat. However, for athletes this may be as large as 120 mL per beat. Therefore, an athlete with a resting heart rate of 45 bpm and stroke volume of 120 mL, would have the same amount of blood pumped around the body each minute (45 bpm x 0.120 L = 5.4 L/min) as an untrained individual with a resting heart rate of 77 beats per minute and a stroke volume of 70 mL (77 bpm x 0.070 L = 5.4 L/min). In fact, regardless of heart rate and stroke volume, the amount of blood pumped by the heart at rest is relatively similar in all individuals (between 5 and 6 L/min). The proper word to describe the amount of blood ejected by the heart (left ventricle) each minute is ***cardiac output***. This can be represented by the formula:

Cardiac output (L/min) = heart rate (beats per minute) x stroke volume (L per beat)

Blood vessels

The body contains over 100, 000 km of blood vessels. Oxygenated blood pumped from the left ventricle of the heart is transported into systemic circulation towards the working muscles via a complex network of blood vessels called the ***arteries***. As the blood travels further away from the heart, the arteries get progressively smaller in size until reaching the ***capillaries***. The capillaries are tiny blood vessels that are so small that only individual

red blood cells can fit through them in single file. Another important feature of capillaries is their thin walls. It is at the site of these capillaries that oxygen, nutrients and carbon dioxide are exchanged with the body tissues through the thin vessel walls. Following the exchange of these gases and nutrients, blood is now lower in oxygen (***deoxygenated***). This deoxygenated blood continues to flow away from the capillaries into the ***veins***. The veins connecting directly with the capillaries are small in size, growing progressively wider in diameter, and smaller veins converge to form larger veins as they travel back towards the right side of the heart from where the deoxygenated blood will be pumped to the lungs via pulmonary circulation to collect fresh oxygen and start the cycle again (Figure 2.30).

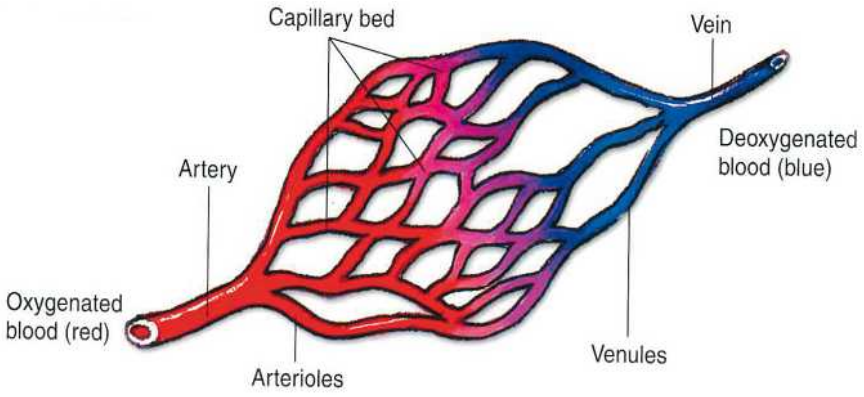


Figure 2.30: *Arteries, capillaries and veins*

Blood

You may be surprised to learn that the average ***blood volume*** is about 5 litres. Blood performs a range of important functions, including transportation (nutrients from gastro-intestinal tract, oxygen from lungs, carbon dioxide from the cells, other waste), defence (phagocytes – ingesting foreign substances, produce antibodies, blood clotting), thermoregulation (heat is a by-product of energy production which is dissipated from core to skin or lungs), and maintenance of pH (buffer both acids and bases, typical pH ~7.35-7.45). Blood is made of a liquid component called ***plasma***, plus a range of different types of cells. The majority of these cells are red blood cells, which make up approximately 40% of blood volume. The percentage of our blood accounted for by red blood cells is called our ***haematocrit***. A slightly higher haematocrit can be an advantage for athletic performance, since the red blood cells are involved in transporting oxygen around the body (so the more red blood cells, the more oxygen that can be carried in the blood). However, there is a limit to this advantage, since too many red blood cells can make the blood thick and therefore difficult to travel through the circulatory system, potentially resulting in clots (blockages). Some athletes try to boost their haematocrit artificially by injecting a hormone called EPO that increases their production. This is especially dangerous since dehydration during exercise will make the blood even thicker and more likely to clot.

Blood pressure

An important concept relating to the transport of blood through systemic circulation is ***blood pressure***. This is the pressure exerted on the blood vessel walls as blood is pumped from the left ventricle into the arterial system and it is this pressure that moves the blood through the blood vessels to the smaller capillaries. The highest pressure at any one time on the arteries results from the pumping of blood into the ***aorta*** (the main artery connected to the heart). This is termed ***systolic blood pressure*** and is

typically about 120 mmHg in a healthy person. Alternatively, the lowest pressure exerted on the artery walls occurs when the heart relaxes to refill with blood. This is known as ***diastolic blood pressure*** and is generally 80 mmHg. These two numbers are often mentioned together, with systolic first, followed by diastolic. These are the numbers you regularly hear when watching medical shows on the television, where they say, 'blood pressure is 120 over 80'. This is written as blood pressure = 120/80 mmHg. A high blood pressure (>140/90 mmHg) can have a negative effect on your health since it can damage the artery walls, leading to cardiovascular disease.

Blood distribution

The distribution of the cardiac output at rest is illustrated in Figure 2.31. As you can see, blood flow is divided amongst a range of organs and tissues, with a large proportion going to the liver, kidneys, brain and skeletal muscle at rest. The distribution of blood flow is dramatically changed with exercise. In particular, there is a rapid redistribution of blood flow towards the working muscles.

Oxygen transport in the blood

Once oxygen has diffused from the alveoli of the lungs into the bloodstream, this oxygen must be transported to the working muscles. This occurs in two main ways. First, a small amount of oxygen is dissolved in the fluid portion (plasma) of the blood; however, this is only enough to sustain life for about four seconds. This is primarily because oxygen is not very soluble in plasma. Therefore, the majority of oxygen is transported in the blood by combining with a molecule called ***haemoglobin*** found in our red blood cells. A single red blood cell contains millions of haemoglobin molecules. Of interest is that the

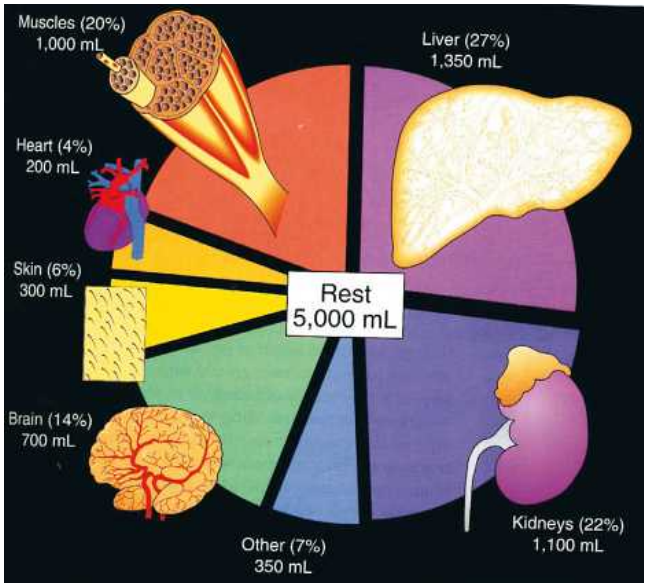


Figure 2.31: *Blood flow distribution at rest*

amount of haemoglobin present in the blood of males and females seems to differ. Men typically have 15–16 g of haemoglobin in each 100 mL of blood, while women have about 14 g. This is one factor contributing to the lower aerobic capacity in women.

Carbon dioxide is also transported in the blood. Once produced at the level of the working muscles, carbon dioxide diffuses into the bloodstream to be transported to the lungs for removal from the body via expiration. However, transport in the bloodstream occurs via three mechanisms. First, like oxygen, a small proportion of carbon dioxide (10%) is transported by dissolving in plasma. Also, like oxygen, some carbon dioxide (20%) is transported in combination with proteins in the blood (including haemoglobin). However, the great majority of carbon dioxide (70%) is transported in the bloodstream in combination with water. The combination of water and carbon dioxide results in the formation of bicarbonate, which is highly soluble.

Oxygen exchange at the tissues

Oxygenated blood is transported to the body tissues, where the oxygen can then be extracted for the purpose of producing energy via the aerobic energy system (Figure 2.32). However, the amount of oxygen extracted varies, based on the needs of the muscles (more oxygen is extracted during times of greater need). The amount of oxygen extracted from systemic circulation can be determined, in theory, by comparing the amount of oxygen in arterial blood to that contained in venous blood. Theoretically, any difference in the oxygen content is accounted for by that which has been extracted by the tissues at the level of the capillary. This is termed the ***arteriovenous oxygen difference*** (a-vO_2diff). In general, the oxygen content of arterial blood is 20 mL per 100 mL at rest. On the other hand, the oxygen content of mixed venous blood at rest is approximately15 mL per 100 mL. Therefore, the oxygen extracted by the body tissues at rest is equivalent to 5 mL of oxygen per 100 mL (20 mL per 100 mL – 15 mL per 100 mL = 5 mL per 100 mL) (Figure 2.33).

Oxygen consumption ($\dot{V}O_2$)

The culmination of each of the above-mentioned processes involving the respiratory and cardiovascular systems (ventilation, oxygen exchange at the lungs, oxygen transport and oxygen exchange at the muscle tissue) is the ***volume of oxygen consumption*** ($\dot{V}O_2$; the volume of oxygen actually used by the body). At rest, the typical $\dot{V}O_2$ is approximately 250–300 mL of oxygen per minute. Another way to think of the amount of oxygen utilised by the body at any one time is that it is related to the amount of blood being transported around the body (cardiac output, which is the product of the heart rate and stroke volume) and the amount of oxygen extracted from this blood (a-vO_2diff). This concept is summarised by rearranging the ***Fick equation***:

$\dot{V}O_2$ = cardiac output x a-vO_2diff

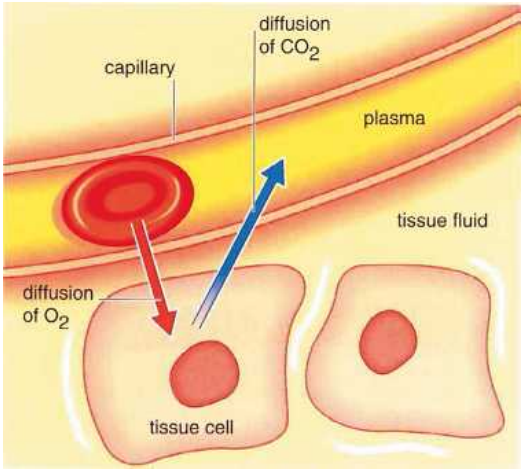


Figure 2.32: *Exchange of oxygen and carbon dioxide at the site of the tissues*

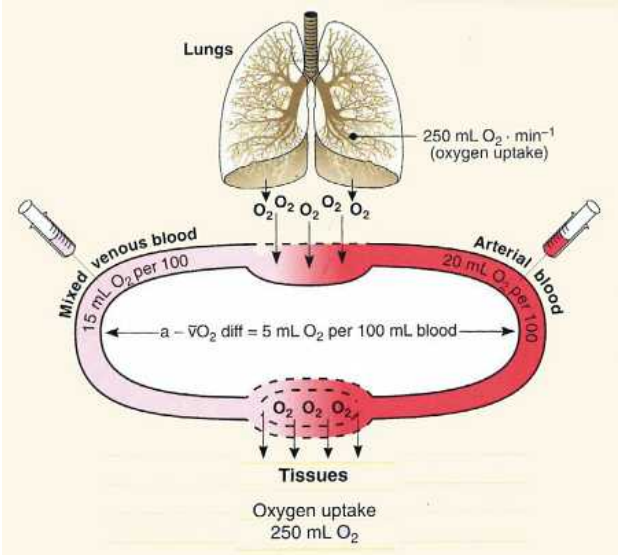


Figure 2.33: *Arteriovenous oxygen difference*

Key point summary:

- The cardiovascular system transports oxygen to the level of the working muscle.
- The amount of blood pumped around the body each minute (cardiac output) is determined by the volume of blood pumped with each beat of the heart (stroke volume) and the number of beats per minute (heart rate).
- Systolic blood pressure represents the highest pressure in the arteries resulting from the contraction of the heart, while diastolic blood pressure occurs when the heart relaxes.
- The majority of oxygen is transported in the blood in combination with haemoglobin in red blood cells.
- The majority of carbon dioxide is transported in the blood as bicarbonate after combining with water.
- The volume of oxygen consumption ($\dot{V}O_2$) represents the volume of oxygen actually used by the body. This is the product of the amount of blood being transported around the body (cardiac output) and the amount of oxygen extracted from this blood (the a-vO_2 difference).

Revision questions:

Test yourself on revision questions 5–10 located at the end of this chapter.

Text outcomes:
Functional anatomy (Unit 2)

- *Understand the use of the musculoskeletal structures in the production of movement.*

Muscle function

Muscle contraction creates movement of limbs and assists in maintaining posture and ensuring joint stability. Muscles have four main characteristics: contractibility, extendibility, elasticity and excitability. All muscles within the body comprise a ***contractile*** component, which shortens when developing tension. Being able to stretch a muscle beyond its normal resting length indicates its ***extensibility***. The ***elasticity*** of muscle refers to its ability to return to its original shape after being stretched. The ***excitability*** of a muscle is its ability to recieve and respond to stimuli (usually neural stimuli). Once excited, the *contractile* component shortens and develop tension.

For movement to occur, the contractile tissue (skeletal muscle) of the body must connect to the rigid structure (bones) of the body. The muscle has two ends and each end attaches to a different bone across a joint. When the muscle contacts and shortens, it pulls the two bones closer together to create movement. It is not possible for muscles to push bones. The following examples highlight the different joints of the body and how movements are restricted due to the anatomical structure of the body.

Crossover Dribble in Hockey

Content that follows:
Crossover dribble in hockey (Unit 2)

- *The pivot joint: Forearm*
- *Muscle attachment site: Origin and insertion*



Figure 2.34: *The right hand forearm supinated (a) and pronated (b)*

The pivot joint

When doing a crossover dribble in hockey, the action of the bottom hand (right hand) requires that the stick, which starts with the ball on the stick side (Figure 2.34a), is eventually turned over or reversed (Figure 2.34b). Figure 2.34a shows the right arm in a ***supinated*** position, with the palm of the right hand (holding the lower part of the stick) facing upwards. Figure 2.34b shows the crossover position, with the right hand palm facing downwards, in a ***pronated*** position.

To achieve the crossover position (Figure 2.34b) requires a number of rotating actions to take place in the upper body at the shoulder, elbow and wrist. The forearm bones, comprising the ulna, which sits on the little finger side and the radius on the thumb side, form a pivot joint. This pivot joint permits longitudinal axis rotation to occur, causing pronation and supination movements. The head of the radius is circular, similar to the top of a golf tee, which sits into a small indent in the ulna. Strong ligaments hold these two bones together, surrounding the radius and attaching it to the ulna (Figure 2.35a). The muscles creating these movements generally originate from the ulna and insert into the radius.

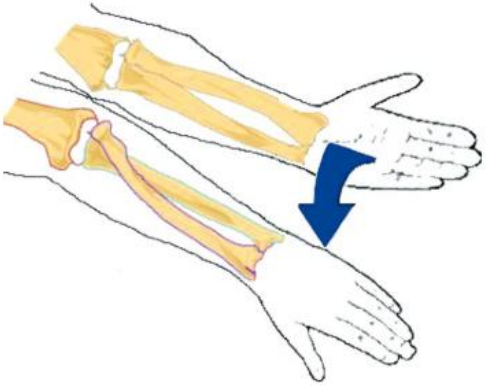


Figure 2.35: *The radius and ulna are parallel when the forearm is supinated (a) and crossed over when pronated (b)*

For the crossover dribble action to be developed, pronation occurs at this pivot joint. The radius rotates (pivots) on the ulna, causing the hand to move from face up to face down (Figure 2.35b).

Key point summary:

- When performing a crossover dribble in field hockey:
  - Bones: radius and ulna.
  - Joint type: pivot joint.
  - Muscles: pronators and supinators.
  - Action: pronation and supination.
- Pronation: occurs when you cross over the radius and ulna (palm down).
- Supination: occurs when the radius and ulna are parallel (palm up).
- Origin: the muscle attachment site (tendon) that is at the static end.
- Insertion: the muscle attachment site (tendon) that is closest to the end that moves.

Practical activity: *Initiating pronation and supination*

Work in pairs. Touch the head of the radius (Figure 2.36) on your partner. Ask them to pronate and supinate the forearm and feel the head of the radius pivot under your fingers.

Equipment:

- None.

Class task: *Examples of pronation and supination*

In small groups, identify sporting activities that require pronation and/or supination of the forearm.

Revision questions:

Test yourself on revision questions 11–14 located at the end of this chapter.



Figure 2.36: *Location of the head of the radius*

Biceps Curl

Content that follows:
Biceps curl (Unit 2)

- *Hinge joint: Elbow.*
- *Agonist: Prime mover.*
- *Reciprocal muscles: Antagonist.*
- *Contraction types: Concentric, eccentric, and isometric.*

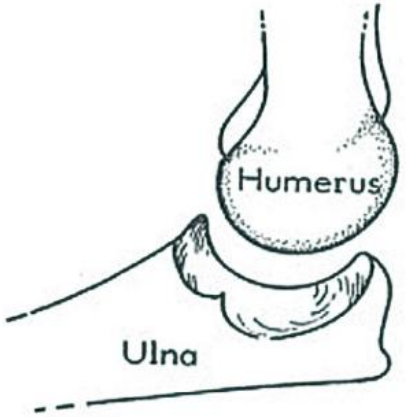


Figure 2.37: *Bones of the elbow forming a hinge joint*

The hinge joint

The ***elbow joint*** is a hinge joint formed between the humerus and the ulna bones (Figure 2.37). The shape of the end of these bones only permits flexion and extension of the forearm at this joint. The end of the humerus (arm) is similar to that of a cotton reel, which is surrounded by a claw-like structure at the end of the ulna on the little finger side of the forearm. This limits any rotation (twisting), abduction (away from the body) or adduction (towards the body) movements.

When the elbow is flexed, such as during a biceps curl, the biceps muscle shortens (***agonist or prime mover***) while contracting (Figure 2.38a, b & c). This is called a concentric contraction. This causes the forearm (ulna and radius) to move towards the arm (humerus). In this instance, the angle between the humerus and ulna is reduced. When the angle at this joint is reduced we have created ***flexion*** at the elbow. How far the forearm can be flexed will be partially determined by the surrounding soft tissue. A larger biceps or greater amounts of fatty (adipose) tissue over the biceps will prevent the forearm moving through full flexion (Figure 2.11a). Also, weak biceps muscles may limit the body's ability to lift the dumbbell through the required range of movement (ROM).

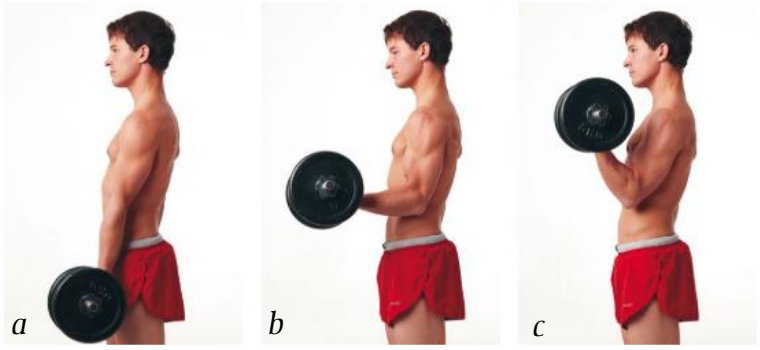


Figure 2.38: *Biceps curl; concentric contraction of biceps muscle causing flexion at the elbow (a, b & c), the antagonistic muscle of the triceps relaxes*

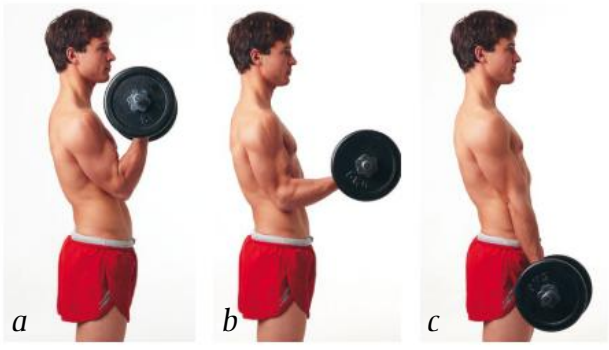
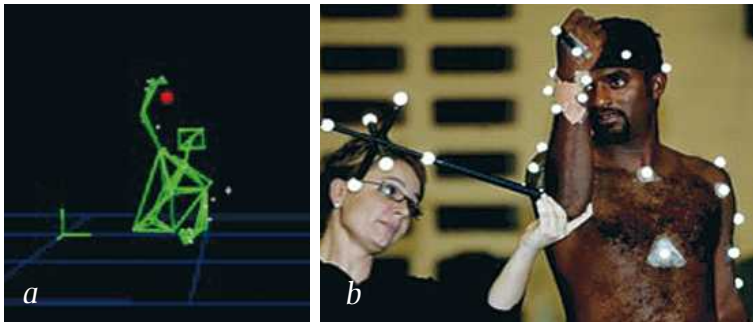


Figure 2.39: *Biceps eccentrically contracting while extending during a biceps curl (a, b & c)*

During the biceps curl, the triceps muscle relaxes (Figure 2.38a, b & c). Muscles work in pairs: when one contracts the opposite muscle relaxes. In this case the triceps muscle relaxes and is, therefore, called the ***reciprocal muscle and is an antagonist***. If the triceps muscle is not flexible this again can reduce the ROM.

In order to return the dumbbell to the starting position, the biceps muscle contracts eccentrically (Figure 2.39a, b & c). An ***eccentric contraction*** occurs when tension is developed in the muscle while it is lengthening. This allows control of the movement, in this case lowering the weight, while the triceps muscle remains relaxed, allowing the forearm to be extended at the elbow. Again, similar anatomical structures may prevent the arm from being fully extended. Tight biceps muscles and large bony mass may cause the movement to be terminated early. In the bowling actions of some cricketers, who are unable to completely extend their arms, it appears to produce an illegal delivery (Figure 2.40a & b). In contrast, having smaller muscles and bones may lead to an increased ROM and possible hyperextension at the elbow joint (Figure 2.10).

In a ***reciprocal movement***, such as a triceps extension exercise, the triceps muscle concentrically contracts, extending the forearm at the elbow and raising the dumbbell against gravity (Figure 2.41a & b). As with the biceps curl, when lowering the weight to its original position, eccentric contraction of the prime mover (triceps) and maintained relaxation of the biceps muscle is required (Figure 2.42). If, during this movement, the weight were to be held steady at one point, the triceps muscle would be required to contract isometrically (Figure



Giving the appearance of an illegal bowling technique. The cricket bowler represented in Figure 2.40 (a) and being measured in Figure 2.40 (b) has bony structures, preventing full extension at the elbow

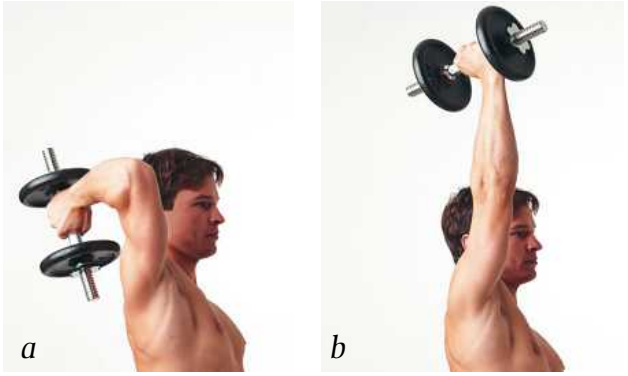


Figure 2.41: *Triceps extension exercise; concentric contraction of triceps muscle causing extension at the elbow (a, & b), the antagonistic muscle, in this case, the biceps, relaxes (b)*

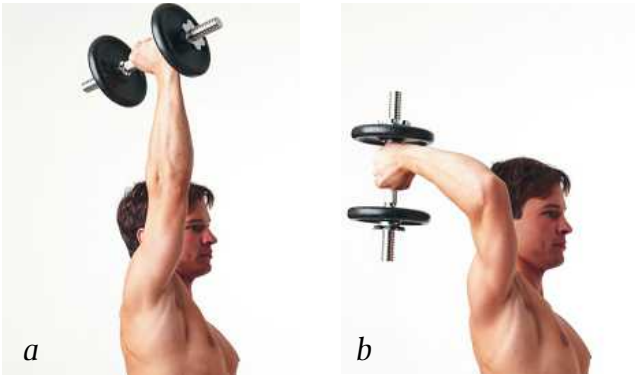


Figure 2.42: *Triceps eccentrically contracting while flexing during a triceps extension (a & b)*



Figure 2.43: *Isometric contraction of triceps muscle. The position is maintained such that there is no change in muscle length*



Figure 2.44: *Isometric contractions used in sport to create a stable platform*

2.43). That is, when a muscle is generating a force but not changing in length, it is ***isometrically contracting*** (iso = same, metric = length).

Examples in sport where isometric contractions occur relate to those activities that require a stable platform from which to work. Examples include archery, shooting and snooker (Figure 2.44). In each of these cases, one arm is used to support the implement, such as the pool cue. In order for this arm and hand to remain still, muscles must contract to maintain the structure, yet not change length, as this would create movement. Thus, isometric contractions are used. The other arm will contract concentrically to create movement of the cue to strike the ball.

In a training sense, many core strengthening exercises (Figure 2.45 a, b) use isometric contractions to improve muscle strength in muscles that are used to stabilise joints or segments during other activities.

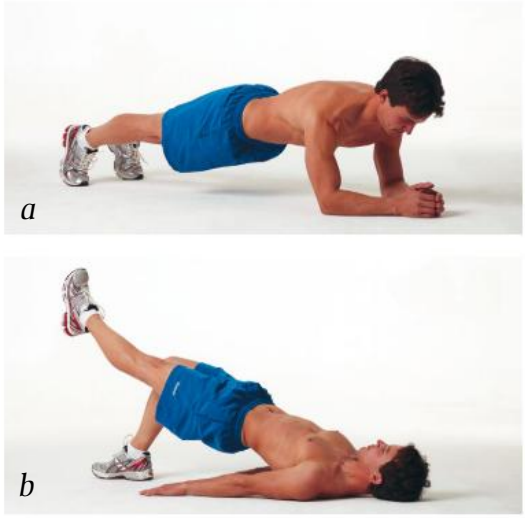


Figure 2.45: *Core strength exercises using isometric contractions. Bridge (a) and reverse bridge (b)*

Revision questions:

Test yourself on revision questions 15–17 located at the end of this chapter.

Practical activity: *Flexing your muscles*

Work in pairs. Have your partner sit on the desk. Place your hand beneath the desk. Your humerus should be by your side with the forearm at 90°. Push up against the desk in an isometric contraction. Touch the biceps and triceps muscles and determine which have been active or relaxed.

Repeat the activity, but this time place your hand above the desk and push down. Again palpate (touch) the muscles and determine which have been active or relaxed.

Using a weight (dumbbell) perform repeated biceps curls until fatigued. Determine which muscle is most tired. Immediately change to performing a triceps extension exercise. How can we do this second exercise, having fatigued during the first activity?

Equipment:

- Desk.
- Heavy dumbbell.

- When performing a biceps curl:
  - Bones: humerus, radius and ulna.
  - Joint type: hinge joint.
  - Muscles: biceps (agonist) and triceps (antagonist).
  - Action: flexion and extension.
- Flexion: the joint angle is decreased and limbs move closer together.
- Extension: the joint angle is increased and limbs move further apart.
- Agonist: the prime muscle, when restricted is responsible for movement.
- Antagonist: muscles that create the opposite movement to that created by the agonist.
- Concentric muscle contraction: muscle shortens when tension is developing.
- Eccentric muscle contraction: muscle lengthens when tension is developed.
- Isometric contraction: no change in length when tension is developed.

Swinging a Softball Bat

Content that follows:
Swinging a softball bat (Unit 2)

- *Gliding joints: Carpals, tarsals, and vertebrae*
- *Rotation*

Gliding joints

The most common joint in the human body occurs when two bones with flat or slightly curved surfaces meet. This is termed a gliding joint. Typically these joints are between short bones in the wrist (***carpals***), ankle (***tarsals***) and ***vertebrae*** (Figure 2.46). Movement between these bones is possible in any direction. Numerous ligaments hold them together as the shapes of the bones do not offer much stability to the joint. However, as these bones are packed tightly together the movement is generally limited.

When swinging the bat in sports such as baseball and softball, a twisting action occurs at the trunk (Figure 2.47). The lower limbs are somewhat stationary and offer a platform for the upper body motion. There is obviously movement occurring at the shoulders and arms to generate bat speed, but for the purposes of this example, we will consider just the movement between the pelvis and the shoulders. This twisting action is defined as ***rotation*** and is permitted by the gliding action between subsequent vertebra. Each individual vertebra has a relatively flat superior and inferior surface, which allows movements in most directions; however, the posterior structures (Figure 2.48) of the vertebra and the numerous ligaments limit trunk extension and rotation.



Figure 2.47: *Hitting a softball*

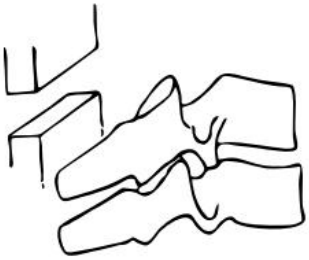


Figure 2.46: *Bones with flat surfaces creating gliding joints: vertebrae*

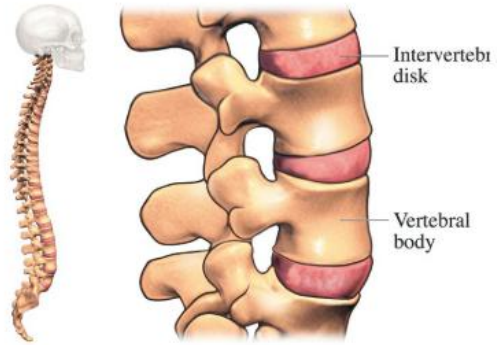


Figure 2.48: *The spine permits rotation as a gliding joint. The facet joints limit this amount of rotation*

The rotational movement in the early phase of swinging the bat is generated by the muscles of the trunk. In this example, the abdominal muscles are split into left and right and act as both the agonist and antagonist. For a right-handed batsman, the abdominal muscles contract and create the rotation about the spine to create the swing. The agonist muscles are abdominal muscles on the left side and are contracted to initiate the swing. The abdominal muscles on the right relax during the swing phase and are the antagonist muscles in this action. These muscles are attached to the pelvis and ribs (Figure 2.49).





Abdominal muscles creating trunk rotation

Key point summary:

- When swinging a softball bat, the trunk:
  - Bones: vertebrae.
  - Joint type: gliding joint.
  - Muscles: left-side abdominals (agonist), right-side abdominals (antagonist).
  - Action: Rotation.

Revision questions:

Test yourself on revision questions 18 and 19 located at the end of this chapter.

Kicking a Football

Content that follows:
Kicking a football (Unit 2)

- *Gliding Joint: Knee*
- *Hinge joint: Knee*

The knee: gliding joint and hinge joint

The ***patella*** forms part of the knee joint with the ***femur*** and ***tibia***. The femur and tibia form a hinge joint and the patella glides over these bones during extension and flexion (Figure 2.50a & b). In the case of kicking a football off one step, the lower limb (thigh, leg and foot) contributes to imparting force to the ball. If we confine our attention to the knee joint during the kicking phase, we note that the quadriceps muscles, originating on the femur and pelvis and inserting through the patella to the tibia, contract concentrically, causing extension at the knee joint with the tibia and ***fibula*** moving forwards (Figure 2.51a & b). The force that is generated at the knee is increased due to the patella improving the gliding over the bones and increasing the mechanical advantage of the quadriceps muscles. As the leg becomes fully extended at the knee, the hamstring muscle group begins to contract eccentrically to slow the leg down and control the movement (Figure 2.51c).

Hamstring injuries

A number of hamstring injuries are usually related to the hamstring being stretched and strained. In the case of kicking this is also true, as the thigh is flexed and the leg extends towards the end of the kick, the hamstring muscles are stretched. If this occurs too quickly and/or with too great a force, the muscle fibres can tear the muscle, causing injury. As described previously, at the end of the kicking action, the hamstring muscles contract eccentrically to try and slow down the movement of the tibia and prevent this overstretching. However, in many footballers, the strength of their quadriceps muscles are so much greater than the strength of the hamstrings that the hamstrings are not able to slow this movement effectively and injury results.

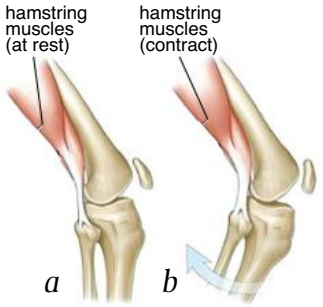


Figure 2.50: *The bones creating the hinge joint at the knee: in extension (a) and flexion (b)*

Key point summary:

- When kicking a football:
  - Bones: femur, patella, tibia, and fibula.
  - Joint type: hinge and pivot joint.
  - Muscles: quadriceps (agonist) and hamstrings (antagonist).
  - Action: extension.
- The patella gives the knee joint a mechanical advantage.
- Because the hamstrings are contracting eccentrically at the end of the kicking phase they are subjected to large or fast forces that can lead to injury.

Revision questions:

Test yourself on revision questions 20–23 located at the end of this chapter.

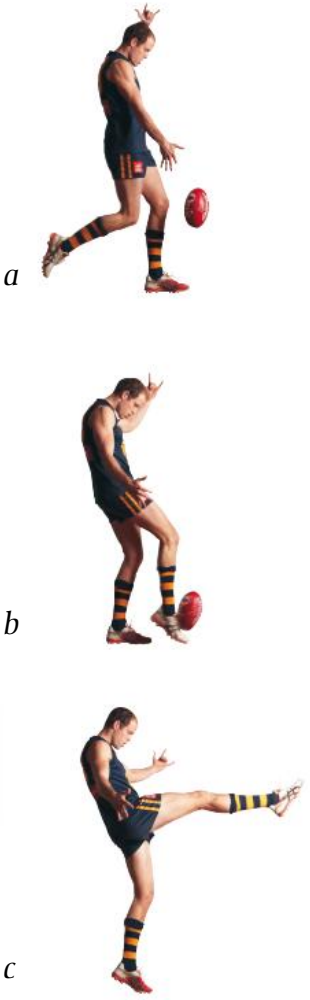


Figure 2.51: *Extension of the leg about the knee during a kick, created by concentric contraction of the quadriceps (a & b) and relaxation of the hamstring muscles (c)*

The Splits and Pitching a Softball

The splits and pitching a softball (Unit 2)

- *Ball and socket joints:*
  - The hip joint
  - The shoulder joint

Ball and socket joints

The hip and shoulder joints are the most mobile of all joints in the body. At the hip, the end of the femur is shaped like a ball, which is inserted into a socket, or cup of the pelvis, allowing the bone to move in most directions: flexion, extension, abduction, adduction, rotation and circumduction (Figure 2.52). This is the same for the shoulder, where the end of the humerus fits into the socket formed by the scapula.

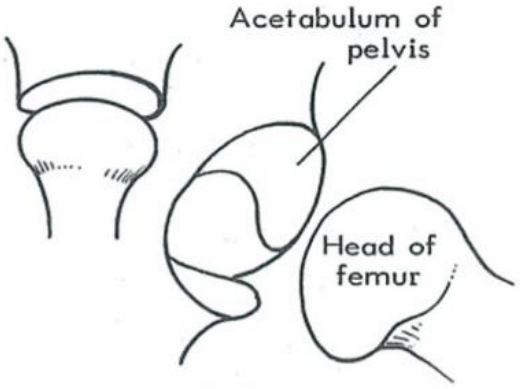


Figure 2.52: *Ball and socket joint of the hip*

Circumduction is basically a combination of flexion, abduction, extension and adduction. For such an action to occur muscles will contract and relax at different times. This can be seen when you flex at a joint, one muscle will contract while its reciprocal muscle relaxes; when we reach the opposite side of the movement the reciprocal muscle will contract and the original muscle relaxes.

To distinguish between ***circumduction*** and ***rotation***, think of the ***shape*** that is formed by the movement. Circumduction forms a ***cone*** with the apex (the top end) situated at the joint and the base at the extremity of the moving limb (Figure 2.53a). Circumduction is seen in actions such as backstroke. In contrast, ***rotation*** forms a ***cylinder*** with the axis of rotation through the length of the long bone (Figure 2.53b).

To allow all of these movements, the joint requires a large number of muscles that attach at different points. In the shoulder joint the bony structure forming the socket is much smaller than that at the hip joint. This has both advantages and disadvantages. It allows a greater range of movement, but it also means the stability of the joint is more reliant on soft tissue (muscles and ligaments) support rather than the bones. This leads to the increased incidence of ***subluxation*** (partial dislocation) or ***dislocation*** of the shoulder.

Gymnastics requires high levels of strength and flexibility of most joints in the body. The range of motion at the hips is vital to successfully performing the splits. When a gymnast performs lateral splits, each femur is abducted until they are at 180° to each other (Figure 2.54). The relaxation of adductor muscles allows these limbs to move apart, but without that flexibility, no matter how strongly the abductor muscles contract, both femurs will be restricted in their movements. To complete the splits in the other direction (forwards and backwards) requires hip flexors and extensors to

Practical activity: *Defining circumduction and rotation*

Attempt to do a two-arm circle. Is this circumduction or rotation?

Attempt the splits and note which aspects prevent you from succeeding–tight adductors or weak abductor muscles?

Equipment:

- None.

Key point summary:

- When performing the splits laterally (Figure 2.54):
  - Bones: pelvis and femur.
  - Joint type: ball and socket joint.
  - Muscles: hip adductors (antagonist) and abductors (agonist).
  - Action: abduction.

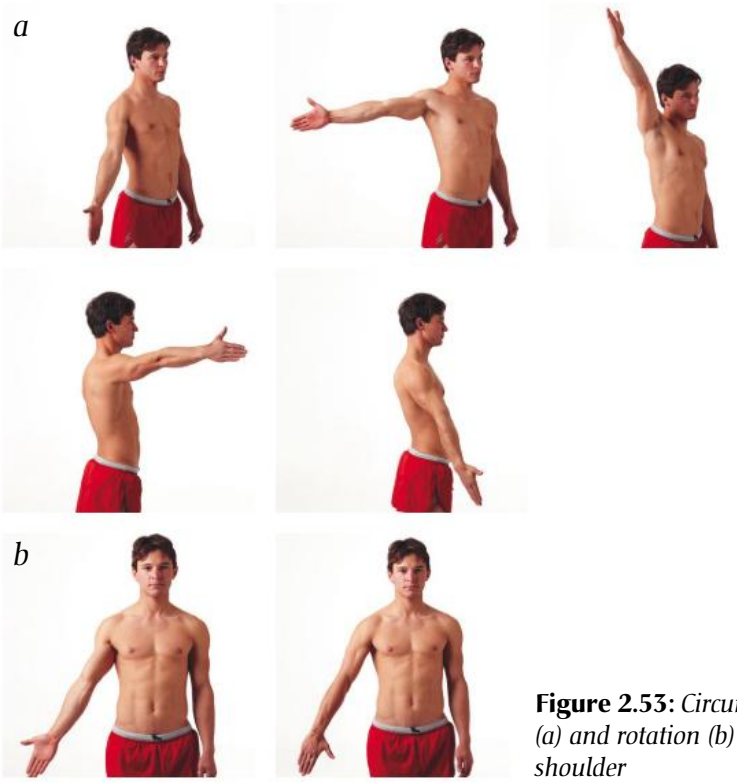


Figure 2.53: *Circumduction (a) and rotation (b) at the shoulder*



Figure 2.54: *Flexibility and relaxation of the adductor muscles permits this gymnast to complete the splits*

be relaxed as one femur is flexed and the other extended.

During the action of pitching in softball, the arm is circumducted. Initially, the humerus is by the trunk of the pitcher (Figure 2.55a) and when entering the delivery stride, the humerus is flexed through contraction of the muscles attached to the ribs and shoulder, such as pectoralis major and anterior fibres of deltoid (Figure 2.55b). As the arm begins to move upward and outward (abduction) new muscles that cross over the top of the shoulder begin to contract (2.55c). The muscles in the back, called the latissimus dorsi, contract, extending the arm and adducting it (Figure 2.55d). Then the muscles in the chest

contract again, to flex the arm and deliver the ball towards the batter (Figure 2.55e).
During this time the trapezius muscle, which sits on the back, extending the length of the spine and inserting into the shoulder, isometrically contracts to maintain joint stability.

Key point summary:

- When pitching a softball (circumduction):
  - Bones: humerus, scapula, and clavicle.
  - Joint type: ball and socket joint.
  - Muscles:
    - ◊ At the initiation of the delivery stride, contraction of the shoulder muscles–pectoralis major and deltoid (agonist) and latissimus dorsi (antagonist).
      - Action: shoulder flexion.
    - ◊ As the arm begins to move upward and outward, contraction of the shoulder and back muscles–latissimus dorsi, (agonist) and pectoralis major (antagonist).
      - Action: shoulder extension.
    - ◊ At the ball delivery towards the batter, contraction of the shoulder muscles–pectoralis major and deltoid (agonist) and latissimus dorsi (antagonist).
      - Action: shoulder flexion.

***Revision questions*:Test yourself on revision questions 24–28 located at the end of this chapter.**



Figure 2.55: *The softball pitch, action of the right humerus: start (a), flexion (b), abduction (c), extending & adducting (d), flexion and release (e)*

Gripping a Hockey Stick and Dribbling

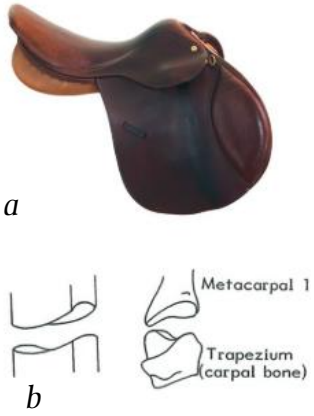
Content that follows:
Gripping a hockey stick and dribbling (Unit 2)

- *The saddle joint: The thumb*

Saddle joint

The joint between the phalanges and metacarpals resembles that of a saddle used when riding a horse (Figure 2.56). This joint is similar to the ball and socket joint; however, movements only occur in two planes, as the bones are both concave and convex. The movements permitted include flexion, extension, abduction, adduction and circumduction. The number of muscles and their insertion points across these joints limits some of these movements. The only true saddle joint in the body is at the thumb.

In hockey, the hands and upper limbs constantly manipulate the stick when tackling, passing or dribbling the ball. Many of these movements have been described above in relation to pronation and supination at the elbow, gliding of the carpal bones and the flexion and extension of the phalanges, but here we will consider the saddle joint of the thumb. This joint comprises the carpal and metacarpal bones. While manipulating the stick, the thumb may move from the front to the back of the stick through a combination of flexion and extension or adduction or abduction.



a

b

Figure 2.56: *A horse's saddle (a) is similar to the saddle joint in the thumb (b)*



Figure 2.57: *The right thumb of the hockey player is flexed and adducted (bottom hand) and his top hand (left) is abducted*

Practical activity: *Defining the actions of a saddle joint*

Work in pairs. Play a game of thumb wrestling. Describe the different actions that occur at this saddle joint.

Equipment:

- None.

Key point summary:

- When gripping a hockey stick, baseball bat, tennis racquet, golf club and so on:
  - Bones: thumb, carpals and metacarpal.
  - Joint type: saddle joint.
  - Action: flexion, extension, abduction, adduction and circumduction.
- When dribbling with a hockey stick:
  - Bones: thumb, carpals and metacarpals.
  - Joint type: saddle joint.
  - Muscles: wrist flexors and extensors.
  - Action: flexion and extension.

The Breaststroke Frog Kick

***The breaststroke frog kick (Unit 2)* Ball and socket joint: The hip**

- *Hinge joint: Knee and ankle*
- *Gliding: Tarsals and metatarsals*



Figure 2.58: *Breaststroke streamlined position, plantar flexion of the foot*

The five phases of breast-stroke kick

One of the more difficult skills to master in swimming is the breaststroke frog kick. This kick requires a number of different joints, bones and muscles, which contract and relax at different times. Rather than try and look at the whole movement at once, we should break it down into its smaller parts, similar to the way it is taught.

The movement cycle of the legs begins with the legs extended and the knees and feet together, ***plantar flexed*** at the ankle joint in the streamlined position (Figure 2.58). The contraction of the ***gastrocnemius*** allows for this to occur, as it has its origin in the femur and inserts into the tarsal bones. While the gastrocnemius contracts the reciprocal muscle, ***tibialis anterior*** relaxes.

Next the heels are brought to the buttocks as the hamstring muscles contract concentrically and the quadriceps relax. The hinge joint between the femur and tibia allows for the flexion at the knee but limits movement in most other directions (Figure 2.59a & b). To ensure the hips are not flexed

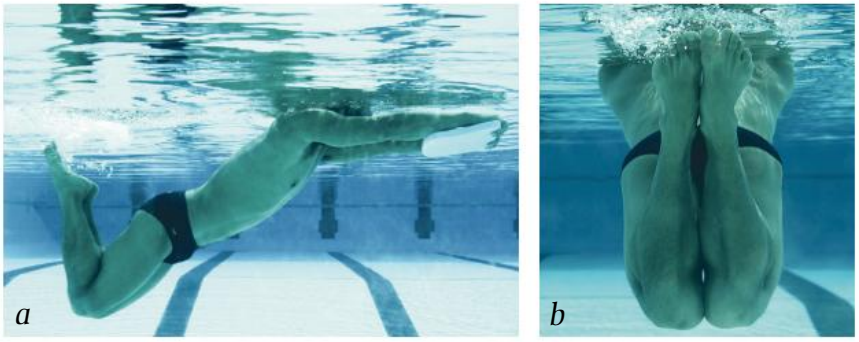


Figure 2.59: *Flexion at the knee*

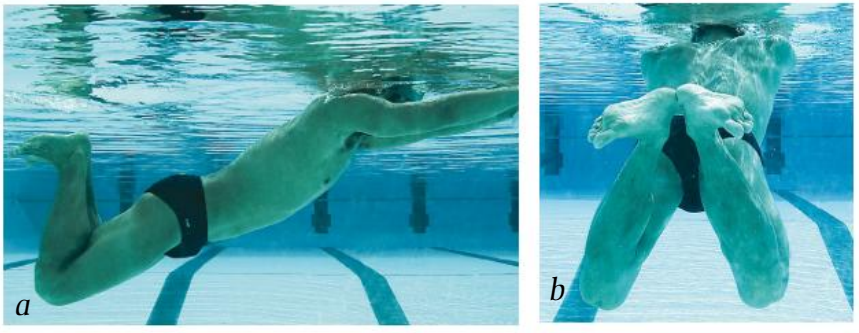


Figure 2.60:

at this point, the gluteal muscles contract, which keep the pelvis and femur in a neutral position.

The feet are then ***dorsi flexed*** and rotated outwards (***everted***) through the contraction of the tibialis anterior (Figure 2.60a & b). This is possible due to the hinge joint between the tarsal bones and the tibia and fibula, and the gliding joints between the tarsal bones. Strong ligaments connecting the bones maintain the integrity of the joint; however, the joint shape allows for manipulation in numerous directions. With the feet everted they are now ready to push against the water to develop propulsion force (Figure 2.60a & b).

While performing the main kicking component, the feet move through an arc from the buttock back to their starting point with legs extended (Figure 2.61a & b). A number of muscles become involved for this to occur. The femur is rotated and abducted at the hip joint. This ball and socket joint formed with the pelvis is one of the most mobile joints in the body, allowing movements in many directions. As the legs are extended through concentric contraction of the quadriceps (Figure 2.61a & b), the adductor muscles located on the inner thigh begin to contract to pull the knees and feet back to the midline of the body. These adductor muscles originate from the centre of the pelvis and attach along the length of the femur and, as the name suggests, when these muscles contract, the femur is adducted (Figure 2.61a & b).

The feet are almost back together (Figure 2.62a & b). The adductor muscles continue to contract and the femur is adducted.

Finally, the feet come back together as the gastrocnemius and ***soleus*** contract and the feet are again plantar flexed (Figure 2.63).

- In the first phase of kicking the legs in breaststroke (Figure 2.58):
  - Bones: tibia, fibula, and tarsals.
  - Joint type: hinge.
  - Muscles: gastrocnemius.
  - Action: plantar flexion.
- In the second phase of kicking the legs in breaststroke (Figure 2.59a & b):
  - Bones: femur and tibia.
  - Joint type: hinge.
  - Muscles: hamstrings.
  - Action: flexion at the knee.
- In the third phase of kicking the legs in breaststroke (Figure 2.60a & b):
  - Bones: tibia, fibula and tarsals.
  - Joint type: gliding joint and hinge joint.
  - Muscles: tibialis anterior.
  - Action: dorsi flexion and eversion.
- In the fourth phase of kicking the legs in breaststroke (Figure 2.61–2a & b):
  - Bones: pelvis and femur.
  - Joint type: ball and socket:
    - Muscles: adductors.
    - Action: adduction.
  - Bones: femur and tibia.
  - Joint type: hinge joint:
    - Muscles: quadriceps.
    - Action: extension.
- The fifth phase involves the swimmer returning to first phase position (Figure 2.63).

Revision questions:

Test yourself on revision questions 29–31 located at the end of this chapter.





Figure 2.61: *The legs are extending and adducting through the main phase of the kick*





Figure 2.62: *The legs are adducting to complete the kick*



Figure 2.63: *Completing the breaststroke kick*

Table 2.1: *The muscles of the body; their action and attachment sites*

Muscle	Action	Origin	Insertion
Biceps	Flex arm Flex forearm	Scapular (shoulder)	Ulna & radius
Triceps	Extend arm Extend forearm	Scapular Humerus	Ulna
Deltoid	Flex arm (anterior fibres) Abduct arm (lateral fibres) Extend arm (posterior fibres)	Clavicle Scapular	Humerus
Pectorals	Flex, adduct & rotate arm	Clavicle Sternum Ribs	Humerus
Trapezius	Elevates scapular (superior fibres) Depresses scapular (inferior fibres)	Skull Vertebra	Scapula Clavicle
Latissimus dorsi	Extend, adduct & rotate arm	Vertebra Pelvis	Humerus
Quadriceps	Flex thigh Extend leg	Pelvis Femur	Tibia
Abdominal	Rotate trunk Flex trunk	Pelvis	Ribs
Hamstrings	Extend thigh Flex leg	Pelvis Femur	Tibia
Adductor group	Adduct thigh	Pelvis	Femur
Gluteus maximus	Extend thigh	Pelvis	Femur
Tibialis anterior	Dorsi flex foot	Tibia	Metatarsal
Soleus	Plantar flex foot	Tibia Fibula	Tarsal
Gastrocnemius	Flex leg Plantar flex foot	Femur	Tarsal

Appendix C (I)

Revision questions

1. The lungs have alveoli. What is their role in the gas exchange?
2. When measuring breathing, the tidal volume represents
   a. breathing rate.
   b. how long you can hold your breath.
   c. the amount of air moved during one cycle of inspiration.
   d. the amount of carbon dioxide that is expelled with breathing.
3. Explain the changes in pressure and volume that occur in the body when the diaphragm contracts. What effect do these changes have on airflow through the nose and mouth?
4. For gas exchange to occur from a capillary to a muscle there needs to be a concentration gradient. What does this mean? Explain how this works for carbon dioxide.
5. Explain the four chambers of the heart and their role in supporting the two pathways of circulation.
6. Name the one vein that carries blood that is highly oxygenated.
7. The diastolic blood pressure is an important indicator of the health and efficiency of arterial function. Explain what this measure tells us.
8. What substance in the blood bonds to oxygen to transport it around the body?
9. What is represented by the term arterio-venous oxygen difference (a-vO2diff)?
10. The majority of carbon dioxide is transported from the working muscle to the lungs through the bloodstream in the form of a highly soluble compound called
    a. haemoglobin.
    b. arterial blood.
    c. plasma.
    d. bicarbonate.
11. When Superman flies through the air what position are his hands in?
12. How are the lower leg and forearm structures similar?
13. The metatarsals of the feet are represented in the hand by ... ?
14. If muscles are attached to bones by tendons, what are ligaments?
15. Bones are moved by muscles working in pairs. Explain this concept.
16. When your gastrocnemius contracts eccentrically, what are you likely to be doing?
17. You make an isometric contraction with your biceps, what is the likely to happen with the triceps?
18. In swinging a baseball bat you create an action at the hips and through the trunk. What is this action called?
19. Having already swung the tennis racket back in preparation for a forehand, what action is created at the shoulder during the swing forward required to make impact with the ball?
20. What is the role of the patella in movements at the knee?
21. When the hamstring muscles contract concentrically, what action occurs about the knee joint?

22a. When kicking down in the freestyle swim action, what action is occurring at the hip?

22b. Name the agonist and antagonist muscles.

23a. How many joints does the quadriceps pass over?

23b. What types of joints are they?

23c. Identify the movement limitations of the joints listed above.

24. When performing the action of circumduction a cone shape is formed. However, what shape is formed when performing rotation?
    a. An abduction shape

b. A cylinder with the axis of rotation through a long bone
c. A saddle shape
d. A hinge shape

25. You raise your arm up and back in preparation to do an overhead volleyball serve. What action is created at the shoulder?
26. Upon landing from a jump, you raise your arms out and up to assist with balance. What action is occurring at the shoulder?
27. Which type of joint in the body has the greatest range of motion? Which type has the least motion?
28. Your latissimus dorsi has a distal attachment. Where is it? What is its proximal attachment site? Which of these is also called the insertion and the origin?
29. When tapping your foot to music, what actions are occurring at the ankle?
30. Abduction of the legs will result in the legs moving further apart or closer together?
31. Contraction of the tibialis anterior muscle will result in what action of the foot?

Appendix C (II)

Revision answers

1. The alveoli are thin-walled, air-filled air sacs, surrounded by a dense network of capillaries. The alveoli are the site of gas exchange, a process in which oxygen and carbon dioxide are transferred between the lungs and the bloodstream across the thin walls of the alveoli and capillaries respectively.
2. c. The amount of air moved during one cycle of inspiration.
3. When the diaphragm contracts, it moves downwards towards the abdominal cavity. This results in an increase in the volume of the thoracic cavity allowing the lungs to expand, causing reduced pressure inside them. Consequently, air moves in through the mouth and/or nose from the external environment (higher pressure) and down the trachea into the lungs (lower pressure).
4. Gases move from areas of high concentration to areas of low concentration. In the reverse direction to the movement of oxygen, carbon dioxide moves from a relatively high concentration in the working muscle to a low concentration in the blood stream. A relatively lower concentration of oxygen in working muscles sees the oxygen move from the oxygen-rich blood in the capillary (area of high oxygen concentration) into the working muscle.
5. Blood is returned to the heart from systemic circulation via the vena cava into the right atrium and passes into the right ventricle. From here, the deoxygenated blood enters pulmonary circulation. This circuit involves blood being transported from the right ventricle to the lungs via the pulmonary arteries. The freshly oxygenated blood then returns to the left atrium of the heart via the pulmonary vein. Having moved into the left ventricle, the blood is then pumped into the systemic circulation. This sees blood travelling away from the heart via the aorta to the body tissues before being returned to the heart via the vena cava.
6. Pulmonary vein.
7. Diastolic pressure is the lowest pressure recorded in the aorta when the heart is relaxing in between beats and refilling with blood. The blood that filled the aorta after the previous beat has moved away and diastolic pressure is a measure of the pressure exerted by the remaining blood in the aorta during rest. If a relatively high pressure remains during this rest time it can damage the arterial walls, leading to cardiovascular disease.
8. Haemoglobin.
9. Arterio-venous oxygen difference (a-vO2diff) represents the amount of oxygen that is extracted by the body tissues. It is determined by comparing the amount of oxygen in the arterial blood to that contained in the venous blood.
10. d. Bicarbonate.
11. Pronation—his palms are facing down.
12. Both the lower leg and forearm are constructed with two bones (radius and ulna or tibia and fibula). All of these are long bones and they articulated with a hinge joint at the proximal end.
13. Metacarpals.
14. Ligaments attach from a bone to a bone and assist with stability.

15. Muscles work in pairs. When a muscle contracts (agonist) it pulls on the tendon attached to the bone and movement occurs, providing the muscle that performs the opposite movement (antagonist) relaxes (reciprocal inhibition).
16. From standing on your toes you are lowering yourself back to normal standing. An alternative is standing on your toes on a step with your heels hanging over the edge and lowering yourself down.
17. No movement. An isometric contraction has no movement in the agonist or the antagonist.
18. Rotation.
19. Flexion and internal rotation.
20. The quadriceps muscles originating from the femur attach to the tibia via the patella. Forces that are generated at the knee are increased due to the patella improving the gliding over the bones and increasing the mechanical advantage of the quadriceps muscles.
21. Flexion.

22a. The action at the hip is flexion.

22b. The agonist is the hip flexor and quadriceps. The antagonist is the gluteus maximus and the hamstrings.

23a/b. Quadriceps passes over two joints (hip = ball and socket joint; and knee = hinge joint).

23c. Ball and socket movements are: flexion, extension, abduction, adduction, circumduction and rotation. Hinge joint movements are: extension and flexion.

24. b. A cylinder with the axis of rotation through a long bone.
25. Extension.
26. Abduction.
27. Greatest range of motion is the ball and socket. Least range of motion is technically the immovable joints between the fused plates of the skull, but of the synovial joints discussed in this book, it is the gliding joint between the ribs and vertebrae.
28. The distal attachment of the latissimus dorsi is the humerus (also called the insertion). The proximal attachment, also called the origin, is the scapula, pelvis and spine.
29. Dorsi flexion is when you lift your foot up towards your tibia or fibula. It is plantar flexion about the ankle joint when you move your foot down towards the floor.
30. Further apart.
31. Dorsi flexion.

Appendix E

Glossary of key terms

Abduction: Moving a segment away from the midline of the body.

Adduction: Moving a segment towards the midline of the body.

Agonist or prime mover: Muscles that, when contracted, are responsible for the movement.

Antagonist: The muscles that create the opposite movement to that created by an agonist prime mover.

Circumduction: Movement that forms a cone with the apex (the top end) situated at the joint and the base at the extremity of the limb that is moving.

Concentric contraction: Muscle shortens whilst contracting.

Contractility: Muscle's ability to develop tension whilst shortening.

Dorsi flexion: Action at the ankle joint that involves pulling the toes back towards the shin.

Eccentric contraction: Muscle develops tension while lengthening.

Ectomorphy: Related to the linearity of the body.

Elasticity: Muscle's ability to return to its original shape after being stretched.

Endomorphy: Related to the body's adiposity or body fat.

Excitability: Muscle's ability to recieve and respond to stimuli.

Extensibility: Muscle's ability to stretch beyond its normal resting length.

Extension: Movement that results in an increase in joint angle.

Fast-twitch muscle fibres (Type II fibres): Muscle fibres with anaerobic characteristics (that is they are well-suited to producing ATP via anaerobic pathways).

Flexion: Movement that results in a decrease in joint angle.

Insertion: Where the muscle attaches to the bone that moves when the muscle contracts.

Isometric contraction: Muscle is generating a force but with no change in its length.

Ligaments: Fibrous connective tissue that attach from a bone to a bone.

Mesomorphy: The robustness of the body characterised by the muscularity of an individual.

Origin: Where the muscle attaches to the more stable or static bone.

Plantar flexion: Action at the ankle joint that involves pointing the toes.

Pronation: Palm of the hand facing downwards.

Reciprocal action: The opposite action to that created by the prime, moving muscles.

Reciprocal muscle: The muscles that relax to allow movement created by an agonist prime mover.

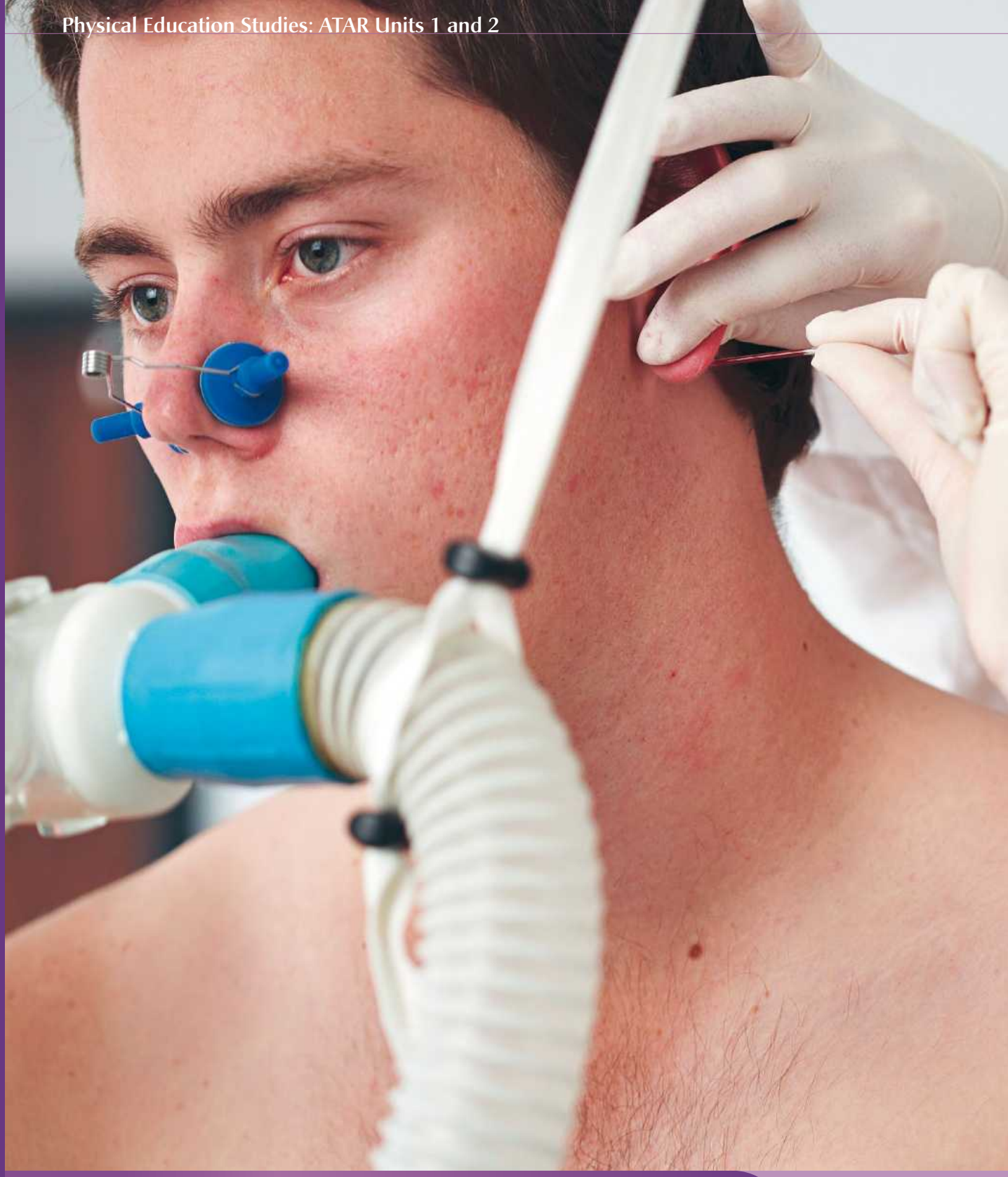
ROM: Range of motion.

Rotation: Twisting movement that forms a cylinder shape.

Slow-twitch muscle fibres (Type I fibres): Muscle fibres with aerobic characteristics (that is they rely predominantly on the aerobic energy system to produce ATP for contraction).

Somatotype: The shape of the body, as a result of the many components within the human anatomy.

Supination: Palm of the hand facing upwards.



Exercise Physiology

Dr Kym Guelfi (Senior Lecturer) and Dr Peter Whipp (Associate Professor)

BACKGROUND INFORMATION

Text outcomes:
Exercise physiology

- *Apply the characteristics of warm-up and cool-down to a selected activity.*

Moving the body comes naturally to us. Right at this moment you could jump out of your chair and do twenty star jumps without a problem. Although such movements appear to occur with ease from our external view of the body, the commencement of exercise is associated with the initiation of numerous complex processes internally. These include increased transport of oxygen through the bloodstream to the working muscles, where microscopic structures perform an incredible number of chemical reactions every millisecond to produce energy to power muscular contraction. The outcome of these processes is movement of the body to participate in the simple activities of daily living like shopping, or more intense activities such as a bout of exercise.

The complex processes involved in producing energy for movement are described in detail later in this chapter. However, one way to assist the body to efficiently initiate these acute responses to exercise is to participate in a ***warm-up***. This is a process whereby the body gradually commences exercise, as opposed to suddenly jumping out of your chair and doing twenty star jumps. For example, prior to a run, it may be useful to participate in a slow jog, gradually increasing in pace until a reasonable speed is achieved. The gradual commencement of exercise allows all of the processes needed to increase at a steady rate. This benefits performance, as well as reducing the potential risk of injury.

The benefit of a warm-up prior to performance is explained by the fact that, although we can rapidly commence exercise from the resting state, some of the body processes involved in producing energy require oxygen and the delivery of oxygen to the level of the working muscles takes time to increase. For example, when you begin to exercise, you don't immediately start puffing; instead you experience a gradual increase in breathing rate. By using a warm-up period, oxygen delivery to the muscles can be increased gradually, so that with the commencement of the ***real*** bout of exercise, less adjustment is necessary. Other benefits of a warm-up include increased blood flow and muscle temperature. A ***warm*** muscle will be more elastic and flexible and, therefore, less likely to be injured than a cold, stiff muscle.

The precise nature of the warm-up will depend upon the activity. Typically, a warm-up involves five to ten minutes of moderate, continuous exercise; similar to that involved in the main activity itself (for example, a swimmer will swim to warm-up). The order of activities should progress from full body movements to more specific exercises focused on the area of the body to be worked (for example, a softball pitcher may perform a light jog, followed by some light pitches, progressing to a full strength pitch). Often stretching exercises are also included in the warm-up to loosen the muscles in preparation for exercise. Stretching is much better performed on a warm muscle, due to increased elasticity.

After exercise, the performance of a ***cool-down*** will assist the body in returning to the resting state. By completing light, rhythmical, continuous exercises, the body is allowed time to gradually decrease all the processes that were operating at a high level during exercise. Like the warm-up, five to ten minutes is common for a cool-down and stretching exercises may also be performed at this time.

Text outcomes:
Exercise physiology

- *Understand how to prevent sports injuries using protective equipment, effective warm-up and cool-down and ensuring a safe environment.*
- *Understand the immediate care used for sporting injuries including the use of TOTAPS, RICER and HARM strategies.*
- *Understand the extended care and rehabilitation of the injured athlete.*

These outcomes of the background information are addressed in a link on the site where this book was purchased. Access this and complete the table provided. However, the following references are recommended:

http://www.sma.org.au/
http://www.smartplay.com.au/Pub/pStart.asp
http://www.elastoplastsport.com.au/
http://www.sportsinjuryclinic.net/

Exercise Physiology: ATAR Units 1 and 2

A similar approach is followed for each section, starting with textbook-related learning outcome statements, followed by a dot-point box identifying the 'Content that follows' and the theory and application for each content area. Suggested class tasks and practical activities are embedded within the sections of the text. A 'Key point summary' box is presented at the end of each section.

Two practical investigations are included as Appendix B1 (Unit 1 content: Energy system interplay and performance of strength and local muscular endurance activities) and Appendix B2 (Unit 2 content: The functional anatomy of hip flexion or extension and the fitness components of speed, agility and flexibility). A format for report writing can be located at the end of this chapter (Appendix A) to assist students with their preparation of the practical investigation. Marking matrices are also included in Appendices B1 and 2. Answers are provided for teachers only.

Revision questions (with answers) are included near the end of each chapter (Appendix C).

Following the revision questions is a 'Personalised project' which requires students to apply knowledge and understanding from Biomechanics, Functional Anatomy and Exercise Physiology (Appendix D). Even if this task is not undertaken for assessment purposes, it provides a valuable tool for revision.

A 'Glossary of key terms' appears on the final pages of this chapter (Appendix E).

Energy for Physical Activity

Content that follows:
Energy systems (Unit 1)

- *Adenosine triphosphate (ATP)*
- *Adenosine diphosphate (ADP)*
- *Inorganic phosphate*
- *ATP repletion*

Every activity that we participate in throughout the day, ranging from sitting at your desk reading this book, to sprinting for the school bus when you are running late, requires energy. But not just any type of energy. Human physical activity can only be fuelled by ***one*** specific energy source called ***adenosine triphosphate*** (ATP). ATP relates to the structure of this molecule, which consists of one adenosine component (a complex unit) attached to three phosphate groups (hence the prefix ***tri***).

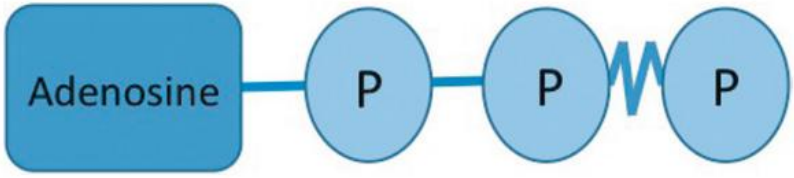


Figure 3.1: *A molecule of ATP consists of one adenosine component attached to three phosphate groups*

Although ATP is a complex molecule, the most important aspect of its structure relates to the bond linking the outermost phosphate group (furthest from the adenosine component) with the rest of the molecule. This particular bond is a high-energy bond and when this bond is broken in a chemical reaction, energy is released to allow the muscle to perform work (movement). During this chemical reaction, when the outermost phosphate group is broken away from the rest of the original ATP molecule, two separate molecules result. The larger molecule consists of the adenosine component plus the two remaining phosphate groups. This is called adenosine diphosphate (ADP), while the single phosphate group released is referred to as inorganic phosphate (Pi).

Although ATP is the only energy source that can be directly used within the body to fuel physical activity (no other fuel will do!), it is interesting to note that we only store a limited amount (80–100 grams in total, which is equivalent to about ¾ of a cup of flour). In fact, the amount of ATP that we have stored in the body at any one time is only enough to provide energy for about the first two seconds of a 100 m sprint. This may cause you to wonder where we get the rest of the energy from to allow us to finish a race. Although we only store a small amount of ATP, the body continually replenishes this supply to ensure it never runs out. This is achieved using chemical energy from the food we eat to rebond ADP and Pi to form ATP again. That is why we normally think of the body as getting its energy from the food we eat. The food we eat gives us energy to make ATP, which is a source of stored energy that can then be used by the body to perform physical activity. In this way, the body constantly replenishes ATP stores so that they never run out.

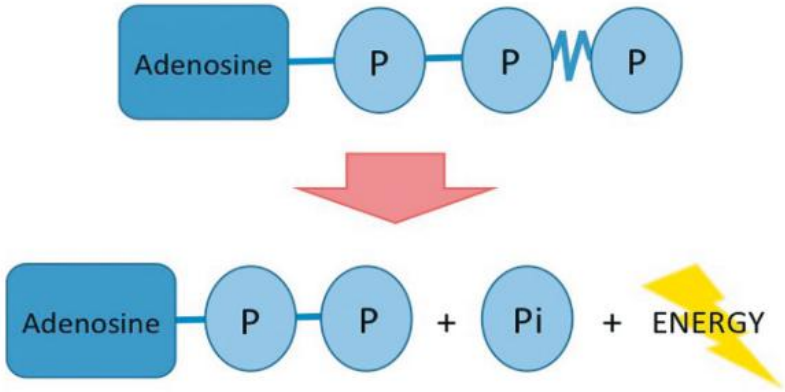


Figure 3.2: *Energy is released for muscular work when the bond joining the outermost phosphate group of ATP is broken to form ADP and Pi*

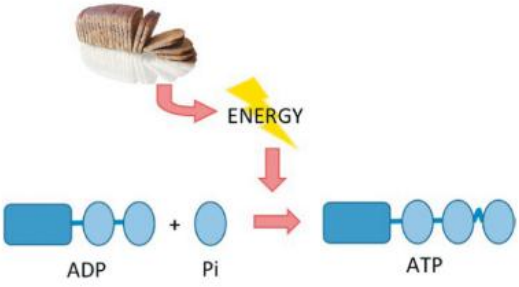


Figure 3.3: *ATP stores in the body are constantly replenished using energy from the breakdown of ingested food*

You may be wondering why we don't just store enough ATP in the body so that it never runs out, instead of constantly replenishing the limited stores available. The reason for this is that ATP is a relatively heavy molecule. It has been estimated that every day we use an amount of ATP equivalent to 75% of our body mass. This would be much too heavy to carry around. For example, a woman weighing 60 kg would need to

carry around an extra 45 kg of ATP just to get through one day! Instead of carrying around this extra mass in the form of ATP, the body takes energy from the food we eat to constantly rebond ADP and Pi to form ATP so that stores never run out.

Key point summary:

- ATP is the basic unit of energy that fuels all of the activities that we participate in throughout the day.
- Energy is released from ATP when the high-energy bond linking the outermost phosphate group to the rest of the molecule is broken to liberate ADP and Pi.
- A limited amount of ATP is stored in the body.
- ATP must be continuously replenished so that our stores never run out. This is achieved by rejoining ADP and Pi using chemical energy from the food we eat.

Energy Sources for Exercise

Text outcomes:
Energy for activity (Unit 1)

- *Explain the utilisation of carbohydrates, fats and proteins as energy sources for physical activity and their role in the onset of fatigue.*

Content that follows:
Energy for activity (Unit 1)

- *Energy released from food*
- *Carbohydrate: Glucose, glycogen, and glycaemic index*
- *Fat: Free fatty acids, saturated or unsaturated, and triglycerides*
- *Protein: Amino acids*
- *Energy requirements for physical activity*

The food and drink that we consume contains energy, which the body then converts to ATP (by rejoining ADP and Pi) since ATP is the only useable form of energy in the body. Food and drink contains three primary macronutrients. These are ***carbohydrate, fat (lipid)*** and ***protein***. Some foods contain mostly one macronutrient (for example, potatoes mainly contain carbohydrate), while other foods may consist of a combination of the macronutrients (for example, many types of cheese contain equal amounts of protein and fat).

Carbohydrate

Carbohydrate accounts for approximately 55% of energy intake in a typical Australian diet. The carbohydrate that we eat can be broadly divided into two main categories. Firstly, we have the ***simple sugars***, which are small molecules and are found in foods such as honey, table sugar and fruit juice. The ***complex carbohydrates*** are larger molecules found mainly in plant-derived foods, such as potatoes, bread, cereal, rice and pasta.

Regardless of the type of carbohydrate eaten, all types are digested to their simplest or smallest unit, which is a single small molecule called ***glucose***. Once in the form of glucose, the carbohydrates from our diet have two main fates. First, some of the glucose obtained from the digestion of carbohydrate is released into the bloodstream to circulate, providing fuel for the brain or remaining a readily available source of energy for ATP repletion when the body might need to spring into action. However, the speed at which glucose is released into the bloodstream after eating carbohydrates varies. This characteristic is termed the ***glycaemic index*** (GI). Carbohydrates that result in a rapid release of glucose into the bloodstream after eating are referred to as high GI foods. Examples include watermelon, jellybeans and Coco Pops™. In contrast, ingested carbohydrates that result in a slow, sustained release of glucose into the bloodstream are termed low GI foods and examples include apples, egg pasta and All-Bran™ cereal (Figure 3.5).

The second main fate of glucose obtained from the digestion of dietary carbohydrate is conversion into the storage form of carbohydrate, called ***glycogen.*** Glycogen results from the combination of a large number of glucose molecules to form one larger molecule. The resulting glycogen is stored in two main locations of the body: a small amount is stored directly in the muscle to be available in times of rapid demand, but the majority of glycogen is stored in the liver. The amount of glycogen that can be stored in the body is limited (a maximum of 600–800g after a high carbohydrate diet). Therefore, the amount of energy that can be provided from this macronutrient is restricted to some extent.



Figure 3.4: *Common sources of carbohydrate in the diet*

Fat

Fat (or lipids) represents approximately 30% of the dietary intake of most individuals. It is recommended that our fat intake does not exceed this amount, since eating too much fat is associated with being overweight, as well as causing diseases of the heart and blood vessels. In the same way that all of the carbohydrate that we eat is digested to the simple glucose molecule, the fats we consume are broken down in the digestive system to ***free fatty acids***. Broadly, there are two main types of fatty acids depending on their chemical structure:

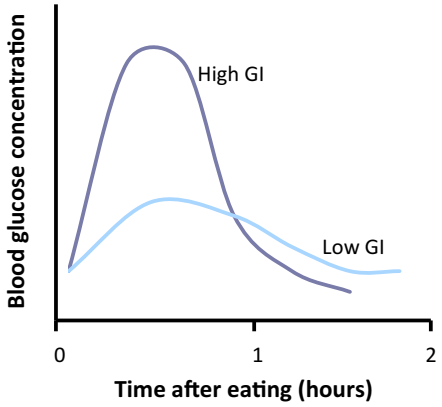


Figure 3.5: *The release of glucose into the bloodstream following the ingestion of carbohydrate with a high or low glycaemic index*

saturated and ***unsaturated fatty acids***. High levels of saturated fat in the diet can increase the risk of heart disease. Foods that are high in saturated fatty acids include most dairy products, such as full cream milk, cheese and fatty meats. In contrast, avocados, fish, nuts and olive oil are examples of foods high in unsaturated fatty acids, which are typically considered healthy fats.



Figure 3.6: *Common sources of fat in the diet*

Once dietary fats have been digested to free fatty acids, some will be released into the bloodstream to circulate, while others will be stored as ***triglycerides*** (a molecule resulting from the combination of three fatty acids) in adipose (fat) tissue. Fat stored as triglycerides in the body provides a plentiful source of energy. In fact, unlike carbohydrate, the amount of fat we can store in the body could provide us with unlimited energy.

Protein

Protein is consumed in the diet from a variety of sources, including eggs, meat and fish. The recommended amount of protein is approximately 15% of dietary intake, or 0.8 g per kilogram of body mass for most active men and women. Therefore, a 70 kg man would require about 56 g of protein each day. This is equivalent to the amount of protein contained in a large piece of steak. Like both carbohydrate and fat, protein consumed in the diet is digested into its simplest unit called the ***amino acid***. Once in this form, amino acids can contribute to ATP repletion; however, this contribution is minor compared to that of carbohydrate and fat. Instead, the main role of ingested protein is to maintain the body's structures. In particular, protein plays a vital role in the growth and repair of muscle tissue.



Figure 3.7: *Common sources of protein in the diet*

Energy requirements for physical activity

It is typically recommended that the general population should obtain approximately 55% of energy intake from carbohydrates, less than 30% from fat, and around 15% from protein. Whether the dietary needs of an athlete varies from that of an inactive individual will depend on their chosen sport. For instance, individuals involved in vigorous training will require a greater consumption of carbohydrate. In addition, the total amount of food (energy) consumed will vary between athletes. For example, AFL players typically consume almost double the total amount of energy eaten by a female gymnast (Jonnalagadda et al., 1998; Schokman et al., 1999).



Figure 3.8: *The dietary needs of an athlete will vary depending on their chosen sport*

Key point summary:

- The food (and drink) we consume provides energy for the repletion of ATP stores in the body.
- The food (and drink) we consume contains three macronutrients: carbohydrate, fat and protein.
- The amount of each macronutrient required in the diet varies, depending on the physical activity level of the individual.

Energy Systems

Text outcomes:
Energy systems (Unit 1)

- *Describe the response of energy systems to physical activity.*
- *Identify the relationship between energy systems and types of physical activity.*

Content that follows:
Energy systems (Unit 1)

- *ATP-CP system*
- *Lactic acid system*
- *Aerobic energy system*
- *Comparing the energy systems*
- *Relationship between energy systems: The energy system continuum*
- *Commencement of exercise*
- *Oxygen deficit*

Pathways of energy release from food

Although ATP is the only energy source that can be directly used within the body to fuel physical activity, we only store enough ATP to provide energy for about the first two seconds of a 100 m sprint, or an activity like the shot put. For this reason, the macronutrients (carbohydrate, fat and protein) contained in the food we eat

provide energy for the continual repletion of ATP stores so that we can participate in activities lasting longer than two seconds. However, the way in which each of these macronutrients contributes to replenishing ATP varies considerably. Indeed, there are three main pathways in the body by which ATP can be produced (that is to say, three processes by which energy can be transferred from the food we eat into ATP). These include the ***ATP-CP (or phosphagen) system, lactic acid system (anaerobic glycolysis)*** and the ***aerobic energy system*** (Figure 3.9). These three systems of energy production operate together to produce ATP, with one particular system being the predominant supplier of ATP at any one time, depending on the body's requirements.

You may be wondering why the body has three systems for the repletion of ATP. This is related to the fact that one of these pathways requires the presence of oxygen for the production of ATP (the aerobic energy system). The other two pathways do not require oxygen for the production of ATP (lactic acid system and the ATP-CP system). For this reason, the latter two systems are often referred to as the ***anaerobic pathways*** of ATP production. Although the transfer of energy from food in the presence of oxygen (via the aerobic system) produces the most ATP, there are often circumstances when there is not enough oxygen available to meet the energy demands of the activity being performed. For example, imagine you are walking down the street when suddenly a vicious dog runs out after you. You immediately sprint away from the dog as fast as you can. In the time between seeing the dog and starting the sprint, your body does not have enough time to get extra oxygen to your muscles. Instead, you need to produce ATP rapidly via anaerobic pathways to sprint away. In this way, the body is actually quite smart. It means that in emergency situations when adequate oxygen is not available (usually because there isn't enough time for oxygen delivery to the muscle to be increased), we can still produce enough ATP to power muscular activity.

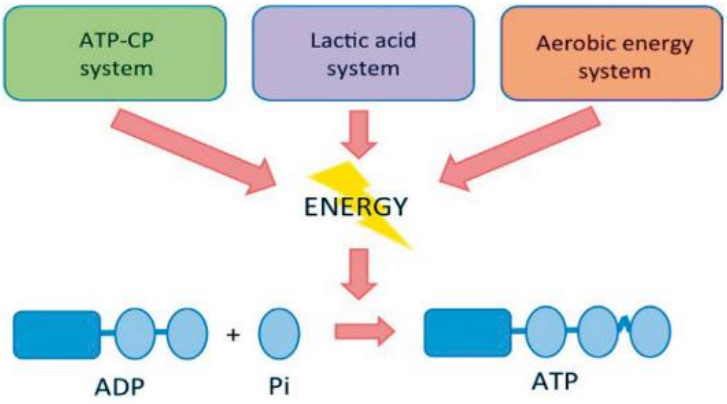


Figure 3.9: *The three pathways of ATP production*

Key point summary:

- There are three ways in which ATP can be replenished:
  - ATP-CP system.
  - Lactic acid system (anaerobic glycolysis).
  - Aerobic system (requires oxygen).

ATP-CP system

The ATP-CP system produces ATP without the involvement of oxygen (an anaerobic pathway). This system results in the repletion of ATP using energy released from the breakdown of a molecule called ***creatine phosphate*** (CP). CP is similar to ATP in that its structure also involves a ***high-energy*** bond to a phosphate group. However, the phosphate group in CP is attached to a creatine molecule, rather than to ADP. In the same way that energy is liberated from ATP to fuel muscular work by breaking the high

energy bond linking the outermost phosphate group, when the bond between creatine and the phosphate group is broken in CP, energy is released. The energy released from the breakdown of CP is then used to produce ATP by rebonding ADP and Pi (Figure 3.10).

Like ATP, CP is stored in the muscle so it is ready for use immediately. Also, the process by which CP is broken down to replenish ATP involves only one simple reaction. In contrast, the repletion of ATP via the other two energy systems described below (lactic acid system and the aerobic energy system) requires a number of chemical reactions. The greater number of reactions involved in the process, the longer it takes to produce ATP. Therefore, the ATP-CP system is ideal for the rapid production of ATP at the start of a race. Another similarity between CP and ATP is that we only store a limited amount of CP in the body. In fact, the amount of stored CP is enough to power approximately eight seconds of intense activity. This would equate to about the first 70–80 m of a 100 m sprint, and explains why sprinters begin to slow in the last few meters of this type of race. Overall, CP provides the most immediate replenishment of ATP since CP is stored directly in the muscle, only one reaction is required to release energy to replenish ATP and this reaction does not require oxygen. For this reason, the ATP-CP system is the predominant energy system for quick, intense activities such as the run-up in a long jump, a maximal sprint in football or the tennis serve.

Ironically, the only way in which CP can be remade after being split into individual creatine and phosphate molecules, is by using energy from the breakdown of ATP. What this means is that once CP stores have been depleted during exercise they cannot be replenished until recovery from the exercise, after the large demand for ATP has slowed

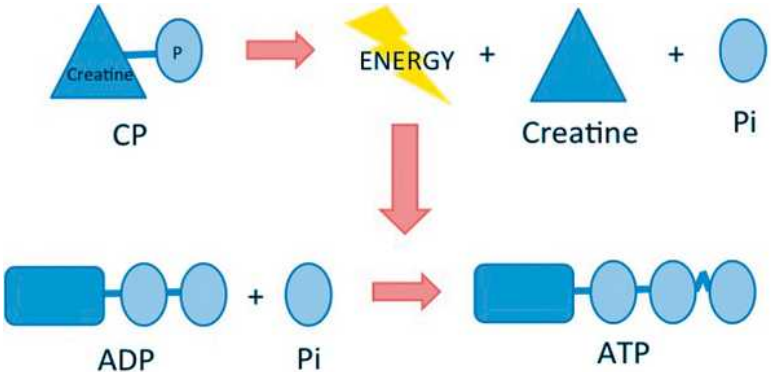


Figure 3.10: *The ATP-CP system replenishes ATP using energy released from the breakdown of CP*



Figure 3.11: *The ATP-CP system is the dominant source of energy production during short sprint activities like the 100 m hurdles*

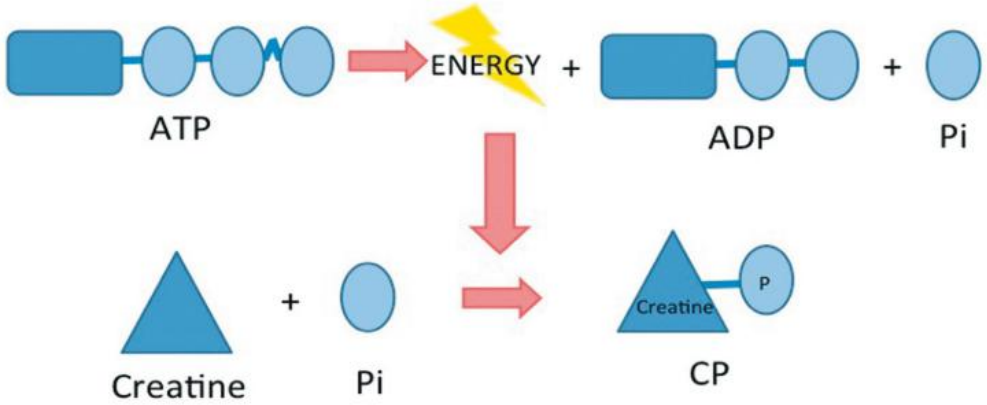


Figure 3.12: *CP stores are replenished using energy from ATP during recovery*

and adequate oxygen is being delivered to allow for the production of ATP via the aerobic system. At this time, a proportion of the ATP restored during recovery from exercise via the aerobic system will then be used to replenish stores of CP, to be ready for the next maximal sprint effort (Figure 3.12). It takes approximately three minutes for repletion of CP levels after a single, short, intense effort.

Key point summary:

- The ATP–CP system replenishes ATP using energy from the breakdown of creatine phosphate (CP) to creatine and Pi.
- The ATP–CP system does not use oxygen (an anaerobic pathway).
- The ATP–CP system allows for the most immediate replenishment of ATP.
- We only store enough CP to power about eight seconds of intense activity.
- CP stores are replenished during recovery from exercise when adequate oxygen becomes available.

Lactic acid system (anaerobic glycolysis)

The lactic acid system releases energy from the breakdown of carbohydrate (in the form of glucose or stored glycogen) to make ATP. Like the production of ATP via the ATP-CP system, oxygen is not required for ATP to be produced via the lactic acid system (it is an anaerobic process). Briefly, the lactic acid system involves the incomplete breakdown of carbohydrate through a series of chemical reactions to an end product called lactic acid. This series of chemical reactions is called ***anaerobic glycolysis*** (Figure 3.13).

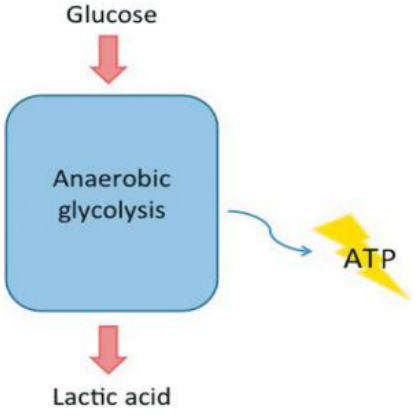
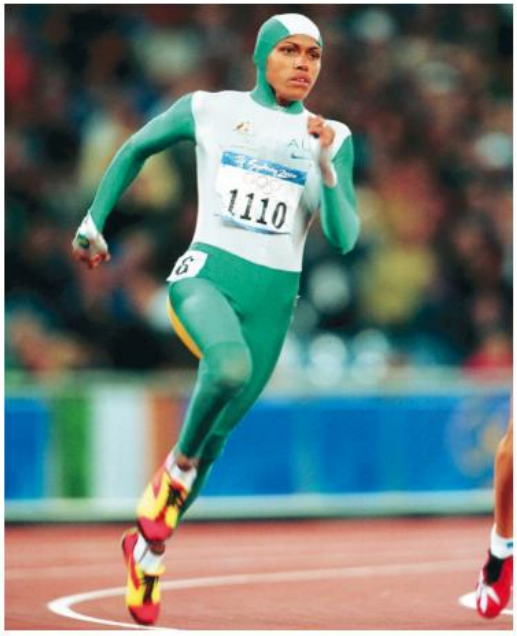


Figure 3.13: *The lactic acid system releases energy from the partial breakdown of carbohydrate via anaerobic glycolysis*

Although one advantage of the lactic acid system is that ATP can be produced in the absence of adequate oxygen, an important limitation to this pathway is that the end product is lactic acid, which is associated with muscular fatigue. This is the burning sensation you feel in your legs after an intense sprint, or in your arms when mixing together the ingredients for a cake. In fact, after about thirty seconds of maximal activity, lactic acid accumulation within the muscle reaches a level at which performance is significantly impaired. This is thought to be the result of increased acidity, which stops continued production of ATP via the lactic acid system, and reduces the ability of the muscle fibres to carry on contracting forcefully.

The lactic acid system is the dominant source of ATP production in high-intensity activities lasting thirty to sixty seconds, such as a 400 m sprint or a 100 m freestyle race (Figure 3.14). In these types of activities, there is not enough time for increased delivery of oxygen to the working muscle (this may take two to three minutes), but more ATP is required than what the ATP-CP system can provide (approximately eight seconds' worth of maximal activity). After exercise is stopped and adequate oxygen becomes available, the accumulated lactic acid can be removed from the muscle.



Practical activity: *The effect of lactic acid accumulation on performance*

Using a light dumbbell (1–3 kg), complete as many dumbbell curls as possible in sixty seconds. The effort should be maximal from the start (so no pacing). Record and compare the number of curls completed during the first thirty seconds and the final thirty seconds. Discuss any differences in performance between the two periods in relation to the energy systems.

Equipment:

- Range of hand weights (light dumbbells).
- Stopwatch or clock.

Although we commonly think of lactic acid when we think of an intense, sustained effort, such as the 400 m sprint, it is important to note that ATP production via the lactic acid system is always operating to some extent, even when at rest. This results in a constant low level of lactic acid production, which is too small to affect the muscle's ability to contract. These constant, low levels are the result of production via anaerobic glycolysis, but there is no build-up, since lactic acid is continuously being broken down at the

Figure 3.14: *The lactic acid system is the dominant source of energy production during intense activities of thirty to sixty seconds in duration like the 400 m sprint*

same time by the aerobic system. Likewise, during light to moderate intensity exercise there is a small contribution of the lactic acid system to ATP production; however, the majority of energy demands can be met by the aerobic system. Consequently, lactic acid removal or breakdown can keep pace with production, stopping accumulation and any negative effect on performance. However, when exercising at higher intensities, there comes a point where the aerobic system cannot meet the majority of the energy demands (it cannot supply ATP for muscular work ***and*** remove accumulating lactic acid). As a result, an increase in blood lactate above resting levels occurs. The exercise intensity at which this occurs is termed the ***lactate threshold*** and this affects exercise performance (Figure 3.15). Individuals that can work at a higher intensity before blood lactate begins to build-up will perform better in endurance events. For example, if an athlete competing in the 12 km City to Surf can run at a speed of 13 km/hr before they experience a build-up of lactic acid, but another athlete can run at 15 km/hr, the second athlete will most likely win the race since that individual can run faster before lactic acid starts to build up in the muscle where it will impair continued performance.

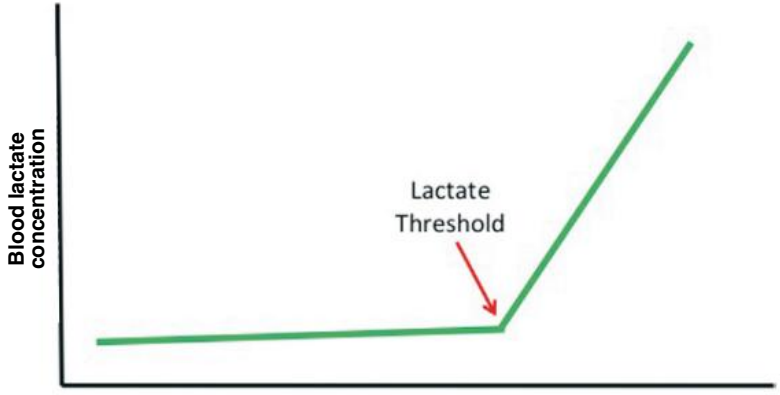


Figure 3.15: *The lactate threshold*

Key point summary:

- The lactic acid system (anaerobic glycolysis) involves the partial breakdown of carbohydrate to lactic acid, which releases energy to make ATP.
- The lactic acid system does not require oxygen (an anaerobic pathway).
- The lactic acid system is the dominant source of ATP production during high-intensity activities lasting thirty to sixty seconds.
- Lactic acid accumulates in the muscle when exercising at an intensity level higher than the lactate threshold, eventually resulting in fatigue.
- Lactic acid is removed during recovery from exercise as adequate oxygen becomes available.

Revision questions:

Test yourself on revision questions 1–4 located at the end of this chapter.

Aerobic energy system

Unlike the lactic acid or ATP-CP systems, the production of ATP via the aerobic system requires the presence of oxygen. During rest (for example, while reading this book), energy requirements are low and can be easily met by the aerobic energy system since adequate oxygen is available. However, with the increased energy demands when you commence exercise, it takes time for the body to increase all the processes necessary to allow for increased delivery of oxygen to the level of the working muscle (such as increased breathing rate, heart rate and so on). In fact, with the commencement of exercise, it typically takes two to three minutes for oxygen consumption to increase enough to provide adequate support for production of the majority of ATP during continuous exercise at a constant intensity, like jogging or cycling.

Both carbohydrate and fat can be broken down via the aerobic system to release energy for the production of ATP. This occurs within the ***mitochondria*** of muscle cells, which are designed specifically for this purpose. Although ATP can be produced aerobically from both carbohydrate and fat, the specific series of chemical reactions involved in breaking down these two macronutrients differ.

Aerobic metabolism of carbohydrate

Aerobic metabolism of carbohydrate begins with the process of glycolysis (partial breakdown of glucose or stored glycogen). This is a series of chemical reactions similar to that of anaerobic glycolysis (the lactic acid system) described earlier. The main difference is that, rather than partially breaking down carbohydrate to lactic acid, the end product when oxygen is available is a molecule called ***pyruvate*** (Figure 3.16).

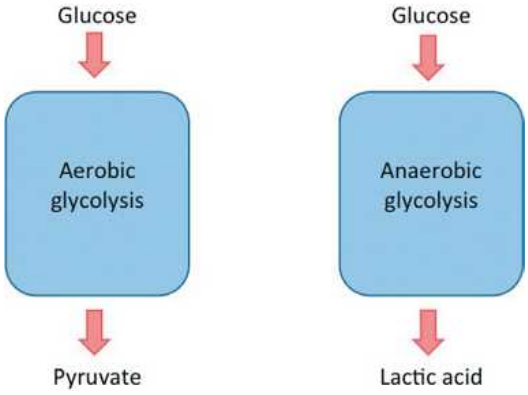


Figure 3.16: *Comparison of anaerobic glycolysis versus aerobic glycolysis*

Following the partial breakdown of carbohydrate to pyruvate, the process continues with another two long series of chemical reactions (the ***citric acid cycle*** and the ***electron transport chain***). The final result is the complete breakdown of carbohydrate to carbon dioxide (CO_2) and water, along with a considerable amount of energy (Figure 3.17). This energy is used to produce ATP from ADP and Pi.

Aerobic metabolism of fat

The aerobic metabolism of fat involves three

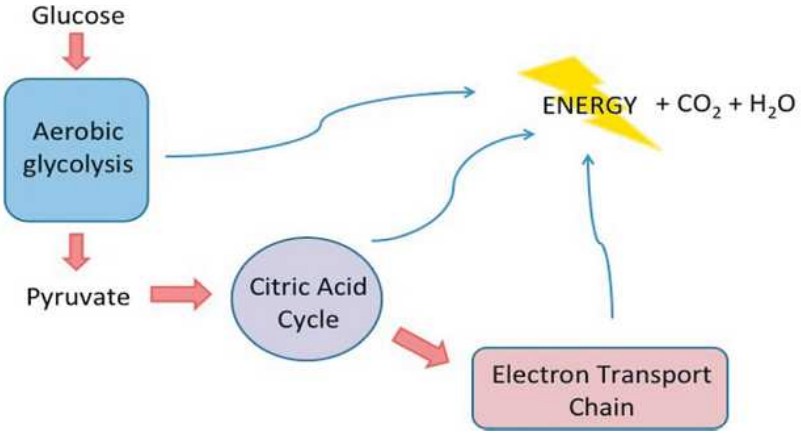


Figure 3.17: *Aerobic metabolism of carbohydrate*

major series of chemical reactions, similar to that involved in the aerobic breakdown of carbohydrate. However, the main difference between the aerobic metabolism of fat and carbohydrate is in the initial part of the process. While carbohydrate breakdown begins with the process of glycolysis, the aerobic metabolism of fat begins with the partial breakdown of free fatty acids (the basic unit of all fats) by a long series of chemical reactions called ***beta-oxidation***. Then, like carbohydrate, the breakdown continues with another two series of chemical reactions (the ***citric acid cycle*** and the ***electron transport chain***), with the final result being a complete breakdown to CO_2, water and a large amount of energy for ATP production (Figure 3.18). The aerobic breakdown of one free fatty acid results in the production of a larger number of molecules of ATP than a molecule of glucose; however, the process is slower due to the greater number of chemical reactions involved.

The aerobic system is capable of producing the largest amount of ATP, but only when adequate oxygen is available. Therefore, this is the dominant system for ATP production at rest and during exercise of a prolonged duration. The main reason for this is that the body stores a relatively large amount of the sources of fuel for aerobic metabolism (particularly fat). Unlike CP, which is rapidly depleted, and anaerobic glycolysis (the lactic acid system), which is limited by the production of lactic acid, the aerobic energy system is not typically limited (except by oxygen availability, of course). We store more fat than could be broken down in a single bout of exercise, while our carbohydrate stores allow us to exercise for approximately two hours at moderate intensity before depletion.

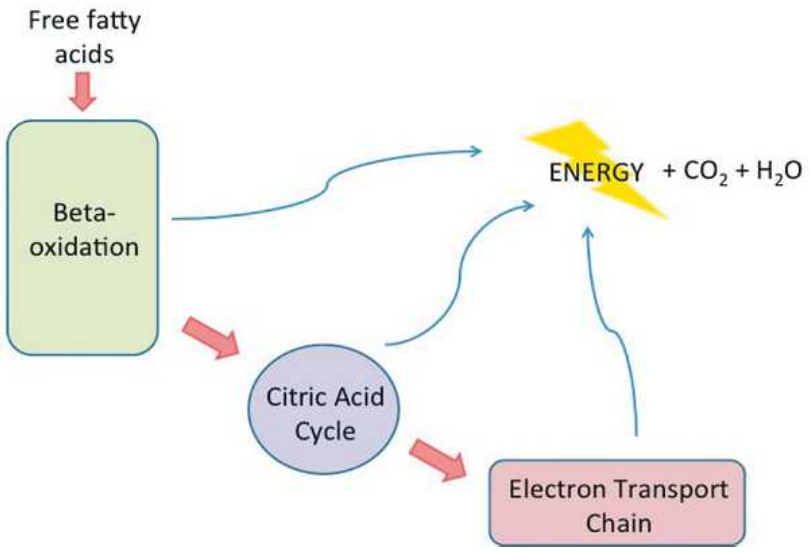


Figure 3.18: *Aerobic metabolism of fat*

The depletion of carbohydrate stores during prolonged exercise affects performance. Since the breakdown of carbohydrate via the aerobic energy system occurs at about twice the rate of aerobic fat metabolism, the aerobic metabolism of carbohydrate supplies ATP at a faster rate than fat. This means that when exercising at higher intensities (when more ATP is required), the majority of energy for ATP production will be provided for by aerobic metabolism of carbohydrate. As carbohydrate becomes depleted after a prolonged effort, like running a marathon, the contribution of fat to energy production must increase to compensate. However, energy cannot be produced at the same rate from fat and therefore, the athlete will not be able to run as fast. When this happens to an athlete in a race it is often termed ***hitting the wall***. Marathon runner Dick Beardsley described this feeling as 'like an elephant jumped out of a tree on top my shoulders and was making me carrying it the rest of the way'.

Protein can also be broken down via the



Figure 3.19: *Marathon runner hitting the wall*

aerobic energy system to produce ATP; however, protein typically only plays a minor role in providing energy for ATP synthesis. In fact, the contribution of protein breakdown to energy production at rest is negligible and generally not more than about 10% of overall energy supply during long-duration, endurance exercise.

Key point summary:

- The production of ATP via the aerobic energy system requires the presence of oxygen.
- Both carbohydrate and fat can be used as fuels in the aerobic energy system.
- The specific series of chemical reactions involved in the breakdown of fat and carbohydrate via the aerobic energy system differ.
- Aerobic metabolism of carbohydrate produces ATP at a faster rate than fat.
- The aerobic system is capable of producing the largest amount of ATP.
- The aerobic system is the dominant source of ATP production at rest and during moderate intensity or prolonged exercise.

Revision questions:

Test yourself on revision questions 5–8 located at the end of this chapter.

Comparing the energy systems

As discussed earlier, each energy system involves the breakdown of different fuels, which may or may not require oxygen and involves a varied number of chemical reactions to produce ATP. Together, these factors affect the total amount of ATP produced, along with the rate (speed) of ATP production by each system. For instance, the ATP-CP system provides the most rapid source of ATP since the least number of chemical reactions is involved and oxygen is not required. However, this system is limited in the amount of ATP that can be produced, since we only store a small amount of CP in the muscle. The lactic acid system also provides a rapid source of ATP production since oxygen is not required, but this system is not as fast as the ATP-CP system, due to the greater number of chemical reactions involved. Although this system can provide a larger amount of ATP than the ATP-CP system, this system is limited by the production of lactic acid. On the other hand, the aerobic energy system can supply an unlimited total amount of ATP, based on the large amount of fat stored by the body. However, the rate of production of ATP is relatively slow using this system, due to the long series of chemical reactions involved and the requirement for oxygen to be present. These characteristics are summarised in Table 3.1.

Table 3.1: *Characteristics of the three pathways of ATP production*

	ATP-CP system	Lactic acid system	Aerobic system
Fuel source	CP	Carbohydrate	Carbohydrate & Fat (& Protein)
O_2 required	No	No	Yes
Speed of energy supply	Most rapid	Rapid	Slow
Limitation / cause of fatigue	Limited stores of CP	Lactic acid production	Unlimited
Duration	~8 sec	~30–60 sec	~1.5–3 hrs
Type of activity	Sprint / power activities	Sprint endurance activities	Long duration endurance
Examples	Long jump, sprint for ball in soccer	400 m sprint, 100 m freestyle race	Marathon, Olympic distance triathlon

The characteristics of each energy system have implications for the types of activities they fuel. For example, at rest, when ATP demands are low and the oxygen transport system is capable of supplying adequate oxygen to the body cells, the predominant source of ATP is the aerobic system. The main fuel metabolised at this time is fat, since our stores of carbohydrate are smaller than fat and therefore need to be saved. On the other hand, with the commencement of exercise, it takes time for the oxygen transport system to adjust. This should be obvious when you think about how your body responds when you start to exercise (you don't immediately start puffing; instead you experience a gradual increase in breathing rate). This means that oxygen supply to the muscle will not be enough at the start of exercise to allow the aerobic system to supply all of the necessary ATP. Instead, an instant source of ATP is required and therefore a large amount of the ATP used at the start of a race will be provided for by the ATP-CP system.

Relationship between the energy systems: The energy systems continuum

No single energy system is in exclusive use at any time. Instead, the three systems work together, with one particular system being predominant, depending on the body's requirements (Figure 3.20). For example, the rapid rate of ATP production resulting from the ATP-CP system makes this the predominant energy system for short maximal sprint efforts or power events, such as the long jump or a sprint for the ball in soccer. However, with the depletion of CP stores after approximately eight seconds of intense activity, the lactic acid system takes over as the predominant source of ATP. The lactic acid system is therefore the predominant energy system in sprint endurance type activities, such as a 200 m

or 400 m sprint, a 100 m freestyle race, or any other event lasting thirty to sixty seconds. After this time, the aerobic system takes over since the accumulation of lactic acid from anaerobic glycolysis impairs performance and prevents further dominance of the lactic acid system. The aerobic system is not the predominant system before this time, since it takes time for the body to increase oxygen uptake in response to exercise. The aerobic energy system is particularly important in prolonged endurance events such as the marathon or an Olympic distance triathlon. A good illustration of how each of the energy systems work together can be demonstrated by examining a team sport such as hockey, netball or football. In these sports, players are required to perform multiple repeated sprints throughout a game, with limited recovery between efforts in which lower intensity activity (such as jogging or walking) or rest is performed. These high intensity sprint efforts are predominantly fuelled by the ATP-CP system since they are typically of two to three seconds in duration. During recovery between sprints, the aerobic system becomes predominant, attempting to replenish CP stores before the next sprint. If adequate recovery time is allowed in between sprint efforts (greater than three minutes), almost full repletion of CP will result, allowing for the next sprint effort to be maximal. However, as is often the case in repeated sprint sports, the recovery time between sprints may be limited to less than thirty seconds, which is not enough time for full repletion of CP levels. In this instance, the lactic acid system begins to make a greater contribution to each subsequent sprint to maintain high rates of ATP production (and therefore a high intensity of work). However, this ultimately results in the accumulation of lactic acid, which will begin to impair performance. Regardless of the amount of recovery time between sprints, during each recovery period, the aerobic energy system continues to attempt to replenish CP stores and also remove lactic acid to be ready for the next effort.

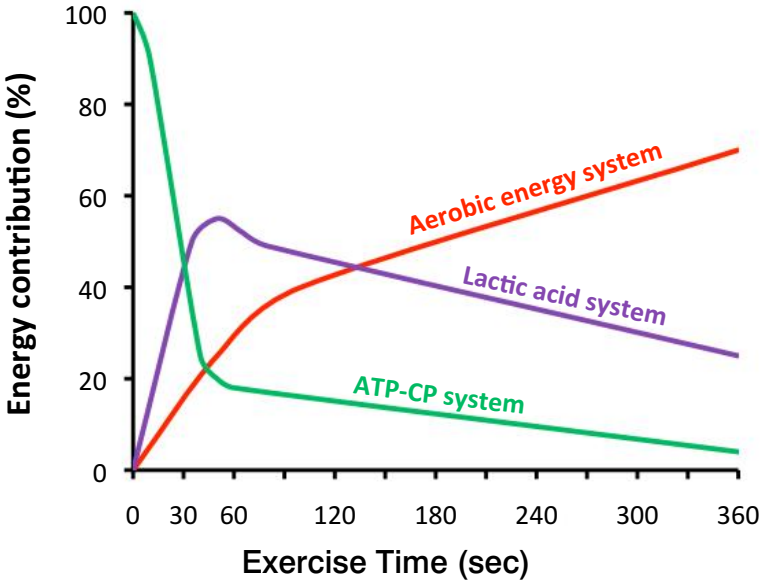


Figure 3.20: *Energy system contribution as a function of exercise duration*

Practical activity: *The effect of recovery duration on CP repletion*

Following an adequate warm-up, select some students to complete two maximal 80 m sprints each. Allow some students three minutes' recovery time between the sprints, while others will only have thirty seconds' recovery time. Compare the difference in performance (80 m sprint time) between the two sprints within each individual and discuss the predominant energy systems in operation throughout the sprints and recovery.

Equipment:

- 80 m running area.
- Stopwatch.

Practical investigation

Evaluate the energy system interplay and the performance of strength and local muscular endurance activities.

See Appendix B1 for a practical investigation, along with questions and report-writing format recommendations.

UWA research snapshot: *CP repletion following repeated sprint efforts (Dawson et al., 1997)*

Most team games involve repeated short sprints, often with limited recovery in between. Researchers from the School of Sport Science, Exercise and Health at The University of Western Australia sought to examine how long it took for CP stores to be replenished following repeated short sprint efforts. They got active sportsmen to perform five repeated short sprints of six seconds in duration (with about thirty seconds in between each effort). The sprints were completed on a cycle ergometer in the laboratory so that small muscle samples could be taken from the leg to measure how much CP was present before and after the sprints. It was found that having thirty seconds of recovery time between each sprint only allowed for replenishment of 70% of CP stores. Therefore, performance declined with each successive sprint. This study shows that thirty seconds of recovery time is not enough for full repletion of CP stores between a series of short sprints similar to that experienced during a team game situation.

Class task: *Specificity of energy systems*

Complete the table below by identifying the predominant energy system (that is ATP–CP, lactic acid or aerobic energy systems) involved in the activities listed.

ACTIVITY	Predominant energy system	Predominant source of fuel
Sitting reading this book	Aerobic energy system	Fat
50 m freestyle race		
Marathon		
400 m track race		
Slam dunking a basketball		
Between sprints in soccer (recovery between efforts)		

Revision questions:

Test yourself on revision question 9 located at the end of this chapter.

The oxygen deficit

As we already know, in the first few minutes of exercise before oxygen consumption has increased, the anaerobic energy systems (ATP-CP and lactic acid systems) play an important role in supplying the necessary ATP. Without these systems, it would take a few minutes to be able to get going from the starting line of a race after the gun goes off! However, it is important to note that the use of these systems at the onset of exercise is not without consequence. This consequence is called the ***oxygen deficit*** and must be repaid post-exercise. The oxygen deficit represents the difference between the actual amount of oxygen consumed during exercise and the amount of oxygen that would have been consumed if oxygen consumption had increased instantaneously with the onset of exercise to immediately reach the required steady state level (Figure 3.21). Repaying the oxygen deficit involves the use of oxygen (via the aerobic energy system) to replenish CP stores and to remove any accumulated lactic acid resulting from having to use these anaerobic energy systems until oxygen consumption could increase to the new, higher level.

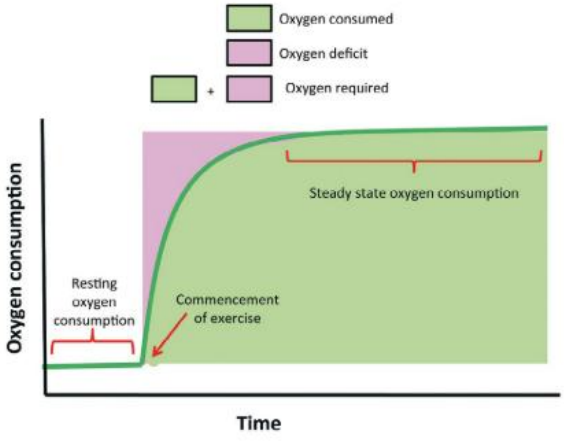


Figure 3.21: *The oxygen deficit*

Key point summary:

- The ATP-CP system provides the most rapid source of ATP, but is limited in the amount of ATP that can be produced.
- The lactic acid system (anaerobic glycolysis) also provides a rapid source of ATP production, but is not as fast as the ATP-CP system.
- The lactic acid system (anaerobic glycolysis) can provide a larger amount of ATP than the ATP-CP system, but is ultimately limited by the production of lactic acid.
- The aerobic system can supply an unlimited total amount of ATP, but the rate of production is relatively slow.
- At rest, aerobic metabolism of fat is the predominant energy source for ATP synthesis.
- The three energy systems all operate at once, with the intensity and duration of the activity determining the percentage contribution of each different system.
- When commencing exercise, it takes time for oxygen consumption to increase, resulting in an oxygen deficit that must be repaid post-exercise.

Immediate (acute) Responses to Exercise

Text outcomes:
Immediate response to physical activity (Unit 1)

- *Explain the body's immediate responses to physical activity.*

Content that follows:
The body's immediate responses to exercise (Unit 1)

- *Tidal volume*
- *Respiratory rate*
- *Minute ventilation*
- *Gas exchange in the lungs*
- *Heart rate*
- *Stroke volume*
- *Cardiac output*
- *Gas exchange at the tissues: Arteriovenous oxygen difference*
- *Blood pressure*
- *Blood redistribution*
- *Oxygen consumption: $\dot{V}O_2$ max and lactate threshold*

The commencement of exercise results in a sudden increase in the amount of ATP required by the working muscle. Although the ATP-CP system provides an immediate source of energy (Figure 3.22), the body automatically responds by increasing all the processes involved in transporting oxygen to the level of the muscle. That is why when we start to exercise we immediately feel our breathing rate quicken and our heart start to beat at a faster rate. In fact, some of the processes discussed below respond even before the commencement of exercise. For example, heart rate may increase while standing on the starting line of a race waiting for the gun to go off. This represents an anticipatory response to exercise and results from changes in the levels of hormones in the body (like adrenaline) that prepare us for exercise.



Figure 3.22: *The ATP-CP system provides an immediate source of energy*

Tidal volume

Although resting tidal volume is approximately 500 mL per breath, this may increase to more than 2 L during exercise. This increase in tidal volume is the result of the diaphragm being assisted by other muscles (the scalene and external intercostal muscles). Together, these muscles lift and expand the ribs, causing a greater expansion of the lungs and therefore, more air to move into the lungs as a result of a greater air pressure gradient. Likewise, with expiration, although a predominantly passive action at rest, during exercise the internal intercostal and abdominal muscles assist in increasing pressure in the thoracic cavity (chest). These muscles lower and move the ribs closer together, at the same time increasing abdominal pressure, thereby forcing the diaphragm back up towards the chest. These actions decrease the size of the chest and increase pressure, causing air to be expelled.

Respiratory rate

The resting respiratory rate of twelve breaths per minute is significantly increased in response to exercise. In fact, the frequency of respiration can increase to 35 to 45 breaths per minute during maximal exercise. In elite athletes, up to 60 breaths per minute may be observed.

Minute ventilation

Together, the increase in tidal volume and the respiratory rate in response to exercise results in a substantial increase in minute ventilation from 6 L at rest to an impressive 100 L of air per minute. In fact, some elite athletes have recorded minute ventilation values of up to 240 L/min (Figure 3.23).

Gas exchange in the lungs

The process of inspiration brings air from the external environment to the level of the alveoli where gas exchange will occur (the transfer of oxygen from the alveoli into the surrounding capillaries via passive diffusion). The rate at which oxygen diffuses through the thin alveolar wall into the bloodstream increases during exercise (increased ***diffusion capacity***). This is mainly the result of increased blood flow through the pulmonary capillaries at the site of gas exchange.

Heart rate

With respect to heart rate, there is a rapid increase with the onset of exercise (Figure 3.24). This increase is proportional to exercise intensity (the higher the intensity, the higher the heart rate). However, if exercising at a steady intensity or workload, heart rate will level off during submaximal exercise after about three minutes. With further increases in exercise intensity, heart rate will continue to increase before stabilising again at the new level.

There is a limit to how fast your heart can beat. In theory, the maximum heart rate can be estimated using the formula 220 – age. Therefore, as a person ages, their estimated

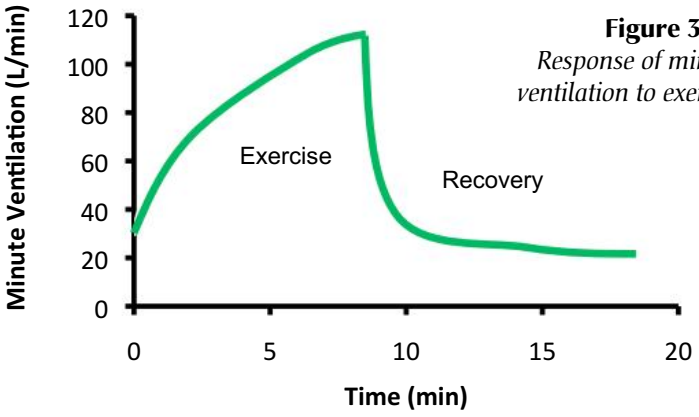


Figure 3.23: *Response of minute ventilation to exercise*

Practical activity: *Respiratory response to exercise*

Check your own resting breathing rate by counting how many breaths you take in one minute. Complete three to five minutes of moderate exercise (such as stair climbing, skipping rope, jogging, stationary cycling) and then reassess your breathing rate. Assuming that your tidal volume is 500 mL at rest, and 1.3 L during exercise, calculate and compare your minute ventilation at rest and in response to exercise.

Equipment:

- Equipment or area for activity.
- Stopwatch or clock.

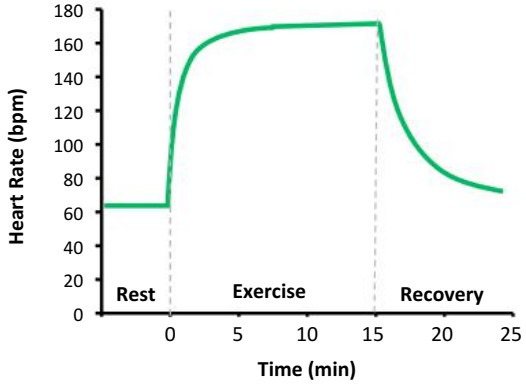


Figure 3.24: *Response of heart rate to exercise*

maximum heart rate declines. For example, the estimated maximum heart rate for a sixteen-year-old would be 204 bpm, while that of a fifty-five-year-old would be 165 bpm. However, this formula simply provides an estimate. For most people the true maximal heart rate falls within ± 12 bpm of this formula. The only way to determine an individual's true maximal heart rate is to conduct a maximal exercise test. This involves exercising an individual at a progressively increasing workload until volitional exhaustion (when the person can no longer continue) and recording the highest heart rate achieved during the test.

Practical activity: *Heart rate response to exercise*

Calculate your own age-predicted maximum heart rate based on the formula 220 – age. Complete three to five minutes of moderate exercise (such as stair climbing, skipping rope, jogging, stationary cycling) and then measure your heart rate by checking your pulse at the radial artery. To do this, palpate with your index and middle finger in line with the base of the thumb. Count how many beats you feel in fifteen seconds and multiply by four to determine the beats per minute. From this, calculate what percentage of your maximum heart rate you were working at. You can also estimate your cardiac output, assuming that your stroke volume was 100 mL during exercise.

Equipment:

- Equipment or area for activity.
- Stopwatch or clock.

Stroke volume

At the same time as an increase in heart rate during exercise, there is an increase in stroke volume from about 70 mL per beat at rest to 110 mL during exercise. This value is higher in athletes (more like 180 mL per beat); although in some elite athletes the stroke volume may be as high as 200 mL per beat.

Cardiac output

Together, the changes in heart rate and stroke volume result in a significant increase in cardiac output. The increase in cardiac output (the amount of blood pumped into systemic circulation by the left ventricle of the heart) is proportional to exercise intensity (the higher the intensity, the higher the cardiac output). Cardiac output increases from a resting value of 5 L/min to approximately 20 L/min in an inactive male, or up to 35 L/min in a top-class endurance athlete.

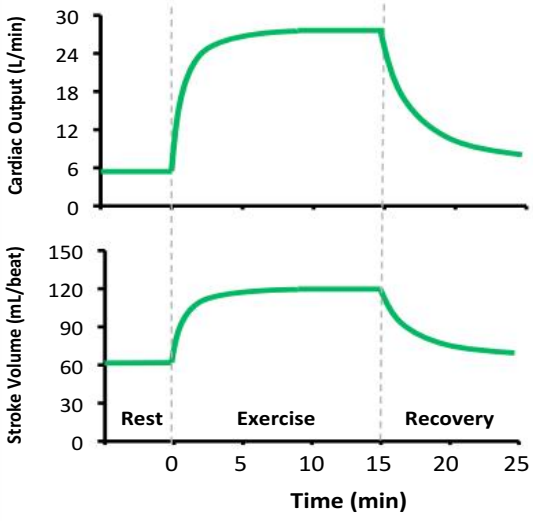


Figure 3.25: *Response of stroke volume and cardiac output to exercise*

Gas exchange at the tissues

With the greater demand for oxygen at the level of the working muscles associated with the commencement of exercise, the ***arteriovenous oxygen difference*** (a-vO_2diff) increases, reflecting the greater extraction of oxygen from the arterial blood into the tissues where it is needed. The oxygen content of arterial blood remains similar whether at rest, or during maximal exercise (approx 20 mL per 100 mL); however, the increased extraction at the level of the tissues results in a lower oxygen content left in mixed venous blood (Figure 3.26). For instance, the oxygen content of venous blood while at rest is approximately 15 mL per 100 mL, but this may be reduced to as low as 3 mL per 100 mL during maximal exercise, indicating an a-vO_2diff of 17 mL per dL (20 mL/100 mL – 3 mL/100 mL = 17 mL/100 mL).

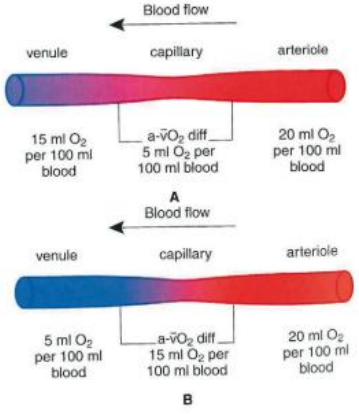


Figure 3.26: *Arteriovenous oxygen difference (a-vO_2diff) at rest (A) and during exercise (B)*

Revision questions:

Test yourself on revision questions 10–14 located at the end of this chapter.

Blood pressure

The response of systolic and diastolic blood pressure to exercise is different. Systolic blood pressure increases with increasing exercise intensity. This means a systolic blood pressure reading of 160 mmHg would not be unusual during exercise, and for some people, systolic blood pressure may climb as high as 200 mmHg. However, diastolic pressure tends to stay relatively stable and should not vary by much more than 10 mmHg (Figure 3.27). Of concern, the increase in systolic blood pressure is substantially greater during resistance exercise (such as lifting weights). This is why it is important not to hold your breath during this type of activity as this may exaggerate the increase in blood pressure further.

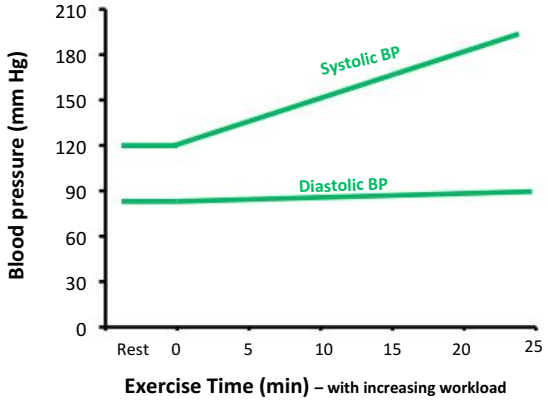


Figure 3.27: *Response of blood pressure to exercise*

Practical activity: *Blood pressure response to exercise*

Using a blood pressure monitor (sphygmomanometer or automatic cuff), measure and record your resting blood pressure. Complete ten minutes of moderate exercise (such as stair climbing, skipping rope, jogging, stationary cycling) and then reassess your blood pressure immediately (or if possible, while still exercising if on a stationary bike). Compare and discuss your results.

Equipment:

- Blood pressure gauge (sphygmomanometer).
- Equipment or area for activity.
- Stopwatch or clock.

Blood redistribution

With the commencement of exercise, there is a rapid redistribution of blood flow towards the working muscles. While resting, the muscles account for approximately 20% of blood flow; however, this may increase to up to 85% during intense exercise. In comparison, the kidneys go from receiving 20% of blood flow at rest to about 1% during exercise. This rapid redistribution of blood flow is achieved by constricting the blood vessels (***vasoconstriction***) supplying the less active tissues, at the same time as widely opening the blood vessels supplying the working muscles (***vasodilation***).

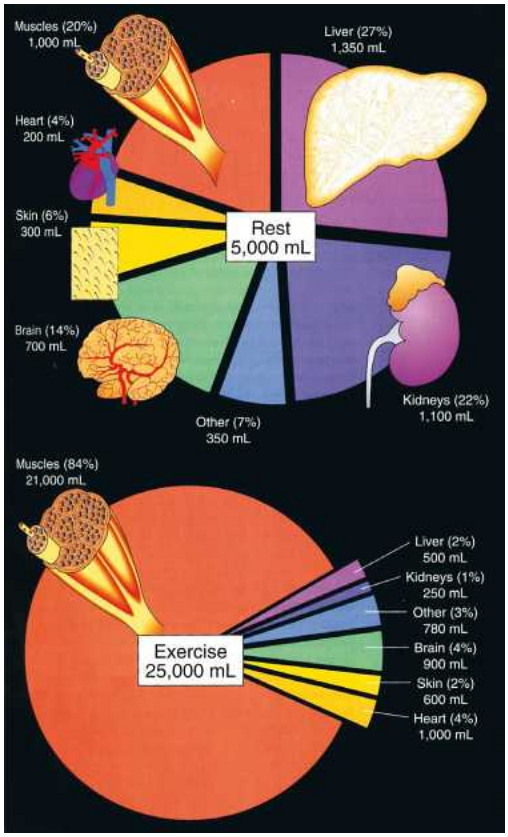


Figure 3.28: *Redistribution of blood flow during exercise*

Oxygen consumption during exercise

The culmination of all of the above-mentioned respiratory and cardiovascular responses to exercise is an increase in the amount of oxygen delivered to and consumed by the working muscles (exercise $\dot{V}O_2$). This increase in $\dot{V}O_2$ is proportional to the intensity of exercise. If exercise is held at a constant submaximal workload, then, like the heart rate, $\dot{V}O_2$ will level off after approximately three minutes representing the achievement of *steady state oxygen consumption* (meaning that oxygen consumption has increased enough to meet the demands of the working muscles) (Figure 3.29 and 3.30).

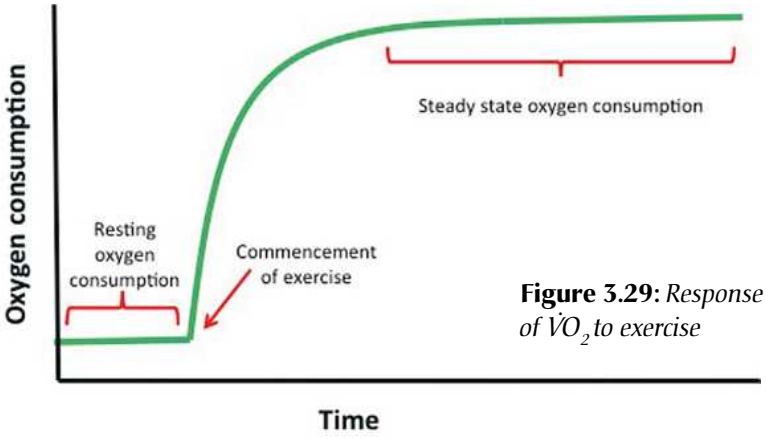


Figure 3.29: *Response of $\dot{V}O_2$ to exercise*

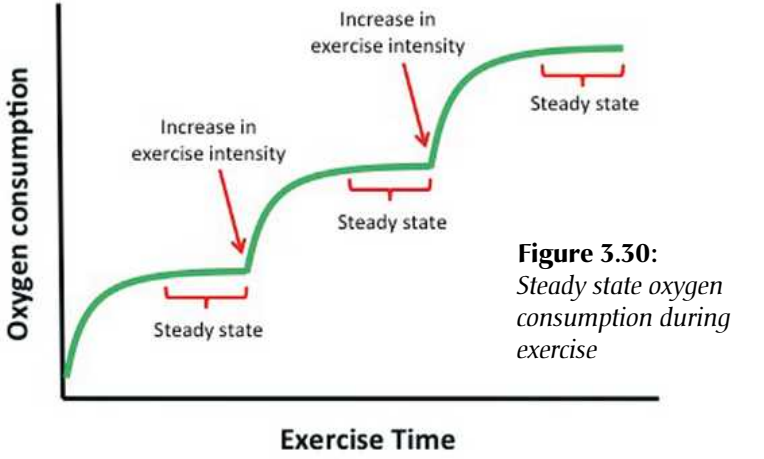


Figure 3.30: *Steady state oxygen consumption during exercise*

However, there is a limit to how much oxygen our body can consume. If the linear relationship between oxygen consumption and exercise intensity continued, there would be no limit to our exercise performance. As we well know, we can't keep running faster and faster over an extended time! This limit to the amount of oxygen we can consume is called our ***maximal oxygen uptake*** ($\dot{V}O_2$max). When exercising at an intensity that exceeds our $\dot{V}O_2$max, oxygen consumption will level off or plateau, despite any further increases in intensity (Figure 3.31).

The average $\dot{V}O_2$max for an untrained individual is 30–40 mL/kg/min, with men typically scoring higher than women. This is due to the lower levels of muscle in women (therefore less muscle mass to consume oxygen), together with lower levels of haemoglobin (which carries oxygen). The following $\dot{V}O_2$max values have been reported for various athletes:

- Brett Delidio (AFL player) 60 mL/kg/min.
- AFL boundary umpire 71 mL/kg/min.
- Elite female cyclist 71 mL/kg/min.
- Elite male triathlete 85 mL/kg/min.
- Elite female triathlete 76 mL/kg/min.

The highest $\dot{V}O_2$max recorded to date was 96 mL/kg/min by a Norwegian cross-country skier. But, if you think that's good, consider the pronghorn antelope (Figure 3.32), which has been recorded as having a $\dot{V}O_2$max of 301 mL/kg/min. These animals are extraordinary endurance athletes, running 11 km in about ten minutes (average speed of 65 km/hr), and have a top running speed of 100 km/hr (Lindstedt et al., 1991). The human equivalent for a man running 11 km at world record pace is about twenty nine minutes (average speed of 22 km/hr).

Determining an athlete's $\dot{V}O_2$max involves measuring oxygen consumption during exercise. Exercise is normally commenced at a low intensity and gets progressively harder until voluntary exhaustion is reached, such that the person cannot continue exercising at the required intensity any longer. Oxygen consumption is measured by breathing through

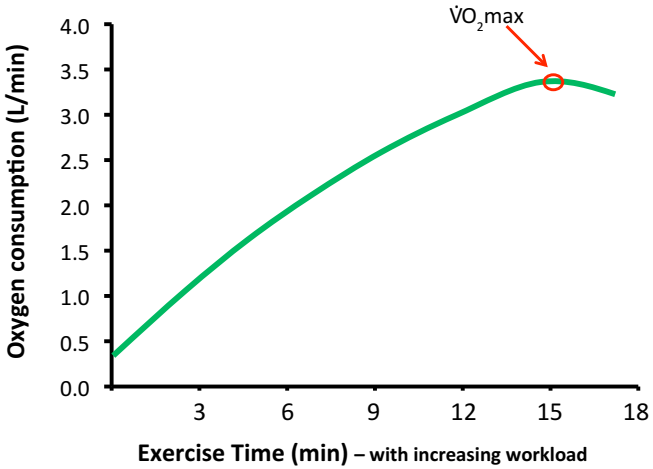


Figure 3.31: *Illustration of maximal rate of oxygen consumption*



Figure 3.32: *The pronghorn antelope*

a mouthpiece or facemask to enable the collection of expired air for analysis, usually by a computerised gas analysis system (Figure 3.33). By calculating the difference between the oxygen content of expired air, compared to that which was inspired from the external environment (which is constant at 20.93%), we can determine how much oxygen has been consumed by the body.

Since not everybody has access to the type of specialised equipment necessary for the determination of $\dot{V}O_2$max, a number of tests have been developed that allow for the estimation of $\dot{V}O_2$max. These can be submaximal (meaning they involve a below maximal effort) or maximal tests. An example of a submaximal test is the 1-mile walk test in which you walk one mile (or 1.6 km) as fast as you possibly can without breaking into a run. Based on the time taken to walk one mile, along with the heart rate immediately post-exercise, prediction equations exist to estimate your $\dot{V}O_2$max. In contrast, the shuttle run or beep test requires a maximal effort. From the level achieved in the beep test, you can also estimate your $\dot{V}O_2$max.



Figure 3.33: *Testing maximal oxygen consumption in the laboratory*

Practical activity: *Estimation of $\dot{V}O_2$max using a submaximal test*

Complete the 1-mile walk test. This test is submaximal, meaning below maximum. In this test you are required to walk a distance of 1-mile (1.6 km) as fast as possible (without running). The total time taken to complete the distance, along with the heart rate immediately post-exercise should be recorded to then estimate your $\dot{V}O_2$max using the formula:

$\dot{V}O_2$max (mL/kg/min) = 132.853 – (0.0769 x weight) – (0.3877 x age) + (6.315 x gender) – (3.2649 x time) – (0.1565 x HR)

(*where weight is in pounds, age is in years, gender is male = 1, female = 2, time is minutes to complete the walk and heart rate is in beats per minute* (Kilne et al., 1987)).

Equipment:

- Marked running area (oval or track).
- Measuring tape.
- Stopwatch.

Practical activity: *Estimation of $\dot{V}O_2$ max from a maximal test*

Complete the multi-stage shuttle run. From the level obtained, estimate your $\dot{V}O_2$max from the norms provided below.

Equipment:

- Multi-stage shuttle run test audio tape and audio player.
- Measuring tape.
- 20 m running area.

Predicted *$\dot{V}O_2$ max* values (mL/kg/min) for the progressive shuttle run test (*from Ramsbottom et al., 1988*)

Level	Shuttle	$\dot{V}O_2$max	Level	Shuttle	$\dot{V}O_2$max
6	2	33.6	7	2	37.1
6	4	34.3	7	4	37.8
6	6	35.0	7	6	38.5
6	8	35.7	7	8	39.2
6	10	36.4	7	10	39.9
8	2	40.5	9	2	43.9
8	4	41.1	9	4	44.5
8	6	41.8	9	6	45.2
8	8	42.4	9	8	45.8
8	11	43.3	9	11	46.8
10	2	47.4	11	2	50.8
10	4	48.0	11	4	51.4
10	6	48.7	11	6	51.9
10	8	49.3	11	8	52.5
10	11	50.2	11	10	53.1
			11	12	53.7
12	2	54.3	13	2	57.6
12	4	54.8	13	4	58.2
12	6	55.4	13	6	58.7
12	8	56.0	13	8	59.3
12	10	56.5	13	10	59.8
12	12	57.1	13	13	60.6

Another way to think of your $\dot{V}O_2$max is that it is your maximum capacity for production of ATP via the aerobic energy system. Therefore, the higher your $\dot{V}O_2$max, the more ATP that can be produced via the aerobic energy system, meaning you will most likely perform well in endurance activities like a marathon or the Tour de France. However, another important indicator of likely success in endurance events is the exercise intensity at which an individual experiences an increase in blood lactate above resting levels (called their ***lactate threshold***). This is the workload at which the aerobic energy system cannot meet the majority of energy demands, as well as remove any accumulating lactic acid from the production of ATP via the lactic acid system. As a result, an increase in blood lactate above resting levels occurs. This affects the endurance athlete, since we know that high levels of lactic acid in the muscle can impair performance. Individuals who can work at a higher intensity before lactic acid begins to accumulate will perform better in endurance events. For example, imagine two athletes with the same running speed at $\dot{V}O_2$max. If one athlete experiences an accumulation of lactic acid when they exercise at 70% $\dot{V}O_2$max, while the other can work to 80% $\dot{V}O_2$max, the athlete with the higher lactate threshold will likely win in a race, since they can run faster before lactic acid starts to build up in the muscle. For this reason, we often measure blood lactic acid levels during a laboratory test of maximal oxygen consumption by taking a small sample of blood from the fingertip or earlobe (Figure 3.34).



Figure 3.34: *Capillary blood sampling of lactic acid during exercise*

Recovery from an acute bout of exercise

As for recovery from exercise, we know that at the beginning of an activity, it takes time for the aerobic system to increase all of the processes to allow for steady state oxygen consumption to be reached. During this time, we bridge the gap in ATP production via the anaerobic energy systems (ATP-CP and lactic acid systems), resulting in an ***oxygen deficit*** that must be repaid during recovery exercise. This is partly the reason why, following exercise, it takes time for oxygen consumption to return to baseline levels. In fact, oxygen consumption may remain elevated from baseline for many hours following exercise. This sustained elevation in oxygen consumption following exercise is called ***excess post-exercise oxygen consumption*** (EPOC) (Figure 3.35).

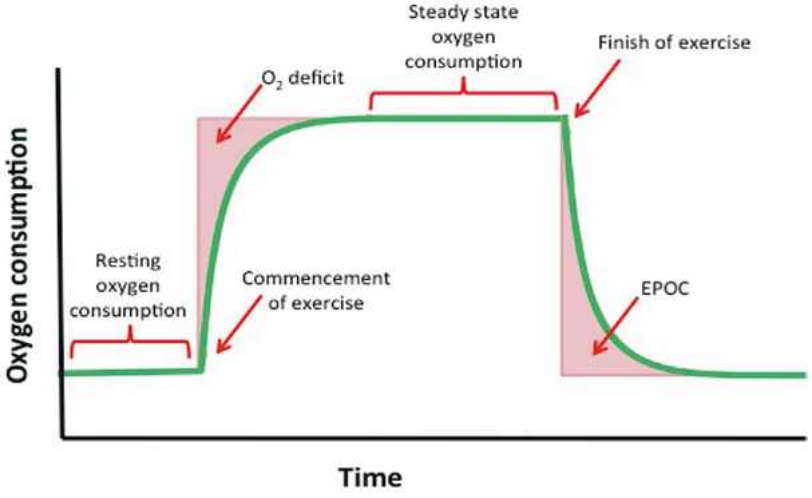


Figure 3.35: *Excess post-exercise oxygen consumption*

Long-term (chronic) Adaptations to Training

Text outcomes:
Adaptations to training (Unit 1)

- *Explain the body's long-term adaptations to training.*

When exercise is performed on a regular basis over a prolonged period of time, the body adapts to improve the transport of oxygen to the working muscles. These adaptations can occur within the cardiovascular system (***central adaptations***) or directly within the muscle itself (***peripheral adaptations***). In the long term, such adaptations enhance our performance by allowing us to complete more work, exercise at a higher absolute intensity, or by simply making the same levels of exercise feel less difficult.

Content that follows:
The body's long-term cardiorespiratory adaptations to training (Unit 1)

- *Ventilation*
- *Gas exchange at the lungs*
- *Heart rate*
- *Stroke volume*
- *Cardiac output*
- *Blood volume and haemoglobin*
- *Blood pressure*
- *Gas exchange at the tissues and capillarisation*
- *Oxygen consumption and $\dot{V}O_2$max*

Key point summary:

- The body responds to the commencement of exercise by increasing all the processes involved in transporting oxygen to the working muscle.
- These include:
  - Increased minute ventilation as a result of an increase in both the tidal volume and the number of breaths per minute.
  - Increased cardiac output due to an increase in both heart rate and stroke volume.
  - Increased oxygen exchange at the tissues (a-vO_2diff).
- Systolic blood pressure increases in direct proportion to exercise intensity, while diastolic blood pressure remains relatively stable.
- Blood is rapidly redistributed to the working muscles with the onset of exercise.
- Oxygen consumption ($\dot{V}O_2$) increases in direct proportion to exercise intensity, until a maximum is reached.
- The lactate threshold is the exercise intensity at which lactic acid begins to accumulate in the blood.
- Oxygen consumption may remain elevated for hours after exercise.

Revision questions:

Test yourself on revision questions 15–20 located at the end of this chapter.

Respiratory Adaptations to Training

Ventilation

Regular exercise training typically has little effect on lung structure and volumes. However, endurance training may improve the efficiency of respiration. Since the muscles involved in respiration are skeletal muscles, they may be trained to a certain extent. If the strength and endurance of these muscles is improved, breathing becomes more efficient. Consequently, trained individuals have lower rates of ventilation compared to inactive people when exercising at a submaximal intensity.

In contrast, during maximal exercise, trained individuals can achieve a higher maximal rate of minute ventilation. While the sedentary individual may experience a minute ventilation of 100 L/min during intense exercise, an elite rower may have a minute ventilation of up to 240 L/min. The higher maximal ventilation observed in trained athletes appears to be the result of both increased breathing frequency and maximal tidal volume.

Gas exchange at the lungs

Oxygen diffusion capacity (the rate of transfer of oxygen from the alveoli into the bloodstream) is increased in response to regular exercise training. This is likely related, in part, to an increase in the number of capillaries surrounding each alveolus, providing a greater surface area over which gas exchange can occur.

Cardiovascular Adaptations to Training

Heart rate

Regular exercise training affects heart rate both when at rest and during exercise (Figure 3.36). When resting, trained individuals experience a lower heart rate compared to their less active counterparts. Elite endurance athletes may have a resting heart rate as low as 40 bpm. With the commencement of exercise, regular training results in a less rapid increase in heart rate and, therefore, a lower heart rate during submaximal exercise. That

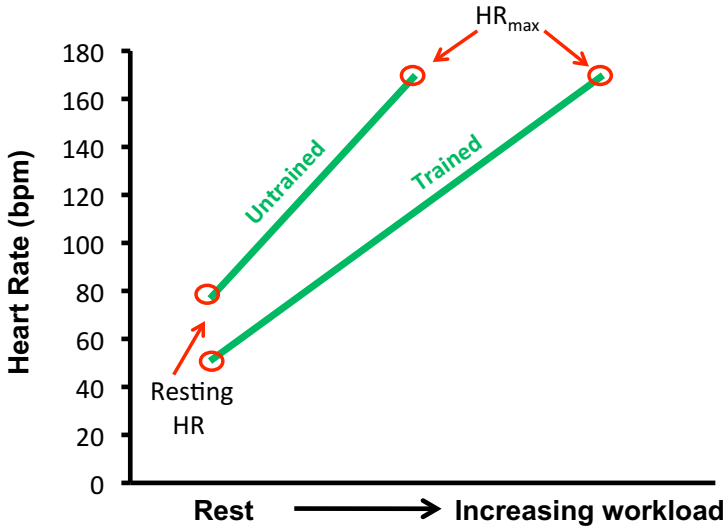


Figure 3.36: *Effect of training on the response of heart rate to exercise*

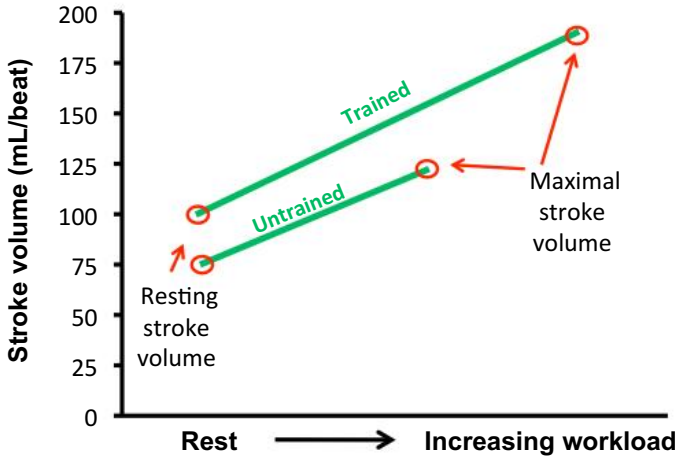


Figure 3.37: *The effect of exercise training on stroke volume*

is why we think of ourselves as 'unfit' if we find our heart beating really fast in response to only a small amount of exercise. On the other hand, exercise training cannot alter the maximal heart rate. Therefore the formula to estimate maximal heart rate (220–age) can be used in both trained and untrained individuals. Sometimes, maximal heart rate may even decrease slightly in response to undertaking a training program, the reasons for which are not well understood.

Stroke volume

Regular exercise training results in an increase in stroke volume both at rest and during exercise (Figure 3.37). One factor contributing to the higher stroke volume following training is an increase in the size of the heart. This increase in heart size in response to training makes sense when you think of the heart as a muscle, since muscles typically increase in size (hypertrophy) with training. The increase in the size of the heart is the result of an increase in both the thickness of the heart muscle wall and the size of the cavities inside (the ventricles). By having a thicker ventricle wall, each contraction (heart beat) can be stronger, thereby pumping more blood. In addition, the larger cavity size inside the heart means it can hold more blood. The more blood that fills the ventricle, the more that can be pumped into circulation with each heartbeat. Together, these factors cause the increase in stroke volume observed following exercise training while resting and during both submaximal and maximal exercise. While the maximal stroke volume may be 110 mL per beat for an untrained individual, an elite endurance athlete may have a maximal stroke volume of up to 200 mL per beat.

UWA research snapshot: *'Athlete's heart' in elite rowers (Naylor et al., 2005)*

To learn more about how the heart responds to exercise training, researchers from the School of Sport Science, Exercise and Health at The University of Western Australia examined the hearts of elite rowers. They used specialised equipment to see the thickness of the heart wall, the size of the cavities inside the heart and looked at how well the heart was pumping. They found that the elite rowers had thicker heart walls and larger ventricular cavities when compared to untrained individuals. They also found that six months of intense rowing training increased the size of the left ventricle in these athletes.

Cardiac output

Although resting stroke volume increases in response to training, the resting cardiac output (amount of blood ejected by the heart each

minute) is the same in both trained and untrained individuals. This is because the resting heart rate is lower in trained individuals (remembering that cardiac output is the product of stroke volume multiplied by heart rate). To demonstrate this point, consider an inactive individual who may have a resting heart rate of 72 bpm and a resting stroke volume of 70 mL. This would result in a cardiac output of 5.04 L/min (72 bpm x 70 mL per beat). Compare this to an elite endurance athlete with a resting heart rate of 42 bpm and a resting stroke volume of 120 mL. The trained individual would have the same resting cardiac output as the sedentary person (42 bpm x 120 mL per beat = 5.04 L/min).

On the other hand, maximal cardiac output is increased with training, as a result of the combination of the same maximal heart rate, but a greater maximal stroke volume. For example, maximal cardiac output in an inactive thirty-year-old woman may be 22.8 L/min (stroke volume x heart rate = 120 mL x 190 bpm). After training, the same woman may have a maximal cardiac output of 36.1 L/min (190 mL x 190 bpm).

Blood volume and haemoglobin

The total volume of blood and the amount of haemoglobin both increase in response to regular exercise training. While blood volume may be around 5 L in a sedentary individual, this increases to 6–7 L after a prolonged training program (20–25% increase). Unfortunately, the increase in the amount of haemoglobin is not to the same extent as the increase in blood volume. Therefore, the concentration of haemoglobin in the blood may in fact decrease slightly (Figure 3.38).

Blood pressure

The effect of regular exercise training on resting blood pressure depends upon an individual's pre-training blood pressure. If resting blood pressure is relatively high (greater than 130/80 mmHg), then exercise training will generally lower blood pressure to within the ideal range (systolic pressure 100–120; diastolic pressure 60–80 mmHg). However, in those individuals with a healthy blood pressure to begin with, regular exercise training will have little effect (other than assisting to maintain it within the healthy range).

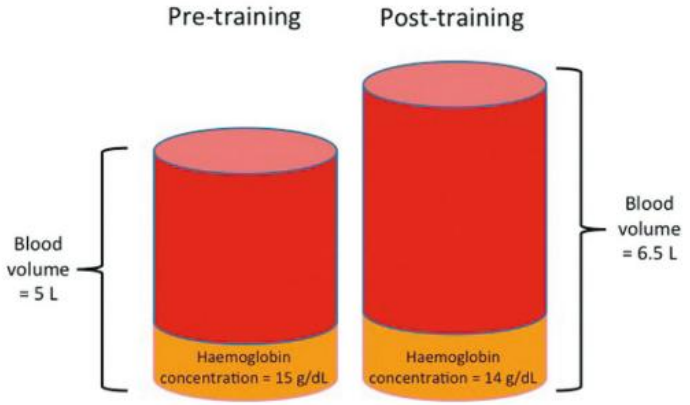


Figure 3.38: *Illustration of the relative decrease in haemoglobin following training*

Gas exchange at the tissues: capillarisation

Exercise training improves the ability of the muscles to extract oxygen from the circulating blood. This increase in oxygen exchange at the tissues is mainly the result of an increase in the ***number of capillaries*** surrounding the skeletal muscle fibres. Inactive individuals typically have one to two capillaries per muscles fibre, while elite endurance athletes may have two or three times this number

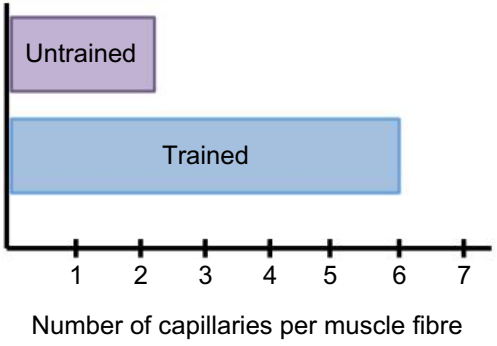


Figure 3.39: *The effect of exercise training on capillarisation*

(Figure 3.39). By having increased capillaries, there is a greater capacity for the delivery of blood (and hence oxygen) to the working muscle.

Oxygen consumption

The culmination of these long-term adaptations to exercise training is improved delivery of oxygen to the working muscle. During steady exercise at a submaximal intensity, $\dot{V}O_2$ remains similar (or may decrease slightly) following training, as a result of increased efficiency of movement (hence lower energy requirements).However, there is evidence to suggest that trained people reach steady-state $\dot{V}O_2$ more quickly and, therefore, have a smaller oxygen deficit. This smaller oxygen deficit may enhance recovery following an acute bout of exercise.

The most significant effect of long-term training on $\dot{V}O_2$ relates to the maximal limit to oxygen consumption. $\dot{V}O_2$ max is increased by 5–25% in response to training. The amount of increase depends on both the type of training undertaken and the initial level of fitness with the greatest improvements occurring in those individuals who were most unfit to start with. The increase in $\dot{V}O_2$ max is the result of increased transport of oxygen to the working muscles (cardiac output) and increased exchange of oxygen at the site of the working muscles (a-vO_2diff).

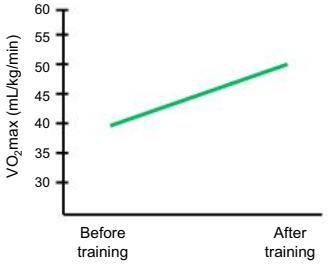


Figure 3.40: *The effect of exercise training on $\dot{V}O_2$ max*

	Pre-training (sedentary)	Post-training	Elite athlete
Ventilation at rest	6 L/min	6 L/min	6 L/min
Ventilation during maximal exercise	100 L/min	140 L/min	190 L/min
Resting heart rate	77 bpm	59 bpm	40 bpm
Heart rate during submaximal exercise	154 bpm	121 bpm	100 bpm
Heart rate at $\dot{V}O_2$max	190 bpm	189 bpm	187 bpm
Stroke volume at rest	68 mL	85 mL	110 mL
Stroke volume during maximal exercise	110 mL	130 mL	190 mL
Blood volume	5 L	5.5 L	6.5 L
Cardiac output at rest	5 L/min	5 L/min	5 L/min
Cardiac output during maximal exercise	22 L/min	26 L/min	35 L/min
$\dot{V}O_2$ at rest	300 mL/min	300 mL/min	300 mL/min
$\dot{V}O_2$ during maximal exercise	46 mL/kg/min	54 mL/kg/min	78 mL/kg/min

Table 3.2: *Cardiorespiratory responses to exercise in both a sedentary individual before and after four months of endurance training and in an elite endurance athlete*

Muscular Adaptations to Training

Content that follows:
Long-term muscular adaptations to training (Unit 1)

- *Muscle hypertrophy: Type I and II fibres*
- *Metabolic adaptations: Fuel storage, mitochondria, enzymes, and removal of lactic acid*
- *Flexibility*

Muscle hypertrophy

Regular exercise training typically leads to hypertrophy (an increase in the size) of muscle fibres. However, the extent of this increase and the specific fibres affected depends on the type of training undertaken, with aerobic training resulting in hypertrophy of different types of fibres when compared with resistance training.

There are two main types of muscle fibres found in the human body. ***Type I fibres***, or slow-twitch fibres have aerobic characteristics since they rely predominantly on the aerobic energy system to produce ATP for contraction. For this reason, they have a slow speed of contraction and do not produce a great amount of force, but they are quite resistant to fatigue. Consequently, these fibres are preferentially recruited during activities that do not require a large amount of force production, such as walking, activities of daily living, or prolonged endurance events like the marathon. Sometimes these fibres are referred to as ***red fibres***. This is partly due to the extensive blood supply they receive (a high level of capillarisation due to high oxygen requirements).

In contrast, ***type II fibres***, or fast-twitch (***white***) fibres, are better suited to producing ATP via anaerobic pathways. The anaerobic ability of type II fibres allows for a rapid speed of contraction and a large amount of force production, but they fatigue relatively quickly. Therefore, they are recruited during activities in which a large amount of force is required in a relatively short period of time (for example, a rapid change of direction in a game of basketball).

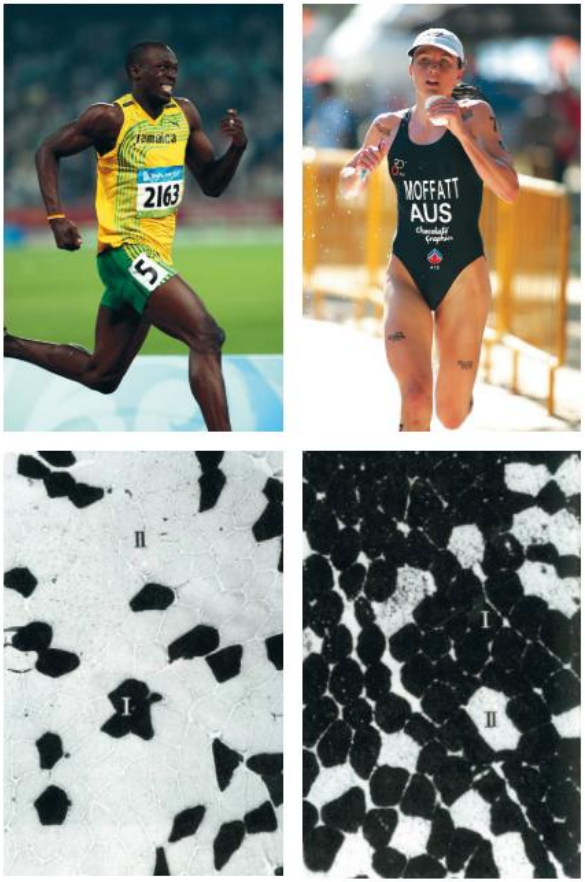


Figure 3.41: *Type I and II muscle fibres. Type I fibres stain dark and type II fibres remain unstained*

Based on the characteristics of type I and II fibre types, it is not surprising that aerobic training often results in selective hypertrophy of type I fibres, causing them to occupy a greater area of the muscle than type II fibres. In contrast, resistance training typically results in hypertrophy of type II fibres. Despite this increase in size, it seems that we cannot change the actual proportion of type I or II fibres. This is limited by our genetic make-up. Instead, we may be able to enhance the capacity of each type of fibre. For instance, aerobic exercise training increases the aerobic ability of both type I and type II muscle fibres.

Given the limited ability to change our fibre type proportions, those individuals with a higher proportion of type II fibres will likely do well in anaerobic type activities involving strength or speed, but not so well in endurance activities. To determine an athlete's proportion of type I and II muscle fibres, they must undergo a muscle biopsy. This involves a sample of muscle being taken from the outer thigh using a large needle. The sampled muscle is then analysed to determine the proportion of type I and II fibres (Figure 3.41). The average, untrained individual typically has around 50% slow-twitch fibres, while distance runners may have up to 70% and a sprinter may have less than 30% type I fibres (Costill et al., 1976).

Metabolic adaptations

Within the muscle, exercise training causes a number of changes that enhance the ability to produce ATP. However, the specific nature of these changes depends upon the type of training undertaken. For instance, endurance training improves the ability of the muscle to use both carbohydrate and fat for the production of ATP via the aerobic energy system. This is due, in part, to increased fuel (carbohydrate and fat) storage directly within the muscle. By storing a greater amount of fuel at the site of ATP production, more will be available at times of urgent need, without the need to transport the fuel from other sites of storage in the body (such as adipose tissue stores of fat or liver stores of glycogen). As well as increasing the storage of fuel within the muscle, endurance exercise training increases the ability of the muscle to break down carbohydrate and fat to produce ATP via the aerobic system. This occurs as a result of an increase in the number and size of ***mitochondria*** (the location within the muscle where the aerobic energy system produces ATP), providing more 'space' for aerobic ATP production to take place. Furthermore, the aerobically trained individual has greater levels of ***enzymes*** involved in the aerobic breakdown of fat and carbohydrate. Enzymes help chemical reactions to occur at a faster rate. Therefore, greater levels of aerobic enzymes means that each of the chemical reactions involved in the aerobic breakdown of fat and carbohydrate can occur more rapidly, resulting in enhanced ATP production.

Although having an increased ability to breakdown both fat and carbohydrate in the presence of oxygen is beneficial to endurance exercise performance, the enhanced ability to use fat is of particular importance. Producing more ATP from our relatively large fat stores during exercise means that glycogen, which is limited, can be spared. This increases the duration of time at which a submaximal effort can be sustained. Another effect of the increased ability to produce ATP via the aerobic energy system following exercise training is a decrease in the accumulation of lactate at a given submaximal workload. By providing more ATP via aerobic pathways, there is less need to use the lactic acid system, which in turn results in less production of lactic acid, which can impact on performance. The trained athlete will also experience improved ability to remove lactate.

If the type of training undertaken is focused on the anaerobic systems of energy production (ATP-CP and lactic acid systems), different metabolic adaptations will result. Under these circumstances, the trained individual will store more anaerobic fuels (ATP, CP and glycogen) directly within the muscle. This is particularly important for the ATP-CP system, since muscle stores of CP are small and the limiting factor for ATP production by this system. In addition, training in such a way that taxes the anaerobic energy systems leads to greater levels of anaerobic ***enzymes.*** These enzymes speed the rate of ATP production from both CP and anaerobic glycolysis.

Flexibility

Flexibility relates to the range of movement achievable at each specific joint. Regular exercise training assists in maintaining a functional range of motion. Alternatively, inactivity causes muscle stiffness and decreased range of motion ('use it or lose it').

The Effect of Long-term Adaptations on Performance

Content that follows:
Long-term adaptations to training (Unit 1)

- *Aerobic capacity*
- *Anaerobic capacity*

The culmination of long-term adaptations to training is improved exercise performance as a result of enhanced ***aerobic capacity, anaerobic capacity*** or a combination of both.

Aerobic capacity

Aerobic capacity relates to the highest amount of ATP that can be produced by the aerobic energy system during intense exercise. This is the primary determinant of performance in sustained endurance activities. Since the aerobic energy system is limited by the rate at which oxygen can be delivered to the working muscles, improved aerobic capacity will result from any of the previously-mentioned adaptations that enhance this process. These include:

- Cardiovascular and respiratory adaptations
  - ↑ maximal cardiac output (due to ↑ maximal stroke volume).
  - ↑ plasma volume and haemoglobin.
  - ↑ gas exchange at the lungs and at the muscles.
- Muscular adaptations
  - Hypertrophy of type I fibres.
  - ↑ aerobic ability of type I and II muscle fibres.
- Metabolic adaptations
  - ↑ aerobic fuel (fat and carbohydrate) storage within muscle.
  - ↑ mitochondria.
  - ↑ aerobic enzymes.

Anaerobic capacity

Anaerobic capacity is the highest amount of ATP that can be produced by anaerobic pathways (ATP-CP and lactic acid systems) during a maximal exertion. This will determine an athlete's success in sprint and power activities such as the high jump or a 200 m sprint. Improved anaerobic capacity as a result of exercise training is contributed to by the following adaptations:

- ↑ anaerobic fuel (ATP, CP, glycogen) storage within the muscle.
- ↑ anaerobic enzymes.
- Hypertrophy of type II fibres.

Key point summary:

- Regular exercise training results in cardiorespiratory adaptations that improve exercise performance including:
  - More efficient respiration.
  - Higher maximal minute ventilation as a result of increased breathing frequency and maximal tidal volume.
  - Increased oxygen exchange at the lungs.
  - Increased maximal cardiac output due to greater maximal stroke volume.
  - Increased total blood volume and haemoglobin (to a lesser extent).
  - Improved oxygen exchange at the tissues (a-vO_2diff) due to increased capillarisation.
  - Quicker attainment of steady state oxygen consumption (and therefore a smaller oxygen deficit).
  - Increased maximal oxygen consumption ($\dot{V}O_2$ max).
- Regular exercise training results in muscular adaptations that improve exercise performance including:
  - Hypertrophy of selective muscle fibres (type I or II depending on the type of training).
- Regular exercise training results in metabolic adaptations that improve exercise performance including:
  - Increased fuel storage within the muscle.
  - Increased number and size of mitochondria for the aerobic energy system.
  - Increased levels of the enzymes involved in the production of ATP.

Revision questions:

Test yourself on revision questions 21–23 located at the end of this chapter.

Components of Fitness

Text outcomes:
Components of fitness (Unit 2)

- *Explain the components of fitness.*

When we think of fitness, we typically imagine how long it would take us to run, cycle or swim a certain distance. However, being fit is not just about having good aerobic fitness (or cardiorespiratory endurance). In fact, there are a number of components of fitness:

- ***Cardiorespiratory endurance***-the ability of the respiratory and cardiovascular systems to supply oxygen to the working muscles during sustained exercise.
- ***Muscular fitness*** including:
  - ***Muscular strength***-the ability to produce force in a single maximal effort.
  - ***Muscular endurance***-the ability to perform repeated contractions without too much fatigue.
  - ***Flexibility***-the range of motion (amount of movement) about a joint.
- ***Body composition***-the amount of fat and lean mass (muscle) in the body.

Each of these components of fitness is important for athletic performance, as well

as for our health. For this reason, these components are often called the ***health-related components of fitness***. Every person (whether athletic or not) should try to keep good levels of each of these components of health-related fitness.

Content that follows:
Health-related components of fitness (Unit 2)

- *Cardiorespiratory endurance*
- *Muscular strength*
- *Muscular endurance*
- *Flexibility*
- *Body composition*

Cardiorespiratory endurance

Cardiorespiratory endurance (or aerobic fitness) relates to the ability of the respiratory and cardiovascular systems to supply oxygen to the working muscle during exercise so that ATP can be produced via the aerobic energy system. Consequently, cardiorespiratory fitness effects our ability to perform tasks involving large muscle groups for a prolonged period of time (such as jogging, cycling or swimming). The better our cardiorespiratory fitness, the longer we can work at a high intensity without a build up of lactic acid, which will limit continued performance. There are a number of ways in which cardiorespiratory fitness can be assessed. The best measure of aerobic fitness is a test of the rate of maximal oxygen consumption ($\dot{V}O_2$max). This test involves collecting and analysing expired air during exercise of progressively increasing intensity (starting at low intensity and increasing every few minutes) until absolute exhaustion. This type of test is called a $\dot{V}O_2$max test.



Figure 3.42: *Testing maximal oxygen consumption in the laboratory*

As you can see from Figure 3.42, this type of test requires specialised and expensive equipment to analyse expired air during exercise. For this reason, we often use field-based tests to assess cardiorespiratory fitness instead like the multi-stage shuttle run.

Practical activity: *Assessment of cardiorespiratory endurance*

Multi-stage fitness test. Complete the multi-stage shuttle run. The best players in the Australian men's hockey team can get to level 17. Dean Cox of the West Coast Eagles was reported to score a high 14.

Alternatively, complete the 1-mile walk test (1.6 km). This test is submaximal, meaning it does not require a maximum effort. In this test you are required to walk a distance of 1-mile as fast as possible (without running). Individuals with higher levels of cardiorespiratory fitness will complete the test in a faster time, with a lower heart rate.

Equipment:
- Multi-stage shuttle run test audio tape and audio player.
- Marked running area for the shuttle run or 1-mile running track.
- Measuring tape.
- Stopwatch.

Muscular strength

Muscular strength refers to the ability to exert force during a single maximal effort, such as pushing in a rugby scrum or bringing an opponent to the ground in a tackle. One way to test this component of fitness is to determine the maximum weight you can lift no more than once in a given activity. This is termed your ***one repetition maximum*** (1RM). Alternatively, you can determine the maximum weight you can lift for up to six repetitions. This is a safer option for inexperienced weightlifters.



Figure 3.43: *Muscular strength testing*

Practical activity: *Assessment of muscular strength*

Five repetition maximum (5 RM) testing. After an adequate warm-up, determine your 5 RM for the bicep curl. Using a range of dumbbells of different weights, find the weight that you can lift no more than five times. It is important not to fatigue, so allow plenty of time between attempts (Figure 3.43).

Equipment:
- Range of hand weights (dumbbells).

Muscular endurance

Muscular endurance is the ability to perform repeated contractions without too much fatigue. An example of this component of fitness is rowers, who are required to repeatedly stroke the oars through the water. Simple tests to assess muscular endurance include counting the number of sit-ups or push-ups in a period of time (often one minute).

Flexibility

Flexibility relates to the amount of movement achievable at each joint. This component of fitness is very important in sports that involve judging the achievement of certain body positions, such as gymnastics or diving. However, high levels of flexibility are also important for increasing the amount of force or speed involved in explosive activities such as the golf swing or the throw of a javelin. This is because a greater range of motion increases the distance or time over which force can be developed. Tests to measure flexibility depend on the specific joint of interest. A common test is the sit-and-reach test (Figure 3.44a), which assesses the flexibility of the lower back and hamstrings.

Practical activity: *Assessment of muscular endurance*

Number of sit-ups in sixty seconds. Lie on your back with your knees bent to 90° and the palms of your hands resting lightly on your thighs. Complete as many sit-ups as you can in sixty seconds. The hands should slide up to touch the top of the knees with each repetition.

Equipment:

- Stop watch or clock.

Phantom chair. This test assesses muscular endurance of the legs. Stand with your back against a wall, with the feet shoulder-width apart and pointing forwards. Slide down the wall until your knees reach a 90°-angle, with your arms hanging by your side (just like sitting on an invisible chair). Hold this position for as long as possible and record the time (Figure 3.45).

Equipment:

- Stopwatch or clock.



Figure 3.45: *Testing muscular endurance using the phantom chair test*

a





b

Figure 3.44: *Testing flexibility using the sit and reach (a) and shoulder stretch tests (b)*

Practical activity: *Assessment of flexibility (Figure 3.44)*

Sit-and-reach test. This assesses the flexibility of the hamstrings and lower back. Following an adequate warm-up, sit on the floor with the legs out straight in front of you and place your bare feet against a step or ledge. Next place a ruler on the step or between your legs and, while keeping your legs straight, without bending your knees, reach forward slowly as far as possible with one hand over the other so that the fingertips are level. Hold for two seconds before checking how far you have reached. An elite gymnast would generally reach more than 20 cm past their toes.

Equipment:

- Ruler.

Shoulder stretch test. This test assesses arm and shoulder flexibility. Students pair up, with one student completing the test, while the other observes and scores. Reach your right hand over your right shoulder and down your back. Then, bring your left hand underneath your left shoulder and up the back and try to reach the fingertips of your right hand. Repeat the same movement with your left hand reaching over your left shoulder. with the right hand under the right shoulder. A score is given for each side and a 'pass' is achieved if the fingertips can touch.

Equipment:

- None.

Body composition

Body composition relates to the amount of fat and lean muscle mass making up the entire body. This component of fitness is particularly important for athletes competing in sports in which excess body fat may inhibit or assist performance. For example, excess body fat would impair the performance of a springboard diver, who needs a streamlined entry into the water. In contrast, a certain amount of body fat may assist an open-water swimmer via enhanced buoyancy and insulation (Figure 3.46). Differing amounts of lean muscle mass may also be desirable for various sports. While muscular hypertrophy may assist a weightlifter, an endurance runner would be disadvantaged if they had to transport excess muscle mass with each running stride.



Figure 3.46: *Body fat may inhibit or assist performance, depending on the sport of interest*

A variety of methods are available to assess body composition. The most accurate methods involve expensive equipment and technical training (such as underwater weighing, skinfold measurement or dual energy x-ray absorptiometry, in which a scan of the body is taken, similar to an x-ray) (Figure 3.47a and b).



Figure 3.47a: *Methods of body composition analysis (dual energy x-ray absortiometry)*



Figure 3.47b: *Methods of body composition analysis (skinfold measurement)*

However, an easy way to measure body composition is bioelectrical impedance. This is a device much like a set of weighing scales that estimates the percentage of body fat. Other common methods used to assess body composition include the measurement of waist and hip circumference, or body mass index (BMI). BMI can be determined by measuring your height (in metres) and your body mass (in kilograms). These values are then used in the formula: body mass (kg) / height (m^2). Although BMI is a commonly used measure, one limitation is that it does not indicate whether a high body mass is due to a large amount of fat or lean muscle mass. This means that muscular people are often classified as overweight using this measure. Take the example of Arnold Schwarzenegger at his peak fitness. His weight of 107 kg and height of 1.83 m would have resulted in a BMI of 31.95 kg/m^2, suggesting he was obese, when, in fact, he had an extremely low level of body fat (Figure 3.48).

Practical activity: *Assessment of body composition*

Body mass index (BMI). Measure your height and body mass and use the formula mass (kg)/height (m^2) to determine your BMI.

- Underweight (BMI < 18.5 kg/m^2)
- Normal weight (18.5–24.9 kg/m^2)
- Overweight (25–29.9 kg/m^2)
- Obese (BMI > 30 kg/m^2)

Equipment:
- Scales.
- Tape measure for height.

Waist-to-hip ratio. Use a measuring tape to assess your waist circumference (the smallest length around your middle) and your hip circumference (the largest length, usually at the greatest protuberance of the buttocks). Calculate your waist-to-hip ratio by dividing the waist measure by your hip measure. Ideally the ratio is < 0.8 for females and < 0.9 for males.

Equipment:
- Measuring tape.



Figure 3.48: *Arnold Schwarzenegger in his prime*

Performance or Skill-related Components of Fitness

Content that follows:
Performance or skill-related components of fitness (Unit 2)

- *Agility*
- *Balance*
- *Coordination*
- *Reaction time*
- *Speed*
- *Power*

Although the previously mentioned components of health-related fitness are important for both athletic performance and overall health, there are other components of fitness that affect performance in sporting activities, but are not typically called upon in everyday life. These additional components of fitness are termed ***performance-related components of fitness*** or ***skill-related components of fitness***. These are listed and defined below.

Agility*:* The ability to rapidly change direction. This is important for activities like sidestepping an opponent on the field, or in court sports such as netball where it is necessary to rapidly pivot or change direction.

Balance*:* The ability to maintain stability while in motion. Balance is vital for activities like completing a tumbling series on the balance beam in gymnastics or when trying to stay on your feet while struggling with an opponent in a wrestling match.

Coordination*:* The ability to integrate the senses and movement of body parts to perform tasks efficiently. This component of fitness is important for most sports. An example is the hockey player controlling the ball while dodging opponents and reading the play.

Reaction time*:* The time taken from when a stimulus is presented to when the appropriate reaction is taken in response. For instance, the time taken to respond to a feint or dummy in rugby.

Speed*:* The ability to perform a movement quickly. Speed is crucial in many events, such as the 100 m sprint, or team sports, where players are required to sprint for the ball.

Power*:* The ability to perform a strong movement quickly (or the rate at which work can be performed). Examples of the use of muscular power in sport include taking a mark in football, the start of a 100 m sprint or track cycling race.

Simple tests for some of these performance or skill-related components of fitness are included on the next page.



Figure 3.49:
10 m agility shuttle run



Figure 3.50:
Vertical jump test

Practical activity: *Assessment of agility*

10 m agility shuttle run. For this test you will need two wooden blocks 10 x 5 x 5 cm (or something similar). Place the blocks 10 m from the starting line. Following an adequate warm-up, get in the 'ready' position with your foot behind the starting line. On the 'go' signal, sprint as fast as you can towards the blocks, picking one up and sprinting back to place it on or behind the starting line. Immediately turn back to pick up the second block and sprint back to place it on or behind the starting line. Record the time taken from the 'go' signal, until the second block is placed on the start line. Trials do not count if the block is dropped or isn't placed on or behind the starting line (Figure 3.49).

Equipment:

- Two wooden blocks.
- Running area.
- Measuring tape.
- Stopwatch.

Practical activity: *Assessment of speed*

40 m sprint. Following an adequate warm-up and a couple of practice sprints, stand ready, with one foot on the starting line. Have a friend ready with a stopwatch at the finish line 40 m away to time your performance. Sprint as fast as you can past the 40 m finish line after the timer calls ready (with their arm up in the air) and signals to go by sweeping their arm down. The timer should start the stopwatch at this time and stop timing when your chest passes the finish line. Former US Sprinter Dwain Chambers is reported to have run 40 m on a grass track in 4.10 seconds.

Equipment:

- Running area.
- Measuring tape.
- Stopwatch.

Practical activity: *Assessment of muscular power*

Vertical jump. Following an adequate warm-up, stand with your preferred side (left or right) next to a wall (ideally outside with no roof!). Reach up as high as you can with the hand closest to the wall and get a friend to mark the point where you reach with some chalk. Next, step slightly away from the wall and rub chalk onto your fingertips. Then jump as high as you possibly can, reaching up to touch the wall at the peak of your jump. You can use your arms and legs as much you like in the jump, but no run-up is allowed. Use a step and a measuring tape to find the distance between your standing reaching height and your jump height (Figure 3.50). AFL player Nic Naitanui had a vertical jump of 78 cm the year he was drafted.

Equipment:

- Vertical jump board or a wall.
- Chalk.
- Measuring tape or ruler.
- Ladder.

Sport-specific Fitness

Content that follows:
Fitness requirements for performance (Unit 2)

- *Sport-specific fitness*

It is rare for athletes to excel in all areas of fitness. Instead, we tend to score well in some components of fitness, but not in others. This often helps us determine what sporting activities we are better suited to do well in. For example, an individual with a naturally high level of muscle mass and muscular strength, but poor flexibility and speed, is probably more suited to weightlifting than artistic gymnastics. However, it is important to note that each component of fitness can be trained, at least to some extent. Deciding which components of fitness to train will depend on the particular sport of interest, since each sport has its own fitness demands. A 100 m sprinter will likely focus on improving their speed, muscular power and reaction time, while a distance runner may be more concerned with their cardiorespiratory fitness and muscular endurance.

Determining the specific fitness demands of a given sport can be complex. For example, Table 3.3 outlines the amount of time an elite-level basketball guard spends standing, walking, jogging, sprinting and jumping during a forty-minute game. Running movements are recorded as average time in seconds, frequency and intensity (high, medium and low). Based on this information, it is evident that this particular athlete must train multiple components of fitness.

In the same way that the fitness demands of different sports may vary, the fitness components of importance within the same sport may vary, depending on the positional role played. For instance, think about the types of activities performed by a soccer goalie compared to a mid-fielder during a game. The goalie requires high levels of agility, muscular power and good reaction time, while the mid-fielder may spend considerable time developing their cardiorespiratory endurance. The differences in fitness demands of various positions in the field are highlighted in the UWA research snapshot: Positional demands in Australian Rules football.

Table 3.3: *Activity patterns of an elite-level basketball guard*

Activity	Intensity level	Average time (s)	Frequency
Sprint	High	1.9	67
Jump	High	0.9	41
Run	High	2.1	103
Jog	Moderate	2.1	113
Walk	Low	2.3	130
Stand	Low	2.2	141

**Frequency and duration of different activities performed during a basketball game by a guard. Adapted from Abdelkrim et, al. 2007. Total time on court: 35:05 minutes; total game time: 40:00 minutes; age of player: 19 years; mean heart rate achieved: 176 bpm; games consisted of 4x10minute quarters, with a fifteen minute, half-time break and two minute breaks between the first and second quarters and third and fourth quarters.*

UWA research snapshot: *Positional demands in Australian Rules football (Dawson et al., 2004)*

Within many team sports, the fitness demands on an individual player may vary, depending on their positional role within the team. This is because different positions on the field may require different types of activities to be performed throughout a game. These activities can be determined by analysing the movements of a player throughout a game. Researchers from the School of Sport Science, Exercise and Health at The University of Western Australia have analysed the movement patterns of Australian Rules Footballers (AFL) in a range of positional roles using GPS. One of their findings was that full forwards and full backs spent much less time jogging and fast-running, compared to midfielders. On the other hand, full forwards and full backs were involved in more sprints than the midfielders. Overall, midfielders covered about 17 km per game, while full forwards and full backs covered around 13.6 km. By measuring the game demands in this way, training can be specifically targeted for certain positional roles.

Class task: *Identifying the contribution of fitness components to performance*

Different activities involve differing degrees of each component of fitness. For the following activities, list the components of fitness that you feel are important in order of their involvement (such as: highly involved, involved to some extent or only minimal involvement). Compare your answers with your friends.

Activity	Highly involved	Involved to some extent	Minimal involvement
Basketball guard			
Springboard diving			
Netball centre			
Taekwondo			
Marathon			
Hockey			
High jump			
Single skull rower			
100 m freestyle			
Triathlon			
Cricket spin bowler			
Shot put			

Key point summary:

- The health-related components of fitness include cardiorespiratory fitness, muscular strength, muscular endurance, flexibility and body composition.
- Cardiorespiratory endurance (or aerobic fitness) relates to the ability of the respiratory and circulatory systems to supply oxygen to the working muscle during exercise.
- Body composition relates to the proportion of fat and lean muscle mass in the body.
- The performance or skill-related components of fitness include agility, balance, coordination, reaction time, speed and power.
- Different sports (and positions within a given sport) have differing demands on each component of fitness.

Practical investigation

Evaluate the functional anatomy of hip flexion or extension and the fitness components of speed, activity, and flexibility.

See Appendix B2 for a practical investigation, along with questions and report-writing format recommendations.

Principles of Training

Text outcomes:
Principles of training (Unit 2)

- *Explain the principles of training.*

Content that follows:
Principles of training (Unit 2)

- *Specificity of training: Nature of activity, position, and roles*
- *Progressive overload: Intensity, duration, and frequency*
- *Reversibility*

Specificity of training

When exercise is performed on a regular basis over a prolonged period, long-term adaptations occur, allowing us to improve our performance. However, the specific types of adaptations that occur are dependent upon the type of training undertaken. If your goal is to run the 12 km City to Surf, you will not get the types of long-term adaptations to training that you desire if your training sessions consist of short 60 m sprints. Likewise, you wouldn't cycle to improve your swimming, or run to improve your upper body strength. This relates to the principle of ***specificity of training***. That is, to improve your ability to complete a certain exercise task, the training that you do must be specific to the nature of that task. Therefore, when designing training programs, it is important to identify the components of fitness and the energy systems

involved in the sport of interest. For instance, the most important components of fitness for a long-jumper include muscular strength and power (for the take-off) and speed (for the approach). The predominant energy system will be the ATP-CP system. Therefore, training should be specifically focused on enhancing these factors in the athlete.

Likewise, we know that the specific components of fitness and energy systems used may vary within a sport depending upon the ***specific positional role*** of a player within a team. Therefore, the type of training undertaken by a hockey goalie might be quite different from a midfielder. While the goalie focuses on training the anaerobic energy systems, together with agility, muscular power and reaction time, the midfielder may spend considerable time developing their cardiorespiratory endurance (Figure 3.51).





Figure 3.51: *The specific fitness component and energy system involvement may vary within a sport depending upon the specific positional role of a player within a team*

Progressive overload

In order to get long-term adaptations to training, the activities performed must ***stress*** or ***overload*** the organs or systems that you wish to train. Without these systems being pushed above the workloads normally encountered, they will not improve and adapt to a new higher level. This principle of training is referred to as ***progressive overload***. The ***progressive*** nature of overload means that the workload should be gradually increased. If the overload is too much, or not gradual enough, then overtraining and injury will often occur. Progressive overload can be applied in three main ways:

- Increased exercise ***intensity*** (how hard you work in a particular session).
- Increased exercise ***duration*** (how long you exercise for).
- Increased exercise ***frequency*** (how often you exercise).

Because adaptations to training occur in response to ***overload***, the ***intensity*** of an exercise session is crucial. There is a minimum intensity, which must be worked at in order to achieve a training effect. For example, walking really slowly around a shopping centre is not a hard enough effort to overload the body. The optimal intensity of training is dependent upon the types of adaptations desired. In order to overload the

anaerobic energy systems (ATP-CP and lactic acid systems) the intensity of exercise must be near maximal. In contrast, aerobic adaptations will result from prolonged exercise at an intensity that causes some ***huff and puff*** (for example, a 20 minute jog).

Exercise ***duration*** is closely related to the intensity of the exercise. If the intensity is high (for example, an all-out sprint), the duration of exercise will be short, since the effort cannot be maintained for very long. For aerobic adaptations, the minimum duration for exercise to be beneficial appears to be about 20 minutes of continuous exercise, although lesser amounts may be useful for extremely unfit people. The ***frequency*** of training will also be affected by the intensity and duration of exercise. Completing long, intense training sessions everyday is very hard and will likely result in overtraining and injury. For this reason, many coaches design programs with hard or intense sessions separated by easier sessions to allow for recovery and repair. The minimum frequency of exercise to get long-term adaptations to training seems to be three days a week.

To illustrate the way in which progressive overload is applied by changing the intensity, duration and/or frequency of exercise, let's take our example of the person training for the City to Surf. If this individual starts out running for 30 minutes three days per week, they can apply progressive overload by a) increasing the exercise intensity by trying to run faster or harder over this 30 minute period, b) increasing the exercise duration by running for longer (for 40 minutes), or c) increasing the frequency by adding in a fourth session each week. Typically, progressive overload is applied each week or each session by increasing only ***one*** of exercise intensity, duration or frequency at a time. Increasing more than one of these factors between sessions often results in a greater overload than is ideal, leading to overtraining or injury. In general, progressive overload should not involve an increase of more than 10% of total training volume each week.

Reversibility of training

Although regular exercise training results in a number of long-term adaptations, it is important to note that these adaptations are not permanent and are easily lost without continued training. This refers to another principle of training called ***reversibility***. In other words, if you don't use it, you lose it! After as little as two to three weeks of stopping training, some of the long-term adaptations to training may start to reverse.

Key point summary:

- The types of long-term adaptations to exercise training gained depends on the type of training undertaken (specificity of training).
- Progressive overload must be applied to achieve training adaptations.
- Progressive overload can be applied by increasing the intensity, duration or frequency of exercise.
- Adaptations to training are not permanent and can be lost with detraining (principle of reversibility).

Training Types

Text outcomes:
Types of training (Unit 2)

- *Define the training types.*
- *Explain the interrelationships between training types, fitness components and the principles of training.*

Content that follows:
Training methods (Unit 2)

- *Continuous training:*
  - *Cross-training*
- *Fartlek training*
- *Interval training*
- *Resistance training: Isometric, isotonic, and isokinetic*
- *Circuit training*
- *Flexibility training: Static, ballistic, and proprioceptive neuromuscular facilitation*
- *Plyometrics*
- *Specificity of training adaptations*
- *Interrelationships between training types, fitness components and the principles of training*

Based on the principle of specificity of training, we know that training programs should aim to develop the components of fitness and the energy systems involved in the sport of interest. Different methods of training will stimulate their own specific adaptations to training. The main types of exercise training and fitness components or energy systems targeted are detailed below.

Continuous training

Continuous training is probably the most common form of training used by athletes, as well as the general population, to improve cardiorespiratory fitness and the aerobic production of ATP. As the name suggests, this form of training involves steadily paced, continuous exercise (like running, swimming, rowing, cycling) for a prolonged period of time (typically longer than 20 minutes). This method of training may be performed for long durations (up to two hours) at below race (or game) pace. Some people refer to this mode of training as ***long, slow, distance*** (LSD).

Alternatively, continuous training may be performed at a faster pace, for a shorter duration of time (30 to 60 minutes). Training at this fast pace will overload the aerobic energy system, as well as stimulate improvements in the ***lactate threshold***. The lactate threshold is the exercise intensity at which lactic acid begins to accumulate when aerobic production of ATP cannot keep up with the energy demands of the muscle as well as the removal of lactic acid. A higher lactate threshold will assist performance in endurance activities by allowing the athlete to work at a higher intensity before lactate begins to build up.

Cross-training

Although we know that it is important to adhere to the principle of specificity of training, many coaches often use continuous bouts of exercise that are different to the athletes' main sport (for example, a footballer might swim). This method of training is called ***cross-training***. The reason for using this type of training is that the effect

of continuous training on the heart and lungs is similar with different modes of endurance exercise. Consequently, cross-training is useful for achieving long-term aerobic adaptations, while decreasing the risk of overuse injuries from always using the same mode of exercise.

Fartlek training

Fartlek (meaning ***speed play***) training is a method of continuous training in which the training intensity is varied to include periods of harder work, alternating with periods of easier work for relief (rather than a steady pace). This training method is commonly used by runners and cyclists to enhance endurance performance. An example of how this technique would be used by a runner throughout a 30-minute run would be to go hard for one minute, then slower for two minutes and keep repeating this pattern throughout the session. Alternatively, a cyclist may sprint on the hills along an undulating course.

Interval training

It is not possible to keep up a high-intensity effort for a prolonged period of time (for example, you cannot sprint flat-out for 40 minutes). However, a large amount of work can be completed at a high intensity if the session is divided into several short bouts of high-intensity work with rest periods in between. This type of training is called ***interval training***.

Interval training can be designed to enhance the aerobic or the anaerobic energy pathways. If the aim is to improve the aerobic production of ATP, the intervals should involve a relatively long period of high-intensity work, with brief recovery between efforts. An example would be a runner completing seven 1 km intervals above race-pace, leaving every five minutes. If it took the runner three and a half minutes to run each kilometre, then they would get approximately one and a half minutes' rest between bouts. This type of ***aerobic interval*** is useful for improving the lactate threshold and endurance performance.

In contrast, if the aim is to enhance the anaerobic production of ATP, the intervals should be shorter in work duration (but much higher in intensity), with a longer duration of recovery between bouts. For example a long jumper may do ten 30 m sprints with approximately two minutes between sprints. This type of ***anaerobic interval*** will enhance the production of ATP via the ATP-CP system as a result of the short work periods and relatively long recovery period to allow for CP stores to be replenished before the next effort. Alternatively, the lactic acid system can be targeted by changing the work and recovery duration of the intervals. For example a 200 m sprinter may perform eight 300 m sprints with three minutes of recovery between efforts.

The recovery between bouts can be active or passive. ***Active recovery*** involves active movement (such as walking or light jogging) between efforts, while ***passive recovery*** requires complete rest. Typically, active recovery is promoted because the movement helps lactic acid removal from the site of the muscle prior to the next effort.

Resistance training

Resistance training uses a variety of types of resistance (opposition) to movement in order to ***overload*** the muscles. In response to this overload, the muscles adapt to cope with heavier loads in the future. This method of training results in the best improvements in muscular strength and endurance. Resistance can be applied with the body weight (such as push-ups and chin-ups), using free weights (dumbbells and barbells) or machine weights. For some people, enough overload can be applied through the use of wide, elasticised bands.

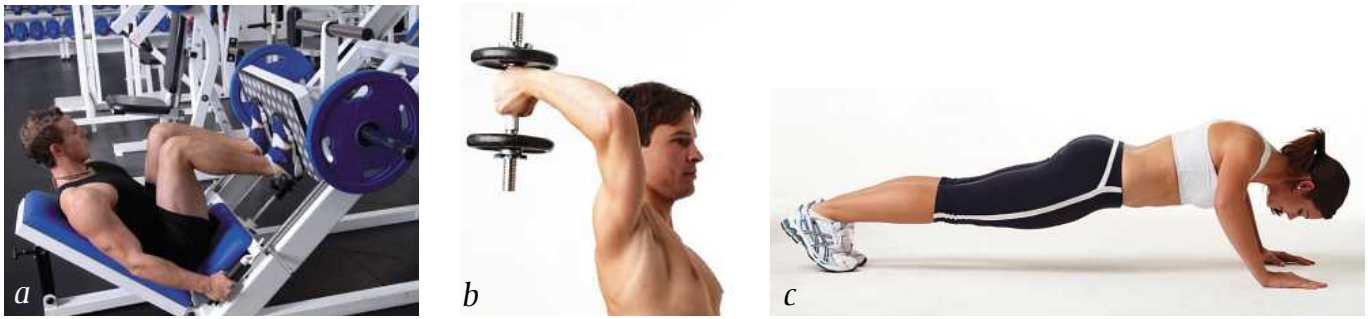


Figure 3.52: *Different methods of resistance training a) machine weights, b) free weights and c) body weight*

There are a number of ways in which resistance training can be used. This is the result, in part, of the fact that our skeletal muscles can perform different types of contractions. Most commonly, resistance training involves ***isotonic*** (dynamic) muscular contractions in which the length of the muscle changes, resulting in movement. There are two types of isotonic contractions. First, ***concentric*** muscle contractions occur when the muscle shortens in length whilst generating force. This is exemplified when lifting the dumbbell during a bicep curl. As you lower the dumbbell back to the starting position, an ***eccentric*** muscle contraction is performed (Figure 3.53). Here, the bicep muscle is lengthening whilst generating tension. Therefore, when lifting dumbbells or using weight machines, isotonic muscle contractions are performed (there is a concentric and an eccentric phase). This is consistent with the principle of specificity of training, since this type of muscle contraction replicates the actions of the skeletal muscles during most sporting activities.

Another form of resistance training involves ***isometric*** muscle contractions. These are static contractions in which no change in muscle length occurs (for example, when pushing against a wall, or when a gymnast holds a handstand on the beam). Isometric resistance training involves the performance of three or four repetitions of a held contraction (typically two to four seconds). The resistance applied may be from a partner applying opposition to movement, or a weight machine where the resistance cannot be moved (Figure 3.54). Although this method of training improves muscular strength, not many sporting activities involve isometric contractions. Therefore, this method of resistance training may be limited in its application, given what we know about the principle of specificity of training.

Isokinetic resistance training involves the use of specialised equipment (different to standard weight machines) that allows for dynamic contractions at a constant controlled speed with the resistance against the muscle adjusted throughout the range of motion. The resistance is adjusted so that there is increased resistance in the section of the range of motion that the individual tends to be strongest and reduced resistance in the weaker parts of the range of motion. This variation in resistance allows the whole range of motion to be worked maximally, giving good improvements in strength. However, we do not tend to perform isokinetic contractions in sport; so, although this is a useful method for enhancing general strength,



Figure 3.53: *Concentric and eccentric phase of a dumbbell curl*

the transfer into actual sporting performance may be limited.

Progressive overload in resistance training may be applied by manipulating:

- the number of ***repetitions*** (how many times you repeat the exercise)
- the number of ***sets*** (how many groups of repetitions you perform)
- the ***load*** (amount of weight lifted with each rep)
- the ***frequency*** of training.

The number of repetitions performed in a set is closely related to the resistance or load. For example, a light load can be lifted many times, while fewer repetitions will be performed with a heavier load. Resistance training can be designed to enhance muscular strength, endurance or power. In order to improve muscular strength, a heavier load and fewer repetitions should be performed (such as six repetitions of 85% of 1RM). If the focus is on muscular endurance, then a greater number of repetitions with a lighter load is recommended (such as sixteen repetitions of 60% 1RM). For improving muscular power, lifts should be performed in a rapid manner. Therefore, lighter loads will be more appropriate. This should make sense when you consider the principle of specificity of training. For instance, performing slow repetitions of a very heavy weight with the upper body is of little value for the high-jumper, whose sport demands power in the lower body. This particular athlete would be better served completing swift, fast lifts with a lower weight, focusing on the lower body. Table 3.4 provides a summary of the general recommendations for applying resistance training for specific training effects.



Figure 3.54: *Isometric exercise*

Table 3.4: *Manipulation of resistance training for enhancing muscular strength, power or endurance*

Training emphasis	Load (%1RM)	Repetitions	Sets	Speed of lift
Muscular strength	75–100%	1–10	3–5	Slow and controlled
Muscular power	30–60%	10–12	2–3	Fast
Muscular endurance	40–60%	15–25	2–3	Medium

Circuit training

While more traditional forms of resistance training generally involve the performance of a specific program of exercises for a prescribed number of sets and repetitions, circuit training typically involves performing as many repetitions as possible in a given period of time (often one minute). Generally the exercises involved are set up in a circular (circuit) fashion, in which athletes move from one exercise ***station*** to the next (Figure 3.55). Often the order of these stations makes sure that exercises alternate between the upper and lower body. Another difference of circuit training from more traditional resistance training methods is that the resistance exercise stations are often interspersed with aerobic activities (such as running, skipping or stationary cycling). This allows for improvement in cardiovascular fitness, as well as muscular strength and endurance (although muscular endurance is the main focus here, given that you perform as many repetitions as you can in the time allowed).



Figure 3.55: *Circuit training*

Flexibility training

The purpose of flexibility training is to maintain or improve the range of motion about a joint. This can be achieved in a number of ways. ***Static stretching*** is the most common method of flexibility training. This involves a slow, gradual stretch that is held for a prolonged period of time (twenty to sixty seconds) at the limit of the range of motion. At this limit, slight tension should be felt, but not pain (Figure 3.56).

On the other hand, ***ballistic stretching*** involves a dynamic movement in which the joint is stretched to the limit of its range of motion through a bouncing action (so that the position is not gradually developed or held like in a static stretch). An example of ballistic stretching is the leg swings that you commonly see football players performing on the boundary line (Figure 3.57). Ideally, the types of ballistic stretches performed mimic the activities involved in the sport, in the

Practical activity: *Effect of static stretching on flexibility*

Using the sit-and-reach test, compare your flexibility before and after completing three 30 second static stretches of the hamstring muscles.

Equipment:

- Ruler.
- Stopwatch or clock.



Figure 3.56: *A static stretch of the hamstring muscle group*



Figure 3.57: *Ballistic stretching of the hamstring muscle group*



Figure 3.58: *A PNF stretch of the hamstring muscle group*

way that the leg swings by footballers mimic a kicking action.

Finally, ***proprioceptive neuromuscular facilitation*** (PNF) is a method of stretching in which the joint is stretched to the limit of its range of motion, followed by a resisted contraction in that position for three to six seconds and then a further stretch. This requires the assistance of a partner (Figure 3.58).

Stretching is an important component of any training program, as is flexibility a vital component of health-related fitness. However, recent research suggests that static stretching immediately before a power or sprint-type event may be detrimental to performance (see UWA research snapshot: *Static stretching and repeated sprint performance*). Therefore, flexibility training should be incorporated into the training program in such a way that it is not performed immediately prior to a ***powerful*** performance (such as a high jump or a short sprint). For example, in a separate training session focused on flexibility or as part of a prolonged cool-down.

UWA research snapshot: *Static stretching and repeated sprint performance (Beckett et al., 2009)*

Athletes competing in team sports that involve repeated short sprints throughout a game can often be seen stretching while waiting on the interchange bench or between breaks in play. Researchers from the School of Sport Science, Exercise and Health at The University of Western Australia examined the effect of static stretching between breaks in play on repeated sprint performance. To do this, they got athletes to perform static stretching of the lower limbs between bouts of repeated short sprints. They compared their sprint performance to when no stretching was performed between efforts. It was found that static stretching of the lower limbs during recovery periods between efforts slightly impaired repeated sprint performance (so that the times were slightly slower). Based on this, it may be better to avoid static stretching during recovery periods between maximal efforts.

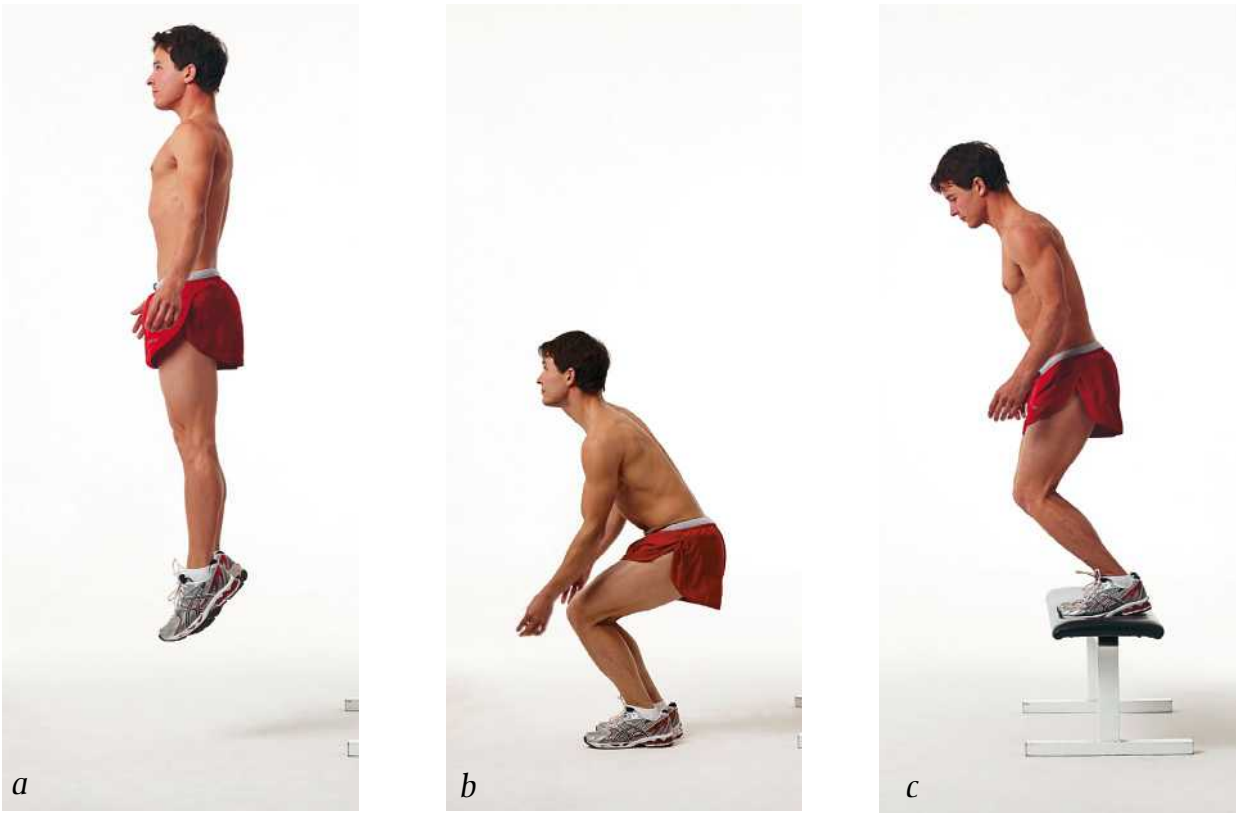


Figure 3.59: *Plyometrics*

Plyometrics

Plyometrics uses the weight of the body to apply overload in dynamic activities. A common example is depth jumping in which an athlete steps off a box (0.5–0.8 m in height, Figure 3.59a) to land on both feet only to immediately jump back into the air (Figure 3.59b and c). Performing this exercise in an explosive manner enhances the development of muscular power. This is based on the principle that a concentric muscular contraction will be enhanced if performed immediately after an eccentric muscle contraction due to the assistance of elastic recoil of the muscle.

Specificity of training adaptations

Each of the previously mentioned training methods will result in different long-term adaptations. Depending on the type of athlete and the physical demands of their chosen sport, different combinations of training methods will be employed. Table 3.5 summarises which methods of training will result in the best improvements in each of the components of fitness.

Fitness component	Training method
Cardiorespiratory endurance	Continuous training Cross-training Fartlek training Interval training Circuit training
Muscular endurance	Resistance training Continuous training Circuit training
Muscular strength	Resistance training Circuit training
Flexibility	Static stretching Dynamic stretching PNF stretching
Speed	Interval training Plyometrics
Power and agility	Interval training Resistance training Plyometrics
Body composition	Most training

Table 3.5: *Relationship between fitness components and training methods*

Key point summary:

- Continuous training involves exercising at a steady pace for a prolonged period of time.
- Cross-training involves an alternative mode of exercise to the one that an athlete is training for.
- Fartlek training is a method of continuous training involving variations in pace between periods of harder work and periods of easier work for relief.
- Interval training involves repeated bouts of work, alternated with periods of recovery. Intervals can be aerobic or anaerobic in nature.
- Resistance training stimulates the body to adapt to coping with heavier loads.
- By changing the load (%1RM), number of sets, repetitions and the speed of motion, we can change the focus from enhancing muscular strength, power or endurance.
- Flexibility may be improved using static stretching, ballistic stretching or PNF stretching.
- Plyometrics uses the weight of the body to apply resistance in dynamic activities such as jumping.

Revision questions:

Test yourself on revision questions 24–34 located at the end of this chapter.

Interrelationships Between Training Types, Fitness Components and the Principles of Training

The following training programs represent one week of in-season training for two different athletes to demonstrate the relationship between training types, fitness components and the principles of training. The first is an Olympic distance triathlon program for a professional female triathlete (twenty-four years old). This event involves a 1.5 km swim, followed by a 40 km cycle and then a 10 km run. The World best time for this event is 1 hr 52 minutes. The female athlete's best time is 1 hr 58 minutes. The second program is representative of one week of in-season training for an AFL midfield player.

Table 3.6: *Olympic distance triathlon program for an elite professional female triathlete (twenty-four years old). Prepared by Dr Grant Landers at the School of Sport Science, Exercise and Health, The University of Western Australia*

Activity	Type of training	Outcome
Monday		
Run 1.5 hr (total distance ~14 km)		
20 min warm-up, stretch & drills, Intervals (3 x 800 m @ 4 min 30sec) + (4 x 400 m @ 2 min 15 sec) + (5 x 200 m @ 1 min 15 sec), 20 min cool-down	Interval training	Aerobic and anaerobic capacity (hard)
Swim 1 hr (total distance ~2.5 km)		
300 m warm-up, Intervals 4 x (5 x 100 m @ 2 min), 200 m cool-down	Interval training	Aerobic energy system (easy recovery)
Cycle 1.5 hr (~40 km with a high cadence)	Continuous training	Aerobic energy system (easy recovery)
Tuesday		
Run 45 min (~10 km undulating terrain)	Continuous training	Aerobic energy system (easy recovery)
Swim 2.5 hr (total distance ~6.8 km)		
1000 m warm-up & drills, Intervals 12 x 100 m @ 1 min 50 sec (50 m freestyle + 50 m medley), 6 x 100 m free @ 1 min 25sec, 6 x 50 m fly @ 60 sec, 6 x 100 m free @ 1 min 30 sec, 6 x 50 m back @ 60 sec, 6 x 100 free @ 1 min 35 sec, 6 x 50 m back @ 65 sec, 6 x 100 m free @ 1 min 30 sec, 6 x 50 m free @ 45 sec, 600 m drills, 200 m free, 200 m back	Interval training	Anaerobic capacity (hard)
Cycle 1.5 hr (~50 km, + 15 min bike skills)	Continuous training	Aerobic energy system (moderate)

Wednesday ***Swim 1.5 hr (total distance ~3.6 km)*** 800 m warm-up & drills Intervals 12 x 50 m @ 60 sec, 20 x (50 m fast + 50 m easy) @ 2 min 30 sec, 200 m back	Interval training	Anaerobic capacity and speed (hard)
Gym 1 hr 8 exercises, 3 x 25 repetitions, low weight	Resistance training	Muscular endurance
Swim 1 hr (total distance ~4 km) 500 m warm-up, 3 x 1000 m hold 14 min, 500 m cool-down	Interval training	Aerobic energy system (easy)
Thursday ***Run 1 hr (total distance ~15 km)*** 15 min warm-up, Fartlek 3 times through: (15 sec fast + 45 sec easy, 30 sec fast + 60 sec easy, 45 sec fast + 75 easy, 60 sec fast + 2 min easy, 90 sec fast + 3 min easy), 10 min cool-down	Fartlek training	Aerobic energy system (moderate)
Cycle 4 hr (total distance ~130 km Group ride (constant change of pace)	Fartlek training	Aerobic and anaerobic capacity (hard)
Swim 1 hr (total distance ~3 km) 500 m warm-up, 2 x (5 x 200 m @ 3 min 30 sec), First set pull, second set free, 500 m cool-down	Interval training	Aerobic energy system (easy)
Friday ***Run 45 min ~10 km***	Continuous training	Aerobic energy system (easy)
Swim 1.5 hr (total distance ~4 km) 1000 m warm-up & drills, 4 x 400 m @ 6 min 30 sec, 400 m choice, 10 x 100 m @ 2 min 30 sec, 600 drills (fins), 200 m free, 200 m back	Interval training	Aerobic and anaery (hard)
Gym 1 hr 8 exercises, 3 x 25 repetitions, low weight	Resistance training	Muscular endurance
Cycle 1.5 hr (total distance ~40 km with a high cadence)	Continuous training	Aerobic energy system (easy recovery)

Saturday ***Run 1.5 hr ~20 km***	Continuous training	Aerobic energy system (easy)
Swim 30 min ~2 km in open water	Continuous training	Aerobic energy system (easy recovery)
Sunday ***Cycle 3 hr (total distance ~80 km)*** 60 min warm-up, 8 x (5 min climb seated, 3 min recovery (descend), 60 min cool-down	Interval training	Aerobic and anaerobic capacity, muscular strength and endurance (hard)
Total ~28 hr: *Swim ~26 km*, *Cycle ~330 km*, *Run ~60 km*		

Table 3.7: *National AFL competition in-season training program for a midfield player. Prepared by Professor Brian Dawson at the School of Sport Science, Exercise and Health, The University of Western Australia*

Activity	Type of training	Outcome
Sunday Walk–jog 15 min on grass Swim 500 m (easy) Cold water immersion 10°C for 10 min	Continuous training Cross-training Recovery	Aerobic energy system (easy recovery)
Monday ***Gym 40 min*** Weights: 2–3 sets of 6–10 repetitions of 6–8 exercises	Resistance training	Muscular strength and power
Strategy meeting 50 min Team meeting (whole squad) 30 min. Review of previous game and early focus on next opponent. Line meeting (midfield players) 20 min. Review of midfield impact in previous game and early focus on next opponent.	Strategy meeting	Strategy/skill
Tuesday ***Team meeting (whole squad) 20 min***	Strategy meeting	Confirm things to work on & put into practice during training
Squad training 45–60 min Skills/game play and conditioning involving 3–4 drills with footballs and tackle pressure in 1–2 drills	Interval training with ball (skill)	Anaerobic capacity (repeated moderate-hard efforts) and skills

Squad training 80 min ***Specific skills 30 min:*** General kicking, kicking for goal, marking ***Flexibility 30 min:*** 8–10 stretches held for 30–40 sec repeat twice on each major muscle group ***Massage 20 min:*** Focus on legs	Individual skill practice Static stretching Massage	Recovery (light). Skill Flexibility Recovery
Wednesday No training. Some choose optional activities (boxing, cycling, swimming)	Cross-training	Aerobic energy system (easy recovery)
Thursday ***Team meeting (whole squad) 20 min*** ***Squad training 45–60 min*** Skills/game play and conditioning involving 2–3 drills with footballs and shadow pressure. Focus on clean, skilled ball movement ***Gym 40 min*** Weights: 2–3 sets of 6–10 repetitions of 6–8 exercises ***Fly East for Game***	Strategy meeting Interval training with ball (skill) Resistance training	Focus on opponent's style of play Anaerobic capacity (repeated, moderate efforts) and skills Muscular strength and power
Friday Squad training 30 min 2–3 drills with emphasis on touch/skills and no pressure ***Strategy meeting 50 min*** Team meeting (whole squad) 30 min. Focus on opposition and own game style. Line meeting (midfield players) 20 min. Focus on match-ups	Interval training Strategy meeting	Aerobic (easy recovery) Strategy/skill
Saturday ***Walk–jog 15 min*** ***Game (including warm-up and recovery) 4 hr*** Total distance~12.6 km, number of high intensity efforts (≥ 15 km/h) ~295, number of high intensity sprints (≥ 20 km/h) ~77. ***Fly West to home***	Continuous training Competition	Aerobic (easy) Loosen-up and wake-up Aerobic and anaerobic capacity (repeated, very hard efforts) and skills

References

Abdelkrim, NB, Saloua, EF, & Jalila, EA 2007, 'Time-motion analysis and physiological data of elite under-19-year-old basketball players during completion', *British Journal of Sports Medicine*, vol. 41 pp. 69–75.

Beckett, JRJ, Schneiker, KT, Wallman, KE, Dawson, BT & Guelfi, KJ 2009,'Effects of static stretching on repeated sprint and change of direction performance', *Medicine and Science in Sports and Exercise,* vol. 41(2) pp. 444–450.

Costill, DL, Daniels, J, Evans, W, Fink, W, Krahenbuhl, G & Saltin, B 1976,'Skeletal muscle enzymes and fibre composition in male and female track athletes', *Journal of Applied Physiology*, vol. 40(2) pp. 149–154.

Dawson, B, Goodman, C, Lawrence, S, Preen, D, Polglaze, T, Fitzsimons, M & Fournier, P 1997,'Muscle phosphocreatine repletion following single and repeated short-sprint efforts', *Scandinavian Journal of Medicine and Science in Sports*, vol. 7(4) pp. 206–213.

Dawson, B, Hopkinson, R, Appleby, B, Stewart, G & Roberts, C 2004,'Player movement patterns and game activities in the Australian Football League', *Journal of Science and Medicine in Sport*, vol. 7(3) pp. 278–291.

Jonnalagadda, SS, Bernadot, D & Nelson, M 1998, 'Energy and nutrient intakes of the United States National Women's Artistic Gymnastics Team', *International Journal of Sport Nutrition*, vol. 8(4) pp. 331–344.

Kilne, GM, Porcari, JP, Hintermeister, R, Freedson, PS, Ward, A, McCarron, RF, Ross, J & Rippe, JM 1987,'Estimation of VO_2max from a one-mile track walk, gender, age and body weight', *Medicine and Science in Sports and Exercise*, vol. 19(3) pp. 253–259.

Lindstedt, SL, Hokanson, JF, Wells, DJ, Swain, SD, Happeler, H & Navarro V 1991, 'Running energetic in the pronghorn antelope', *Nature*, vol. 353 pp. 748–750.

Naylor, LH, Arnolda, LF, Deague, JA, Playford, D, Maurogiovanni, A, O'Driscoll, G & Green DJ 2005, 'Reduced ventricular flow propagation velocity in elite athletes is augmented with the resumption of exercise training', *Journal of Physiology*, vol. 563(pt 3) pp. 957–963.

O'Brien, K & White, D 2001, 'The thinking platform', *K.D Publications*, NSW.

Ramsbottom, R, Brewer, J & Williams, C 1988,'A progressive shuttle run test to estimate maximal oxygen uptake', *British Journal of Sports Medicine*, vol. 22(4) pp. 141–144.

Schokman, CP, Rutishauser, IH & Wallace, RJ 1999,'Pre- and postgame macronutrient intake of a group of elite Australian Rules football players', *International Journal of Sport Nutrition*, vol. 9(1) pp. 60–69.

Appendix A
Writing the practical investigation report

Writing the report

If you are required to write a report as part of your practical investigation, you may choose to use the following format.

Title: Title of the practical investigation.

Aim: State what you hope to achieve in the experiments (~30–50 words).

Introduction: Define and discuss the sport science principles being investigated (~200 words).

Hypotheses: Identify the expected results or anticipated outcomes (statements).

Method: Identify the steps taken to complete the experiments (~100 words).

Results: Present the data and findings in the appropriate format (for example, graphs, diagrams and tables).

Response to the questions: Write the questions out and respond.

Discussion: Provide a detailed discussion of the results. Apply the sport science principles under investigation to other sporting contexts (~400 words).

Conclusion: Summarise the discoveries made. Make links to each hypothesis and include limitations of the experiment (~100 words).

Appendix B1
Practical Investigation and Report: Exercise Physiology

Energy system interplay and performance of strength and local muscular endurance activities

Weighting: Unit 1

Type: Investigation

Content:

- Describe the responses of energy systems to physical activity.
- Identify the relationship between energy systems and types of physical activity.

Task outline

By completing this experiment outlined below you are to observe and evaluate the interplay of energy systems whilst performing a range of bicep curls that demand muscular strength and muscular endurance.

Total marks = /30

Experiment

The class will be divided into three equal groups. Each group will complete tasks one, two or three.

Task one:
Heavy load bicep curls: for one-third of the class only

Method:

1. Accurately measure the maximum circumference of their flexed bicep on their preferred arm.
2. Record this measurement in millimetres.
3. Determine a hand weight (dumbbell) for each student that they can bicep curl using their preferred arm three to six times maximum.
4. Stand with your back against a wall.
5. Perform bicep curls to 90° of elbow flexion until fatigued (or when six repetitions are achieved).
6. Stop when the movement is no longer continuous, 90° is not achieved or six repetitions are achieved.
7. Record the number completed.
8. Now measure the maximum circumference (in millimetres) of their non-preferred flexed bicep.
9. Repeat the bicep curls using the same weight as used previously using the non-preferred arm.
10. Record the number completed.
11. Stop when the movement is no longer continuous, or 90° is not achieved or six repetitions are achieved.
12. Record the number completed.



Figure 3.60: *Measuring the circumference of a flexed bicep*

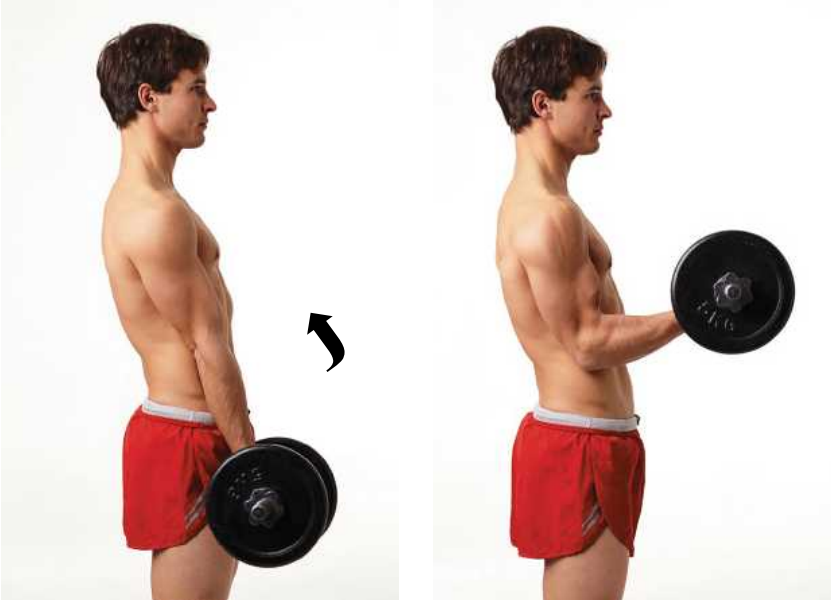


Figure 3.61: *Bicep curl to 90° of flexion*

Task two:
Five minutes of bicep curls: for one-third of the class who did not do task one.

Method:

1. Accurately measure the maximum circumference of their flexed bicep on their preferred arm.
2. Record this measurement in millimetres.
3. Determine a weight for each student that they can bicep curl using their preferred arm for 3 minutes (minimum) to five minutes (maximum).
4. Stand with your back against a wall.
5. Perform bicep curls to 90° of elbow flexion until fatigued (or when five minutes' work time is achieved).
6. Stop when the movement is no longer continuous, 90° is not achieved or when five minutes' work time is achieved.
7. Measure and record the number of curls completed and the time elapsed until they stop.
8. Now measure the maximum circumference of their non-preferred flexed bicep.
9. Repeat the bicep curls using the same weight as used previously with the non-preferred arm.
10. Stop when the movement is no longer continuous, 90° is not achieved or when five minutes' work time is achieved.
11. Measure and record the number of curls completed and the time elapsed until they stop.

Task three:
Bicep curl for sixty seconds: for the final third of the class who have not done task one or two.

Method:

1. Determine a weight for each student that they can bicep curl using their non-preferred arm for three to five minutes maximum.
2. Allocate one person to do the bicep curl, and two partners to collect data. One partner must count the curls during the first thirty seconds and separately count the number of curls that happen during the second thirty-second period. The other partner is to inform the counter when the first thirty seconds has elapsed and record the repetitions completed. They should do the same for the second thirty-second period.
3. Stand with your back against a wall.
4. Complete as many bicep curls to 90° of elbow flexion using the non-preferred arm, as possible in sixty seconds. ***Do not stop*** lifting at the thirty-second mark.
5. The effort should be maximal from the start (so no pacing).
6. Record the number of curls completed during the first thirty seconds and the final thirty seconds.

Questions

a. Explain any differences in the length of time that each individual subject was able to perform task one on their preferred and non-preferred arms (2 marks).
b. Explain any differences in the weight that the different subjects were able to perform task one (2 marks).
c. Explain any differences in the length of time that each individual subject was able to perform task two on their preferred and non-preferred arms (2 marks).
d. Identify which of the energy systems task one and task two predominantly sourced. Explain your thinking in coming to this decision (1 mark).
e. Explain any differences in the number of repetitions achieved in the first thirty seconds compared to the second thirty-second period in task three (2 marks).
f. Predict and account for the results, if there was a task four, where you would be required to complete the following (2 marks):
    i. Determine a weight that can be bicep-curled using the preferred arm for three to five minutes maximum.
    ii. Stand with your back against a wall.
    iii. Perform bicep curls to 90° until fatigued.
    iv. Stop when the movement is no longer continuous (or five minutes' work time is achieved).
    v. Measure and record the number of curls completed and the time elapsed until fatigued.
    vi. Take two days of complete rest.
    vii. Apply an occlusive device to the preferred arm (bicep) that does not prevent the bicep curl to an angle of 90°. The device may be an inflated blood pressure cuff or an elastic bandage or something similar.
    viii. Repeat the method undertaken on the preferred arm as done two days ago.
g. Explain the interplay of energy systems in:
    i. Team games of netball and AFL football (2 marks).
    ii. Individual events of high jump and golf (2 marks).

Equipment

- Adjustable hand-held weight (multiple dumbbells or a bucket with sand or water).
- Measuring tape (soft or flexible).
- Stopwatch.

Task: Energy system interplay and performance of strength and local muscular endurance activities: 30 marks

Components and Performance Standards	Marks
Hypotheses (2 marks)	
Provides simple statements of the expected results or anticipated outcomes in relation to strength and muscular endurance.	**1 mark**
Provides clear statements of the expected results or anticipated outcomes in relation to strength, muscular endurance and energy systems interplay.	**2 marks**
Introduction (3 marks)	
Identifies and defines the variables associated with strength, muscular endurance and energy systems.	**1 mark**
Shows an understanding of the principles that govern strength and muscular endurance and the factors that can enhance and limit these variables. Identifies the energy systems.	**2 marks**
Shows a comprehensive understanding of the principles that govern strength and muscular endurance and the factors, including oxygen supply and physiological variations that can enhance and limit these variables. Discusses the interplay of energy systems.	**3 marks**
Results (2 marks)	
Satisfactory presentation of data.	**1 mark**
Accurate and relevant presentation of data.	**2 marks**
Response to Questions (15 marks)	
Questions a–c: *2 marks for each correct answer (6 marks).* ***Question d:*** *(1 mark).* ***Questions e–f:*** *2 marks for each correct answer (4 marks).* ***Question g:*** *i 2 marks, ii 2 marks (4 marks).*	
Discussion (6 marks)	
Shows little comprehension of the variables associated with the activities undertaken.	**1 mark**
Limited discussion of the results found and few links made to the variables associated with the activities undertaken.	**2 marks**
Uses other sporting contexts to discuss the results found and identifies some of the variables associated with strength and muscular endurance. Identifies the energy systems.	**3 marks**
Uses other sporting contexts to discuss the results found and identifies and defines most of the variables associated with strength and muscular endurance. Discusses the factors that impact on the energy system continuum and the interplay of energy systems.	**4 marks**
Uses other sporting contexts to show an understanding of the results found and discusses these in reference to the principles that govern strength and muscular endurance and the factors, including oxygen supply and physiological variations that can enhance and limit these variables. Discusses the energy system continuum and the interplay of energy systems.	**5 marks**
Uses other sporting contexts to show a comprehensive understanding of the results found and discusses these in application to the principles that govern strength and muscular endurance and the factors, including oxygen supply and physiological variations that can enhance and limit these variables. Discusses the factors that impact on the energy system continuum and the interplay of energy systems.	**6 marks**
Conclusion (2 marks)	
Summarises some of the factors associated with strength and muscular endurance in relation to the hypotheses.	**1 mark**
Fully summarises the impact of the factors affecting strength and muscular endurance in relation to the hypotheses. Limitations discussed.	**2 marks**
Comment:	**Total** **/30**

Appendix B1.1 – Answers

Practical Investigation and Report: Exercise Physiology

Energy system interplay and performance of strength and local muscular endurance activities

Answers

a. Explain any differences in the length of time that each individual subject was able to perform task one on their preferred and non-preferred arms (2 marks).
Answer: Potentially inferior (less repetitions) performance on the non-preferred arm. Potentially a larger bicep circumference on their preferred arm evidenced a greater training (regular usage) effect and larger muscle fibres (hypertrophy) and an ability to generate greater force. The preferred arm may have been working at less percentage of 1RM for each individual lift and therefore able to complete more lifts before fatiguing.

b. Explain any differences in the weight that the different subjects were able to perform task one (2 marks).
Answer: Some subjects may be able to lift more weight than others. They potentially have a greater number of muscle fibres and/or may have a greater percentage of Type 2 (fast twitch fibres) which are better suited to strength activities. They may also have more experience at lifting relatively heavy weights using actions like the bicep curl and better trained for this task.

c. Explain any differences in the length of time that each individual subject was able to perform task two on their preferred and non-preferred arms (2 marks).
Answer: Potentially inferior (less repetitions) performance on the non-preferred arm. Potentially there is a preferred arm muscle training (regular usage) effect and greater aerobic qualities and therefore an ability to generate greater force over a period of time. The preferred arm may have been working at less percentage of 1RM for each individual lift and therefore able to complete more lifts before fatiguing.

d. Identify which of the energy systems task one and task two predominately sourced. Explain your thinking in coming to this decision (1 mark).
Answer: Task one: With intense work (strength) and work times of less than ten seconds the predominate energy source was ATP-CP. Task two: With relatively low intensity (endurance) and work times exceeding three minutes the predominate energy supply was from the aerobic energy system.

e. Explain any differences in the number of repetitions achieved in the first thirty seconds compared to the second thirty second period in task three (2 marks).
Answer: The number of lifts (repetitions) completed in the first thirty second period may have exceeded the lifts (repetitions) completed in the second thirty second period. The activity was high intensity and of one minutes duration and therefore sourced energy primarily from the lactic acid system. The lower work capacity in the second thirty second period is a reflection of fatigue. The fatigue is directly related to the accumulation of lactic acid in the working muscles.

f. Predict and account for the results if there was a task four, where you would be required to complete the following (2 marks): (see text i-viii).

Answer: Task four: The unrestricted lifts on their preferred arm would potentially be superior to the number of lifts (or time) of their occluded preferred arm lifts. When performing the unrestricted lifts the oxygen supply and waste removal from the working muscles and the fibres cells were uninhibited. An unrestricted blood supply potentially permitted a longer working time with greater energy production before fatigue resulted in the inability to lift the object and a need for rest.

During the occluded arm lifts on the preferred arm the blood supply was restricted and the volume of oxygen available to the working muscles was reduced. The predominant energy source for the occluded lifts would have been the lactic acid system. The ability to remove waste products from the working muscle was inhibited. Both factors contributed to the muscles potentially fatiguing earlier and doing less work, in the form of lifting the object.

g. Explain the interplay of energy systems in:

i. Team games of netball and AFL football (2 marks).

Answer: Sports such as netball and AFL football require aerobic energy production for periods of light intensity activity (standing, walking, jogging) to moderate intensity exercise (running). They also require anaerobic energy production (ATP-PC and lactic acid system) for high intensity exercise (sprints) and explosive activity (jumping, diving, scrambling)

ii. Individual events of high jump and golf (2 marks).

Answer: Short duration individual events such as performing a high jump are explosive of approximately 3-5 seconds duration and require anaerobic energy production (ATP-PC). However, there are times when the athlete is waiting for their jump and resting or performing stretching or some practice activities. These activities are generally of low intensity and use predominately aerobic energy pathways.

h. Playing golf predominately requires walking which is low intensity and requires aerobic energy production. However, the action of making a golf swing is relatively explosive of approximately 1-2 seconds duration and sources energy predominately from the ATP-PC system.

Appendix B2

Practical Investigation and Report: Functional Anatomy and Exercise Physiology

The functional anatomy of hip flexion or extension and the fitness components of speed, agility and flexibility

Weighting: Unit 2

Type: Investigation

Content:

- Explain the relationship between the musculoskeletal system and joint movement in the creation of movement.
- Explain the components of fitness.

Task outline

By completing the experiment outlined below you will measure some components of fitness. You will also observe and determine the effects of warm-up on the following:

- Speed.
- Agility.
- Flexibility.

Total marks = /30

Experiment

Task one:

Trunk flexion. Perform the stand OR sit-and-reach test (with no warm-up)



Figure 3.62: *Sit and reach test*

Method:

1. **Option 1.** Standing on a chair with legs straight, bend forward without bouncing, reaching down towards your toes and beyond if possible.
2. **Option 2.** Sit and perform a sit-and-reach test, bending forward without bouncing, reaching towards your toes and beyond if possible.
3. Hold the position for two seconds.
4. Measure and record the point where the tips of the fingers touch the ruler that is taped to the chair.



Figure 3.63: *Trunk extension test*

Task two:

Trunk extension. Perform a front-lying, trunk extension test (with no warm-up).

Method:

1. Lie face-down on a mat with your partner holding down your lower legs and hips. Interlock your fingers and clasp your hands behind your head.
2. In one smooth action (without bouncing) lift the chest from the floor.
3. Hold the position for two seconds.
4. Measure and record the distance from the chin to the floor.

Task three:

Post-warm-up trunk flexion and trunk extension. Repeat tasks one and two.

Method:

1. Perform a warm-up that includes aerobic activity (five minutes' duration or raises your heart rate and sweat on your forehead), static and dynamic stretching.
2. Repeat tasks one and two.

Task four:
Dynamic flexibility test

Method:

1. Stand half a metre from a wall, positioned with your back to the wall.
2. Mark an X on the floor, directly in front of your feet.
3. Mark an X on the wall directly behind you at chest height.
4. Stand upright in the ready position, with your feet shoulder-width apart, facing away from the wall.
5. One cycle: On the command 'go', bend and touch with both hands the X on the ground, then rise and twist to the right and touch the X on the wall with both hands.
6. Second cycle: Without stopping, bend and touch with both hands the X on the ground, then rise and twist to the left and touch the X on the wall.
7. Work at a maximum level for twenty seconds. Measure and record the number of cycles completed.

Task five:
Speed test

Method:

1. Measure and record the time to sprint a 40 m run.

Questions

a. Draw, label and describe the actions at the hip for flexion and extension. Ensure that you identify and label the type of joint involved, the agonist and antagonist muscles and the muscles attachment sites (3 marks).
b. List any anatomical variations that could impact on flexibility (2 marks).
c. Review and discuss the test results for trunk flexion and extension variations within the class individuals (2 marks).
d. What was the impact of the warm-up on the trunk flexion and extension tests? Explain any changes (2 marks).
e. List and discuss activities that may improve flexibility (2 marks).
f. List and explain the variables that can limit speed and agility (2 marks).
g. Discuss the physical qualities of any subjects who scored well in all of the speed and flexibility tests (2 marks).



Figure 3.64: *Dynamic flexibility test*

Equipment

- Chair.
- Ruler.
- Mat.
- Markers.
- Tape measure.
- Stopwatch.
- Chalk or marking tape.

Task: Describe the functional anatomy about the hip joint and measure the fitness components of speed, agility and flexibility: 30 marks

Components and Performance Standards	Marks
Hypotheses (2 marks)	
Provides simple statements of the expected results or anticipated outcomes in relation to speed, agility and flexibility.	**1 mark**
Provides clear statements of the expected results or anticipated outcomes in relation to speed, agility and flexibility and the factors that impact on these variables.	**2 marks**
Introduction (3 marks)	
Identifies and defines the variables associated with speed, agility and flexibility.	**1 mark**
Shows an understanding of the principles that govern speed, agility and flexibility and the factors that can enhance and limit these variables.	**2 marks**
Shows a comprehensive understanding of the principles that govern speed, agility and flexibility and the factors, including warm-up, anatomical and physical variations that can enhance and limit these variables.	**3 marks**
Results (2 marks)	
Satisfactory presentation of data.	**1 mark**
Accurate and relevant presentation of data.	**2 marks**
Response to Questions (15 marks)	
Questions a: *3 marks.* ***Questions b–g:*** *2 marks for each correct answer (12 marks).*	
Discussion (6 marks)	
Shows little comprehension of the variables associated with the activities undertaken.	**1 mark**
Limited discussion of the results found and few links made to the variables associated with the activities undertaken.	**2 marks**
Uses other sporting contexts to discuss the results found and identifies some of the variables associated with speed, agility and flexibility.	**3 marks**
Uses other sporting contexts to discuss the results found and identifies and defines most of the variables associated with speed, agility and flexibility and the factors that can impact on these variables.	**4 marks**
Uses other sporting contexts to show an understanding of the results found and discusses these in reference to the principles that govern speed, agility and flexibility and the factors, including warm-up, anatomical, physical variations and training activities that can enhance and/or limit these variables.	**5 marks**
Uses other sporting contexts to show a comprehensive understanding of the results found and discusses these in application to the principles that govern speed, agility and flexibility and the factors, including warm-up, anatomical, physical variations and training activities that can enhance and/or limit these variables.	**6 marks**
Conclusion (2 marks)	
Summarises some of the factors associated with speed, agility and flexibility in relation to the hypotheses.	**1 mark**
Fully summarises the impact of the factors affecting speed, agility and flexibility in relation to the hypotheses. Limitations discussed.	**2 marks**
Comment:	**Total** **/30**

Appendix B2.1 – Answers

Practical Investigation and Report: Functional Anatomy and Exercise Physiology

The functional anatomy of hip flexion or extension and the fitness components of speed, agility, and flexibility

Answers:

a. Draw, label and describe the actions at the hip for flexion and extension. Ensure that you identify and label the type of joint involved, the agonist and antagonist muscles and the muscles attachment sites (3 marks).	**Answer Question a.** Trunk flexion: 1. Joints involved: Ball and socket (hip) and gliding (vertebrae) 2. Agonist: Abdominals and hip flexors Attachment sites: Abdominals (ribs, spine, pelvis), Hip flexors (femur and pelvis) 3. Antagonist: Hamstrings, lower-back, gluteal muscles Attachment sites: Hamstrings (pelvis and femur), lower back muscles (spine and pelvis), gluteal muscles (pelvis and femur) Trunk extension: 1. Joints involved: Ball and socket (hip) and gliding (vertebrae) 2. Agonist: Hamstrings, lower-back and gluteal muscles Attachment sites: Hamstrings (pelvis and femur), lower back muscles (spine and pelvis), gluteal muscles (pelvis and femur) 3. Antagonist: Abdominals and hip flexors Attachment sites: Abdominals (ribs, spine, pelvis), Hip flexors (femur and pelvis)
b. List any anatomical variations that could impact on flexibility (2 marks).	**Answer Question b.** 1. bone structure 2. muscle bulk and elasticity 3. ligaments 4. joint capsule 5. tendons and connective tissue 6. skin 7. height and weight 8. amount of adiposity

c. Review and discuss the test results for trunk flexion and extension variations within the class individuals (2 marks).	**Answer Question c.** Similarities: List and discuss Differences: why – identify the specific qualities of the participants who were different/extreme (sports/ activities undertaken, anatomical variations)
d. What was the impact of the warm-up on the trunk flexion and extension tests? Explain any changes (2 marks).	**Answer Question d.** Generally most will achieve higher scores in the second performance (post warm up) Increased muscle temperature leads to increased muscle elasticity
e. List and discuss activities that may improve flexibility (2 marks).	**Answer Question e.** Regular stretching routine: 3 times per week Static stretching (held for 20-60 seconds) Dynamic (ballistic) stretching PNF stretching (resistance for 3-6 seconds)
f. List and explain the variables that can limit speed and agility (2 marks).	**Answer Question f.** 1. Hereditary factors i. height ii. weight iii. somatotype 2. Fitness factors i. muscular power ii. muscular strength iii. flexibility 3. Psychological factors i. motivation ii. arousal level iii. persistence 4. Type of activities undertaken i. familiarity with activity ii. activity related skill

g. Discuss the physical qualities of any subjects who scored well in all of the speed and flexibility tests (2 marks).	**Answer Question g.** A correlation may have existed for some individuals who did well on all of the flexibility tests. A correlation may have existed for some who did well on all of the tests. These people often perform well on most fitness tests and are relatively active and, as a consequence, fit.

Appendix B2.2

Practical Investigation Preparation: Functional Anatomy and Exercise Physiology

The functional anatomy of hip flexion or extension and the fitness components of speed, agility and flexibility

Unit 2

Type: Investigation

Outcome 3: Knowledge and understanding of movement and conditioning concepts for physical activity.

Content:

- Explain the relationship between the musculoskeletal system and joint movement in the creation of movement.
- Explain the components of fitness.

Task outline

By completing the experiment outlined you will measure some components of fitness. You will also observe and determine the effects of warm-up on the following:

- Speed.
- Agility.
- Flexibility.

Once the experiment is completed you need to:

1. Compose an accurate and relevant presentation of the results. (Bring with you and submit at the completion of the In-Class Assessment Task.)
2. Answer all of the questions outlined. Some of these questions, along with additional questions will appear in the In-Class Assessment Task.
3. Develop a comprehensive understanding of the principles that govern speed, agility and flexibility and the factors, including warm-up, anatomical and physical variations that can enhance and limit these variables.
4. Through research, use other sporting contexts to show a comprehensive understanding of the results found and discuss these in application to the principles that govern speed, agility and flexibility and the factors, including warm-up, anatomical, physical variations and training activities that can enhance and/or limit these variables.
5. Discuss the limitations of this experiment.

Experiment

Task one: Trunk flexion. Perform the stand OR sit-and-reach test (with no warm-up)

Method:

1. **Option 1.** Standing on a chair with legs straight, bend forward without bouncing, reaching down towards your toes and beyond if possible. OR
2. **Option 2.** Sit and perform a sit-and-reach test, bending forward without bouncing, reaching towards your toes and beyond if possible.

3. Hold the position for two seconds.
4. Measure and record the point where the tips of the fingers touch the ruler that is taped to the chair.



Figure 3.62: *Sit and reach test*

Task two: Trunk extension. Perform a front-lying, trunk extension test (with no warm-up).
Method:

1. Lie face-down on a mat with your partner holding down your lower legs and hips. Interlock your fingers and clasp your hands behind your head.
2. In one smooth action (without bouncing) lift the chest from the floor.
3. Hold the position for two seconds.
4. Measure and record the distance from the chin to the floor.



Figure 3.63: *Trunk extension test*

Task three: Post-warm-up trunk flexion and trunk extension. Repeat tasks one and two.
Method:

1. Perform a warm-up that includes aerobic activity (five minutes' duration or raises your heart rate and some sweat on your forehead), static and dynamic stretching.
2. Repeat tasks one and two.

Task four: Dynamic flexibility test
Method:

1. Stand half a metre from a wall, positioned with your back to the wall.
2. Mark an X on the floor, directly in front of your feet.
3. Mark an X on the wall directly behind you at chest height.
4. Stand upright in the ready position, with your feet shoulder-width apart, facing away from the wall.
5. One cycle: On the command 'go', bend and touch with both hands the X on the ground, then rise and twist to the right and touch the X on the wall with both hands.
6. Second cycle: Without stopping, bend and touch with both hands the X on the ground, then rise and twist to the left and touch the X on the wall.
7. Work at a maximum level for twenty seconds. Measure and record the number of cycles completed.



Figure 3.64: *Dynamic flexibility test*

Task five: Speed test

Method:

Measure and record the time to sprint a 40 m run.

Equipment

- Chair.
- Ruler.
- Mat.
- Markers.
- Tape measure.
- Stopwatch.
- Chalk or marking tape.

Questions

a. Identify type of joint involved, the agonist and antagonist muscles and the muscles attachment sites for hip flexion and extension.

b. List any anatomical variations that could impact on flexibility.

c. Review and discuss the test results for trunk flexion and extension variations within the class individuals.

d. What was the impact of the warm-up on the trunk flexion and extension tests? Explain any changes.

e. List and discuss activities that may improve flexibility.

f. List and explain the variables that can limit speed and agility.

g. Discuss the physical qualities of any subjects who scored well in all of the speed and flexibility tests.

Appendix B2.3

Practical Investigation Assessment Task: Functional Anatomy and Exercise Physiology

An outline of the task has been provided to you.

The functional anatomy of hip flexion or extension and the fitness components of speed, agility and flexibility

Unit 2

Type: Investigation

Outcome 3: Knowledge and understanding of movement and conditioning concepts for physical activity.

Content: Explain the relationship between the musculoskeletal system and joint movement in the creation of movement. Explain the components of fitness.



Total: _____ / 40 marks

Having completed the functional anatomy of hip flexion or extension and the fitness components of speed, agility and flexibility experiment you are required to address the questions outlined.

Experiment
Task one: Trunk flexion. Perform the stand OR sit-and-reach test (with no warm-up)
Method:

1. **Option 1.** Standing on a chair with legs straight, bend forward without bouncing, reaching down towards your toes and beyond if possible. OR
2. **Option 2.** Sit and perform a sit-and-reach test, bending forward without bouncing, reaching towards your toes and beyond if possible.
3. Hold the position for two seconds.
4. Measure and record the point where the tips of the fingers touch the ruler that is taped to the chair.



Figure 3.62: *Sit and reach test*

Task two: Trunk extension. Perform a front-lying, trunk extension test (with no warm-up).
Method:

1. Lie face-down on a mat with your partner holding down your lower legs and hips. Interlock your fingers and clasp your hands behind your head.
2. In one smooth action (without bouncing) lift the chest from the floor.
3. Hold the position for two seconds.
4. Measure and record the distance from the chin to the floor.



Figure 3.63: *Trunk extension test*

Task three: Post-warm-up trunk flexion and trunk extension. Repeat tasks one and two.
Method:

1. Perform a warm-up that includes aerobic activity (five minutes' duration or raises your heart rate and some sweat on your forehead), static and dynamic stretching.
2. Repeat tasks one and two.

Task four: Dynamic flexibility test
Method:

1. Stand half a metre from a wall, positioned with your back to the wall.
2. Mark an X on the floor, directly in front of your feet.
3. Mark an X on the wall directly behind you at chest height.
4. Stand upright in the ready position, with your feet shoulder-width apart, facing away from the wall.
5. One cycle: On the command 'go', bend and touch with both hands the X on the ground, then rise and twist to the right and touch the X on the wall with both hands.
6. Second cycle: Without stopping, bend and touch with both hands the X on the ground, then rise and twist to the left and touch the X on the wall.
7. Work at a maximum level for twenty seconds. Measure and record the number of cycles completed.



Figure 3.64: *Dynamic flexibility test*

Task five: Speed test
Method:

1. Measure and record the time to sprint a 40 m run.

Equipment

- Chair.
- Ruler.
- Mat.
- Markers.
- Tape measure.
- Stopwatch.
- Chalk or marking tape.

Section One – Results

1. What was the impact of the warm-up on the trunk flexion and extension tests? Explain any changes.

_____

_____

_____

_____

_____

_____

(3 marks)

2. Review and discuss the test results for trunk extension variations within the class individuals.

_____

_____

_____

_____

_____

(2 marks)

3. Identify and account for any differences in the results that may have occurred between individuals for Task 4, the dynamic flexibility test.

_____

_____

_____

_____

_____

(2 marks)

4. What does the sit and reach test measure?

_____

_____

(2 marks)

5. Outline two limitations of the experiment and how they may be overcome. You may wish to include any potential limitations that may not have been observed.

_____

_____

_____

_____

_____

_____

(2 marks)

6. Presentation of results (teacher to indicate).
   - Accurate and relevant presentation of data. (2 marks)
     OR
   - Satisfactory presentation of data. (1 mark)

Section Two – Application

7. Complete the table below to identify the type of joint involved, the agonist and antagonist muscles and the muscles attachment sites for hip flexion and extension.

	Hip Flexion	Hip Extension
Type of joint		
Agonist muscles		
Antagonist muscles		
Muscle attachment sites		

(8 marks)

8. List two anatomical variations that could impact on flexibility.

_____

_____

(2 marks)

9. Identify and discuss two training activities that may improve flexibility.

_____

_____

_____

_____

_____

_____

(4 marks)

10. Identify and explain one variable that can limit agility.

_____

_____

_____

_____

_____

_____

(2 marks)

11. Discuss the physical qualities of any subjects who scored well in all of the speed and flexibility tests.

_____

_____

_____

_____

_____

_____

(2 marks)

Section Three – Extension

Components of fitness can be categorised into health related and skill related components.

12. Identify and describe any two health related and any two skill related components of fitness.__

_____

_____

_____

_____

_____

_____

_____

_____

(4 marks)

13. Identify and justify which health related component of fitness it most relevant for a marathon runner.

_____

_____

_____

_____

_____

_____

(2 marks)

14. Identify and justify which skill related component of fitness it most relevant for a high jumper.

_____

_____

_____

_____

_____

_____

(2 marks)

15. Identify a fitness test that assesses the skill related component of fitness for the high jumper?

_____

(1 mark)

Teachers – maintain the security of these documents. Do not provide them to students.

Appendix B2.4

Practical Investigation Marking Key: Functional Anatomy and Exercise Physiology

An outline of the task has been provided to you.

The functional anatomy of hip flexion or extension and the fitness components of speed, agility and flexibility

Unit 2

Type: Investigation

Outcome 3: Knowledge and understanding of movement and conditioning concepts for physical activity.

Content: Explain the relationship between the musculoskeletal system and joint movement in the creation of movement. Explain the components of fitness.



Experiment

Task one: Trunk flexion. Perform the stand OR sit-and-reach test (with no warm-up)

Method:

1. **Option 1.** Standing on a chair with legs straight, bend forward without bouncing, reaching down towards your toes and beyond if possible. OR
2. **Option 2.** Sit and perform a sit-and-reach test, bending forward without bouncing, reaching towards your toes and beyond if possible.
3. Hold the position for two seconds.
4. Measure and record the point where the tips of the fingers touch the ruler that is taped to the chair.



Figure 3.62: *Sit and reach test*

Task two: Trunk extension. Perform a front-lying, trunk extension test (with no warm-up).

Method:

1. Lie face-down on a mat with your partner holding down your lower legs and hips. Interlock your fingers and clasp your hands behind your head.
2. In one smooth action (without bouncing) lift the chest from the floor.
3. Hold the position for two seconds.
4. Measure and record the distance from the chin to the floor.



Figure 3.63: *Trunk extension test*

Task three: Post-warm-up trunk flexion and trunk extension. Repeat tasks one and two.
Method:

1. Perform a warm-up that includes aerobic activity (five minutes' duration or raises your heart rate and some sweat on your forehead), static and dynamic stretching.
2. Repeat tasks one and two.

Task four: Dynamic flexibility test
Method:

1. Stand half a metre from a wall, positioned with your back to the wall.
2. Mark an X on the floor, directly in front of your feet.
3. Mark an X on the wall directly behind you at chest height.
4. Stand upright in the ready position, with your feet shoulder-width apart, facing away from the wall.
5. One cycle: On the command 'go', bend and touch with both hands the X on the ground, then rise and twist to the right and touch the X on the wall with both hands.
6. Second cycle: Without stopping, bend and touch with both hands the X on the ground, then rise and twist to the left and touch the X on the wall.
7. Work at a maximum level for twenty seconds. Measure and record the number of cycles completed.



Figure 3.64: *Dynamic flexibility test*

Task five: Speed test
Method:
Measure and record the time to sprint a 40 m run.

Equipment
Chair.
Ruler.
Mat.
Markers.
Tape measure.
Stopwatch.
Chalk or marking tape.

Section One – Results

1. What was the impact of the warm-up on the trunk flexion and extension tests? Explain any changes.
   - **Generally most will achieve higher scores in the second performance (post warm up).**
   - **Increased muscle temperature leads to…**
   - **Increased muscle elasticity.**

   (3 marks)

2. Review and discuss the test results for trunk extension variations within the class individuals.
   - **Similarities: list and discuss.**
   - **Differences: identify the specific qualities of the participants who were different/extreme (sports/activities undertaken, anatomical variations).**

   (2 marks)

3. Identify and account for any differences in the results that may have occurred between individuals for Task 4, the dynamic flexibility test.

   Some students may have performed better than others based on:
   - **Greater dynamic flexibility related to:**
     - **Muscle fibre composition**
     - **Neuromuscular activation.**
   - **Height.**
   - **Experiences in similar tasks.**

   (2 marks)

4. What does the sit and reach test measure?
   - **Flexibility** (1 mark)**.**
   - **Flexibility of the lower back and hamstrings** (2 marks)**.**

   (2 marks)

5. Outline two limitations of the experiment and how they may be overcome. You may wish to include any potential limitations that may not have been observed.
   - **Inaccurate implementation of each test.**
   - **Some students may have been physically active in the time period before beginning the experiment.**
   - **Recording of the results.**
   - **Single data sample.**

   (2 marks)

6. Presentation of results (teacher to indicate).
   - Accurate and relevant presentation of data.

   (2 marks)

   OR
   - Satisfactory presentation of data.

   (1 mark)

Section Two – Application

7. Complete the table below to identify the type of joint involved, the agonist and antagonist muscles and the muscles attachment sites for hip flexion and extension.

	Hip Flexion	Hip Extension
Type of joint	Ball and socket (hip) Gliding (vertebrae)	Ball and socket (hip) Gliding (vertebrae)
Agonist muscles	Abdominals Hip flexors	Hamstrings Lower back muscles Gluteal muscles
Antagonist muscles	Hamstrings Lower back muscles Gluteal muscles	Abdominals Hip flexors
Muscle attachment sites	Hamstrings: pelvis and femur. Lower back muscles: spine and pelvis. Gluteal muscles: pelvis and femur.	Abdominals: ribs, spine and pelvis. Hip flexors: femur and pelvis.

(8 marks)

8. List two anatomical variations that could impact on flexibility.
   - **Bone structure.**
   - **Muscle bulk.**
   - **Muscle elasticity.**
   - **Ligaments.**
   - **Joint capsule.**
   - **Tendons and connective tissue.**
   - **Height and weight.**
   - **Amount of adiposity.**

   (2 marks)

9. Identify and discuss two training activities that may improve flexibility.
   - **Static stretching. This involves a slow, gradual stretch that is held for a prolonged period of time (twenty to sixty seconds) at the limit of the**

range of motion. At this limit, slight tension should be felt, but not pain.

- **Dynamic (ballistic) stretching. This involves a dynamic movement in which the joint is stretched to the limit of its range of motion through a bouncing action (so that the position is not gradually developed or held like in a static stretch).**
- **PNF stretching. Proprioceptive neuromuscular facilitation (PNF) is a method of stretching in which the joint is stretched to the limit of its range of motion, followed by a resisted contraction in that position for three to six seconds and then a further stretch. This requires the assistance of a partner.**

(4 marks)

10. Identify and explain one variable that can limit agility.
    - **Hereditary factors: height, weight and somatotype.**
    - **Fitness factors: muscular power, muscular strength and flexibility.**
    - **Psychological factors: motivation, arousal level and persistence.**
    - **Type of activity undertaken: familiarity with the activity and activity related skill.**

    (2 marks)

11. Discuss the physical qualities of any subjects who scored well in all of the speed and flexibility tests.
    - **A correlation may have existed for some individuals who did well on all of the flexibility tests.**
    - **A correlation may have existed for some who did well on all of the tests. These people often perform well on most fitness tests and are relatively active and, as a consequence, fit.**

    (2 marks)

Section Three – Extension

Components of fitness can be categorised into health related and skill related components.

12. Identify and describe any two health related and any two skill related components of fitness.

    Health-related components of fitness
    - **Cardiorespiratory endurance: the ability of the respiratory and cardiovascular systems to supply oxygen to the working muscles during sustained exercise.**
    - **Muscular strength: the ability to exert force in a single maximal effort.**
    - **Muscular endurance: the ability to perform repeated submaximal contractions without undue fatigue.**
    - **Flexibility: the range of motion about a joint.**
    - **Body composition: the proportion of fat and lean mass in the body.**

    Performance or skill-related components of fitness
    - **Balance: The ability to maintain stability while in motion. Balance is vital for activities like completing a tumbling series on the balance beam in gymnastics or when trying to stay on your feet while struggling with an opponent in a wrestling match.**

- **Coordination: The ability to integrate the senses and movement of body parts to perform tasks efficiently. This component of fitness is important for most sports. An example is the hockey player controlling the ball while dodging opponents and reading the play.**
- **Reaction time: The time taken from when a stimulus is presented to when the appropriate reaction is taken in response. For instance, the time taken to respond to a feint or dummy in rugby.**
- **Speed: The ability to perform a movement quickly. Speed is crucial in many events, such as the 100 m sprint, or team sports, where players are required to sprint for the ball.**
- **Power: The ability to perform a strong movement quickly (or the rate at which work can be performed). Examples of the use of muscular power in sport include taking a mark in football, or the start of a 100 m sprint or track cycling race.**

(4 marks)

13. Identify and justify which health related component of fitness it most relevant for a marathon runner.
    - **Cardiorespiratory endurance: the ability of the respiratory and cardiovascular systems to supply oxygen to the working muscles during sustained exercise.**
    - **A marathon involves potentially more than 2 hours and 30min of sub maximal (aerobic) continuous exercise.**

    (2 marks)

14. Identify and justify which skill related component of fitness it most relevant for a high jumper.
    - **Power: The ability to perform a strong movement quickly (or the rate at which work can be performed).**
    - **The high jump requires an explosive vertical leap to complete the skill effectively.**

    (2 marks)

15. Identify a fitness test that assesses the skill related component of fitness for the high jumper?
    - **Vertical jump test.**

    (1 mark)

Appendix C (I)

Revision questions

1. The amount of ATP stored in the body is enough to provide energy for short, explosive activities of two seconds duration. True or false?
2. What is the role of creatine phosphate in the resynthesis process of ATP?
3. How are creatine phosphate stores replenished after a short bout of intense exercise?
4. Explain the production of energy (ATP) via the lactic acid system.
5. The lactate threshold is defined as the point where
   a. aerobic energy production is finished.
   b. the ATP-PC system is finished.
   c. the exercise intensity where lactic acid begins to accumulate.
   d. the exercise intensity where anaerobic energy production is at its highest.
6. The aerobic energy system is
   a. unable to work until the ATP-PC system is finished.
   b. predominantly used when at rest and low to moderate intensity exercise.
   c. best used at the start of exercise.
   d. The third system to be used when starting exercise.
7. Is fat a more or less efficient fuel source than carbohydrate during aerobic exercise?
8. Explain in physiological terms what happens when an athlete 'hits the wall'.
9. When playing a game of touch football, energy is consistently produced from the three energy systems. Explain this statement.
10. Even before you commence a bout of exercise, the body starts to prepare itself for the work. State one of these changes.
11. How does cardiac output continue to rise with increased exercise intensity although the stroke volume has reached its maximum?
    a. Because the arteriovenous oxygen difference continues to rise.
    b. Because the minute ventilation continues to rise.
    c. It doesn't continue to rise, they both plateau at the same time and fatigue occurs.
    d. Because heart rate continues to rise.
12. Heart rate increases during exercise in direction proportion to...?
13. The cardiac output of an athlete during exercise can be more than five times that of rest. Explain the changes that have to take place for this to happen.
14. Why might the arterio-venous oxygen difference (a-vO_2diff) increase during exercise?
15. Why might your systolic blood pressure elevate to dangerous levels during resistance exercise when you hold your breath?
16. During exercise, blood flow is redistributed to the working muscles. Why might this make it more difficult to absorb food or fluid from the stomach and intestine during exercise?
17. The amount of oxygen being consumed by the working muscle can be indirectly measured by sampling an athlete's expired gas (air that they breathe out). Explain the principle behind this.
18. During exercise, the rate of oxygen consumption of an athlete is measured and has attained a steady state. The athlete can comfortably maintain this pace for thirty minutes. What are two things that you can identify about the exercise undertaken?

19. Oxygen deficit is consistent with the
    a. energy used from anaerobic pathways at the start of exercise whilst waiting for the aerobic system to achieve steady state.
    b. amount of energy used in a warm-up.
    c. total amount of energy sourced from aerobic pathways.
    d. the amount of training needed to perform better.
20. What is the lactate threshold and can work be sustained above the threshold level for extended periods of time?
21. After three months of undertaking a well-designed aerobic training program, list two physiological parameters that you would expect to increase and two that might decrease during:
    a. rest
    b. sub-maximal exercise
    c. maximal exercise.
22. Identify two training-induced muscular (peripheral) and two cardiovascular (central) physiological factors that, when increased, could assist to improve your $\dot{V}O_2$max.
23. When comparing pre and post-measures after two months of undertaking a well-planned aerobic training program, you might expect
    a. to take longer to achieve a steady state exercise response.
    b. an increase in resting blood levels of lactic acid.
    c. an increase in the carbohydrate fuel stores within the muscle.
    d. a significant hypertrophy of all of the fast-twitch muscle fibres.
24. You are undertaking an interval training session with ten repetitions of twenty seconds of high-intensity exercise and sixty seconds of rest. Which one of the following is likely to best improve the recovery process?
    a. Walk recovery.
    b. Sit down.
    c. Stand up.
    d. Running at 75% of $\dot{V}O_2$max.
25. List four variables that can be manipulated in an interval training program.
26. What variable is controlled in isokinetic training?
27. What is the rationale behind plyometrics?
28. The more time you have dedicated to developing a training effect, the longer it takes to lose it. What principle of training is this statement referring to?
29. Why do you need to progressively increase the training load?
30. What component of health-related fitness, is least likely to be improved by undertaking a fartlek training program?
31. Muscular power is best developed with a resistance training program that has a load of
    a. 80%1RM with a slow speed of lift.
    b. 50%1RM with a fast speed of lift.
    c. 40%1RM and 25 repetitions for 1 set.
    d. 50%1RM with a slow speed of lift.
32. What fitness component is most likely to be improved by undertaking a resistance training program of three sets of twenty repetitions at 40% 1RM?
33. Give three reasons why a golfer might undertake resistance training.
34. Your parents, having done little exercise for years, ask you if they should undertake a high %RM, low repetitions, strength-oriented, resistance training program. What is your advice to them? Include a list of what to do and what not to do.

Appendix C (II)

Revision answers

1. True.
2. When the bond between creatine and the phosphate group is broken in CP, energy is released. The energy released from the breakdown of CP is then used to resynthesise ATP from ADP and Pi.
3. To remake creatine phosphate (CP), ATP is required. CP is restored during recovery from exercise via the aerobic system. It takes approximately three minutes for the full repletion of CP stores after a single, short, intense effort of exercise.
4. The lactic acid system involves the partial breakdown of carbohydrate in the absence of oxygen to an end-product called lactic acid (anaerobic glycolysis). This process produces energy which can then be used to make ATP from ADP and Pi.
5. c. The exercise intensity where lactic acid begins to accumulate.
6. b. Predominantly used when at rest and low to moderate intensity exercise.
7. Fat is less efficient. The breakdown of carbohydrates via aerobic metabolism occurs at about twice the rate of aerobic fat metabolism; therefore, the aerobic metabolism of carbohydrate supplies ATP at a faster rate than fat.
8. As carbohydrate becomes depleted during prolonged exercise (more than two hours), the contribution of fat to energy production increases. Since the energy cannot be produced at the same rate from fat, the athletes will not be able to perform at the same intensity. This is called 'hitting the wall'.
9. No single energy system is in exclusive use at the one time. Which system is predominantly used depends on the workload intensity and the time period of work and rest. In games of touch football, players are required to perform multiple repeated sprints, with limited recovery (for example, walking or jogging) between each sprint. These high-intensity sprint efforts are predominantly fuelled by the ATP-CP system. During recovery between sprints, the aerobic system becomes predominant, attempting to replenish CP stores before the next sprint. When the recovery time between sprints is not enough time for full repletion of CP levels, the lactic acid system begins to make a greater contribution to each subsequent sprint to maintain high rates of ATP production. Regardless of the amount of recovery time between sprints, during each recovery period, the aerobic energy system continues to attempt to replenish CP stores and also remove lactic acid to be ready for the next effort.
10. Anticipatory heart rate rise. The release of adrenaline in response to thinking about exercise stimulates an increase in heart rate.
11. d. Because heart rate continues to rise.
12. Workload or intensity of exercise.
13. The changes include an increase in the heart rate from 50 bpm at rest to 220 – age. This is potentially more than a threefold increase. An increase in stroke volume from 120 mL to 160–180 mL. An increase in the number of beats per minute (more than three times) and an increase in the volume of blood pumped out by the heart per beat (approximately 1.5 times) equates to more than a fivefold increase in the volume of blood pumped through the heart in one minute.

14. With an increase in exercise intensity and a corresponding increase in energy requirements, there is an increased demand for oxygen at the working muscle.
15. The increase in systolic blood pressure is substantially greater during resistance type exercise. Holding your breath increases pressure in the chest cavity and cardio-respiratory system. Therefore, holding your breath during this type of activity may exaggerate the increase in blood pressure further.
16. With up to 85% of blood flow going to the working muscles during intense exercise, there is considerable redistribution of blood flow away from the stomach and intestine.
17. We know that the concentration of oxygen in the external environment (and therefore our inspired air) is approximately 21%. Since the athlete extracts oxygen from the air they inspire, the concentration of oxygen in their expired air should be lower. The difference will have been extracted and used by the athlete to produce energy.
18. Firstly, the exercise intensity must be consistent since oxygen consumption has reached a steady state. Secondly, the exercise must be below maximal and below the person's lactate threshold, as the lactic acid produced as a consequence of the exercise demands is not accumulating and they can easily maintain the pace for 30 minutes.
19. a. Energy used from anaerobic pathways at the start of exercise whilst waiting for the aerobic system to achieve steady state.
20. The lactate threshold is the workload at which blood lactate levels increase above resting. The aerobic energy system cannot meet the majority of the energy demands and continue to remove the lactic acid. Workloads cannot be sustained for extended periods above this threshold level, as accumulating lactic acid will impair muscular performance.
21. Some of the answers in the **table below** are not necessarily physiological parameters; however, it could be argued that changes in physiology lead to these changes.

	Increase	**Decrease**
Rest	Total blood volume. Stroke volume. Use of fat in the fuel mix. Fuel stores of glucose and triglycerides.	Heart rate. Blood pressure. Ventilation. Adiposity levels.
Submaximal exercise	Stroke volume. Ventilation. a-vO_2diff (oxygen extraction by muscle). Lactate threshold. Rate of energy production. Use of fat in the fuel mix. Pulmonary diffusion capacity. Blood flow to working muscles. Sweating and cooling efficiency.	Heart rate. Levels of lactic acid. Oxygen deficit. Minute ventilation. Fatigue levels. Recovery time.
Maximal exercise	Stroke volume. Cardiac output. Ventilation. $\dot{V}O_2$max. a-vO_2diff. Peak lactic acid levels. Pulmonary diffusion capacity. Sweating and cooling efficiency.	Recovery time.

22.

Peripheral increases in capacity	Blood flow to working muscles (capillarisation). a-vO_2diff (oxygen extraction by muscle). Sweating and cooling efficiency. Energy production. Fuel stores of glucose and triglycerides. Use of fat in the fuel mix Mitochondria. Aerobic enzymes.
Central increases in capacity	Total blood volume and haemoglobin. Stroke volume. Ventilation. Ventilator efficiency. Cardiac output. Pulmonary diffusion capacity.

23. c. An increase in the carbohydrate fuel stores within the muscle.
24. a. Walk recovery.
25. 1. Intensity of exercise. 2. Duration of exercise. 3. Number of work repetitions. 4. Number of sets. 5. Duration of rest. 6. Work-to-rest ratio. 7. Type of rest (active versus passive).
26. The speed of the contraction.
27. By pre-stretching the muscles, the force of the contraction that follows is greater. This provides a greater stimulus for overload.
28. Reversibility.
29. Because the body's organs, systems and muscles adapt to the existing training stimulus they require an additional load to further stimulate them to change again.
30. Flexibility.
31. b. 50%1RM with a fast speed of lift.
32. Local muscular endurance.
33. To develop core and general muscular strength, develop local muscular endurance, develop muscle tone, improve posture, improve general health or fitness, improve balance and body control, reduce the risk of injury and to rehabilitate an injury.
34. This is a not an appropriate program to begin re-exercising.

    What to do: Get a medical check by your doctor. Do something that you enjoy that involves large muscle activation. Apply the training principles related to frequency, duration and intensity. Undertake the activity at least three times per week and continuously exercise for a minimum of twenty minutes' duration. Start with a relatively low-intensity activity (for example, brisk walking) and use your heart rate response to gauge the appropriateness of the intensity (approximately 60% of maximum {220 – age}).

    What not to do: Do not undertake a program intensity that cannot be sustained. This leaves you unable to talk because of excessive ventilation or with a heart rate response beyond the recommended or is a program that cannot be undertaken regularly, leaving you sore or chronically fatigued. Avoid exercises that increase blood pressure, including intense exertion activities like heavy-load resistance training and breath-holding activities.

Appendix D

Personalised project – Unit 1 – Unit 2: Performance evaluation

This assessment task is framed by the principles of Bloom's taxonomy. The mark allocations respect the level of complexity of individual task requirements. The following table differentiates for the complexity of each task, beginning with Level 1 (for example, label) to Level 6 (for example, create) (adapted from O'Brien & White 2001).

This project could be undertaken as the respective content areas are studied (biomechanics, functional anatomy, exercise physiology) or at the end of studying these units.

1 REMEMBERING	2 UNDERSTANDING	3 APPLYING	4 ANALYSING	5 EVALUATING	6 CREATING
Label		Measure Undertake	Identify Analyse Compare & contrast	Justify Evaluate	Create Predict

Weighting:

- Unit 1 – 25 marks
- Unit 2 – 25 marks

Type: Investigation

Content:

- Biomechanics
- Functional Anatomy
- Exercise Physiology

Total marks = /50

Content

1. Use a diagram/s *label and analyse* one of the following options (Unit 1: 4 marks):
   - the freestyle swimmer (400 m) as a projectile during the freestyle start until they surface to swim
   - the long-jumper as a projectile for the run-up, take-off and flight phase
   - the AFL football as a projectile for the run-up of the player carrying the ball, the player's kicking action of the leg kicking the ball, and the flight phase of the ball.
2. *Measure* your own performance in the sport-specific action chosen above. Ensure that you record data for all of the variables that contribute to the quality of the action performed. For example, in the dive start, include the distance from the block to entry, in-air velocity, distance travelled under water and underwater velocity (0 marks).
3. Using biomechanical principles *compare and contrast* with a high-performance athlete (Units 1 and 2: 10 marks).
4. *Predict* for yourself, the four primary technical (skill) limiting factors to your performance success. Consider the contributions of technical actions using biomechanical principles (Units 1 and 2: 4 marks).
5. *Identify and evaluate* three key components of fitness and how they contribute to a

high-performance athlete undertaking the sport chosen (Unit 2: 6 marks):
- The swimmer competing in a 400m freestyle race.
- The long-jumper performing one jump.
- The AFL player in a game of football.

6. *Create* three different sessions of a training program specific to the action chosen. The program should be targeted to you. *Identify* training principles that will serve to enhance your performance in the specific action chosen and more generally to the selected sport (Unit 2: 12 marks).
7. *Predict, analyse* and *evaluate* any physiological changes (chronic) that would occur over a three-month training period and how these changes could impact on performance (Unit 1: 14 marks).

Process or support
- Individual and elite performance evaluation assisted by the teacher.
- Review texts or scientific journals and, in a small group, hold a teacher-facilitated debate and discussion of the evidence at hand.
- Review video material.

Product or outcome

Verbal or written explanation
- Variables that contribute to or impact on a projectile.

Written
- Variables that contribute to or impact on a personal performance.
- Personal and high-performance athlete qualitative and quantitative evaluation.
- Identify and evaluate fitness components.
- Create a training program.
- Predict, analyse and evaluate the impact of training adaptations on performance.

Tabulate or graph
- Diagrams and label.
- Measure and record personal performance.
- Tabulate and identify the differences between personal and elite performance.

Appendix E

Glossary of key terms

Active recovery: Involves light activity, such as walking or light jogging, between efforts.

Adenosine diphosphate (ADP): A molecule consisting of one adenosine component plus two phosphate groups. A product of ATP breakdown.

Adenosine triphosphate (ATP): A molecule consisting of one adenosine component (a complex unit) attached to three phosphate groups. The only molecule from which energy is derived for human physical activity.

Aerobic capacity: Relates to the highest amount of ATP that can be produced by the aerobic energy system during sustained, intense exercise.

Aerobic interval training: Aims to improve the aerobic production of ATP. The intervals involve a relatively long period of high-intensity work, with brief recovery between efforts.

Aerobic system: Both carbohydrate and fat are broken down in the presence of oxygen to release energy for the production of ATP.

Agility: The ability to rapidly change direction.

Amino acid: The smallest unit of protein.

Anaerobic capacity: The highest amount of ATP that can be produced by anaerobic pathways (ATP-CP and lactic acid systems) during a maximal exertion.

Anaerobic interval training: Aims to enhance the anaerobic production of ATP. The intervals involve relatively short work duration (very high in intensity), with a relatively long duration of recovery between bouts.

Arteries: Complex network of blood vessels that carry oxygenated blood pumped from the left ventricle of the heart and transport it towards the working muscles.

Arteriovenous oxygen difference (a-vO_2diff): The amount of oxygen extracted from the systemic circulation, accounted for by what has been extracted by the tissues at the level of the capillary.

ATP-CP system: A pathway by which ATP can be produced without the involvement of oxygen (an anaerobic pathway). This system results in the repletion of ATP using energy released from the breakdown of a molecule called creatine phosphate (CP).

Balance: The ability to maintain stability while in motion or stationary.

Ballistic stretching: Involves a dynamic movement in which the joint is stretched to the limit of its range of motion through a bouncing action.

Body composition: The proportion of fat and lean mass in the body.

Breathing rate: The frequency of breaths per minute.

Capillaries: Smallest of all blood vessels, such that only single red blood cells can fit through them in single file. Permeable to gases and nutrients.

Cardiac output: The amount of blood ejected by the heart (left ventricle) each minute.

Cardiorespiratory endurance: The ability of the respiratory and cardiovascular systems to supply oxygen to the working muscles during sustained exercise.

Cardiovascular system: Consists of several anatomical structures that work together to transport oxygen around the body. These include the heart, arteries, capillaries and veins.

Central adaptations to training: Respiratory and cardiovascular system changes to training.

Circuit training: Involves moving from one exercise station to the next, performing as many repetitions as possible in a given period of time (often one minute).

Concentric muscle contraction: Contraction in which the muscle shortens in length whilst generating force.

Continuous training: Involves steadily paced, continuous exercise (for example, running, swimming, rowing, cycling) for a prolonged period of time (typically longer than twenty minutes).

Coordination: The ability to integrate the senses and movement of body parts to perform tasks efficiently.

Creatine phosphate: A chemical store of energy found in muscles. The energy released from the breakdown of CP is then used to produce ATP by rebonding ADP and Pi.

Cross-training: Continuous bouts of alternative modes of exercise (for example, a footballer might swim).

Diaphragm: A dome-shaped sheet of muscle that separates the thoracic cavity, containing the lungs and heart, from the abdominal cavity below.

Diastolic blood pressure: The lowest pressure exerted on the artery walls when the heart relaxes to refill with blood.

Diffusion capacity: The rate at which oxygen diffuses through the thin alveolar wall into the bloodstream.

Duration: How long you exercise for.

Eccentric muscle contraction: Contraction in which the muscle lengthens whilst generating force.

Enzymes: Protiens that help chemical reactions to occur at a faster rate.

Excess post-exercise oxygen consumption (EPOC): The sustained elevation in oxygen consumption observed post-exercise.

Fartlek (speed play) training: Continuous training in which the training intensity is varied to include periods of harder work, alternating with periods of easier work for relief (rather than a steady pace).

Fatty acids: The smallest unit of fats.

Flexibility: The range of movement achievable at each specific joint.

Frequency: How often you exercise.

Gas exchange: The transfer of gases between the alveoli and bloodstream or between the bloodstream and tissues.

Glucose: A small sugar molecule. The basic unit of carbohydrate.

Glycogen: The storage form of carbohydrate. Results from the combination of a large number of glucose molecules together to form one larger molecule.

Haematocrit: The percentage of blood accounted for by red blood cells.

Haemoglobin: Substance found in blood. Responsible for the transportation of gases, mainly oxygen, in the blood.

Hypertrophy: An increase in the size of muscle fibres.

Intensity: How hard you work.

Interval training: Several short bouts of high intensity work with rest periods in between.

Isokinetic resistance training: Dynamic contractions at a constant, controlled speed with the resistance against the muscle adjusted throughout the range of motion.

Isometric muscle contraction: Static contraction in which no change in muscle length occurs.

Isotonic (dynamic) muscular contraction: Contraction in which the length of the muscle changes, resulting in movement.

Lactate threshold: The exercise intensity where the aerobic system cannot meet the majority of the energy demands (when it cannot supply ATP for muscular work *and* remove accumulating lactic acid). As a result, an increase in blood lactate above resting levels occurs.

Lactic acid system (anaerobic glycolysis): Releases energy from the breakdown of carbohydrate (in the form of glucose or stored glycogen) to synthesise ATP in the absence of oxygen (an anaerobic process).

Maximal oxygen uptake ($\dot{V}O_2$max.): The maximum amount of oxygen that the body can consume.

Minute ventilation: Represents the amount of air in litres that is inspired each minute.

Mitochondria: Parts within a muscle cell where aerobic energy production (ATP) occurs.

Muscular endurance: The ability to perform repeated submaximal contractions without undue fatigue.

Muscular strength: The ability to exert force in a single, maximal effort.

Oxygen deficit: Represents the difference between the actual amount of oxygen consumed during exercise and the amount of oxygen that would have been consumed if oxygen consumption had increased instantaneously with the onset of exercise to immediately reach the required steady-state level.

Passive diffusion: Where a particular gas will move from an area of higher concentration to an area of lower concentration in order to attempt to reach equilibrium (to create an equal concentration in both areas).

Passive recovery: Requires complete rest.

Peak oxygen uptake ($\dot{V}O_2$peak): The highest $\dot{V}O_2$ achievable for that particular individual (that is not necessarily the highest physiological limit of their body).

Peripheral adaptations to training: Changes that occur at the level of the muscle in response to training.

Plyometrics: Resistance training that uses the weight of the body to apply overload in dynamic activities involving acceleration and deceleration of the body.

Power: The ability to perform a strong movement quickly (that is the rate at which work can be performed).

Progressive overload: Designing training activities that are harder, more intense or of a longer duration to stress the body to elicit a training effect.

Proprioceptive neuromuscular facilitation (PNF): Stretching in which the joint is stretched to the limit of its range of motion, followed by a resisted contraction in that position for three to six seconds and then a further stretch.

Pulmonary circulation: Circulation of blood between the heart and lungs.

Reaction time: The time taken from when a stimulus is presented to when the appropriate reaction is taken in response.

Repetitions: How many times you repeat an exercise.

Resistance training: Employs a variety of forms of resistance (opposition) to movement in order to overload the muscles.

Reversibility: Long-term physiological adaptations are not permanent and are easily lost without continued training.

Sets: How many groups of repetitions you perform.

Specificity: Undertaking training to meet the physiological needs of a sport or skill.

Speed: The ability to perform a movement quickly (that is within a short period of time).

Static stretching: Involves a slow, gradual stretch that is held for a prolonged period of time (twenty to sixty seconds) at the limit of the range of motion.

Steady-state oxygen consumption: A plateau in oxygen consumption indicating that oxygen delivery to the working muscle is at a sufficient level to provide adequate ATP production via the aerobic energy system.

Stroke volume: The volume of blood pumped with each beat of the heart.

Systemic circulation: Circulation of blood between the heart and body tissues.

Systolic blood pressure: The highest pressure at any one time on the arteries resulting from the pumping of blood into the aorta (the main artery connected to the heart).

Tidal volume: The amount of air moved during one cycle of inspiration.

Triglycerides: A molecule resulting from the combination of three fatty acids.

Type I muscle fibres (slow-twitch fibres)**:** Muscle fibres with aerobic characteristics (meaning they rely predominantly on the aerobic energy system to produce ATP for contraction).

Type II muscle fibres (fast-twitch fibres)**:** Muscle fibres with anaerobic characteristics (meaning they are well suited to producing ATP via anaerobic pathways).

Vasoconstriction: A reduction in the diameter of blood vessels.

Vasodilation: An increase in the diameter of blood vessels.

Veins: Blood vessels that carry blood away from the tissues towards the right side of the heart.

Volume of oxygen consumption ($\dot{V}O_2$): The volume of oxygen used by the body.


LEXUS CUP

Sport Psychology

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and Ms Monica Leslie

BACKGROUND INFORMATION

What is Sport and Exercise Psychology?

Imagine that you are playing in the AFL grand final. The game is intense and closely fought and your team trails by three points into added time. Then, just seconds before the final siren, you take a mark in the forward pocket. The result of the contest and the title now depend on your kick. Think how nervous you would feel. What would you be thinking? Would you be more likely to kick a goal from this position during a training session? Sport and exercise psychology is a field of study that deals with these types of questions, but the field is by no means limited to these questions. In fact, most people possess one of two objectives when studying sport and exercise psychology. Firstly, as indicated by the previous questions, people may wish to understand how psychological factors can influence performance in sport and exercise. Secondly, people may study this field to identify how performance in sport and exercise can influence a person's psychological development, health and wellbeing. This Background Information section focuses on the first of these objectives. That is, the influence of thoughts, emotions and past behavious on physical activity are discussed.

Factors to Consider when Preparing Mentally for Physical Activity

Text outcomes:
Preparing for physical activity

- *Factors to consider when preparing mentally for physical activity:*
  - *Personal attitudes*
  - *Behaviours*
  - *Values*
  - *Participation.*

Personal attitudes

Attitudes toward behaviour reflect the degree to which performance of the behaviour is considered to be positive or negative. Needless to say, attitudes toward physical activity are important in determining the likelihood that physical activity will be performed and

maintained. An athlete is unlikely to continue to participate in sport, for example, if they do not think positively about their participation. Given the importance of attitudes in predicting physical activity, a key challenge is to help people develop positive attitudes towards sport and exercise.

Behaviours

Behaviour influences our mental preparation for physical activity in a number of ways. For instance, athletes who might have low levels of confidence prior to competition can strategically act confidently, an approach that can serve two benefits. Firstly, acting confidently can influence our own confidence, and secondly, acting confidently can influence the confidence of our teammates (positively) and opponents (negatively). Please see our discussion of this issue in the section on self-confidence later in this chapter.

Values

Values are sets of beliefs or ideas that are considered to be important and they are powerful in preparing people for physical activity. Consider an athlete who strongly values sportspersonship. This value is likely to govern the athlete's choice of sport and continued participation in sport. It is likely that the athlete will be drawn to sports and teams in which etiquette is encouraged and cheating is discouraged. Golf is a sport that places emphasis on the participant valuing etiquette and honesty. As a second example, consider a person who values good health and an attractive appearance. This person is likely to participate in physical activity that provides these benefits. Triathlon, with a strong requirement for aerobic training, may be such a sport that appeals.

Participation

Our past participation strongly influences our mental preparation for sport. A forward in hockey who has failed to score in any of the last three matches is likely to feel anxious in the build-up to the next game. Conversely, a forward who has scored in each of the three previous games will feel confident and upbeat about the next contest. Past participation bears a strong influence on our exercise behaviour as well as our sport behaviour. Consider an overweight child who has been bullied during physical education at school. These experiences are likely to impact the child's enjoyment and confidence in future physical education classes.

Text outcomes: *Team building*

- *Identify skills and strategies required for team building:*
  - *Compromise*
  - *Commitment to group goals*
  - *Respect for others' values*
  - *Trust.*

Strategies to Influence Team Building

Unit 1APES offered an opportunity for you to see how the thoughts of team members can influence team performance. Team cohesion and performance is positively influenced when team members are able to compromise, commit to group goals, respect each others' values and trust each other. This next section provides a brief review of this material.

Compromise

Regardless of the size of a sport team or the similarities between its members, differences in opinion will always exist. Compromise is necessary in healthy marriages and

friendships, and it is necessary in sport teams, too. Wayne Rooney, who currently plays soccer for Manchester United and England, epitomises the selfless approach that is necessary in successful teams. Despite his preference to play as a striker, Rooney has consistently spoken about his willingness to play in any position. He has subsequently played in a number of positions and to great effect.

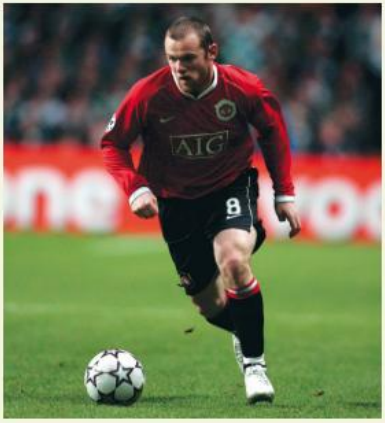


Figure 4.1: *Wayne Rooney – A team player*

Commitment to group goals

Problems exist if players do not commit to the goals of the team. Consider a basketball team with talented players who have developed a goal to win the championship. The performance of the team will be compromised if some of the players fail to commit to this goal. Perhaps some individuals pursue selfish objectives, such as increasing their average points per game. These players are likely to disrupt team cohesion and the team's ability to reach its goal. A traditional saying represents this concept: 'A champion team is likely to achieve more than a team of champions'.

Respect for others' values

Effective team building requires an environment in which members respect each others' values. Seeds of animosity between team members should not be planted, and respecting the values of teammates is important to avoid this process. It is generally thought that team cohesion is facilitated when team members are similar to each other (Carron, Hausenblas & Eys 2005), perhaps because players who are similar tend to embrace the same values. The important point, though, is that you don't have to share the values of your teammates, but it is important that you at least respect them.

Trust

Effective teams require an atmosphere of trust. Imagine that you have been elected as a spokesperson for your team and your teammates want you to approach the coach about an issue. How would you feel if your teammates did not support you on the issue in a subsequent team meeting with the coach? You would surely feel let down by your teammates. The need for trust extends into the playing arena, too. A basketball player is unlikely to lead a full-court press, for example, unless he/she trusts that teammates will support his/her efforts.

Text outcomes: *Improving performance*

- *Understand the role of mental skills in creating a mind-set to improve performance:*
  - *Knowing yourself and learning from feedback*
  - *Self-talk and self-belief*
  - *Mental imagery.*

Creating a Mindset to Improve Performance

How can you use psychology to improve your performance in your favourite sport? Unit 1BPES provided an introduction to this area by

highlighting the importance of the following factors on performance: knowing yourself and learning from feedback, positive self-talk and self-belief, and imagery.

Knowing yourself and learning from feedback

An honest appraisal of one's strengths and weaknesses is vital for performance. In the short-term, you will be able to focus on your strengths and limit the effects of your weaknesses during competition. In tennis, you might have a strong forehand but a very weak backhand. Your strategy in the short-term should focus on dictating points with your forehand and perhaps even 'running around' the court to prevent backhand shots. An honest appraisal of your strengths and weaknesses is also vital for skill development. In order to improve performance in the long-term, for example, it might be necessary to devote more time in training to the improvement of your weaknesses.

Many novice golfers may only experience a handful of good shots over 18 holes. But as these golfers go to sleep at night, you can bet that they will be re-living these good shots in their minds. Elite athletes often do this, too, but they also tend to be interested in what caused their bad performances. Learning from feedback is essential for improving performance and it is linked to an honest appraisal of one's strengths and weaknesses. In other words, an athlete who is honest in appraising their performances is likely to learn from the positive and negative feedback that is received from their appraisal.

Self-talk and self-belief

Many athletes engage in self-talk before or during a performance. Self-talk involves any internal or external dialogue with the self. In other words, the dialogue can be made inside your head or you can verbalise it and make it audible. Examples of positive self-talk include statements such as 'you can do this' or 'nice work'. Positive self-talk has the effect of increasing confidence (self-belief), and studies have shown that confident athletes are more likely to achieve success than less confident athletes. We will provide a more comprehensive discussion of confidence and self-talk later in this chapter.

Mental imagery

Close your eyes and imagine yourself shooting a free-throw in basketball. Think about your pre-shot routine, imagine the weight and feel of the basketball in your hands, see the ball in flight, and imagine the sight and sound of the ball as it passes through the net. Imagery, if used correctly, can be a powerful mechanism to boost confidence, enhance motivation and prepare the body for successful performance. Unfortunately, if we allow our minds to think of unwanted events, such as the basketball missing the ring, imagery can have adverse consequences on our confidence, motivation and performance. It is important that athletes attempt to use imagery in real-time. In the previous basketball example, your imagery experience from the pre-shot routine until the outcome of the shot should be of similar length to the time it would take if you had actually taken the shot. The topic of imagery will be discussed once more in a later section of this chapter.



Figure 4.3: *Kylie Wheeler, Australian heptathlete, performing mental imagery*



Figure 4.2: *A novice golfer*

Practical activity: *Testing the concept of imagery*

Tie a bolt to the end of a piece of string (about 60 cm long). Hold the string at one end so that the bolt dangles in the air, suspended by the string. Now rest your forearm over a table to stabilise your arm and wait for the string to stop swaying. Once the bolt is completely stationary and suspended in mid-air, focus your eyes on the bolt and vividly imagine it moving in a clockwise direction. Even though you are not consciously moving any muscles, you might find that the bolt moves in a clockwise direction. Psychoneuromuscular theory argues that, when we use imagery, our brain sends subliminal (below the level of consciousness) commands to our muscles and our muscles subsequently respond with movement.

Equipment:

- Piece of string (about 60 cm long).
- Bolt.
- Table.

Text outcomes: *Setting goals*

- *Understand how to set simple goals:*
  - *Short-term goals*
  - *Long-term goals*
  - *SMART (specific, measurable, achievable, realistic, timely) goals*
  - *Performance versus outcome goals.*

Class task: *Setting goals*

In small groups, discuss: Have you ever set yourself a goal or know someone who has set a goal? Did you or they successfully achieve what was being sought?

Unit 1CPES focuses on goal setting. This topic is very important because, for a variety of reasons, goals can help athletes to improve their performance. Goals are effective because they:

- direct attention to important elements of the skill being performed
- mobilise the performer's efforts
- prolong the performer's persistence
- foster the development of new learning strategies.

How to Set Simple Goals

The next section will review the goal-setting material from 1CPES.

Set long-term goals and short-term goals

Long-term goals are those goals that are not likely to be achieved in the near future. A 10-year-old boy, for example, might have a long-term dream to

play for the West Coast Eagles. ***Short-term goals*** can be used to help people achieve their long-term aspirations. It is useful to develop a goal-setting staircase that you can ascend step-by-step after achieving each short-term goal. The long-term goal is positioned at the top of the staircase. A short-term goal that the 10-year-old boy might like to pursue is to kick sixty goals in his upcoming junior season by increasing his set-shot kicking accuracy.

Set SMART goals

Specific — Goals should be specific rather than general and broad.

Measureable — An athlete should be able to measure goal accomplishment.

Achievable — } Moderately difficult goals are best.
Realistic — }

Timely — A timeframe for goal achievement should be identified.

An example of a SMART goal for an elite cyclist would be the following:
'I wish to finish the 106 km Great Perth Bike Ride this year in less than two and a half hours.'

This goal satisfies all of the components of the SMART acronym. It is ***specific*** because a time for completion is provided (under two hours). The goal is also ***measurable***–it will be easy to determine whether the cyclist has achieved his/her goal after the event. If the cyclist is reasonably strong, the goal might be perceived as moderately difficult (and therefore ***achievable/realistic***). Finally, a timeframe **(*timely*)** for goal achievement is implicit within the goal because the Great Perth Bike Ride will only occur on one date this year.

Class task: *SMART criteria*

Discuss: Would the goal listed above satisfy the SMART criteria for a novice cyclist? Why/why not? What would an alternative goal look like for the novice?



Figure 4.4: *Cyclist in preparation for the Great Perth Bike Ride.*

Set performance and outcome goals

Outcome goals focus on the competitive result of an event and achievement of them depends on the performance of others. A goal to win the school swimming tournament this year is regarded as an outcome goal because the performances of other swimmers will influence goal achievement. ***Performance goals***, on the other hand, focus on the achievement of a particular standard irrespective of the performance of others. A goal to run the City-to-Surf in one hour would represent a performance goal–its achievement does not depend on others.

Both outcome goals and performance goals can direct behavioural change and athletes are encouraged to set both types of goals. Nevertheless, athletes should also bear in mind that failure at outcome goals may not mean poor performance. In fact, if Jan Ullrich had only set outcome goals to win the Tour de France each year, he would've been extremely disappointed. Despite being one of the greatest cyclists of all time, Ullrich was unfortunate in that he finished five Tour de France races in second position–three of which were behind Lance Armstrong (who wsa subsequently disqualified for drug use).



Fig 4.5: *Jan Ullrich, five-time runner-up in the Tour de France*

Text outcomes:
Using goal setting

- *Use goal setting in coaching programs.*
- *Understand the links between goal setting and motivation when coaching others.*

Use goal setting in coaching programs to motivate athletes

Later in the chapter we will indicate that self-determined goals are important. This means that, wherever possible, athletes should have input into their goals so that they feel a sense of ownership towards them. This does not mean that coaches should not incorporate goal-setting programs into their training sessions. In fact, we strongly recommend that coaches spend a good deal of time helping their athletes to set goals. It is possible for the coach to offer guidelines on effective goals without compromising the athletes' ownership of their goals.

The setting of team goals as well as individual goals is important for sporting teams. During pre-season, it would be wise for coaches of team sports to overview the guidelines for effective goal setting with the whole team. The coach can then facilitate group involvement in the setting of team goals for the upcoming season. Both team goals and individual goals should then be reviewed and evaluated at multiple points throughout the season. This review and evaluation is important for a number of reasons. Firstly, some goals might need altering in response to unforeseen circumstances. Secondly, reminding athletes about individual and team goals can serve to increase motivation once again. Finally, periodic evaluation of goals is important because some goals may have been accomplished and should be rewarded.

Sport Psychology: ATAR Units 1 and 2

A similar approach is followed for each section of the curriculum for Units 1 and 2. Sections start with textbook-related learning outcome statements, followed by a dot-point box identifying the 'Content that follows' and the theory and application for each content area. Suggested class tasks and practical activities are embedded within the sections of the text. A 'Key point summary' box is presented at the end of each section.

Two practical investigations are included in this chapter and they are identified as Appendix B1 (Unit 1 content–Concentration: Attentional Focus) and B2 (Unit 2 content–Arousal, Motivation and Concentration and an Individual's Performance). A format for report writing can be located at the end of this chapter (Appendix A) to assist students with their preparation of the practical investigation. Marking matrices are also included in Appendix B1 & 2. Answers are provided for teachers only.

Revision questions (with answers) are included near the end of each chapter (Appendix C). A 'Glossary of key terms' appears in the final pages of this chapter (Appendix E).

At the end of the chapter titled 'Motor Learning and Coaching' is a 'Personalised project', which requires students to apply knowledge and understanding from Sport Psychology and Motor Learning and Coaching (Appendix D). Even if this task is not undertaken for assessment purposes, it provides a valuable tool for revision.

This chapter focuses on the impact of psychology on performance. We start by explaining the zone of optimal functioning model, which is a framework that can help you to appreciate the influence of emotion on performance. Our discussion then focuses on four factors that can influence athletes' emotions and therefore their ability to enter the 'zone'. These four factors are motivation, stress management and arousal regulation, concentration, and confidence. We will then discuss mental skills and strategies that can assist us to improve performance. Embedded within each separate section we will consider the influence of age,

Text outcomes: *Sport psychology (Units 1 and 2)*

- *Understand the mental skills required for improving performance and achieving the ideal performance state ('the zone') (Unit 1):*
  - *Intrinsic motivation*
  - *Arousal regulation related to individual performance*
  - *Inverted-U hypothesis*
  - *Stress management*
  - *Self-confidence*
  - *Concentration or attentional control.*
- *Understand the mental skills and strategies used to manage stress, motivation, concentration and arousal level (Unit 1):*
  - *Self-talk*
  - *Self-imagery*
  - *Relaxation.*
- *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 (Unit 2).*

skill level and the type of activity on mental skills. The final Unit 2 outcome related to goal setting concludes this chapter.

Content that follows:
The 'zone' (Units 1 and 2)

- *Individual zone of optimal functioning*

Individual Zone of Optimal Functioning

The individualised zone of optimal functioning model (IZOF; Hanin 1997) is a relatively recent framework that has been used to understand the influence of emotions on performance. A major premise of the model is that athletes are likely to differ in the extent to which emotions influence their performance. For instance, a high level of anxiety might be beneficial for one athlete but might be detrimental to another athlete. The IZOF model also indicates that optimal performance is thought to occur within a range of scores (bandwidth). Thus, performance is likely to be facilitated when an athlete's emotional state is within a range defined by a lower point and an upper point. Figure 4.6 displays zones for two athletes in relation to optimal levels of state anxiety. A sport psychologist could use the following procedure when applying ideas from the IZOF model.

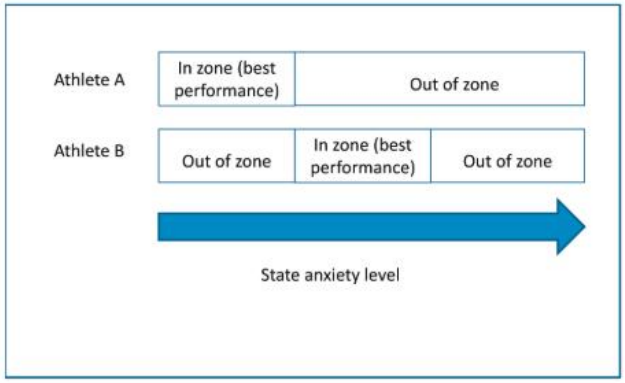


Figure 4.6: *Individual zone of optimal functioning (IZOF) for two different athletes*

Firstly, the athlete could be monitored over a series of games or events. Hopefully, for the purposes of the sport psychologist, the athlete will engage in some very good performances and some poor performances during this monitoring stage. After each competition, the athlete could be asked to report their thoughts and feelings they experienced before and during the performance. The psychologist could use questionnaire instruments that have already been developed to help capture this

Key point summary:

- The IZOF model proposes that individual athletes react differently to the same level of an experienced emotion.
- Optimal performance is more likely when the intensity of an athlete's emotion falls within a specific bandwidth that is right for him/her.

Practical activity: *Measuring your level of anxiety*

Table 4.1 offers an activity for assessing an athlete's level of state anxiety (Martens et al. 1990).

Equipment:

- Table 4.1.

information. For example, the psychologist could administer the Competitive State Anxiety Inventory-2 (Martens, Burton, Vealey, Bump & Smith 1990; see the Practical activity that follows) to measure anxiety, an emotion that will be discussed later. After analysing this information, the psychologist could help the athlete to develop zones of optimal performance for different emotions. The plotting of optimal zones for different emotions is a crucial first step in helping athletes to prepare for future performance.

Table 4.1: *Measuring levels of anxiety*

Complete the following questions just prior to taking part in a competitive event.
Please read each statement and then circle the appropriate number to the right of the statement to indicate how you feel at this moment. There are no right or wrong answers. Don't spend too much time on any one statement, but choose the answer that best describes your feelings.

	Not at all	Somewhat	Moderately so	Very much so
1. I am concerned about this competition.	1	2	3	4
2. I feel nervous.	1	2	3	4
3. I feel at ease.	1	2	3	4
4. I have self-doubts.	1	2	3	4
5. I feel jittery.	1	2	3	4
6. I feel comfortable.	1	2	3	4
7. I am concerned that I may not do as well in this competition as I could.	1	2	3	4
8. My body feels tense.	1	2	3	4
9. I feel self-confident.	1	2	3	4

How to score: For items 3, 6 and 9, change your score so that if you circled 1, give yourself 4 if you circled 2, give yourself 3; if you circled 3, give yourself 2; and if you circled 4, give yourself 1. Then tally all of the 9 items to give yourself an overall score of state anxiety.

A second crucial step is to equip athletes with the necessary skills to regulate their emotional states. In the next section, we overview four factors that can influence emotional states and therefore an athlete's ability to enter the 'zone'. The first of these is motivation.

Motivation and The 'Zone'

Content that follows:
Motivation and the 'zone' (Units 1 and 2)

- *Motivation: Intrinsic and extrinsic*
- *Motivation: Age, skill level, and type of activity*
- *Rewards*

Motivation

Motivation is an important concept to understand because there would be no behaviour without it. ***Motivation*** refers to the psychological factors that account for an individual's willingness to engage in particular activities. An understanding of motivation therefore helps us to appreciate the reasons why people behave the way they do and helps us to predict the likelihood of people performing a particular behaviour in the future. Moreover, an understanding of this area helps practitioners to develop strategies to increase people's involvement and performance in sport and exercise.

Motivation is often categorised according to whether it is intrinsic or extrinsic. ***Intrinsic motivation*** refers to the pursuit of an activity for the sake of the activity itself. In other words, intrinsic motivation reflects a desire to perform a behaviour because it is enjoyable and inherently satisfying. Two brothers who kick a football between themselves in a park are intrinsically motivated if they are undertaking this behaviour simply for fun. People are ***extrinsically motivated***, on the other hand, when they perform a behaviour for rewards other than those inherent in the activity. Perhaps the simplest form of extrinsic motivation is termed external regulation, which refers to the pursuit of an activity to obtain an external reward (for example a prize or trophy) or to avoid a punishment. Extrinsic motivation would be evidenced if two brothers kick a football together because they think that their parents will praise them for doing so.

Research has indicated that intrinsic motivation is associated with persistence in sport and exercise. People who engage in sport or exercise for intrinsic reasons are also more likely to derive satisfaction and wellbeing from their activity. In other words, people who are intrinsically motivated in sport or exercise are likely to participate longer in their activity and they are more likely to obtain psychological wellbeing as a result of this participation. Athletes who are extrinsically motivated often feel obligated

Key point summary:

- People who pursue an activity for the inherent satisfaction (enjoyment) that the activity provides are demonstrating intrinsic motivation.
- People use extrinsic motivation when they pursue a task for rewards other than inherent satisfaction.
- An athlete's current type of motivation can influence their emotions. It is therefore an important consideration when preparing athletes to perform within their zone of optimal functioning.

or controlled and their emotional profile prior to a competition is likely to be considerably different to those athletes who are intrinsically motivated. Type of motivation is therefore a key consideration when helping athletes to prepare for performance within their zone of optimal functioning.

The influence of age, skill level and the type of activity on motivation

Age and skill level

People can exhibit intrinsic or extrinsic motivation irrespective of their age or skill level. A young boy might thoroughly enjoy playing soccer in a field with friends, even if he hasn't played much soccer in the past. On the other end of the spectrum, it is likely that world-class players such as Lionel Messi also possess abundant amounts of intrinsic motivation.

Our point that experts and novices can both exhibit intrinsic or extrinsic motivation is valid, but it should be made in the context of another consideration. Intrinsic motivation tends to flourish when people feel competent at what they're doing, so you might expect highly skilled athletes to exhibit a stronger profile of intrinsic motivation than novice athletes, with all other things being equal. A problem with this conclusion is that all other things are rarely equal, and the environment surrounding highly skilled athletes is often very different to the environment surrounding amateur athletes. Highly skilled athletes might be more likely to find themselves in environments that do not satisfy other needs that are essential for intrinsic motivation. Feeling pressure from coaching staff and supporters, for example, might diminish intrinsic motivation among highly skilled athletes. Overall, research results indicate that the more *amateur* the level of sport, the more likely it is that athletes will possess intrinsic motivation.

Type of activity

You might be wondering whether people can be intrinsically motivated for all tasks. The answer to this question is 'no'. People will only be intrinsically motivated for activities that have interest to them, activities that have the appeal of novelty, challenge, or aesthetic value. It is important to note that intrinsic motivation is commonly experienced in sport and exercise and it is particularly apparent among participants in organised sport.

Key point summary:

- It is possible to possess intrinsic and/or extrinsic motivation, regardless of your age.
- Intrinsic motivation depends on satisfying needs such as competence, so developing a higher skill level may serve to increase motivation (so long as other needs are met).
- Intrinsic motivation is only possible for tasks that are perceived to be interesting, novel, challenging or to have aesthetic value.

Intrinsic motivation and rewards

Class task: *Intrinsic motivation and the impact of rewards*

Ask yourself the following and discuss with a partner: Do you think that people's long-term enjoyment of a task (intrinsic motivation) might be influenced by offering them rewards to engage in the task? Why/why not?

One of the most interesting aspects of studying people's motivation to participate in sport is the impact of external rewards on intrinsic motivation. In the past, it was commonly thought that intrinsic motivation and extrinsic motivation were additive and that the more motivation an individual possessed (extrinsic plus intrinsic) the better. This belief is no longer considered to be correct. A series of interesting studies have been undertaken to highlight a potential problem in offering rewards to people who enjoy a task. In a study by Lepper, Greene & Nisbett (1973), for example, nursery school children were allowed to engage in the enjoyable task of drawing. Prior to starting, some of the children were told that they would be given a reward (a good player certificate) for their drawing (expected reward condition). Other children in the experiment were not told this information before the drawing, but were rewarded with the certificate afterwards (unexpected reward condition). A third group of children were not given a reward after the drawing, nor were they told about a possible reward before the drawing (no reward condition). All of the children in the groups returned after an absence of one week and were given the opportunity to draw once again. This time, no mention of a reward was given to any of the children. The findings indicated that the children who had been in the expected reward condition spent less time drawing in the second free-time session, indicating that their intrinsic motivation may have reduced as a result of receiving an expected reward in the first session.

Revision questions:

Test yourself on revision questions 1–3 located at the end of this chapter.

Arousal and Anxiety

Content that follows:
Arousal and Anxiety (Unit 1)

- *Defining: Arousal and anxiety*
- *Arousal*
- *Anxiety: Cognitive and somatic anxiety. State and trait anxiety*

Defining arousal and anxiety

People sometimes use the terms ***arousal and anxiety*** interchangeably, but in this next section we will describe the differences between them. Arousal and anxiety are important considerations when preparing athletes for optimal performance. The zone of optimal functioning model, described earlier in this chapter, is often discussed within the literature on anxiety. In fact, the model is often applied to understand the potential impact of anxiety (as an example of an emotion) on performance. In this next section we discuss the concepts of arousal and anxiety and later in the chapter we discuss the concept of 'stress'.

Arousal

Arousal refers to a mixture of physiological and psychological activation. Think about your thoughts and feelings in the twelve hours prior to an important grand final. In the middle of the night as you sleep deeply, you will have very low levels of arousal. But as you sit in the changing rooms your mind is likely to be racing, thinking about your role in the team and whether you've run through the right pre-game preparation. You are likely to experience physical as well as psychological changes.



Figure 4.7: *A young netball player*

You might feel 'butterflies' in your stomach, you might notice some sweat on your brow and you might sense that your breathing has become shallow and fast. You are experiencing ***arousal***, a heightened activation of the mental and physical systems. It is important to note that arousal is not inherently associated with positive or negative events. Psychological and physical activation can be obtained in relation to your excitement about the grand final (a positive experience), or it can be associated with anxiety in relation to the grand final (a negative experience).

Key point summary:

- Arousal refers to a state of heightened psychological and physical activation.
- Arousal can stem from positive or negative events.

Anxiety

You may have noticed in the previous sentence that the term ***anxiety*** was used. ***Anxiety*** is a negative emotional state involving nervousness, apprehension and worry, and it is associated with arousal of the body. It is clear that anxiety and arousal are related, but they are also different. Anxiety is associated with a negative experience, but arousal can be associated with either negative *or* positive experiences.You might gather from our definition of anxiety that it consists of a thought component, which is often termed ***cognitive anxiety***, and a physical component, which is termed ***somatic anxiety***.

Class task:
State and Trait Anxiety

Sport psychologists also differentiate between two other types of anxiety:

1. State anxiety: refers to a changing mood state
2. Trait anxiety: refers to an enduring tendency to interpret events as threatening.

Someone with high trait anxiety is more likely to experience a heightened level of state anxiety when confronted with a given stressor.

With a partner, discuss what someone with high trait anxiety might be thinking about before an important game. How might these thoughts be different to those of an individual with low trait anxiety?

Table 4.2: *Definitions of anxiety*

Term	Definition
Cognitive anxiety	The degree to which one worries or has negative thoughts.
Somatic anxiety	A heightened state of physical activation.

What are some symptoms of high levels of state anxiety? Table 4.3 lists some common symptoms that are outlined by Weinberg and Gould (2007).

Table 4.3: *Symptoms of high state anxiety*

Cold, clammy hands	Need to urinate frequently	Profuse sweating	Negative self-talk	Dazed look in the eyes	Increased muscle tension	Butterflies in the stomach
Feeling ill	Headache	Dry mouth	Constant sickness	Difficulty sleeping	Inability to concentrate	Consistently better performance in non-competitive situations

Key point summary:

- Anxiety is a negative emotional state characterised by nervousness, apprehension and worry (cognitive anxiety), and it is associated with arousal of the body (somatic anxiety).

Arousal and Anxiety

Content that follows:
Arousal and anxiety (Units 1 and 2)

- *Arousal or anxiety and performance*
- *Inverted-U hypothesis*
- *Arousal: Age, type of activity, skill level, and individual differences*
- *Arousal influencing performance: Muscles and attention or vision*

The arousal or anxiety–performance relationship

Sport psychologists have been interested in establishing the relationship between arousal and performance for some time. About sixty years ago, drive theory was popular as an explanation of the effect of arousal on performance. Drive theory indicates that arousal increases the chance that a dominant response will be made. When performance errors are frequently made, such as when athletes learn a new skill, the dominant response is likely to be incorrect. Conversely, when the dominant response is correct, such as when an elite basketball player takes a free throw, arousal is likely to benefit performance. However, in recent times a number of frameworks have become more popular than drive theory, but perhaps the most widely used of these frameworks is the inverted-U hypothesis.

The inverted-U hypothesis

This hypothesis has its origins in the early work of Yerkes and Dodson (1908), who examined the ability of mice to differentiate between stimuli as a function of differing intensities of

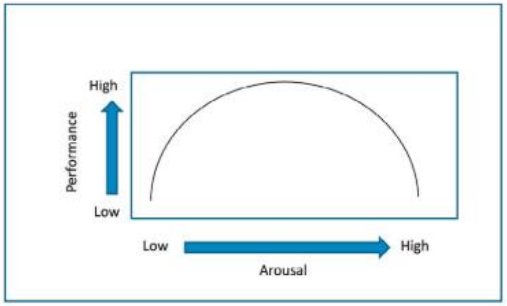


Figure 4.8: *The inverted-U hypothesis*

electric shock. They found that mice performed the task best under moderate levels of shock, thereby establishing a possible relationship between human performance and arousal. Sport psychologists have used the inverted-U hypothesis to speculate that athletes perform best when they experience a moderate level of arousal. In other words, performance will not be the best when athletes experience either very low or very high levels of arousal. To think about this relationship, imagine that you are attempting to shoot a free throw in basketball under extremely low or extremely high levels of activation. It is unlikely that you would perform the task well if you had only just woken from a deep sleep and felt lethargic (low arousal). It is also unlikely that you would perform the task well if you had just been told that you had won a $5 million lottery (highly aroused). You would be most likely to perform your best under moderate levels of arousal. This simple relationship is portrayed in Figure 4.8.

Key point summary:

- The inverted-U hypothesis indicates that performance is best when athletes experience a moderate level of arousal. Performance can suffer when arousal is above or below this level.

The influence of age, type of activity, skill level and individual differences on arousal

In reality, the arousal–performance relationship is a bit more complex than what is portrayed in Figure 4.8. Sport psychologists have recognised that four factors can potentially shift the inverted-U to the right or the left for different people and circumstances.

Age of the person

You might be wondering whether age influences the relationship between arousal and performance. In other words, does the influence of arousal on performance differ as people age? The straightforward answer to this is 'no'. With all other things equal, there is nothing inherent in age that influences the effect of arousal on performance. Nevertheless, people may develop or lose technical skills as they age and this might influence the arousal–performance relationship (please see our discussion of skill level in this section).

Type of activity

A premise of the inverted-U hypothesis is that task complexity influences the optimal level of arousal for performance. High arousal is likely to be beneficial for some tasks but not for others. Complex tasks, tasks that require fine motor skills or tasks that require information processing are likely to be performed best under low levels of arousal. Putting in golf would require low levels of arousal, for example, because it is a complex task that requires fine motor movements and a sense of 'feel'. Conversely, easy tasks, tasks that require gross motor movements, or tasks that require strength or endurance can be performed best under higher levels of arousal. A person

performing a bench press, for instance, would benefit from high arousal. In other words, the peak of the curve might be expected to shift right for the weightlifter but shift left for the golfer making a putt (see Figure 4.9).

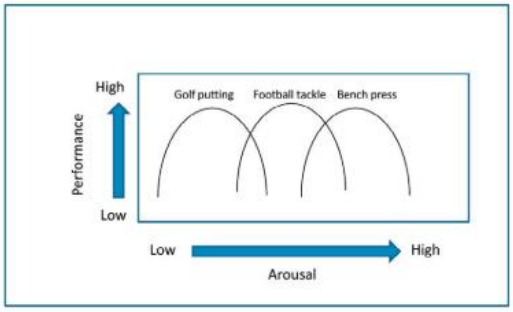


Figure 4.9: *Shifted inverted-U to reflect different types of activities*

perform best at relatively low levels of anxiety (by their own standards). The optimal level of arousal for performance is therefore likely to shift in accordance with individual dispositions relating to anxiety.

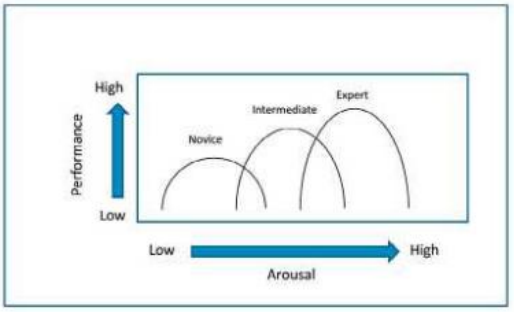


Figure 4.10: *Inverted-U for players with different levels of skill*

Skill level of the performer

Although there are some tasks that are undoubtedly more complex and difficult than others, the complexity of a movement is strongly influenced by the skill level of the performer. An adult is likely to be able to ride a bicycle and keep their balance without difficulty, but a child on training wheels is likely to experience great difficulty when converting to two-wheeled cycling. Consequently, less skilled performers generally require lower levels of arousal for optimal performance (see Figure 4.10).

Individual differences

It is obvious that people differ in their personalities and some of these stable dispositions influence the relationship between arousal and performance. Some people, for example, are anxious in their disposition, and a low level of anxiety by their standards might represent a moderate level of anxiety for other people. For a given task, a naturally anxious individual might

Key point summary:

- A number of factors can influence the relationship between arousal and performance, such as the nature of the task, skill level of the performer and individual differences.

How arousal influences performance

After discussing the factors that influence the relationship between arousal and performance, it is logical to ask; '*how*' arousal influences performance. Below we give consideration to this issue.

Arousal influences muscle tension, fatigue and coordination

When aroused, our body adopts a

fight-or-flight response that involves increased muscle tension. Within reason, this can be beneficial for some simple physical tasks that require strength (for example, weightlifting), but is likely to be bad if we want to perform difficult tasks that require fine movements, a high level of coordination, or a sense of 'feel' (for example, putting in golf).

Arousal influences attention and vision

You may be familiar with the phrase 'peripheral vision'. A netballer, despite looking at one teammate, may spot an onrushing defender in the corner of her eye and decide not to pass the ball. This decision to hold the ball and pass to a different teammate is made because of information obtained from her wide attentional field. Our field of attention is influenced by arousal, such that high levels of arousal narrow the field of information that is attended to (Figure 4.11). Consequently, arousal tends to be detrimental when athletes require a wide field of attention, but can be beneficial in sports in which a narrow focus is required.

Arousal also influences our visual search strategies. This means that an athlete who is highly aroused is likely to scan the playing environment less often. Tim, a cricketer who experiences high levels of arousal and state anxiety, has been asked to open the batting on his debut. When batting, many elite cricketers will choose to scan the changes in the fielding positions after every delivery or few deliveries. Tim, on the other hand, is likely to survey these positions less often and instead might become preoccupied with his attempt at one particular stroke (for example, through the covers). Tim may therefore miss opportunities to score runs in other areas and increases his chances of being dismissed.

Key point summary:

- Arousal influences performance by causing changes to muscle tension, fatigue, coordination, attention and vision.

Revision questions:

Test yourself on revision questions 4–7 located at the end of this chapter.

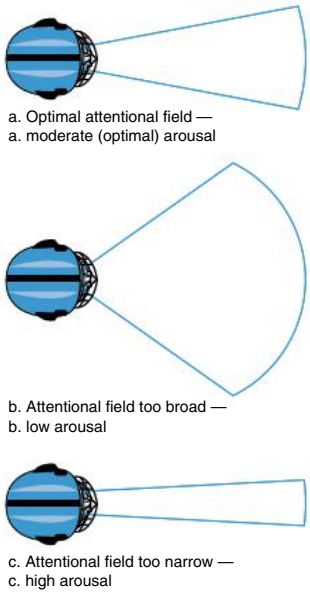


Figure 4.11: *Showing how the field of attention is influenced by arousal*

The 'Zone': Reducing Arousal and Anxiety

Content that follows:
The 'zone': Reducing arousal and anxiety (Unit 1)

- *Arousal regulation*
- *Reducing somatic anxiety: Relaxation and breath control*
- *Reducing cognitive anxiety: Autogenic training and thought stopping*
- *Multimodal anxiety reduction: Stress inoculation*
- *When to reduce arousal*

Arousal regulation

Do you remember the difference between arousal and anxiety? Anxiety refers to a negative emotional state involving arousal of the body. The term arousal, however, can be associated

with positive or negative experiences. In this next section we discuss strategies that are often used to regulate anxiety. Bear in mind, though, that many of these techniques are useful for regulating arousal generally. Thus, they could be used to change the state of an athlete who is overly excited and enthusiastic as well as an athlete who is apprehensive and worried.

Class task: *Modifying arousal*

Ask yourself the following and discuss with a partner: Have you ever tried to energise yourself? What did you do and was it successful?

Have you ever tried to relax yourself? What did you do and was it successful?

Practical activity: *The impact of muscle tension*

Lay your forearm on a table with the palm of your hand facing the table. Tense all of the muscles in your hand and wrist and then try to tap your index and middle fingers back-and-forth as quickly as possible. After performing this action for about ten seconds, relax the muscles in your hand and wrist and attempt this movement once again. You will probably notice that you performed faster in the second condition, when your muscles were relaxed. This is because muscle tension slows movements and makes them less coordinated.

Equipment:

- Table.

As we have learnt in a previous section, anxiety consists of a physical component (somatic) and a psychological component (cognitive). As well as leading to muscle tension, athletes who are anxious often experience inappropriate thoughts. For example, some anxious students might worry before a fitness test about whether they have trained enough for the fitness component being tested. In general, individuals are likely to experience a high level of somatic anxiety when they experience a high level of cognitive anxiety. However, the relationship between the two is not necessarily perfect and many arousal reduction strategies focus more specifically on either cognitive or somatic anxiety. Other strategies are multimodal and focus on both types of anxiety.

Reducing somatic anxiety

We will begin this section by discussing some techniques that can be used to focus on the somatic component of anxiety. These techniques are useful for reducing the physical symptoms of anxiety, such as muscle tension and fast, shallow breathing.

Progressive relaxation

This technique requires the performer to tense and relax the muscles of the body in a set order. The idea is to focus on the different sensation between the relaxed and tense states. After practising this technique over time, athletes learn to detect tension in areas of their body and can subsequently relax that area. Athletes may spend about thirty minutes performing this technique in the early learning stages, but once learned, athletes are able to utilise this technique in short breaks during games.

Breathing control

Many professional basketball players have developed a pre-shot routine to facilitate their performance on the free-throw line. Despite incredible variation from player to player, a feature of many of these routines is a deep breath

prior to shot execution. There is a good reason for this. Exhalation relaxes the muscles and centres the athlete's attention for performance.

Breath control is perhaps a more commonly used tactic to reduce anxiety than progressive relaxation. Although it can indirectly reduce cognitive anxiety, its focus is on reducing physical tension and it is therefore classified as a somatic anxiety-reduction technique. When you are confident and in control, your breathing will be smooth, deep and regular. When you are anxious, your breathing is likely to be shallow and irregular.

Australian heptathlete, Kylie Wheeler (dual Olympian and dual silver medallist in the Commonwealth Games), used breathing techniques before some of her events. Before running the 800 m event, for example, Kylie strategically focused on breathing patterns in which she imagined inhaling blue air and exhaling red air. Perhaps a focus on these specific colours reflected a desire to calm the body and expel feelings of anxiety.

Reducing cognitive anxiety

The next section deals with strategies that are useful for controlling thoughts related to worry and apprehension. You'll see that one of the techniques listed under this section, autogenic training, requires a mental focus on physical symptoms. You might subsequently wonder why this technique is included in the section on cognitive anxiety rather than somatic anxiety. The answer is that autogenic training is useful for ridding the mind of anxiety-related thoughts and it is therefore appropriately regarded as a cognitive anxiety-reduction technique.

Autogenic training

Autogenic training is a form of self-hypnosis that requires a mental focus on sensations in the body. This strategy takes months of daily practice, so it is less commonly used than other anxiety reduction techniques. There are six thought stages to successful autogenic training:

- Heaviness in the extremities
- Warmth in the extremities
- Regulation of cardiac activity
- Regulation of breathing
- Abdominal warmth
- Cooling of the forehead

The athlete can use a series of self-statements to help himself/herself to experience these states. Such statements might include 'my right leg is heavy', 'my right arm is warm', 'my breathing is slow, calm and relaxed', and so on.

Practical activity: *Breath control*

To practise breath control, take a deep breath by first filling the lower part of your lungs. Push your stomach out and feel the lower portion of your lungs expand. Once this section is full, try to fill the middle portion of your lungs by filling the section beneath your rib cage. The sensation of your rib cage pushing outwards is a sign that this portion of the lungs is filling. The final section of the inhalation requires you to fill the top portion of your lungs. Your shoulders might lift slightly during this stage. It is important that you exhale slowly. In fact, a 1:2 ratio of inhalation to exhalation is recommended as a mechanism to strengthen the relaxation response. So, your exhalation would be eight seconds if you spent four seconds inhaling.

Equipment:

- Clock.



Figure 4.12: *Figure of basketball player using breath control*

Table 4.4: *Autogenic training program*

1.	Locate a quiet room or environment where you will not be disturbed.
2.	Find a comfortable area where you can sit or lie down on your back.
3.	Close your eyes and put away thoughts of the outside world.
4.	Engage in some deep breathing to help you to relax.
5.	Each time you exhale, ***feel*** the tension being expelled from your body.
6.	Once you start to feel relaxed, begin suggesting to yourself that your limbs are beginning to feel heavy.
7.	'My right arm feels heavy', 'my left arm feels heavy', 'both of my arms feel heavy', 'my right leg feels heavy', 'my left leg feels heavy', 'both of my legs feel heavy', 'my arms and legs feel heavy'.
8.	'My right arm feels warm', 'my left arm feels warm', 'both of my arms feel warm', 'my right leg feels warm', 'my left leg feels warm', 'both of my legs feel warm', 'my arms and legs feel warm'.
9.	'My chest area feels warm and my heartbeat feels slow and regular.'
10.	Focus for a few minutes on your heart rate. Keep repeating to yourself that your heartbeat feels slow and regular.
11.	Focus for a few minutes on your breathing. Keep repeating to yourself that your breathing feels calm and relaxed.
12.	Repeat several times: 'My stomach area feels warm'.
13.	Repeat several times: 'My forehead feels cool'.
14.	Imagine that you are on a warm, sandy beach with your eyes closed and enjoying the warmth from the sun. Repeat relaxing statements to yourself, such as 'I feel quiet', 'I feel warm and relaxed', or 'My mind is at ease'.

Practical activity: *Autogenic training program*

Table 4.4, adapted from Cox (2002), offers a class activity for an autogenic training presentation.

Equipment:

- Table 4.4.

Thought stopping

When anxious, many athletes find it difficult to control the negative self-talk in their minds. 'What if I make a fool of myself in front of the spectators'? 'I've got a bad feeling about today'. 'I bet I'll get substituted after only a few minutes on the court'. Thought stopping is a technique that helps athletes to cope with this type of negative self-talk. It can be used in the lead-up to games or during gaps in play. The idea is to

use a word or a physical cue, such as a pat on the hip, whenever a negative thought comes to mind. This cue should then be followed by an attempt to reframe the negative thought into a positive one. Thought stopping could be used by a tennis player, after losing an important point. As soon as a negative thought enters the mind of the player, he/she could pat himself/herself on the hip and then engage in positive self-talk. After the pat on the hip, the player could think 'let's stay focused, I know I can win this'. Kobie McGurk, who represented Australia in hockey at the Beijing Olympics, uses cue words such as 'footwork' and 'follow through' to improve her performance during games.



Figure 4.13: *A tennis player using a physical cue (pat on the hip) to stop negative thoughts*

Multimodal anxiety reduction techniques

The techniques in the previous two sections focus more strongly on either cognitive or somatic anxiety. Multimodal techniques offer a more comprehensive opportunity to reduce anxiety as they focus on both cognitive and somatic anxiety. They therefore equip the athlete with skills to deal with a wide variety of stressors. One such technique is termed stress inoculation training.

Stress inoculation training

If a venomous snake ever bites you, you are likely to be given antivenin to counter the effect of the snake's poison. Antivenin is created by injecting small doses of snake venom into a horse. The horse subsequently develops antibodies, which enable it to tolerate increasing doses of venom. After increasing the dosage of venom that is injected into the horse, the antibodies that the horse has developed are extracted and used as antivenin in humans. This type of strategy bears resemblance to stress inoculation training. In this technique, athletes are taught methods to cope with demands and are then exposed to stress in increasing amounts. By learning to cope with low levels of stress, athletes become equipped with the necessary resources to deal with moderate and, subsequently, large amounts of stress. Stress inoculation training could be used with players from a soccer team to prepare them for penalty kicks. After being taught some coping techniques, the players could use the techniques in a variety of situations. At first, the techniques could be used in a relatively stress-free context, such as while taking penalties after training. Then, the techniques could be used in a penalty kick competition among teammates during training. Finally, the techniques could be used in games and in penalty shoot-outs.

Key point summary:

- Techniques to reduce anxiety can focus more specifically on cognitive anxiety or somatic anxiety.
- Multimodal techniques focus equally on both cognitive and somatic anxiety.

Table 4.5: *Anxiety reduction techniques*

Anxiety reduction techniques	Focus	Description
Progressive relaxation	Somatic anxiety	A technique involving tension and then relaxation of muscle groups.
Breathing control	Somatic anxiety	A strategic focus on taking a deep breath followed by slow exhalation.
Autogenic training	Cognitive anxiety	A series of exercises designed to produce sensations, especially related to warmth and heaviness.
Thought stopping	Cognitive anxiety	Involves the use of a cue or trigger to stop a negative thought and clear it from the mind.
Stress inoculation training	Multimodal	A training technique in which coping mechanisms are learned and are then applied in increasingly stressful situations.

When these techniques should be used

We could write an entire book on methods to reduce cognitive and somatic anxiety, but a few examples are sufficient for your understanding at this point. You might now be wondering about the most appropriate time to use these various techniques. Are there certain circumstances in which some methods are likely to be more effective than others?

Prior to a competitive event, as a first priority, it is necessary for an athlete to be receptive to their current level of anxiety or arousal and to understand the level of arousal that they require for optimal performance. Please see our discussion on the individualised zone of optimal functioning for more information on this idea. It can be detrimental to performance if an individual applies anxiety or arousal reduction techniques when they actually need to increase their level of arousal.

Assuming that an athlete does indeed need to reduce anxiety, which of the many anxiety reduction techniques should be used? Sport psychologists are still interested in this question and a significant amount of research has been conducted on it. In general, it has been proposed that cognitive anxiety should be treated with mental relaxation, whereas somatic anxiety should be treated with physical relaxation (Weinberg & Gould 2007). However, a crossover effect has commonly been found, such that cognitive anxiety reduction techniques

can also reduce somatic anxiety and vice versa. This crossover effect is partially due the fact that since cognitive anxiety and somatic anxiety are related, when one increases (or decreases), the other is likely to also increase (or decrease).

Key point summary:

- In general, cognitive anxiety should be reduced with mental relaxation, whereas somatic anxiety should be reduced with physical relaxation.

Revision questions:

Test yourself on revision questions 8–12 located at the end of this chapter.

Increasing Arousal and The 'Zone'

Content that follows: *Increasing arousal and the 'zone' (Unit 1)*

- *Increasing arousal*
- *Acting energised*
- *Using upbeat music*
- *Energising imagery*
- *Positive self-talk*

Increasing arousal

One implication of the inverted-U hypothesis is that athletes can be under-aroused or over-aroused. We have introduced some strategies to reduce levels of arousal, strategies that should be used when we are too stimulated to perform at our optimal level. In this section we briefly discuss some strategies that can be used to increase our arousal. Sometimes you might feel lethargic, unable to concentrate and/or heavy in the legs. It might be appropriate at these times to act energised, listen to upbeat music, use energising imagery, or use energising positive self-talk.

Acting energised

Walking at a fast pace and with a swagger before a game can serve to increase both confidence and arousal. Acting as if you are energised helps to provide you with the natural energy that you are seeking. Sometimes you might see some athletes pacing the changing rooms with their eyes focused on the ground. It is highly likely that they are attempting to increase their level of arousal by acting energised. Kobie McGurk, a current member of the Hockeyroos, uses this technique prior to games to increase her levels of activation.

Listen to upbeat music

There is little doubt that upbeat music can provide us with enthusiasm and energy. Many athletes use music players prior to competition as a method to increase arousal. Never underestimate the power of music–studies in



Figure 4.14: *Kylie Wheeler, Australian heptathlete, using music to increase arousal*

consumer behaviour (Milliman 1982) have found that supermarket music influences the rate at which people shop and the amount they buy! Music is clearly important in influencing our behaviour and our levels of energy, but it has to be the right type of music. Kylie Wheeler (dual Olympic heptathlete; Figure 4.14) identified *Eye of the Tiger* as her song of choice for increasing her arousal level in preparation for the shot put.

Practical activity: *Using music to influence arousal and the performance of a simple, gross motor task.*

With a piece of a chalk in your writing hand, stand next to a wall with the hand holding the chalk next to the wall. Jump as high as you can and place a mark of chalk on the wall at the top of your leap. After this, use some earphones to listen to some loud, upbeat music that you like. While you are listening to this music, imagine yourself performing an explosive leap and outperforming your first effort. Perform a second jump with the chalk after the song has finished. Was your second jump higher than the first? Could a change in arousal account for the performance outcomes?

Equipment:

- Chalk.
- Earphones, iPod.
- Up-beat music.

Use energising imagery

One of the authors of this chapter used to play soccer in the state league of Western Australia. A method that he used on a regular basis to increase arousal was to pace the changing rooms, imagining himself performing a vigorous tackle in midfield and swinging defence into attack. In fact, the effectiveness of this technique at increasing his soccer performance was the main reason that he chose to study sport psychology at university! A tip for using this technique is to use as many of the senses as possible. When you picture yourself making a tackle, for example, also try to 'feel' the tackle and 'hear' the tackle.

Some athletes like to use imagery as if they are seeing their own performance through their own eyes. Kylie Wheeler, an Olympic heptathlete, is an example of a high-level athlete who frequently uses this type of imagery. Others prefer to 'see' their performance through the eyes of others (for example, spectators). These two different styles of imagery are termed internal and external imagery, respectively. Some athletes, including numerous Olympic athletes, use both types of imagery.



Figure 4.15: *Player acting energised before a game*

Practical activity: *Using self-imagery*

Sit quietly, you may wish to close your eyes. Concentrate on creating a vision of you executing a skill within your favourite sport. One after the other, try using internal imagery (seeing your own performance through your own eyes) and then external imagery (see your performance as a spectator). Discuss your experiences with a classmate.

Equipment:

- None.

Use positive self-talk

Positive self-talk can provide athletes with energy for performance. Phrases such as 'get tough', 'go hard' and words such as 'fight'

and 'push' can help to move the athlete away from an under-aroused state. Consider the numerous examples of positive self-talk in sport. Lleyton Hewitt's famous catch-cry of 'come on' is clearly energising to both himself and his fans and he seems to use this phrase in key situations to spur him on to victory. It is important to note that self-talk does not need to be heard by others. In fact, it can be silent to others, but as long as it is heard in your own mind then you are likely to draw benefit. When you watch Serena Williams prepare to serve in tennis you will sometimes see her lips move very slightly. She is clearly engaging in a type of self-talk that nobody can hear.



Figure 4.16: *Lleyton Hewitt with his famous catch-cry*

Key point summary:

- Techniques such as listening to up-tempo music, acting energised, using energising imagery and engaging in positive self-talk can increase arousal.

Revision questions:

Test yourself on revision question 13 located at the end of this chapter.

Table 4.6: *Strategies for arousal modification*

Potential strategies to use for under-aroused and over-aroused athletes	
Under-aroused	**Over-aroused**
Act energised	Progressive relaxation
Listen to upbeat music	Breathing control
Use energising imagery	Autogenic training
Use positive self-talk	Thought stopping
	Stress inoculation training

The 'Zone': Stress

Content that follows: *The 'zone': Stress management (Unit 1)*

- *Stress*
- *Environmental and perceptual demand*
- *Stress response*
- *Behavioural consequences*
- *Stress management: Coping with stress*

Stress

For the purpose of differentiating stress from arousal and anxiety, you can consider anxiety to be part of a stress process. Arousal and anxiety often result as a consequence of an athletes perception of threat. ***Stress*** is often defined as a process in which there is perceived to be a substantial imbalance between demand and response capability, under conditions where failure to meet that demand has important consequences. In other words, stress involves a demand, a perception of the demand relative to available resources, and a sense that failure to meet the demand has important consequences.

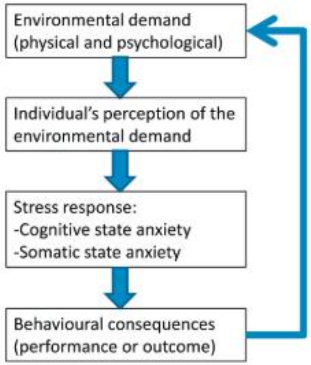


Figure 4.17: *The stress process (McGrath 1970)*

Class task: *The Stress Process*

An athlete's experience of anxiety represents one stage of the stress process (McGrath 1970). In your class, break up into small groups and discuss a sporting example in which each of the following stages of the stress process can be observed:

- Stage 1: An environmental demand is placed on the athlete, requiring them to perform under a particular set of circumstances.
- Stage 2: The athlete's perception of the environmental demand will determine their stress response. This process is largely determined by whether or not athletes believe they have the necessary skills required to meet the environmental demand.
- Stage 3: The athlete experiences a stress response, which consists of both psychological worry (cognitive state anxiety) and physiological arousal (somatic state anxiety).
- Stage 4: The athlete produces behavioural consequences, in the form of sport performance. The success of the athlete's performance will depend upon both the stress response experienced, and the athlete's ability to cope with anxiety.

Key point summary:

- Stress is a process in which athletes come to perceive a substantial imbalance between demand and response capability, under conditions where failure to meet that demand has important consequences.
- Arousal and anxiety can result from an athlete's perception of threat.

Stress Management

In our definition of stress, we have just highlighted 3 key components of the stress process:

1. An environmental demand
2. The perception that this demand exceeds available resources
3. The belief that failure has important consequence

As mentioned above, the perception of threat can often lead athletes to experience high levels of arousal and anxiety.

Therefore, in order to better manage stress, athletes can use techniques that impact on the stress process at any of these levels. For example, an athlete may choose to compete in the same division for a second year if they feel that they are not equipped for the intensity of a higher-level division. This decision would therefore reduce the environmental demands placed on an athlete.

An athlete may use self-talk to talk themselves into, or out of, participation in a particular sporting activity. Therefore, self-talk can affect an athlete's experience of stress via its impact on the athlete's choice of sporting activities.

Athletes also have the potential to influence their experience of stress by altering their perceptions of the situation. For example, an athlete may use positive self-talk containing phrases such as, "I can do this." These phrases can be beneficial in helping athletes to convince themselves that their abilities are sufficient to meet environmental demands. Self-imagery that incorporates the visualisation of successful sporting performance can also be used by athletes to convince themselves that successful performance is within their grasp, which reduces the perception of threat.

An athlete can also use relaxation techniques in order to return their body to their personal ideal performance state. Bringing the body to a state that is more conducive to effective performance may also contribute to an athlete's belief that they are capable of meeting the demands of a sporting activity.

Intervention strategies can also be used to temper the belief that failure has important consequences. While athletes are encouraged to take competitions seriously so that they are motivated to work hard, some over-motivated and naturally anxious athletes may place too much importance on their performance (magnifying and catastrophising). These thought processes involve considering all of the worst possible outcomes of poor performance and inflating the consequences of failure. Such over-motivated athletes may benefit from self-talk exercises in which the athletes generate more realistic perceptions of the threat posed by an event. For example, an over-motivated athlete might say to himself, "Even if it doesn't go the way I want, it's not the end of the world," or, "My team will still support me as long as I try my best."

Finally, athletes may also use the arousal regulation techniques described in the 'Arousal' section to manage the anxiety that often results as an outcome of the stress process. Many of these techniques involve the use of personal relaxation in order to relieve cognitive and/or somatic anxiety.

Key point summary:

- Athletes can use techniques such as self-talk, self-imagery and relaxation to intervene at each level of the stress process.

Class task: *Coping with Stress*

Methods for coping with stress have been categorised into two basic types: ***problem-focused coping methods and emotion-focused coping methods***. Problem-focused methods involve managing the issue that is causing the problem, while emotion-focused methods involve regulating our response to a problem (e.g. using relaxation techniques to reduce anxiety). In general, problem-focused coping methods tend to be more effective when the athlete has control over the situation that is causing them stress, while emotion-focused methods are more appropriate when a stressor cannot be changed.

In small groups, describe a time when you used a problem-focused method to cope with stress. Can you think of another situation in which an emotion-focused coping method might be more appropriate?

Revision questions:

Test yourself on revision questions 14–17 located at the end of this chapter.

Self-confidence and The 'Zone'

Confidence

For many years prior to 1954, sportswriters wondered whether the running of a mile in less than four minutes was possible. Of course, many athletes tried to accomplish the feat and some even came very close to achieving it. Runners obtained times of four minutes and three seconds and even four minutes and two seconds, but the four-minute mile was a barrier that seemed difficult to break. When Roger Bannister broke the four-minute time for the mile in 1954, any doubts about the possibility of this accomplishment were erased. What is interesting, though, is that in the year after the four-minute mile was broken, more than a dozen other athletes accomplished the same feat. Could this be a case of confidence

Content that follows: *Self-confidence and the 'zone' (Unit 1)*

- *Confidence*
- *Self-confidence and self-efficacy*
- *Sources of self-confidence:*
  - *Performance*
  - *Observing others*
  - *Persuasion*
  - *Emotions*
- *Improving self-confidence:*
  - *Performance*
  - *Acting confident*
  - *Self-talk*
  - *Imagery*
  - *Planning and preparation*



Figure 4.18: *Sir Roger Bannister breaking the four-minute mile*

influencing success? ***Confidence***, which refers to our expectations about success, strongly influences performance, but what is the nature of the relationship between confidence and performance?

Confidence is usually a wonderful attribute for athletes to draw upon–it reduces anxiety and influences concentration, emotions, goal setting and persistence at tasks. In most cases, confidence is beneficial for performance, and

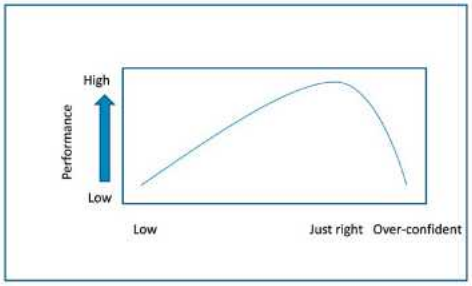


Figure 4.19: *Relationship between confidence and performance*

most sport psychologists tend to work on increasing confidence among athletes.

Confidence is good when an athlete feels that they will succeed if they work hard at their pursuit, but there are occasions when confidence can be detrimental. These situations occur when athletes are so confident, that they think they don't have to try hard to win. Complacency can set in with athletes (and teams) that are overly confident and performance can suffer as a result of this complacency. The relationship between confidence and performance is sometimes drawn as a skewed inverted-U (Figure 4.19).

It is clear that expectations for success are usually beneficial for performance. The positive expectations of others are also likely to benefit an athlete's performance. A classic study by Rosenthal and Jacobson (1968) has provided strong support for this idea. In their study, Rosenthal and Jacobson told teachers that results from an academic ability test had identified some pupils who were likely to make significant academic gains over the next year. In reality, the pupils that had been identified were selected at random, but the teachers did not know this. At the end of the school year, the pupils that had been identified by the researchers had achieved greater performance gains. What could be the reason behind this finding? By using video cameras in the classrooms, it was noticed that the teachers changed their behaviour towards the students identified as 'bloomers'. The positive expectations of the teachers may have led the teachers to provide more attention, reinforcement and instruction to the identified students, which may have subsequently facilitated the students' performance.



Figure 4.20: *Student–teacher interaction*



Figure 4.21: *Lauren Jackson, successful Australian basketball player*

Self-confidence and self-efficacy

When we talk about being ***self-confident*** we can also talk about self-efficacy. ***Self-efficacy*** refers to an individual's belief that they can successfully undertake a particular behaviour to produce a given outcome (Bandura 1997). In other words, it is a situation-specific form of self-confidence. In the present chapter, however, the terms self-confidence and self-efficacy will be used interchangeably.

Self-confidence and self-efficacy influence (Bandura 1997):

- the activities that individuals approach
- the effort expended on those activities
- the degree of persistence in the face of failure or adversity.

An abundance of research in sport and exercise psychology has subsequently provided support for these ideas. In fact, recent research indicates that ***confidence*** is the factor that most consistently distinguishes highly successful

from less successful athletes.

Sources of self-confidence

Self-confidence is influenced by four primary sources of information (Bandura 1986). These sources are:

- performance accomplishments
- vicarious experiences
- verbal persuasion
- physiological and emotional states

This next section discusses each of these. sources of self-confidence in turn.

Performance accomplishment

Successful performance of a given behaviour in the past is a fantastic source of self-confidence and self-efficacy. You are likely to possess a high amount of confidence for a three-point shot in basketball, for example, if you have recently executed a series of three-point shots in a game situation. Of course, past performance accomplishments are likely to be particularly influential on self-efficacy when the behaviour to be performed is similar to past behaviour. It is also likely to be more influential when the previously performed behaviour has been executed in the recent past rather than the distant past.

Vicarious experience

Vicarious experience involves the observation of similar people performing behaviour successfully and without adverse consequences (known as social modelling). Essentially, people persuade themselves through watching other people perform a given behaviour that they too can execute the action. The influence of this type of information on confidence is determined by the perceived similarity between the individual and the model on relevant dimensions. If a 10-year-old boy observed a friend, who he thinks shares a similar skill level to himself in Australian Rules football, successfully execute a 'banana' kick into the goal, he might derive self-confidence in relation to his own ability to perform this task. The self-confidence derived from this situation is likely to be stronger than that derived from watching a player of a different skill level, such as Steve Johnson, perform the kick.

Figure 4.22: *Steve Johnson executing a difficult shot in AFL*

Verbal persuasion

A



third source of self-confidence is verbal persuasion. Confidence can be obtained through a process of suggestion, such that people can obtain beliefs about their own ability to perform a task based on verbal information from other people. This source of information is more likely to be influential when the person providing the information is deemed as possessing expert knowledge. Additionally, positive self-talk represents another form of verbal persuasion that can be used to influence self-confidence.

Physiological and emotional states

Another source of efficacy information involves the interpretation of physiological states. Athletes might associate some physical symptoms (such



Figure 4.23: Player–coach interaction

as a racing heartbeat) with poor performance and failure. Other athletes might associate the very same physiological symptoms with good performance and success. As a consequence of these associations, an athlete might develop or lose confidence about an upcoming event in the presence of certain physical feelings.

Emotions or moods can also influence self-confidence. Athletes who experience positive emotional states prior to a game, such as vigour and happiness, are more likely to feel confident than athletes who experience negative emotional states, such as depression. An athlete who becomes disillusioned about being omitted from the starting line-up is likely to lose more confidence than another substitute who does not experience such disillusionment.

Improving self-confidence

In this next section we detail some common methods to increase confidence.

Key point summary:

- Confidence reduces anxiety and influences concentration, emotions, goal setting and persistence levels.
- Highly successful athletes generally have more confidence than less successful athletes.
- Self-confidence and self-efficacy are primarily influenced by:
  - performance accomplishments (having done it well)
  - vicarious experience (watching others)
  - verbal persuasion (being encouraged by others and oneself)
  - physiological (how you physically feel at the time) and emotional states (your mood at the time).

Focus on performance accomplishments

We have already indicated that past performance is one of the most important contributors to self-confidence and self-efficacy. It may seem difficult to use this tactic for teams or athletes who are experiencing a losing streak, but there are usually rays of light in most teams. Sometimes an outcome (win/loss) was not what a coach had hoped for, but elements in the performance can still be satisfying. It is important to recognise the positives among a team or an athlete to build confidence, or at least minimise the damage to it.

Acting confidently

Acting confidently is an important tactic to build self-confidence, but conveying a sense of confidence might also be beneficial at reducing the confidence of opponents. When we feel confident, our heads tend to be held high, our shoulders are pushed back and we possess a 'spring' in our step. Acting these behaviours can stimulate our mind into thinking that we are confident and can also serve to reduce the confidence of competitors.

In one study (Greenlees, Bradley, Holder & Thelwell 2005), participants were asked to view images of table tennis players in either table tennis sportswear or in general sports clothing. The players also differed according to whether they were acting confidently or not. Participants were not aware of the intention of the research and were not told about the differences between the experimental conditions. After asking the participants about their expectations for success if they were to play against the people in the images, the researchers found interesting results. More specifically, participants were not as confident in their chances of success against opponents wearing table tennis clothing or against

opponents portraying positive body language.

Positive self-talk

Eliminating negative self-talk and engaging in positive self-talk can generate confidence. Statements such as "I know I can win", "I'm confident" and "I have the ability", can be automatically programmed into athletes if they are repeated enough. These self-statements can provide an effective and efficient boost to confidence if an athlete starts to doubt themselves before or during competition.

Imagery

Imagery involving effective performance can be used to build confidence. Prior to executing a tee shot, many elite golfers will point their club down the fairway and imagine the ball following this line (Figure 4.24). Similarly, a hockey player might imagine the ball thumping into the goal prior to a penalty stroke. Such imagery can help the athlete feel that effective performance is within their grasp.

Planning and preparation

It is a good idea to enter competitive events with a plan of attack. Knowing how you will approach success is integral to the building of expectations for success. Low levels of confidence can spread throughout a team when players lack knowledge about their roles in the team. Also important are contingency plans, which are strategies to employ when original plans do not deliver the desired results.

Another determinant of confidence is physical preparation. Doubts about physical performance can arise when athletes do not feel physically fit or strong, so appropriate physical conditioning is required to prevent the onset of these doubts. Toward the end of the season or during congested periods in the season, the athlete or coach would be wise to schedule rest days to prevent physical fatigue.

The use of pre-game and pre-shot routines is also recommended for the development or maintenance of confidence. Athletes can allay any self-doubts in the build-up to important games by entering into a set pre-game routine. Focusing exclusively on a constant set of task-relevant thoughts and actions helps to put self-doubt out of mind. A basketball player, for instance, can control self-doubt in relation to an important free throw by entering into an established pre-shot routine.

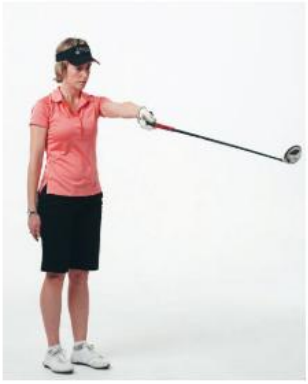


Figure 4.24: *Golfer using imagery*

Key point summary:

- A variety of techniques can be used to increase self-confidence, such as focusing on performance accomplishments, acting confidently, using positive self-talk, engaging in imagery, and carefully planning and preparing for events via pre-game and/or pre-shot routines.

Revision questions:

Test yourself on revision questions 18–20 located at the end of this chapter.

Concentration and The 'Zone'

Content that follows:
Concentration and the 'zone' (Units 1 and 2)

- *Concentration*
- *Are you concentrating?*
  - *Selective attention*
  - *Focusing over time*
  - *Awareness*
  - *Shifting attention*
- *Types of attentional focus:*
  - *Nideffer*
  - *Broad vs narrow*
  - *External vs internal.*
- *Concentration: Age, skill level, and type of activity*

Concentration

Concentration is crucial to effective performance in sport. Sport coaches often plead with their athletes to remain focused, fearing that a loss of concentration among the player group will jeopardise the team's position. A golfer can play a tournament for days, but one small lapse in concentration can sometimes spell disaster for his/her chances of success. It is clear, then, that a momentary lapse in concentration by a single athlete can result in the conceding of goals, baskets, events, games and even tournaments. This next section provides a definition of concentration and an overview of a popular model in relation to concentration in sport. Strategies to develop the skill of concentration are also provided.

Are you concentrating?

According to Weinberg and Gould (2007), a useful definition of concentration in sport and exercise settings is that ***concentration consists of four parts***:

Focusing on the relevant cues in the environment (selective attention)

Tiger Woods is well recognised for his psychological skills. In fact, his resilience, work ethic and confidence have helped Tiger to become one of the greatest golfers of all time. A psychological skill that Tiger Woods excels at is concentration and it is little wonder that he excels at this skill when one considers his training at a young age. Tiger's father, Earl Woods, encouraged his son to pick up a golf club at the age of three and he subsequently began to hone his son's ability to focus. As Tiger practised, his father would shout, wave things in the air, run around, and try anything that could distract his son. Earl Woods declared that 'I tried to break my son down mentally, tried to intimidate him verbally, by saying, "water on the right, OB (out of bounds) on the left", just before his downswing.'



Figure 4.25: *Tiger Woods with his father Earl*

Earl Woods had understood that golfers must focus on relevant cues and disregard or eliminate irrelevant cues. By attempting to distract his son during practice, Earl Woods hoped that Tiger would eventually learn to filter out the irrelevant environmental cues (such as noise) and focus more intently on the relevant cues.

Maintaining that attentional focus over time

It is important to maintain attention for a period of time, but the amount of time required to concentrate will vary according to the individual sport. Burke (1992) has suggested that different attentional styles should be adopted according to whether the sport is continuous (like hockey), whether it has a number of breaks (as in basketball), or whether it has many breaks (as in cricket). Dr Sandy Gordon, sport psychologist and academic at The University of Western Australia, says that cricket players should practise changing between channels of concentration. By 'switching down a level' between plays, cricketers can refresh so that they are prepared to 'switch up' again when required.

Having awareness of the situation

Athletes who are skilled at concentration tend to have an increased ability to understand the situation around them. Known as situation awareness, this ability allows players to size up game situations, opponents and competitions to make appropriate decisions based on the situation. This skill is constantly evidenced by elite ball-sport players. As well as concentrating on the position of the ball, for example, elite players are aware of the positions that many of their teammates and opponents are occupying.

Shifting attentional focus

Athletes are frequently required to shift the nature of their concentration throughout a game or event. A goal attack (GA) player in possession of the ball in the middle third during netball is required to attend to a multitude of cues, such as where the defenders are positioned, where teammates are positioned and the eye movements of their teammate with the ball. However, if the GA subsequently takes possession in the circle, she is required to develop a narrow focus in order to successfully execute the set shot. This example illustrates that athletes might be required to alter their attentional style according to different situations within a game. In the next section, we describe four different types of attentional focus.

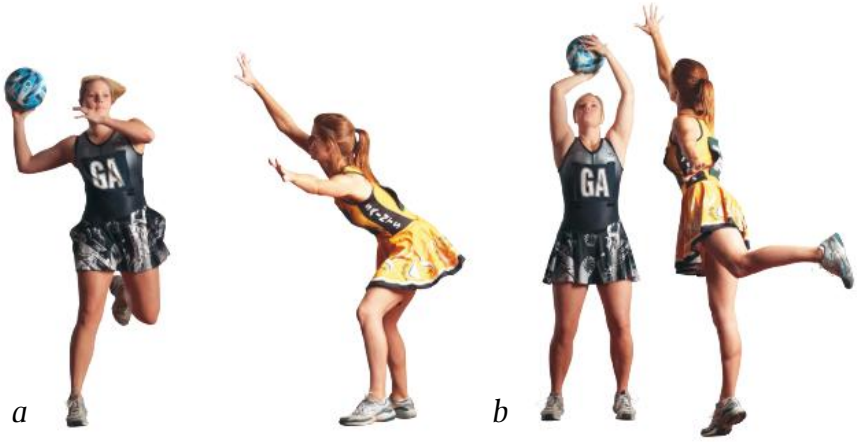


Figure 4.26: *Netball player using broad focus to determine her next passing option (a). Netball player using a narrow focus to shoot at goal (b)*

Key point summary:

- Concentration involves an ability to:
  - focus on relevant cues in the environment
  - maintain that focus over time
  - possess situational awareness
  - shift attentional focus.



Figure 4.27: *An AFL player using a broad attentional focus to determine his next option*

Types of attentional focus

Nideffer and colleagues (Nideffer 1981; Nideffer & Segal 2001) provided one of the most important contributions to our understanding of concentration. Nideffer argued that attentional focus could vary along two dimensions: width (broad versus narrow) and direction (external versus internal).

A ***broad attentional focus*** involves attention to multiple cues. Examples of this type of focus are provided in many sports, such as when team sport athletes are engaged in open play. During these times, the players are required to 'take in' a wide variety of information at the same time, adopting what Nideffer refers to as a ***broad focus***. For example, an AFL footballer in possession of the ball will scan the field for the movements of teammates into good positions (Figure 4.27).

A ***narrow attentional focus*** occurs when an athlete focuses on only one or two cues. A novice golfer who only focuses on maintaining a straight left elbow during their swing is engaging in a narrow focus (Figure 4.28).

An ***external attentional focus*** is one in which attention is directed outward towards an object. When Nic Naitanui jumps during a ruck contest, it is likely that his attention will be focused on external objects such as the ball and the position and movements of his teammates (Figure 4.29).

An ***internal attentional focus*** constitutes concentration on one's thoughts and feelings. Thinking about how you might react to a particular situation in a game would constitute an internal attentional focus.



Figure 4.29: *Nic Naitanui using an external attentional focus*

Key point summary:

- Nideffer argues that attentional focus can vary according to whether it is narrow or broad, internal or external.

Nideffer argues that people have a preferred attentional style: broad internal, broad external, narrow internal or narrow external. Individuals can certainly change between these styles, but the ease and speed with which these changes take place can vary according to personal preference and factors such as anxiety.



Figure 4.28: *Novice golfer using a narrow attentional focus*

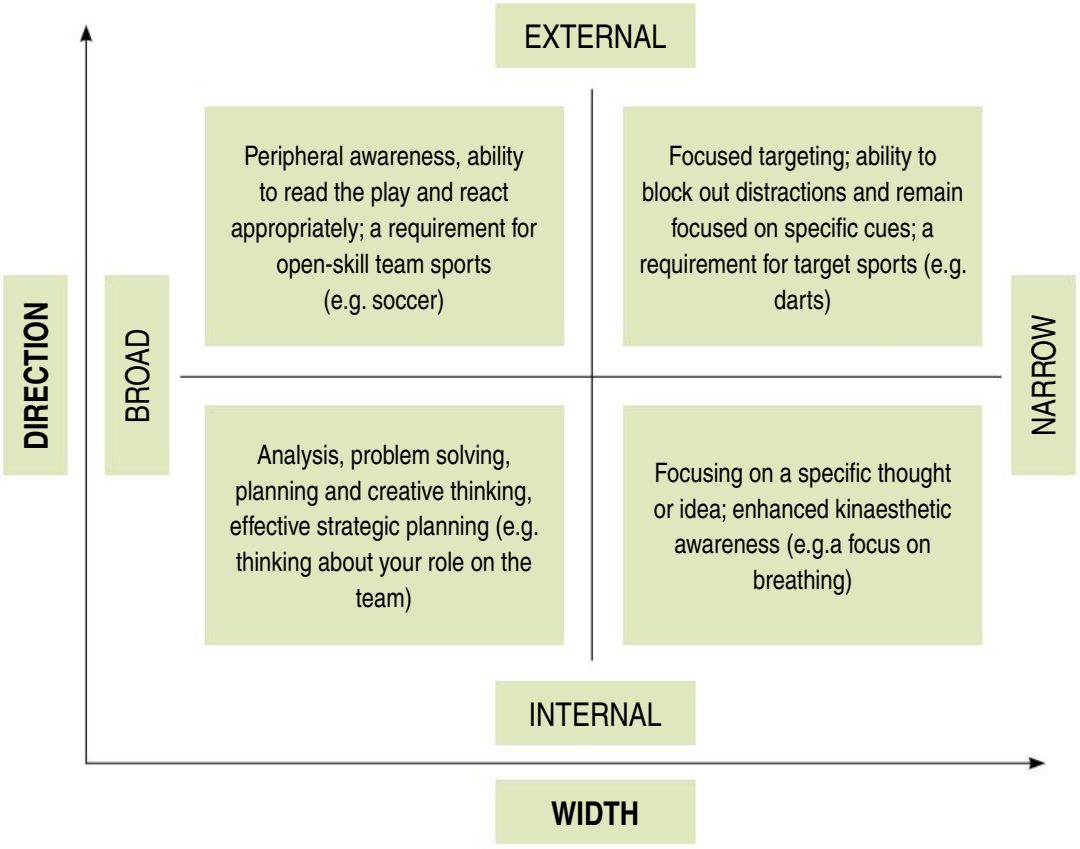
Practical activity: *Shifting your attention*

Stand about 5 m away from a clock. Firstly, try to devote all of your attention to this clock. Observe the second hand ticking and hear the noise of each tick. After about ten seconds of this focus, shift your attention to a broad focus. Take in as much of the room around you as possible, without moving your eyes from the clock. Hear other sounds and see other parts of the room with your peripheral vision. After adopting this broad focus for ten seconds, return to the narrow focus on the clock once more. Discuss with the class why this type of training might be important for some high-level athletes, such as cricket players or AFL players.

Equipment:

- Clock.

Figure 4.30: *Attentional focus varies as a function of width and direction*



Practical investigation

Concentration: Attentional focus

See Appendix B1 for a practical investigation, along with questions and report-writing format recommendations.

The influence of age, skill level, and the type of activity on concentration

Age

It is generally understood that attention span varies with age, such that young children are less capable of attending to information over a span of time. If you have ever watched a junior sport game, you will notice that many of the participants lose their focus on a regular basis. Coaches of junior sport teams should, therefore, be wary of the difficulties that young athletes might face in terms of maintaining attention on relevant stimuli.

Skill level

The skill level of performers also influences their ability to attend to relevant environmental cues. Consider a novice basketball player relative to an experienced player. An experienced player will be able to bounce the ball as well as listen to the coach's orders and attend to the movement of teammates and opposition. A novice player, on the other hand, might only be able to focus on the skill of bouncing the ball. It will be significantly more difficult for this novice player to attend to other relevant stimuli, such as the movement of players.

Type of activity

Finally, you would have gleaned from our previous discussion that attentional demands vary considerably between, and even within, sports. A goalkeeper in soccer might be able to 'switch off' when the ball is at the other end of the field, but a midfield player will need to maintain concentration at all times. Moreover, our ability to maintain concentration on a task seems to depend on whether we find the task to be enjoyable or intrinsically motivating. Most of us are able to maintain concentration during a two-hour movie that we thoroughly enjoy, but our attention might start to wander during a thirty-minute speech that we find uninteresting.

Practical investigation

Arousal, motivation and concentration, and an individual's performance

See Appendix B2 for a practical investigation, along with questions and report-writing format recommendations.

Revision questions:

Test yourself on revision questions 21–23 located at the end of this chapter.

Goal Setting

Text outcomes:
Goal setting (Unit 2)

- *Evaluate and reassess personal goals according to changing situations (age, skill level, and type of activity).*

Athletes can enhance their motivation by setting and pursuing goals. There is abundant evidence to suggest that goal setting is extremely useful as a motivator if it is used appropriately. Goals can also influence emotion and are, therefore, important to consider in relation to the zone of optimal functioning.

Imagine that you have set yourself a goal to win a golf tournament and, as you approach the final day of play in one tournament, you find yourself in the lead. Clearly, your goal is becoming relevant and achievable. As a result, you are likely to experience a variety of emotions. If you had set yourself a goal of finishing in the top fifty in a golf tournament, then you would be likely to experience a different emotional profile prior to the final day of play. Athletes should be mindful of their zones of optimal functioning and structure their goals to help, rather than hinder, their ability to enter the zone prior to important performances. In the sections below we define goals and we build upon the guidelines for goal setting that were discussed in the background information prior to Units 1 and 2.

Definition of goals

Content that follows:
Goal setting (Unit 2)

- *Goals*
- *Principles of goal setting*
- *SMARTS goals*
- *Goal setting: Age, skill level, and type of activity*

Athletes who pursue ***objective goals*** focus on attaining a specific standard of proficiency on a task, usually within a specified time frame (Locke, Shaw, Saari & Latham 1981). For example, an elite tennis player might set a goal of securing a top-ten spot in the ATP rankings by the end of the year. On the other hand, ***subjective goals*** refer to general statements of intent that are not measurable. An example of a subjective goal is when an athlete claims that they 'just want to do well'.

Principles of goal setting

Set specific rather than general goals

In general, it is better to encourage athletes to set specific rather than general goals. Furthermore, when setting specific goals, it is good practice to describe how the goal is to be achieved. Consider the two goals listed below:

> Athlete 1: I want to finish the upcoming Rottnest marathon in less than three hours by keeping a steady pace of 15 km/h.
>
> Athlete 2: I want to do my best in the upcoming Rottnest marathon.

The first goal is more specific and provides the athlete with information about how the goal is going to be achieved. The second goal is subjective and is less likely to provide direction and motivation to the athlete.

Set moderately difficult goals

Moderately difficult goals are superior to easy or difficult goals. An athlete's capabilities may not be fully utilised when pursuing easy goals. The athlete is unlikely to be energised as a result of easy goals and may even become bored. Goals that are too difficult, on the other hand, are likely to be demoralising for the athlete. With the expectation that they are unable to achieve the goal, the athlete is likely to give up on the task. Moderately difficult goals that extend the athlete's abilities and resources are therefore recommended. An elite

basketball player who averages 70% from the free-throw line might set a target of making 75% from the line in the upcoming game. This new target is likely to be perceived as difficult but possible and will subsequently be an effective goal–especially if it is linked to behavioural strategies (see principle 4).

Record goals

Many athletes set goals but they do not write them down. The benefit of writing a goal down is two-fold. Firstly, if the goal is placed in a visible place (such as the fridge door or bedroom wall), then family members and friends are likely to be reminded of the goal and give you support. Secondly, making goals visible to yourself reminds you of your own goal and will keep you focused on its achievement.

Develop strategies for goal achievement

A runner might have a goal to run the Rottnest marathon in under three hours by keeping a steady pace of 15 km/hr, but this goal should be supplemented by a clear understanding of strategies that will be used to accomplish the task. For example, the runner could set a training schedule for the weeks leading up to the event, carefully altering the training load in the sessions. Without these strategies the athlete is unlikely to achieve the desired endpoint.

Reassess goals according to changing situations

Consistent with the notion that athletes should set moderately difficult goals, it is important that these goals are re-evaluated as athletes develop or lose skills. Sometimes an athlete might develop a set of skills faster than expected; at other times athletes might lose a set of skills (for example, when injured). Goals are most effective when athletes perceive them as moderately difficult by athletes in their current state, so it is important to reassess goals according to current skill levels.

It is noteworthy that people's priorities and values can change over time and that goals must be adjusted to accommodate to these changing circumstances. A netball player who is approaching the tertiary entrance examinations might wish to reconsider her short-term netball goals if she is feeling unprepared in her studies. Also, an AFL midfielder might wish to reconsider his desire to kick twenty-five goals in an upcoming season if the head coach announces that he wishes to see development in the player's tagging skills. Perhaps a new goal relating to tagging would be more suitable for this player.

Provide feedback and reinforcement

Providing feedback about goal progress is essential for maintaining athletes' focus and motivation. A golfer who has a desire to reduce his handicap from twenty to fifteen could track his score for each round on a graph. Furthermore, achievement of the strategy that he is using to achieve his goal, such as visiting the local driving range three times per week, could be tracked. The provision of encouragement and positive reinforcement is an essential ingredient in the feedback process. Adherence to goal-related strategies is made easier when coaches, family and friends provide encouragement and reward for such adherence. The athlete can also provide rewards for themselves for the same adherence.

Self-determined goals

Knowledgeable coaches, parents and other support staff can help athletes to set effective goals, but the goals themselves should essentially be self-determined. Athletes are much more likely to persist toward fulfilment of the goal if they feel that they own it, and by setting the goal in the first place they are likely to increase this sense of ownership. To appreciate this phenomenon, consider a scenario in which you set yourself a goal to get an 'A' grade in Physical Education

Studies. You are much more likely to work harder at this goal than if your parents had told you that your goal was to achieve the same grade.

SMARTS goals

All of the principles outlined above are directly or indirectly included in the SMARTS structure of goal setting. In Units 1 and 2 we introduce SMARTS goals rather than the SMART goal principle that is outlined in the background information at the start of this chapter. Our SMARTS principle differs from the SMART principle in two ways. Firstly, given the conceptual overlap between 'Achievable' and 'Realistic' in the SMART approach, we have chosen to incorporate a different guideline for goal setting, 'Action–oriented', to represent our 'A'. Secondly, the addition of an 'S' to our principle reflects the importance of 'Self-determined goals' to the goal-setting process. The section that follows explains SMARTS goal setting.

Set SMARTS goals

Specific	—	Goals should be specific rather than general and broad.
Measureable	—	An athlete should be able to measure goal accomplishment.
Action-oriented	—	Athletes should specify how a goal is going to be achieved.
Realistic	—	Moderately difficult goals are best.
Time-bound	—	A timeframe for goal achievement should be identified.
Self-determined	—	Goals should have input from the participant.

Key point summary:

- Goal setting is a proven method to influence performance. A simple tactic to encourage effective goal setting is to use the SMARTS acronym.

Class task: *Using SMARTS in PE Studies*

Use the SMARTS framework to write down your goals for PE Studies.

Goal setting

Personal goal setting and age

The SMARTS principle is a useful framework for a variety of age groups. It is also relevant to athletes in different sports and can be used by athletes with varying levels of skill. When considering a goal-setting program, however, it is important to bear in mind that some young athletes might not cope with failure as well as mature athletes. Performance goals should perhaps be emphasised with junior performers as a result of this issue.

Another issue in relation to age and goal setting is that young people tend to have different priorities and goals to adults. Adolescents and young adults are likely to be particularly motivated by their desire to maintain and enhance peer and intimate relationships. Whereas goals relating to appearance (such as muscle gain and weight loss) might generally be motivating for this age group, such goals are likely to be less effective for children in primary school. In summary, age is likely to influence our priorities and our motivation to pursue different types of goals.

Personal goal setting and skill level

As mentioned in the Principles of goal setting section, goals should be set so that they are moderately difficult. This principle applies for elite

athletes as well as for novices. A junior tennis player might set herself the goal to win next year's local D-grade tennis tournament, whereas Serena Williams might set herself a goal to win next year's Wimbledon. Both of these goals are reasonable if they are perceived by the athletes to be moderately difficult.

Type of activity

The type of sport might also influence the extent to which outcome goals or performance goals are set. Some sports, such as marathon running, are ideal for performance goals. It is easy in these types of sports to measure personal performance against a criterion (time) that is independent of the performance of others. In other sports personal performance is very dependent on the performance of others and it becomes more difficult to set performance goals. Tennis is an example of such a sport. One's own performance in a tennis match is heavily dependent on the performance of the opponent.

Revision questions:

Test yourself on revision questions 24 and 25 located at the end of this chapter.

References

Bandura, A 1986, *Social foundations of thought and actions: A social cognitive theory*, Prentice Hall, Englewood Cliffs, NJ.

Bandura, A 1997, *Self-efficacy: The exercise of control*, Freeman, New York, NY.

Burke, KL 1992, 'Understanding and enhancing concentration', *Sport Psychology Training Bulletin,* vol.*4*, pp. 1–8.

Carron, AV, Hausenblas, HA & Eys, MA 2005, *Group dynamics in sport,* 3rd edn, Fitness Information Technology, Morgantown, WV.

Cox, RH 2002, *Sport psychology: Concepts and applications,* 5th edn, McGraw Hill, Boston, MA.

Frederick, CM & Ryan, RM 1993, 'Differences in motivation for sport and exercise and their relations with participation and mental health', *Journal of Sport Behavior,* vol.*16*, pp. 124–146.

Greenlees, I, Bradley, A, Holder, T & Thelwell, R 2005, 'The impact of opponents' non-verbal behaviour on the first impressions and outcome expectations of table-tennis players', *Psychology of Sport and Exercise,* vol. *6,* pp. 103–115.

Hanin, YL 1997, 'Emotions and athletic performance: Individual zones of optimal functioning', *European Yearbook of Sport Psychology,* vol.*1*, pp. 29–72.

Hardy, L 1990, 'A catastrophe model of performance in sport', in G Jones & L Hardy (eds), *Stress and performance in sport,* Wiley, Chichester, UK, pp. 81–106.

Lazarus, RS & Folkman, S 1984, *Stress, appraisal and coping*, Springer-Verlag, New York.

Lepper, M.R., Greene, D., & Nislett, R.E. (1973). Undermining children's intrinsic interest with extrinsic reward: A test of the "overjustification" hypothesis. *Journal of personality & social Psychology, 28*, 129-137.

Locke, EA, Shaw, KN, Saari, LM & Latham, GP 1981, 'Goal setting and task performance', *Psychological Bulletin,* vol. *90*, pp. 125–152.

Martens, R, Burton, D, Vealey, RS, Bump, LA & Smith, D 1990, 'Development and validation of the competitive state anxiety inventory', in R Martens, RS Vealey & D Burton (eds), *Competitive anxiety in sport*, Human Kinetics Books, Champaign, IL, pp. 117–190.

Maynard, IW, Smith, MJ & Warwick-Evans, L 1995, 'The effects of a cognitive intervention strategy on competitive state anxiety and performance in semi-professional soccer players', *Journal of Sport and Exercise*

Psychology, vol.*17*, pp. 428–446.
McGrath, JE 1970, 'Major methodological issues', in JE McGrath (ed.), *Social and psychological factors in stress*, Holt, Reinhart & Winston, New York, NY, pp. 19–49.
Milliman, RE 1982, 'Using background music to affect the behavior of supermarket shoppers', *Journal of Marketing, vol. 46*, pp. 86–91.
Nideffer, R 1981, *The ethics and practice of applied sport psychology,* Mouvement, Ithaca, NY.
Nideffer, R & Segal, M 2001,'Concentration and attention control training', In JM Williams (ed.), *Applied sport psychology: Personal growth to peak performance,*4th edn, Mayfield, Mountain View, CA, pp. 312332.
Rosenthal, R & Jacobson, L 1968, *Pygmalion in the classroom: Teacher expectations and pupils' intellectual development*, Holt, Rinehart & Winston, New York, NY.
Ryan, RM & Deci, EL 2000, 'Self-determination theory and the facilitation of intrinsic motivation, social development and well-being', *American Psychologist, vol. 55*, pp. 68–78.
Ryan, RM & Deci, EL 2007, 'Active human nature: Self-determination theory and the promotion and maintenance of sport, exercise and health',in MS Hagger & NLD Chatzisarantis (eds), *Intrinsic motivation and self-determination in exercise and sport*, Human Kinetics, Champaign, IL.
Vealey, RS 2005, *Coaching for the inner edge*. Fitness Information Technology, Morgantown, WV.
Weinberg, RS & Gould, D 2007, *Foundations of sport and exercise psychology,*4th edn, Human Kinetics, Champaign, IL.
Yerkes, RM & Dodson, JD 1908, 'The relation of strength of stimulus to rapidity of habit-formation', *Journal of Comparative Neurology and Psychology*, vol.*18*, pp. 459–482.

Appendix A: Writing the practical investigation report

Writing the report

If you are required to write a report as part of your practical investigation, you may choose to use the following format.

Title: Title of the practical investigation.

Aim: State what you hope to achieve in the experiments (*~30–50 words*).

Introduction: Define and discuss the sport science principles being investigated (*~200 words*).

Hypotheses: Identify the expected results or anticipated outcomes (*statements*).

Method: Identify the steps taken to complete the experiments (*~100 words*).

Results: Present the data and findings in the appropriate format (*for example, graphs, diagrams and tables*).

Response to the questions: Write the questions out and respond.

Discussion: Provide a detailed discussion of the results. Apply the sport science principles under investigation to other sporting contexts (*~400 words*).

Conclusion: Summarise the discoveries made. Make links to each hypothesis and include limitations of the experiment *(~100 words).*

Appendix B1

Practical Investigation and Report: Sport Psychology
Concentration: Attentional Focus

Weighting: Unit 1

Type: Investigation

Content:
Understand the mental skills required for improving performance and achieving the ideal performance state (the 'zone').

Task outline
You are to observe and measure the performance impact of differing opportunities to concentrate on, and visually attend to, important cues. Content that will be accessed includes:

- Concentration.
- Attentional focus.
- Nideffer's model.

Total marks = /30

Experiment
Task one

1. Form groups of seven students per group.
2. Select one student to be the catcher.
3. The remaining six students stand 5 m from the catcher–spaced out in a fan shape.
4. Each of the throwers has a foam tennis ball.

Condition (A)

1. Five of the tennis balls are all one colour (for example, yellow) and one of them is a different colour (for example, red).
2. Instruct the catcher that they are to catch only the red ball. Use a different player to throw the red ball each time.
3. On the command 'ready go' (said by one of the throwers), all of the throwers release the ball with an underarm throw. Gently throw at the catcher's mid-stomach height.
4. Record the number of successful catchers of the red ball out of ten trials.

Condition (B)

1. Six of the tennis balls are all one colour (for example, yellow), but one of the balls has a small pen mark on it, which makes it identifiable to the person holding it.
2. Instruct the catcher that they are to catch only the yellow ball with the dot.
3. Well before throwing the balls, announce to the catcher who is holding the marked ball. Use a different player to throw the marked ball each time.
4. On the command 'ready go' (said by one of the throwers), all of the throwers release the ball with an underarm throw. Gently throw at the catcher's mid-stomach height.
5. Record the number of successful catchers of the marked yellow ball out of ten trials.

Condition (C)

1. Six of the tennis balls are all one colour (for example, yellow), but one of the balls has a small pen mark on it, which makes it identifiable to the person holding it.
2. Instruct the catcher that they are to catch only the yellow ball with the dot.
3. Prior to throwing the balls do not identify to the catcher who is holding the marked ball. Use a different player to throw the marked ball each time.
4. The catcher must turn away from the

throwing team, until the throwing team gives the command 'ready'.

5. The command is 'ready' (catcher turns around) and then name the person holding the ball. It is said by one of the throwers who are not holding the marked ball. As soon as the name of this person is said, all of the throwers release the ball with an underarm throw. Gently throw at the catcher's mid-stomach height.
6. Record the number of successful catchers of the marked yellow ball out of ten trials.

Questions: Task one

In presenting your findings, respond to the following:

a. Compare, contrast and briefly discuss the scores for each member of the class undertaking Task one A–C (2 marks).
b. Compare, contrast and briefly discuss the overall scores for Task one A–C (2 marks).
c. Account for any variations that appear in the scores recorded for individuals and between tasks (including scores recorded, skill level, type of activity, concentration, selective attention, awareness, shifting attentional focus, type of attentional focus, Nideffer's model, self-confidence and arousal) (5 marks).

Task two

Playing in a game of hockey requires the hitting of a ball and so does playing golf.



Figure 4.31a: *Hockey player making decisions in a crowded environment*



Figure 4.31b: *Golfer preparing to make a putt*

Questions: Task two

a. Discuss how the concentrational needs of passing a ball in hockey in a crowded environment and a lengthy putt in golf differ (2 marks).
b. Some people are said to cope better in different situations. Using Nideffer's model, explain why some individuals might consistently perform better in one of the tasks (hockey or golf) compared to the other. Consider the type of activity undertaken and its attentional needs (4 marks).

Equipment

- Sets of six foam tennis balls (one colour, such as yellow).
- Sets of one foam tennis ball (different colour to the sets identified above, such as red).
- Pen to mark a yellow ball.

Task: Concentration: Attentional focus: 30 marks

Components and Performance Standards	Marks
Hypotheses (2 marks)	
Provides simple statements of the expected results or anticipated outcomes in relation to concentration and attentional focus.	**1 mark**
Provides clear statements of the expected results or anticipated outcomes in relation to performance and concentration and attentional focus.	**2 marks**
Introduction (3 marks)	
Identifies and defines the variables associated with concentration.	**1 mark**
Shows an understanding of performance and concentration and attentional focus and the factors that can enhance and limit these variables.	**2 marks**
Shows a comprehensive understanding of performance and concentration and attentional focus and the factors that can enhance and limit these variables.	**3 marks**
Results (2 marks)	
Satisfactory presentation of data.	**1 mark**
Accurate and relevant presentation of data.	**2 marks**
Response to Questions (15 marks)	
Task one: *Question a: 2 marks, Question b: 2 marks, Question c: 5 marks (9 marks).*	
Task two: *Question a: 2 marks, Question b: 4 marks (6 marks)*	
Discussion (6 marks)	
Shows little comprehension of the variables associated with the activities undertaken.	**1 mark**
Limited discussion of the results found and few links made to the variables associated with the activities undertaken.	**2 marks**
Uses other sporting contexts to discuss the results found and identifies some of the variables associated with performance and concentration.	**3 marks**
Uses other sporting contexts to discuss the results found and identifies and defines most of the variables associated with performance and concentration and attentional focus and the factors that can impact on these variables.	**4 marks**
Uses other sporting contexts to show an understanding of the results found and discusses these in reference to performance and concentration and attentional focus and the factors that can enhance and limit these variables.	**5 marks**
Uses other sporting contexts to show a comprehensive understanding of the results found and discusses these in application to performance and concentration and attentional focus and the factors that can enhance and limit these variables.	**6 marks**
Conclusion (2 marks)	
Summarises some of the impact of concentration and attentional focus on performance in relation to the hypotheses.	**1 mark**
Fully summarises the impact of concentration and attentional focus on performance in relation to the hypotheses. Limitations discussed.	**2 marks**
Comment:	**Total** **/30**

Appendix B1.1 – Answers

Practical Investigation and Report: Sport Psychology

Concentration: Attentional focus

Answers: Task One

a. Compare, contrast and briefly discuss the scores for each member of the class undertaking Tasks one A-C (2 marks).

Answer

Some individuals will perform better at the tasks than others. Two ingredients are essential for effective performance in the catching tasks. First, people must be reasonably skilled at catching. Many people are taught the skills that are required for catching at an early age and take them for granted, but to others, catching a ball is a difficult task. A second factor that will cause performance differences between class members is concentration. Participants might be skilled at catching, but they will perform the tasks poorly if they are unable to concentrate. These issues will be addressed once more in our answer to (c).

b. Compare, contrast and briefly discuss the overall scores for Task one A-C (2 marks).

Answer

Task A is the easiest task, followed by Task B and then Task C. In both tasks A and B, the catcher can determine the appropriate ball to catch before the balls are thrown. The benefit of task A is that, once thrown, the red ball is easy to distinguish from the other balls and so it is easy to focus upon. Task C is difficult because the participant is required to quickly decide who is throwing the appropriate ball. They are then required to focus on the relevant ball while filtering out competing but similar stimuli (other yellow balls).

c. Account for any variations that appear in the scores recorded for individuals and between tasks (including i-xi) (5 marks).

iv. scores recorded
v. skill level
vi. type of activity
vii. concentration
viii. selective attention
ix. awareness
x. shifting attentional focus
xi. type of attentional focus
xii. Nideffer's model
xiii. self-confidence
xiv. arousal

Answer

The conditions will require a broad external focus followed by a narrow external focus. In the first and second conditions, participants will have ample time to determine the appropriate ball to catch (using a broad external focus). In the first task, the surveying of the environment will occur before the balls are thrown to determine who is holding the red ball.

In the second task, the catcher will use a broad external focus to survey the environment to identify the person holding the relevant ball. This same process will occur in the third condition, but the participants will need to be more efficient at this process. A narrow external focus is required once the relevant ball has been identified.

As previously indicated, participants in the third condition will need to be efficient at identifying the relevant ball using a broad external focus. This is because they will have only a limited amount of time to shift to a narrow external focus (which is required to catch a ball).

(ii) As indicated in our answer to (a), skill level is likely to influence performance on the tasks. Those participants who find the skill of catching to be difficult will perform poorly at the tasks. Some participants, especially those that are experienced at catching, might be able to perform well in all conditions.

(iii) The type of activity will also have a strong bearing on performance. It is likely that performance will be better on Task A than it will be on Task C, for example. Although all of the tasks require the participants to catch a tennis ball and to use the same attentional foci, there are differences in the speed with which these processes must be engaged.

(iv) As indicated in our answer to (a), concentration is key to performance in these tasks. The requirement to concentrate at the right thing at the right time is particularly important for less skilled performers. See the answers below to understand why this is the case.

(v) In general, performers who are able to selectively attend to the relevant stimuli are likely to perform well at the tasks. In other words, participants are likely to perform the tasks well if they focus intently on the relevant ball to catch and filter out the irrelevant, competing stimuli (e.g. other tennis balls).

(vi; vii; viii; ix) Concentration involves an awareness of the situation. As has been indicated previously, most participants will use a broad external focus (to determine the location of the appropriate tennis ball) and then revert to a narrow external focus (attend only to the relevant ball). Highly skilled performers, however, might prefer to maintain the broad external focus for longer throughout the task. In other words, even after the appropriate ball has been identified, highly skilled participants might partially attend to the location and speed of the other tennis balls. They will then be in a position to move aside (or brace themselves) if a ball is going to hit them at considerable speed. Highly skilled athletes might revert to a narrow external focus early after the throw to gauge speed and direction of the appropriate ball, and then temporarily return to a broad external focus, or they might retain a broad external focus until the relevant ball is near to them (and then revert to a narrow external focus).

(x) Performers who are self-confident are likely to perform better at the tasks than others. Those with low self-confidence will be likely to experience anxiety (and the associated arousal), which will harm performance (see answer to xi).(xi) Arousal is likely to be detrimental for performance, particularly in the third condition. This condition requires a broad external focus to identify the person holding the relevant ball, and this task needs to be done with speed so that attention can shift (to a narrow external focus) before the ball arrives. Arousal is likely to narrow the attentional field available to the athlete and will lengthen the time that participants will take to identify the relevant ball. This won't be so much of a problem in Tasks A and Task B because sufficient time will

be available to survey the environment even among highly aroused participants. Performers with very high levels of arousal, however, might find that their coordination is influenced such that they drop catches even if they have appropriate time to identify the relevant ball.

Answers: Task Two

a. Discuss how the concentrational needs of passing a ball in hockey in a crowded environment and a lengthy putt in golf differ (2 marks).

Answer

A hockey player would require a broad external focus of attention in this situation. He/She would need to attend to the position of the ball as well as to the movements of a variety of players. The hockey player would then adopt a narrow external focus as they look at the ball to hit it. The golfer, on the other hand, might use a variety of foci for their putt. For instance, the golfer could start their pre-shot routine by using a broad internal focus to decide upon an overall strategy for the putt. Perhaps the golfer could remind themselves about their strategy to 'not leave any putts short of the hole'. They might then shift to an external focus to evaluate wind strength, slope of green, and grain of grass, before adopting a narrow internal focus to steady breathing. Perhaps the golfer would then adopt a narrow external focus during performance. That is, they could focus on a cue such as a dimple on the golf ball as they draw the club back and then through.

b. Some people are said to cope better in different situations. Using Nideffer's model, explain why some individuals might consistently perform better in one of the tasks (hockey or golf) compared to the other. Consider the type of activity undertaken and its attentional needs. (2 marks).

Answer

Two key differences emerge in these two examples. First, the speed with which participants must attend to relevant stimuli and switch between attentional foci differs. The hockey player is required to switch between the broad external focus and the narrow external focus very quickly, but the golfer is not under such time constraints. Second, the examples differ in the type of attentional foci that are required. Whereas the hockey player will focus attention on external stimuli, the golfer will focus on both external and internal stimuli/processes. People might consistently perform one task better than the other for a couple of reasons. First, individuals might possess a natural preference for a particular type of attention. Some people might enjoy using introspective thinking associated with an internal focus, for example, and it could be expected that this type of athlete would be likely to perform better at the golf skill. Second, athletes might develop their skills at using a particular form of attention. These individuals are likely to perform well at activities requiring forms of attention that they have practised.

Appendix B2

Practical Investigation and Report: Sport Psychology
Arousal, motivation and concentration and an individual's performance

Weighting: Unit 2

Type: Investigation

Content:
Evaluate the influence of age, skill level and type of activity on mental skills in relation to:

- motivation
- arousal regulation (inverted-U hypothesis)
- concentration.

Task outline
By completing the experiment outlined below and the discussion questions, you are to observe and evaluate the influence of age, skill level and type of activity on motivation, arousal and concentration on performance. This investigation involves groups of three students working together. Having selected the group please read the next statement.

Total marks = /30

Important instruction: Only one group member (the non-participant observer) should read the following task instructions.

Experiment
Task one (A)
1. Form groups of three students per group.
2. Select a pair of students to handball the football to each other. They do not read the following instructions. **Only the non-participant observer reads the following instructions** and then directs the active participants to complete the task requirements.

Instructions:
1. Tell the handballers to stand a distance of 6 m apart.
2. Put markers at the distance chosen.
3. Tell them not to start until you are ready.
4. **Do not tell them** that you are scoring the accuracy of the handpasses.

The non-participant will:
Stand to the side of the handballers and make judgements about the accuracy of each of the handballs. Use the following chart (Figure 4.33) to score for both participants. Only score for every second handball that each participant delivers. Continue until ten handballs are recorded for each participant.

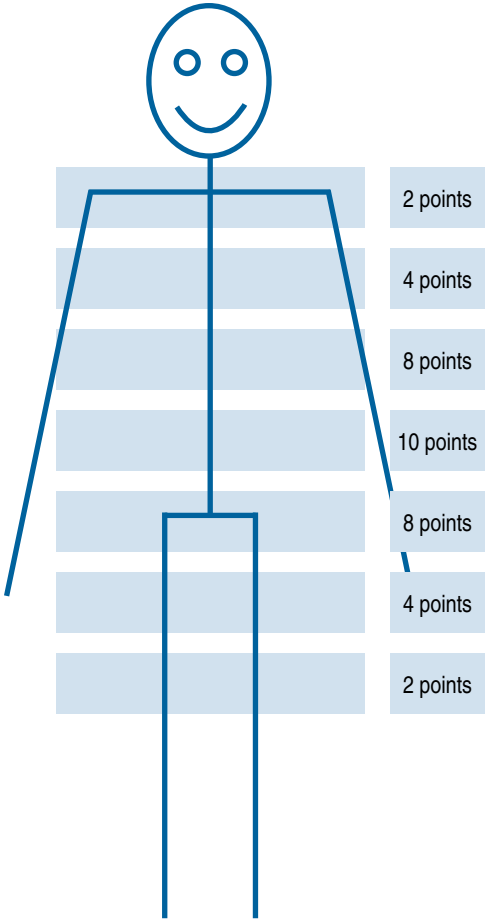


Figure 4.33: *Accuracy chart for handballing*

Task one (B)

1. Draw the rectangles onto a hard wall (for example, brick) with the same proportions as recorded above.
2. Using the same two participants who handballed in Task one (A), take them to the wall target and ensure they stand 6 m from the wall.
3. Ask the participants to handball until you tell them to stop.
4. Do not encourage competition or comparison with the previous task, their partner or others.
5. Stand to the side of the handballers and only score for every second handball that each participant delivers. Continue until ten handballs are recorded for each participant.

Task one (C)

1. Swap one of your handballers with another group.
2. Inform them that they are now in a competition with each other.
3. Inform them that they have only ten handballs to score the most points possible.
4. Inform them that the teacher has prizes for each winner (for example, a chocolate frog)
5. Stand to the side of the handballers and score the accuracy of each handball. Record the ten scores for each participant.

Task one (D)

1. The teacher will select two of the best-performing students from Task one (C).
   a. **Option:** Before announcing the final instructions, apply a heart rate monitor to the two selected players. Record their heart rate at this point in time. Once heart rate is recorded, read the instructions for Task one (D). Re-record the heart rate immediately after each handball in Task one (D).
2. The teacher informs everyone that this final competition is for the annual championship with prizes awarded to the winner (for example, a chocolate frog).
3. All other players are divided into two groups. One group is allocated as a cheer squad or support team for one of the players. The other group is allocated to support the other player. The winning player will receive a prize for their cheer squad (for example, a chocolate frog).
4. Cheer squads line the pathway from the handball line to the target. They are

encouraged to cheer for their player and against the other (within appropriate limits!).

5. Record the ten scores for each participant.

Questions: Task one

In presenting your findings, respond to the following questions.

a. Compare, contrast and discuss the scores for the each member of the class undertaking Task one A–C and for the different tasks (Task one A–C) in general. Account for any variations that appear (including; scores recorded, skill level, type of activity, motivation, arousal regulation and concentration) *(5 marks)*.

b. For Task one (D) identify the likely psychological and physiological impact of the situation. Consider the impact on both the participants and their performance and the impact on the cheer-squad *(4 marks)*.

Task two: Questions

a. Predict and account for, using the principles of sport psychology, how the following individuals may have performed during this practical investigation, compared to performance scores recorded by the members of your class *(6 marks)*.

   i. Primary school student who is seven years of age (who has not played AFL).

   ii. Primary school student who is seven years of age (who won the MVP for their AusKick season).

   iii. AFL player–Chris Judd.

Equipment

- At least eight AFL balls.
- Targets on a wall.
- Prizes provided by the teacher: for example, chocolate frogs.
- Optional: two heart rate monitors.

Task: Arousal, motivation and concentration and an individual's performance: 30 marks

Components and Performance Standards	Marks
Hypotheses (2 marks)	
Provides simple statements of the expected results or anticipated outcomes in relation to arousal, motivation and concentration.	**1 mark**
Provides clear statements of the expected results or anticipated outcomes in relation to arousal, motivation and concentration.	**2 marks**
Introduction (3 marks)	
Identifies and defines the variables associated with arousal, motivation and concentration.	**1 mark**
Shows an understanding of personal performance and arousal, motivation and concentration, including the influence of age and skill level of the performer and the type of activity undertaken.	**2 marks**
Shows a comprehensive understanding of personal performance and the relationship of arousal, motivation and concentration, including the influence of age and skill level of the performer and the type of activity undertaken.	**3 marks**
Results (2 marks)	
Satisfactory presentation of data.	**1 mark**
Accurate and relevant presentation of data.	**2 marks**
Response to Questions (15 marks)	
Task one: *Questions a: 5 marks, Question b: 4 marks (9 marks).*	
Task two: *Question a: 6 marks.*	
Discussion (6 marks)	
Shows little comprehension of the variables associated with the activities undertaken.	**1 mark**
Limited discussion of the results found and few links made to the variables associated with the activities undertaken.	**2 marks**
Uses other sporting contexts to discuss the results found and identifies some of the variables associated with personal performance and the relationship of arousal, motivation and concentration.	**3 marks**
Uses other sporting contexts to discuss the results found and identifies and defines most of the variables associated with an understanding of personal performance and the relationship of arousal, motivation and concentration, including the influence of age and skill level of the performer and the type of activity undertaken.	**4 marks**
Uses other sporting contexts to show an understanding of the results found and discusses these in reference to an understanding of personal performance and the relationship of arousal, motivation and concentration, including the influence of age and skill level of the performer and the type of activity undertaken.	**5 marks**
Uses other sporting contexts to show a comprehensive understanding of the results found and discusses these in application to an understanding of personal performance and the relationship of arousal, motivation and concentration, including the influence of age and skill level of the performer and the type of activity undertaken.	**6 marks**
Conclusion (2 marks)	
Summarises some of the factors associated with personal performance and the relationship of arousal, motivation and concentration in relation to the hypotheses.	**1 mark**
Fully summarises the impact of the factors affecting personal performance and the relationship of arousal, motivation and concentration, including the influence of age and skill level of the performer and the type of activity undertaken in relation to the hypothesis. Limitations discussed.	**2 marks**
Comment:	**Total** **/30**

Appendix B2.1 – Answers

Practical Investigation and Report: Sport Psychology

Arousal, motivation and concentration and an individual's performance

Answers: Task One

a. Compare, contrast and discuss the scores for the each member of the class undertaking Task one A-C and for the different tasks (Task one A-C) in general. Account for any variations that appear (including; scores recorded, skill level, type of activity, motivation, arousal regulation and concentration) (5 marks).

Answer:

Individuals are likely to differ in their performance of the tasks. Those performers who are skilled at Australian Football are more likely to score highly on these tasks. Furthermore, performance is likely to vary according to the type of activity that is undertaken (Task A versus Task B versus Task C).

Task B, because of the inclusion of a target, is more likely to increase the performer's level of concentration and motivation (relative to Task A). The participants may find Task B to provide greater goal clarity and find it more interesting. Consequently, the participants may be more focused on handballing than when performing Task A, resulting in an improved handballing performance.

Task C is more difficult than Task B. This is because the competitive environment will be arousing, and arousal is potentially detrimental for performance of this complex skill. Individuals who are able to regulate their arousal (e.g. take a few deep breaths before each handpass) are likely to negate the potentially damaging effects of arousal. Individuals who possess intrinsic motivation for the activities will probably perform better. These individuals are likely to remain committed even if they experience poor results. Thus, these participants are more likely to persist and remain effortful in the face of poor performance. Finally, athletes who can concentrate on relevant stimuli (e.g. bullseye in target) and filter out irrelevant stimuli (e.g. other students performing the same task) are more likely to perform well.

b. For Task one (D) identify the likely psychological and physiological impact of the situation. Consider the impact on both the participants and their performance, and the impact on the cheer-squad (4 marks).

Answer:

Task D is likely to be experienced as arousing for the participants. For some individuals, the situation might be interpreted as threatening and their arousal will be in the form of anxiety. Other participants might interpret this situation as fun and exciting. They, too, will experience arousal but they will not experience this as anxiety. All participants are likely to experience an increased heart rate, shallow breathing, and a variety of other physiological symptoms associated with arousal.

Although participants in Task D will be competent relative to their peers, their performance in this particular task is likely

to be poor. The situation (cheer squad, reward, competition) is likely to result in high levels of arousal, and it is therefore likely that the performance of fairly complex motor task (handpassing) will be compromised.

Members of the cheer squad will also experience arousal. Unlike some of the participants, they are unlikely to interpret the situation as threatening and their arousal will not be associated with anxiety. Rather, their arousal is likely to be characterised by feelings of enjoyment (from being part of a noisy crowd of people).

Answers: Task Two

a. Predict and account for, using the principles of Sport Psychology, how the following individuals may have performed during this practical investigation, compared to performance scores recorded by the members of your class (6 marks).

ii. Primary school student who is seven years of age (who has not played AFL)

iii. Primary school student who is seven years of age (who won the MVP for their AusKick season)

iv. AFL player – Chris Judd

Answer:

Members of your class are likely to perform better at the tasks than a seven year old with no experience in Australian Football. With age comes physical strength, and a seven year old might struggle to reach the target in the tasks. Furthermore, an older student who has not played Australian Football is more likely to have undertaken skills that are similar to handpassing (e.g. underarm serving in volleyball). Thus, members of your class are likely to perform better due to their practice at other similar tasks.

It is likely that the experienced AusKick player will perform better than the seven year old that has not played before. A seven year old who has AusKick experience might possibly have more skill at the task than the average member of your class, but once again, physical strength could hinder their performance at the activity.

An AFL player such as Chris Judd is likely to perform extremely well regardless of the condition. Even if an AFL player was competing against another AFL player, they would still perform the task extremely well (and could even perform better). Highly skilled athletes often perform at their best when experiencing relatively high levels of arousal (see the discussion of the inverted-U hypothesis). Thus, a highly competitive handpass challenge might lead to poorer performance among young and less skilled athletes, but to an improvement in performance among elite AFL players.

Appendix B2.2

Practical Investigation Preparation: Sport Psychology

Arousal, motivation and concentration and an individual's performance

Unit 2

Type: Investigation

Outcome 4: Knowledge and understanding of sport psychology concepts for physical activity.

Content:

- Evaluate the influence of age, skill level and type of activity on mental skills in relation to:
  - motivation
  - arousal regulation (inverted-U hypothesis)
  - concentration

Task outline

By completing the experiment outlined, you are to observe and evaluate the influence of age, skill level and type of activity on motivation, arousal and concentration on performance. This investigation involves groups of three students working together. Having selected the groups please read the next statement.

Important instruction: Only one group member (the non-participant observer) should read the task instructions.

Equipment

- At least eight AFL balls.
- Targets on a wall.
- Prizes provided by the teacher: for example, chocolate frogs.
- Optional: two heart rate monitors.

Once the experiment is completed you need to:

1. Compose an accurate and relevant presentation of the results. (Bring with you and submit at the completion of the In-Class Assessment Task.)
2. Answer all of the questions outlined. Some of these questions, along with additional questions will appear in the In-Class Assessment Task.
3. Develop a comprehensive understanding of personal performance and the relationship of arousal, motivation and concentration, including the influence of age and skill level of the performer and the type of activity undertaken.
4. Through research, use other sporting contexts to show a comprehensive understanding of the results found and discuss these in application to an understanding of personal performance and the relationship of arousal, motivation and concentration, including the influence of

age and skill level of the performer and the type of activity undertaken.

5. Discuss the limitations of this experiment.

Experiment

Task one (A)

1. Form groups of three students per group.
2. Select a pair of students to handball the football to each other. They do not read the following instructions. **Only the non-participant observer reads the following instructions** and then directs the active participants to complete the task requirements.

Instructions:

1. Tell the handballers to stand a distance of 6 m apart.
2. Put markers at the distance chosen.
3. Tell them not to start until you are ready.
4. **Do not tell them** that you are scoring the accuracy of the handpasses.

The non-participant will:

1. Stand to the side of the handballers and make judgements about the accuracy of each of the handballs. Use the following chart (Figure 4.33) to score for both participants. Only score for every second handball that each participant delivers. Continue until ten handballs are recorded for each participant.

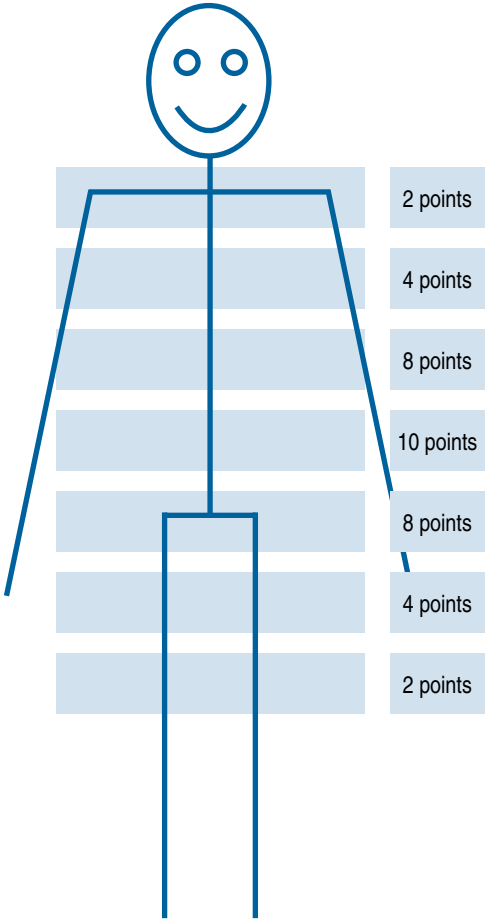


Figure 4.33: *Accuracy chart for handballing*

Task one (B)

1. Draw the rectangles onto a hard wall (for example, brick) with the same proportions as recorded above.
2. Using the same two participants who handballed in Task one (A), take them to the wall target and ensure they stand 6 m from the wall.
3. Ask the participants to handball until you tell them to stop.
4. Do not encourage competition or comparison with the previous task, their partner or others.
5. Stand to the side of the handballers and only score for every second handball that each participant delivers. Continue until ten handballs are recorded for each participant.

Task one (C)

1. Swap one of your handballers with another group.
2. Inform them that they are now in a competition with each other.
3. Inform them that they have only ten handballs to score the most points possible.
4. Inform them that the teacher has prizes for each winner (for example, a chocolate frog)
5. Stand to the side of the handballers and score the accuracy of each handball. Record the ten scores for each participant.

Task one (D)

1. The teacher will select two of the best-performed students from Task one (C).
   a. **Option:** Before announcing the final instructions, apply a heart rate monitor to the two selected players. Record their heart rate at this point in time. Once heart rate is recorded, read the instructions for Task one (D). Re-record the heart rate immediately after each handball in Task one (D).
2. The teacher informs everyone that this final competition is for the annual championship with prizes awarded to the winner (for example, a chocolate frog).
3. All other players are divided into two groups. One group is allocated as a cheer squad or support team for one of the players. The other group is allocated to support the other player. The winning player will receive a prize for their cheer squad (for example, a chocolate frog).
4. Cheer squads line the pathway from the handball line to the target. They are encouraged to cheer for their player and against the other (within appropriate limits!).
5. Record the ten scores for each participant.

Questions: Task one

a. Compare, contrast and discuss the scores for the each member of the class undertaking Task one A–C and for the different tasks (Task one A–C) in general. Account for any variations that appear (including; scores recorded, skill level, type of activity, motivation, arousal regulation and concentration).
b. For Task one (D) identify the likely psychological and physiological impact of the situation. Consider the impact on both the participants and their performance and the impact on the cheer-squad.

Questions: Task two

a. Predict and account for, using the principles of sport psychology, how the following individuals may have performed during this practical investigation, compared to performance scores recorded by the members of your class.
   ii. Primary school student who is seven years of age (who has not played AFL).
   iii. Primary school student who is seven years of age (who won the MVP for their AusKick season).
   iv. AFL player—Chris Judd.

Appendix B2.3

Practical Investigation Assessment Task: Sport Psychology

Arousal, motivation and concentration and an individual's performance

Name: _____

Unit 2

Type: Investigation

Outcome 4: Knowledge and understanding of sport psychology concepts for physical activity.

Content: 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.



Total: _____ / 40 marks

Having completed the Arousal, Motivation and Concentration experiment you are required to address the questions outlined.

An outline of the task has been provided for you.

Task outline

By completing the experiment outlined, you are to observe and evaluate the influence of age, skill level and type of activity on motivation, arousal and concentration on performance. This investigation involves groups of three students working together. Having selected the group please read the next statement.

Task (A)

1. Form groups of three students per group.
2. Select a pair of students to handball the football to each other. They do not read the following instructions. **Only the non-participant observer reads the following instructions** and then directs the active participants to complete the task requirements.

Instructions:

Tell the handballers to stand a distance of 6 m apart.

Put markers at the distance chosen.

Tell them not to start until you are ready.

Do not tell them that you are scoring the accuracy of the handpasses.

The non-participant will:

1. Stand to the side of the handballers and make judgements about the accuracy of each of the handballs. Use the following chart (Figure 4.33) to score for both participants. Only score for every second handball that each participant delivers. Continue until ten handballs are recorded for each participant.

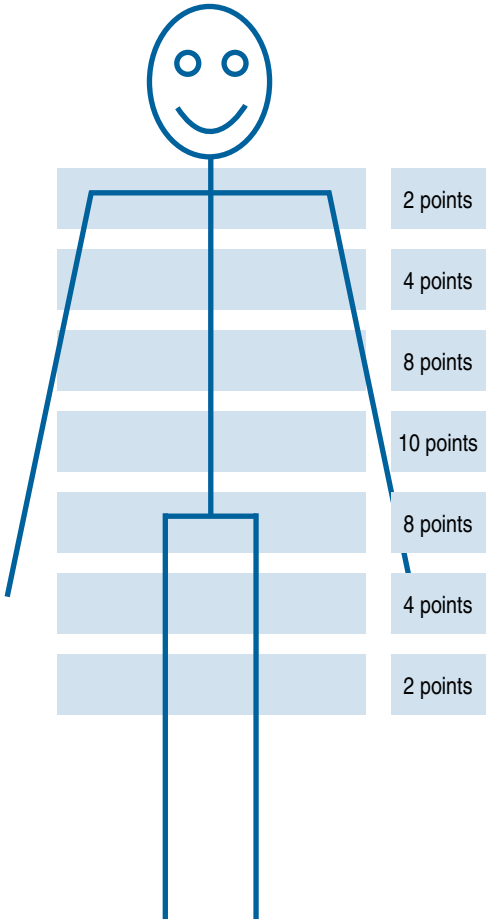


Figure 4.33: *Accuracy chart for handballing*

Task (B)

1. Draw the rectangles onto a hard wall (for example, brick) with the same proportions as recorded above.
2. Using the same two participants who handballed in Task one (A), take them to the wall target and ensure they stand 6 m from the wall.
3. Ask the participants to handball until you tell them to stop.
4. Do not encourage competition or comparison with the previous task, their partner or others.
5. Stand to the side of the handballers and only score for every second handball that each participant delivers. Continue until ten handballs are recorded for each participant.

Task (C)

1. Swap one of your handballers with another group.
2. Inform them that they are now in a competition with each other.
3. Inform them that they have only ten handballs to score the most points possible.
4. Inform them that the teacher has prizes for each winner (for example, a chocolate frog)
5. Stand to the side of the handballers and score the accuracy of each handball. Record the ten scores for each participant.

Task (D)

1. The teacher will select two of the best-performed students from Task one (C).
   a. **Option:** Before announcing the final instructions, apply a heart rate monitor to the two selected players. Record their heart rate at this point in time. Once heart rate is recorded, read the instructions for Task one (D). Re-record the heart rate immediately after each handball in Task one (D).

2. The teacher informs everyone that this final competition is for the annual championship with prizes awarded to the winner (for example, a chocolate frog).
3. All other players are divided into two groups. One group is allocated as a cheer squad or support team for one of the players. The other group is allocated to support the other player. The winning player will receive a prize for their cheer squad (for example, a chocolate frog).
4. Cheer squads line the pathway from the handball line to the target. They are encouraged to cheer for their player and against the other (within appropriate limits!).
5. Record the ten scores for each participant.

Section One – Results

1. Explain and account for any expected or actual differences in the results between Task B and C.

_____

_____

_____

_____

_____

_____

(4 marks)

2. In a hypothetical competition in Task D between two participants, Callum and Lara, Callum 'won' achieving a total score of 70. However, in Task C it was Lara who not only achieved a higher score of 72 but also scored higher in Task C than Callum did in Task D. Account for why Lara did not win Task D.

_____

_____

_____

_____

_____

_____

(2 marks)

3. Outline the likely and relevant qualities of an individual who performed well across Tasks B, C and D.

_____

_____

_____

_____

(2 marks)

4. For Task D identify the likely psychological and physiological impact of the situation. Consider the impact on both the participants and their performance.

_____

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_____

_____

(4 marks)

5. Outline three limitations of the experiment and how they may be overcome. You may wish to include any potential limitations that may not have been observed.

_____

_____

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_____

_____

_____

(3 marks)

6. Presentation of results (teacher to indicate).
   - Accurate and relevant presentation of data. (2 marks)
     OR
   - Satisfactory presentation of data. (1 mark)

Section Two – Application

7. Identify and describe the type of attentional focus that was used in Task D.

   _____

   _____

   _____

   _____

   (2 marks)

8. Describe how attentional focus may be impacted on when an athlete experiences a state of under arousal.

   _____

   _____

   _____

   _____

   (2 marks)

9. Identify three techniques and athlete can use to increase their level of arousal.

   _____

   _____

   (3 marks)

10. Describe an example of an athlete and the skill/activity they perform that would benefit from a high level of arousal.

    _____

    (1 mark)

11. Discuss in detail the sports psychology principle of motivation. In your response you must make reference to the following:
    i. Direction
    ii. Intensity
    iii. Intrinsic
    iv. Extrinsic

(4 marks)

12. Describe two ways the participant's level of motivation may have been enhanced during this experiment.

(2 marks)

13. Motivation can influence an athletes selection of and preference for an activity or sport. Describe two other ways motivation may have positively influenced the participant and their performance in this experiment.

_____

_____

_____

_____

_____

_____

(2 marks)

Section Three – Extension

14. Using a graph, illustrate the relationship between performance and arousal when comparing a novice, expert and intermediate athlete.

(3 marks)

15. Predict and account for, using the principles of sport psychology, how the following individuals may have performed during this practical investigation, compared to performance scores recorded by the members of your class.

    a. Primary school student who is seven years of age (who has not played AFL).

    _____

    _____

    _____

    _____

    (2 marks)

    b. An elite AFL player.

    _____

    _____

    _____

    _____

    (2 marks)

Teachers – maintain the security of these documents. Do not provide them to students.

Appendix B2.4

Practical Investigation Marking Key: Sport Psychology

Arousal, motivation and concentration and an individual's performance

Unit 2

Type: Investigation

Outcome 4: Knowledge and understanding of sport psychology concepts for physical activity.

Content: 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.



Having completed the Arousal, Motivation and Concentration experiment you are required to address the questions outlined.

An outline of this task has been provided for you.

Task outline

By completing the experiment outlined, you are to observe and evaluate the influence of age, skill level and type of activity on motivation, arousal and concentration on performance. This investigation involves groups of three students working together. Having selected the group please read the next statement.

Task (A)

1. Form groups of three students per group.
2. Select a pair of students to handball the football to each other. They do not read the following instructions. **Only the non-participant observer reads the following instructions** and then directs the active participants to complete the task requirements.

Instructions:

1. Tell the handballers to stand a distance of 6 m apart.
2. Put markers at the distance chosen.
3. Tell them not to start until you are ready.
4. **Do not tell them** that you are scoring the accuracy of the handpasses.

The non-participant will:
Stand to the side of the handballers and make judgements about the accuracy of each of the handballs. Use the following chart (Figure 4.33) to score for both participants. Only score for every second handball that each participant delivers. Continue until ten handballs are recorded for each participant.

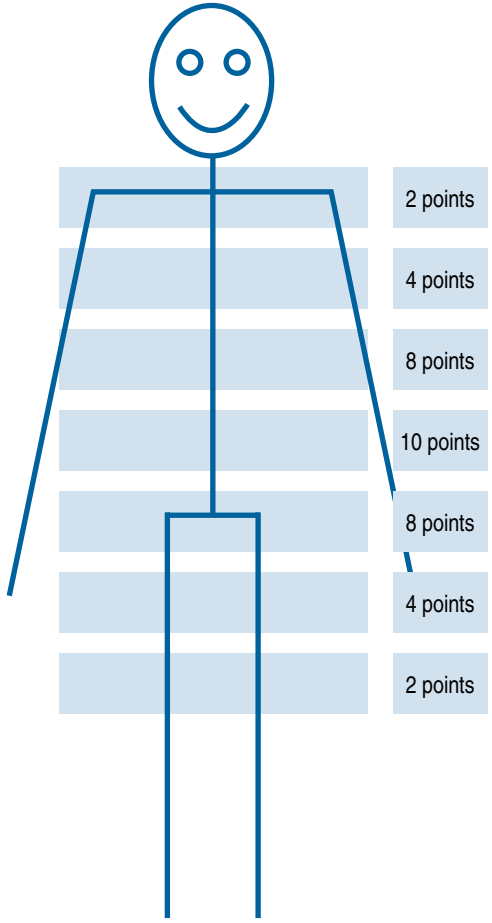


Figure 4.33: *Accuracy chart for handballing*

Task (B)

1. Draw the rectangles onto a hard wall (for example, brick) with the same proportions as recorded above.
2. Using the same two participants who handballed in Task one (A), take them to the wall target and ensure they stand 6 m from the wall.
3. Ask the participants to handball until you tell them to stop.
4. Do not encourage competition or comparison with the previous task, their partner or others.
5. Stand to the side of the handballers and only score for every second handball that each participant delivers. Continue until ten handballs are recorded for each participant.

Task (C)

1. Swap one of your handballers with another group.
2. Inform them that they are now in a competition with each other.
3. Inform them that they have only ten handballs to score the most points possible.
4. Inform them that the teacher has prizes for each winner (for example, a chocolate frog)
5. Stand to the side of the handballers and score the accuracy of each handball. Record the ten scores for each participant.

Task (D)

1. The teacher will select two of the best-performed students from Task one (C).
   a. **Option:** Before announcing the final instructions, apply a heart rate monitor to the two selected players. Record their heart rate at this point in time. Once heart rate is recorded, read the instructions for Task one (D). Re-record the heart rate immediately after each handball in Task one (D).

2. The teacher informs everyone that this final competition is for the annual championship with prizes awarded to the winner (for example, a chocolate frog).
3. All other players are divided into two groups. One group is allocated as a cheer squad or support team for one of the players. The other group is allocated to support the other player. The winning player will receive a prize for their cheer squad (for example, a chocolate frog).
4. Cheer squads line the pathway from the handball line to the target. They are encouraged to cheer for their player and against the other (within appropriate limits!).
5. Record the ten scores for each participant.

Section One – Results

1. Explain and account for any expected or actual differences in the results between Task B and C.
   - **Task C is more difficult than Task B.**
   - **This is because the competitive environment will be arousing, and arousal is potentially detrimental for performance of this complex skill.**
   - **Individuals who are able to regulate their arousal (e.g. take a few deep breaths before each handpass) are likely to negate the potentially damaging effects of arousal.**
   - **Individuals who possess intrinsic motivation for the activities will probably perform better. These individuals are likely to remain committed even if they experience poor results. Thus, these participants are more likely to persist and remain effortful in the face of poor performance.**
   - **Finally, athletes who can concentrate on relevant stimuli (e.g. bullseye in target) and filter out irrelevant stimuli (e.g. other students performing the same task) are more likely to perform well.**

   (4 marks)

2. In a hypothetical competition in Task D between two participants, Callum and Lara, Callum 'won' achieving a total score of 70. However, in Task C it was Lara who not only achieved a higher score of 72 but also scored higher in Task C than Callum did in Task D. Account for why Lara did not win Task D.
   - **For Lara the situation might be interpreted as threatening and her arousal may have been in the form of anxiety.**
   - **Callum may have been better placed than Lara to regulate negative arousal/anxiety.**
   - **Callum may be more successful at blocking irrelevant cues.**

   (2 marks)

3. Outline the likely and relevant qualities of an individual who performed well across Tasks B, C and D.
   - **Individuals who possess intrinsic motivation for the activities are likely to perform better. These individuals are likely to remain committed even if they experience poor results.**
   - **Athletes who can concentrate on relevant stimuli (e.g. bullseye in target) and filter out irrelevant stimuli (e.g. other students**

performing the same task) are more likely to perform well.
- **Individuals who are able to regulate their arousal are more likely to perform well.**
- **Skill level.**

(2 marks)

4. For Task D identify the likely psychological and physiological impact of the situation. Consider the impact on both the participants and their performance.

   Task D is likely to be experienced as arousing for the participants.

   Psychological
   - **For some individuals, the situation might be interpreted as threatening and their arousal will be in the form of anxiety.**
   - **Other participants might interpret this situation as fun and exciting. They, too, will experience arousal but they will not experience this as anxiety.**

   Physiological
   - **All participants are likely to experience an increased heart rate, shallow breathing, and a variety of other physiological symptoms associated with arousal.**

   Impact
   - **Although participants in Task D will be competent relative to their peers, their performance in this particular task is likely to be poor.**

   (4 marks)

5. Outline three limitations of the experiment and how they may be overcome. You may wish to include any potential limitations that may not have been observed.
   - **Recording of the results.**
   - **Accuracy in determining where the ball hit the target.**
   - **Single data sample.**

   (3 marks)

6. Presentation of results (teacher to indicate).
   - Accurate and relevant presentation of data.

   (2 marks)

   OR
   - Satisfactory presentation of data.

   (1 mark)

Section Two – Application

7. Identify and describe the type of attentional focus that was used in Task D.
   - **Narrow external attentional focus.**
   - **Focused targeting; ability to block out distractions and remain focused on specific cues; a requirement for target sports (e.g. darts).**

   (2 marks)

8. Describe how attentional focus may be impacted on when an athlete experiences a state of under arousal.
   - **Attentional field becomes too broad.**
   - **The athlete may miss important/ relevant environmental cues.**

   (2 marks)

9. Identify three techniques and athlete can use to increase their level of arousal.
   - **Act energised.**
   - **Listen to upbeat music.**
   - **Use energising imagery.**
   - **Use positive self-talk.**

   (3 marks)

10. Describe an example of an athlete and the skill/activity they perform that would benefit from a high level of arousal.
    - **Weight lifting i.e. simple tasks.**

    (1 mark)

11. Discuss in detail the sports psychology principle of motivation. In your response you must make reference to the following:
    i. Direction
    ii. Intensity
    iii. Intrinsic
    iv. Extrinsic

    Definition
    - **Motivation is the direction or intensity of ones efforts.**
    - **Motivation can limit performance i.e. you are more likely to perform well if you are highly motivated. Performance may be poor if you have little enthusiasm.**

    Direction
    - **Your selection of and preference for an activity.**

    Intensity
    - **The level of persistence you display.**
    - **The amount of effort you give.**

    Intrinsic motivation:
    - **The pursuit of an activity for the inherent satisfaction (enjoyment) that the activity provides.**
    - **E.g., Two brothers kicking a football together for fun.**

    Extrinsic motivation:
    - **The pursuit of a task for contingencies other than inherent satisfaction.**
    - **E.g., Two brothers kicking a football together to receive praise from a parent.**

    (4 marks)

12. Describe two ways the participant's level of motivation may have been enhanced during this experiment.
    - **The provision of extrinsic rewards i.e. chocolate.**
    - **Cheering, encouragement and/or support from peers.**

    (2 marks)

13. Motivation can influence an athletes selection of and preference for an activity or sport. Describe two other ways motivation may have positively influenced the participant and their performance in this experiment.
    - **How persistent and determined the participants were towards successful completion of the task.**
    - **The amount of effort the participants put in to the task at hand.**
    - **The achievement level of the participant comparative to their ability level.**

    (2 marks)

Section Three – Extension

14. Using a graph, illustrate the relationship between performance and arousal when comparing a novice, expert and intermediate athlete.
    (3 marks)

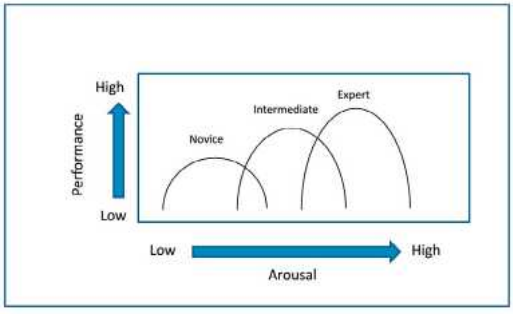


Figure 4.10: *Inverted-U for players with different levels of skill*

15. Predict and account for, using the principles of sport psychology, how the following individuals may have performed during this practical investigation, compared to performance scores recorded by the members of your class.

a. Primary school student who is seven years of age (who has not played AFL).

- **Members of your class are likely to perform better at the tasks than a seven year old with no experience in Australian Football.**
- **With age comes physical strength, and a seven year old might struggle to reach the target in the tasks.**
- **Furthermore, an older student who has not played Australian Football is more likely to have undertaken skills that are similar to handpassing (e.g. underarm serving in volleyball).**
- **Thus, members of your class are likely to perform better due to their practice at other similar tasks.**

(2 marks)

b. An elite AFL player.

- **An elite AFL player is likely to perform extremely well regardless of the condition.**
- **Even if an AFL player was competing against another AFL player, they would still perform the task extremely well (and could even perform better).**
- **Highly skilled athletes often perform at their best when experiencing relatively high levels of arousal.**
- **Thus, a highly competitive handpass challenge might lead to poorer performance among young and less skilled athletes, but to an improvement in performance among elite AFL players.**

(2 marks)

Appendix C (I)

Revision questions

1. Explain how you would use the IZOF model to help an athlete find an optimal amount of state anxiety for their sport.
2. If your primary motivation to go jogging is because you enjoy the feeling of freedom and challenge that it brings, then are you demonstrating intrinsic or extrinsic motivation?
3. Imagine that you have been told that you will be paid to play your favourite sport as a full-time professional athlete. This may appear as a fairytale, but would you expect your enjoyment of the sport to remain strong for the long-term? Explain why or why not.
4. Explain the differences between anxiety and arousal.
5. Explain the difference between cognitive and somatic anxiety.
6. When drawing and labelling a diagram that represents the inverted-U hypothesis, what labels should appear on the vertical and the horizontal axis?
7. Indicate whether you think the following athletes would benefit from a high or a low level of arousal:
   a. An Olympic weightlifter attempting to perform a simple but heavy lift.
   b. A novice snooker player attempting a difficult shot into a corner pocket.
   c. A tennis player attempting to establish a new serving technique.
   d. A group of students in a tug-of-war match with other students.
8. A technique that involves tensing and relaxing muscles in a set order is
   a. called progressive relaxation and is best used for reducing the cognitive symptoms of a warm up
   b. also called breathing control.
   c. also called thought stopping.
   d. called progressive relaxation and is useful for reducing the physical symptoms of anxiety.
9. Breath control involves using deep, controlled breathing. Is it useful to reduce somatic or cognitive anxiety?
10. What is the name of the technique employed when using a physical action combined with positive self-talk to reduce cognitive anxiety?
11. What would be the benefit of exposing an athlete to small, but increasing amounts of stress and anxiety during training?
12. Two players from the Fremantle Dockers come to you for advice on their pre-match states. One of the players indicates that he often feels physically tense and ill prior to games, even though he doesn't feel cognitively anxious. The other indicates that his physical symptoms aren't too bad but he worries about how he is going to perform and finds himself engaging in negative self-talk. What types of anxiety-reduction techniques would you recommend for these two players?
13. What symptoms are reflective of someone who needs to increase their arousal to optimise performance?
14. Two high school students have been asked to perform a difficult volleyball skill in front of the class. One of the students feels threatened by this task but the other student does not appraise the situation as threatening at all. Which stage in McGrath's stress model describes

the importance of these appraisals?

15. Problem-focused coping strategies used to manage stress are focused on dealing with
    a. regulating the response to the problem.
    b. the issue that is causing the problem.
    c. the coach's behaviour.
    d. being too successful in the early part of a performer's career.
16. Identify whether the following are types of problem-focused coping or emotion-focused coping:
    a. A young gymnast engages in a deep breathing technique to lower anxiety prior to an important final.
    b. A tennis player watches videos of a highly-ranked opponent to determine their weaknesses.
    c. A rugby player, who is feeling exhausted and burnt out from the game, asks the manager for permission to skip a couple of training sessions.
    d. An experienced soccer player is frustrated by the manager's decision to place him on the substitute bench. He watches a comedy after arriving home to lighten his mood.
17. Think of one time that you engaged in problem-focused coping and another time that you engaged in emotion-focused coping. Why did you choose to employ these forms of coping for these stressors?
18. The relationship between confidence and performance is best represented as which one of the following options?
    a. A skewed inverted-U where the optimum level of confidence is relatively low
    b. The more confident I am the better I will perform
    c. A skewed inverted-U where the optimum level of confidence is relatively high
    d. An inverse relationship where a high level of confidence will be matched by a low level of self-efficacy
19. Imagine that you are playing for an AFL team and you have converted two difficult set-shots in a row in the forward pocket. You take another mark in a similar position once again. In a game the following week, you have missed two difficult set-shots in the same forward pocket position. You take the mark once again in the forward pocket. Explain the types of thoughts that you are likely to entertain in both of these instances.
20. A 17-year-old has been recruited into the first team squad at the Perth Glory soccer club. He seeks your advice because he does not believe that he is capable of performing at this level. What would you do to improve this player's confidence?
21. A broad attentional focus (Nideffer, 1981), is best represented by which one of the following options.
    a. A player scans the field, attends to variety of cues and selects the player who is in best position to receive a pass
    b. Focusing on the ball when receiving a pitch in softball
    c. Looks for their best friend to receive a pass
    d. Ensuring that you have the same number of steps when you perform a kick for goal in an AFL game
22. Whilst swimming a 400 m medley race in a pool, the athlete is approaching the wall to complete the first 100 m (butterfly). They will hit the wall and turn and begin the second 100 m (backstroke). Explain how the swimmer could employ broad, narrow, internal and external attentional focus.
23. Some athletes are said to make better decisions during performance and have

'old heads on their shoulders'. What does this mean relative to their ability to concentrate during performance?

24. A 10-year-old girl indicates that her dream is to play for the Hockeyroos. Identify the principles of short-term goal setting that the girl could adopt to progress her towards this long-term ambition.
25. A 10-year-old girl indicates that her dream is to play for the Hockeyroos. Identify using two specific examples as to 'how and why' her goals might need to be reassessed during her progress to becoming a Hockeyroo.

Appendix C (II)

Revision answers

1. Firstly, the athlete could be monitored over a series of games or events. The athlete could be asked to report their thoughts and feelings before, during or after the performance. After analysing this information, the athlete could develop optimal zones of emotions that they exhibited during successful performances. This information could be used to help the athlete to prepare for future performance.
2. Intrinsic motivation.
3. The level of success experienced (related to skill level), injury, performance of others in the team and the expectations of others (external regulators) may impact on your motivational focus. As your career unfolds and, with the ever-increasing demands and expectations of coaches, fellow players, club officials, sponsors, supporters and the media, it is possible that these external regulators may serve to decrease your enjoyment of playing the game and more specifically the inherent enjoyment and intrinsic motivation for simply playing. In addition, with the need to compete with others for a spot in the team, your reasons for playing may become more externally motivated than when you were playing at school in a lunchtime game with friends.
4. Anxiety is associated with a negative experience, but arousal can be associated with either negative or positive experiences.
5. Cognitive anxiety refers to a thought component of anxiety: what we are thinking (such as; 'I am scared and nervous'). Somatic anxiety refers to the physical component of anxiety: how we physically feel (such as; 'I am sweating and breathing fast').
6. The vertical axis should be labelled 'performance', with best performance labelled at the top end of the axis and poor performance labelled at the lower end or end closest to the horizontal axis. The horizontal axis should be labelled 'arousal', with the middle identified as 'optimal arousal', the end closest to the vertical axis labelled 'low arousal' and the end furthest from the vertical axis labelled 'high arousal'.
7.
   a. High level of arousal.
   b. Low level of arousal.
   c. Low level of arousal.
   d. High level of arousal.
8. d. Called progressive relaxation and is useful for reducing the physical symptoms of anxiety.
9. Somatic anxiety, which is related to physical feelings.
10. Thought stopping.
11. Consistent with the principles of 'stress inoculation', by learning to cope with low levels of stress, athletes at training become equipped with the necessary resources to deal with moderate and subsequently large, amounts of stress during performance. This is a multimodal technique that will potentially have positive effects on both cognitive and somatic anxiety.
12. The first player has described symptoms of somatic anxiety. He should use progressive relaxation or breath control techniques (or other techniques that are not described in this book that focus on reducing somatic anxiety). The second player has described cognitive anxiety. For the second

player, autogenic training or thought-stopping techniques could be employed. In addition, the coach could employ the stress inoculation technique (multimodal) at training to assist both athletes.

13. Feeling lethargic, unable to concentrate and/or heavy in the legs.
14. Perception of demand: Stage 2 of McGrath's model.These athletes have appraised the stressors differently.
15. b. The issue that is causing the problem.
16.
    a. Emotion-focused.
    b. Problem-based.
    c. Problem-based.
    d. Emotion-based.
17. The choice of a coping strategy should depend on whether a long-term stressor causes the stress and if there is a possibility of changing the stressful situation. Problem-focused coping is superior to emotion-focused coping for dealing with long-term stressors. If the cause of the stress is not likely to change, then emotion-focused coping is best employed.
18. c. A skewed inverted-U where the optimum level of confidence is relatively high
19. In the first instance, successfully kicking two goals is likely to be a source of self-confidence and self-efficacy. You are likely to possess a high amount of confidence for the kick at goal and believe that you have a high chance of success and are therefore entitled to shoot for goal. The second instance is not as easily defined. Your decision to take the kick or pass it off will depend on external factors (wind, game score and so on), level of preparation (fitness, skill practice and so on) and successful use of techniques to improve self-confidence (focusing on performance accomplishments, acting confidently, using positive self-talk, engaging in imagery and pre-shot routines). Importantly, in the second instance, you are more likely to experience self-doubt and, as a consequence, your attention may be given to the variables listed above and you will be somewhat distracted. This may serve to impact not only on your decision, but your performance, should you choose to kick for goal.
20. Engage the player in a variety of techniques to increase self-confidence, such as focusing on performance accomplishments, acting confidently, using positive self-talk, engaging in imagery and carefully planning and preparing for events via pre-game and/or pre-shot routines. Having explained each technique, they should be rehearsed at training and in preparation for games and during games. Through debriefing the effect of each technique with the player and observation, evidence should be collected as to the most successful performance outcomes. A plan for the inclusion of the most effective techniques to improve confidence should be further rehearsed and included in their sporting routines.
21. a. A player scans the field, attends to variety of cues and selects the player who is in best position to receive a pass.
22. Broad attentional focus may be used to scan the pool to determine their position relative to other swimmers. Worthy of note, this may not be recommended by coaches as it is seen to potentially have a negative effect on performance. A narrow attentional focus would be on the levelling of the head position to assist the body to minimise the amount of drag through the water. An internal attention focus would allow the swimmer to focus on how they are feeling: slow and fatigued or fast and full of energy. The swimmer exemplifies an external

attentional focus by focusing on the black 'T' on the bottom of the pool to judge their distance from the wall and when to initiate their turn.

23. Age and skill level are seen to influence concentration. The older the athlete, the more experienced they are likely to be in a given situation. They are more likely to attend to the most relevant or important cues in the performance environment. A higher skill level potentially allows the athlete to focus less on their skill execution, allowing the athlete to attend to external environmental cues that influence performance outcomes.
24. It is important that each short-term goal that is identified is developed in accordance with SMARTS criteria. It is also important that the athlete is prepared to alter their goals over time.
25. Goals need to be reassessed for a variety of reasons. Below are some reasons why athletes should be prepared to reassess goals:
    - Injury.
    - Loss of form/confidence.
    - Issues away from hockey (such as family moving to rural area; need to commit extra time to studying for exams and so on).
    - Slow physical maturation (meaning that they are not physically strong enough or quick enough to compete at defined levels).
    - External decision making (for example, the junior hockey coach doesn't play you in your favourite position).

Appendix E

Glossary of key terms

Anxiety: A negative emotional state involving nervousness, apprehension and worry.

Arousal: A heightened activation of the mental and physical system.

Autogenic training: A series of exercises designed to produce sensations, especially related to warmth and heaviness.

Breathing control: A strategic focus on taking a deep breath followed by slow exhalation.

Broad attentional focus: Attention to multiple cues.

Cognitive anxiety: The degree to which one worries or has negative thoughts.

Confidence: Refers to our expectations about success.

Emotion-focused stress coping: Does not involve attempts to alter the problem, but regulating their emotions in response to the stressor.

External attentional focus: Attention is directed outward towards an object.

Extrinsic motivation: The pursuit of an activity for contingencies other than those inherent in the activity.

Individual zone of optimal functioning model (IZOF): Framework used to understand the influence of emotions on performance.

Internal attentional focus: Concentration on one's thoughts and feelings.

Intrinsic motivation: The pursuit of an activity for the sake of the activity itself, because it is enjoyable and inherently satisfying.

Narrow attentional focus: Attention to only one or two cues.

Objective goals: Focus on attaining a specific standard of proficiency on a task, within a specified time.

Outcome goals: focus on the competitive result of an event and achievement of them depends on the performance of others.

Performance goals: Focus on the achievement of a particular standard irrespective of the performance of others.

Problem-focused stress coping: Methods to manage the issue that is causing the problem.

Progressive relaxation: A technique involving tension and then relaxation of muscle groups.

Self-efficacy: An individual's belief that they can successfully undertake a particular behaviour to produce a given outcome.

Somatic anxiety: A heightened state of physical activation.

State anxiety: Temporary and changing mood state of apprehension and tension and associated with arousal.

Stress inoculation training: A training technique in which coping mechanisms are learned and are then applied in increasingly stressful situations.

Stress: A process in which there is perceived to be a substantial imbalance between demand and response capability and a sense that failure to meet the demand has important consequences.

Subjective goals: General statements of intent, which are not measurable.

Thought stopping: Involves the use of a cue or trigger to stop a negative thought and replace it with a positive one.

Trait anxiety: An enduring disposition to perceive situations as threatening and to then respond with state anxiety.


KELME
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Motor Learning and Coaching

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BACKGROUND INFORMATION

What is Motor Learning?

Have you ever watched Christiano Ronaldo play soccer, Serena Williams play tennis or Gary Ablett in the AFL and wondered why they are so good? How did they get to be the best of the best? Were they just lucky to be born with what it takes to be the best? Or is it that they all have trained hard and practised developing the skills required for their specific sports? The field of motor learning is interested in discovering the best ways to learn and practise motor skills. ***Motor learning*** is the study of the relatively permanent changes in motor skill capabilities that are associated with practice or experience. A part of that is to investigate how elite athletes became experts, because one could consider copying what they did. However, motor learning also includes studying the best way for a teacher or coach to structure the practice environment to maximise the learning outcomes of athletes. This includes determining the best way to practise motor skills (the methods used), how often should the practice be carried out and for how long (for example, three one-hour sessions per week). Other considerations include; the best group size and amount of equipment that provides appropriate time on task and rest periods.

The role of the teacher or coach in developing and fine-tuning an athlete's skill reveals the importance of studying motor learning. A teacher or coach needs to understand the motor learning principles covered in this chapter and the content regarding organisation of practice sessions and skill analysis. Teachers' or coaches' responsibilities and leadership qualities are also discussed.

Text outcomes:
Understand the basic process of teaching or coaching a skill

- *Introduce*
- *Demonstrate*
- *Practise*
- *Feedback*

The Basic Process of Teaching or Coaching a Skill

The four-phase model below outlines the important steps to follow when teaching or coaching skill development with classes or squads and can be used with large groups or an individual.

Introduce the skill

Whether coaching elite athletes, or novices learning a motor skill for the first time, it is important to introduce the skill to be learned in an organised and succinct manner. An effective introduction to a skill should:

- Provide a name to help athletes to categorise and remember the skill.
- Minimise the number of teaching points to avoid information overload. Generally, students can absorb no more than three teaching points at any one time.
- Ensure that the athletes understand the task; teachers or coaches should provide opportunities for questions to clarify any confusion.
- If the practice area is set up beforehand, time on task can be maximised following the brief verbal introduction of not more than one to two minutes.

Demonstrate the skill

As detailed in Unit 1 ('Cues to improve performance'), many learners will benefit from a demonstration of the skill in conjunction with a verbal introduction. A demonstration is the most common means of communicating how to perform a skill. During any demonstration, it is crucial that you gain the class's full attention and ensure that everyone has a clear view from the best location. The skill demonstration should highlight and incorporate the major teaching points on which the class should focus. Usually, the whole skill should be performed first, then broken down into sub-components where required. For example, one would demonstrate a complete Australian Rules football punt kick before highlighting some particular aspect(s), such as the ball drop or body angle, later. The demonstration should mostly occur at normal speed so that important information about timing and sequencing of body parts is demonstrated along with the spatial aspects.

It has been found that learners can gain a lot of useful information to develop their own motor learning by watching other learners. A lot of learners can mimic or copy a skill after seeing it performed well. Hence, a skilled performer should be used so that learners see the desired result; it can be demonstrated live, or via a video of an elite performer.

Practise the skill

It is important that the skill is practised as soon as possible after the introduction and demonstration. To facilitate the best practice conditions, the teacher or coach should have considered a number of factors relating to the environment and the skill itself and these include:

- Ensure that there is adequate space and equipment for all athletes to maximise practice time.
- For efficiency of practice, the teacher or coach should develop clear routines for moving individuals or groups between any skill practice drills.
- Throughout practice sessions, teachers or coaches position themselves so they can view the whole practice area and not have their backs to a class. They can then deliver short verbal cues of key points, which enhance individual performances, while maintaining the class's attention on the task.

Contained within the following background information, different types of practice (***whole*** vs ***part***, ***specific*** or ***variable;*** whether to emphasise ***speed*** or ***accuracy*** and ***mental*** vs ***physical***) and when they are best applied, are briefly discussed.

Provide feedback about the skill

Providing feedback after the performance of a motor skill is the single best method to improve performance and learning. Unit 2 covers different types of feedback and when they should be

provided; the content and purpose of feedback; and some practical applications of feedback for different learners in different situations.

Teachers or coaches need to remember that feedback should incorporate some positive aspects of the performance and no more than two features for improvement. Depending on the age or skill level and the teaching or coaching methodology used, the performer might be directed by the teacher or coach as to how to improve the skill, or the learner left to try and find a way to improve the skill by her/himself. It is important that learners have a chance to rehearse the skill further after feedback is provided.

Text outcomes:
Observe skills using basic tools, schema, and rubrics

A rubric describes the performance qualities that represent a standard of achievement. Rubrics allow performers to identify their standards of performance and to identify areas needing improvement to achieve a higher level. The following are two examples of performance rubrics. The over-arm throw is described in the first rubric (Table 5.1) and the second rubric describes a range of volleyball skills and strategies (Table 5.2).

Table 5.1: *A rubric to observe the over-arm throw*

Throwing component	Description of component	Performance rating
Grip: Loose for a good throw	Base of two fingers	
	Support hand close by	
	Soft fingers and wrist	
Coiling-phase: Chin over knee and over toe	Looking at target/head and chin up	
	Pointing at/above target for flat/distance throw	
	Side-on shoulder rotation	
	Hips coiled	
	Stop sign position of the throwing arm	
	Un-weight the front foot, pivoting on back leg	
Release-phase 1–lower body: Make a bow (reverse 'C')	Stepping forward with opposite foot to throwing arm	
	Front foot landing heel down first, then flattened	
	Front foot landing in front of lead shoulder	
	Feet positioned with the width of hips	
	Pivoting on a braced front leg	
	Back foot begins to drag and heel lift	
Release-phase 2–upper body: Make a bow (reverse 'C')	Non-throwing elbow to hip	
	Hips rotated to square with target	
	Throwing shoulder rotates forward to square with target	
	Throwing elbow to shoulder	
	Throwing forearm and ball held back	
	Wrist cocked	

Throwing component	Description of component	Performance rating
Release-phase 3–final: Let it go And finish up on the toe	Release elbow level/above shoulder	
	Shoulders near parallel to ground	
	Release hand higher and wider than shoulder	
	Back foot on toe with drag	
	Wrist release	
	Let it go with a 90° angle between the trunk and elbow	
Recovery-phase: Ready to catch a return throw	Upper arm internally rotates	
	Forearm pronates	
	Throwing hand down and across the body midline	
	Release the drag toe	
	Watch the ball to target	
	Recover to a catching position	
Performance: 0 = absent in performance; ☒ = needs improvement; ☑ = consistently employed; ☑☑☑ = excellent.		

Table 5.2: *A volleyball skills and strategies rubric*

Demonstrating the effective application of skills, movement patterns and strategies in a competitive situation.
SATISFACTORILY DEMONSTRATED LEVEL OF SKILLS, MOVEMENT PATTERNS AND STRATEGIES *The student works with others to demonstrate the application of basic skills, movement patterns and strategies in the competitive situation.* • Can serve the ball over the net and execute an overhead serve. • Displays a level of anticipation. • Attempts to employ the appropriate shot. • Executes the shot with intention. • Maintains a ready or activated position. • Can perform a block. • Uses motion to affect a shot. • Applies attack strategies (6/6, 4/2, 6/2, 5/1). • Works with teammates to execute a three-hit strategy.
HIGHLY DEMONSTRATED LEVEL OF SKILLS, MOVEMENT PATTERNS AND STRATEGIES *The student works with others to demonstrate the application of a range of skills, movement patterns and strategies in the competitive situation.* • Able to overhead serve the ball over the net. • Displays a level of anticipation and moves into position early to play the shot.

- Employs verbal communication and makes a call for the ball.
- Maintains balance during the performance.
- Attempts to employ the appropriate shot.
- Executes the shot with intention and some accuracy.
- Maintains a ready position and an appropriate level of activation.
- Attempts to perform a block at the appropriate time.
- Moves into position during the rally in preparation for the spike.
- Uses lateral and forward and backward motion.
- Stands in the designated position before the ball is served.
- Applies attack strategies (6/6, 4/2, 6/2, 5/1) and defensive positioning.
- Works with teammates to effectively implement a three-hit strategy.

VERY HIGHLY DEMONSTRATED LEVEL OF SKILLS, MOVEMENT PATTERNS AND STRATEGIES

The student works with others to demonstrate the effective application of a wide range of skills, movement patterns and strategies in the competitive situation.

- Able to consistently overhead serve the ball over the net with directional control and a variety of spin.
- Displays a high level of anticipation and moves into position early to play the shot.
- Employs a high level of verbal communication and makes an early call for the ball.
- Maintains balance during the performance and recovers to the most appropriate position.
- Able to employ the appropriate shot, regularly, to the advantage of teammates.
- Executes the shot with variety, accuracy and intention.
- Maintains a ready position and an appropriate level of activation.
- Performs a block at the appropriate time.
- Moves into position during the rally in preparation for the spike and spikes with power or control.
- Uses lateral and forward and backward motion.
- Strategically defends the blocker and spiker.
- Stands in the designated position before the ball is served.
- To the advantage of the team, applies attack strategies (6/6, 4/2, 6/2, 5/1) and defensive positioning.
- Works with teammates to maximise the benefits of a three-hit strategy.

Elements of a Training Session

Text outcomes:
Know the basic elements of a training session

- *Warm-up*
- *Fitness component*
- *Skill development*
- *Culmination*
- *Cool-down*

Warm-up

A warm-up prepares the body physically and mentally for the load about to be imposed.These activities should induce a light sweat level to raise the body temperature mildly and incorporate ~10–15% of the session time. Warm-ups can be passive, active and/or specific. A passive warm-up might involve sitting in a sauna or hot bath to warm the body without expending energy. An active warm-up is more usual and uses large muscle groups in activities such as walking, running, bicycling, skipping or swimming. Specific warm-ups refer to performers ***replicating the motions*** of the activity used in a competition. For example, before a butterfly race, swimmers perform some butterfly strokes for short distances at, or near, race pace to prepare the body for their events. In winter, gloves and hats might be worn to raise and retain heat and longer warm-ups are necessary; whereas in summer, cool clothing and shorter warm-ups are sufficient because the body temperature will already be raised by exposure to the environment.

Fitness component

After warming up, the various body systems and parts are activated according to the specific needs of the sport and relative to the existing fitness of the individual. The time allocated to fitness component training should be equivalent to ~25–30% of total session time. The specific fitness components and training principles are covered in the Exercise Physiology chapter of this book.

Generally, flexibility activities are undertaken, before focusing on the priority fitness areas. Aerobic activities generally precede more intense activities, such as anaerobic power or strength training.

Activities can be modified to suit individual needs even when working in groups. For example, a bent knee sit-up can move from just raising the head » head and shoulders » hands to touch knees » hands placed on shoulders » small weight held under chin to develop abdominal muscular strength or endurance. These activities are limited only by one's imagination to adjust the body position to mobilise gravity assistance or resistance. You can also use any available apparatus, such as free weights, machines, therabands, stairs or bricks as weights.

Skill development

Once the body is warm, stretched and strengthened, the teacher or coach teaches the skill section over ~30–35% of the session. This can be done as a class activity, where everyone is doing the same thing, such as using a basketball and performing on-the-spot dribbling. Variations include dribbling quickly, slowly, with changed hands, watching the ball or watching your partner. Or you could divide the class or squad into three or four groups to work on different skills or stages of a skill. If equipment is limited or the group is of mixed abilities, the new activity might be introduced to one small group at a time. Then, one group might be revising the skill introduced last session; one to two groups could be learning the new skill and a fourth group could be refining a known skill. After adequate practice time, the groups can rotate so that all have equal time at each station.

Culmination
When the skills section is completed, one can then can use a minor, modified or full game scenario to implement the new and previously learned skills. This could take ~20–25% of the session time, depending on the degree of previous practice and experience.

Cool-down
A cool-down comprises a gentler period of activity for at least two to five minutes, or ~10–15% of the session time. The aim is to return the body to a state of homeostasis (near rest-level functioning) before showering and returning to class or home. A cool-down provides an opportunity for the body to remove waste and oxidise products from muscles.

The Roles and Responsibilities of a Teacher or Coach

Text outcomes:
Understand the role and responsibilities of a coach

- *Organising*
- *Building rapport*
- *Providing instruction and explanation*
- *Demonstrating*
- *Observing*
- *Analysing*
- *Providing feedback*
- *Providing safe learning environments*

Organising
It is important that adequate time is spent on preparing each class or session. Factors to be taken into consideration include: the area to be used, weather, availability of equipment (for example, not being used by someone else at same time and it is where you expect it to be), class or squad size, ages, experience levels and time available for the session. To maximise skill learning, the group must move smoothly from warm-up through to cool-down sections.

Building rapport
Providing well-organised, well-thought-out and well-thought-through sequential activities that enhance learners' feelings of success via obvious skill improvements helps to build respect and rapport, between teacher or coach and class or squad. The teacher or coach needs to show genuine empathy for those having difficulties with the skill and genuine enthusiasm for the successes of learners. Even though you are 'Coach', you remain a little distant, but, nonetheless, are recognised as being 'with them'.

Providing instructions and explanations
Again, the flow of the session largely depends on smooth movement between activities. Some teacher-training institutions require novice teachers to write down the starting position, each teaching point in that position, then the finishing position for every activity and how learners move from there to the next starting position and so on. While this might seem extreme, it does make for smooth transition between activities and the class recognises that the teacher has thought through the lesson plan for the most efficient use of their time. Be brief, succinct and to the point. Physical activity has a wonderful extra dimension in

that one gets some muscle into the learning. It gives credence to that saying: '*I hear, I forget; I see, I know; I do, I understand*'.

Demonstrations

If the teacher or coach can perform the skill well, it might be the fastest way to convey the message and have the group practising as soon as possible. If the skill was in gymnastics, it might be best for the teacher or coach to have a skilled student perform while the teacher or coach demonstrates and explains the safety 'catching' requirements of partners. As humans can copy very well and place images in the subconscious mind, poor demonstrations should be avoided. Watching a high-profile athlete perform via video can be valuable as the group sees an excellent demonstration and there is a 'wow' factor of then trying to emulate that performer.

Observing

The teacher or coach should be positioned to view the whole class or squad to give a quick teaching point, issue a compliment, stop the activities if a dangerous situation is arising and give extra support or coaching to someone who is in need. Such involvement makes the class or squad aware that the teacher is present and engaged and actually sees and notes what is happening. Also, if an activity is just not working, it can be modified or replaced immediately. Don't be a teacher or coach who listens but doesn't hear; watches but does not see!

Analysing

Other sections of this chapter provide checklists of specific items to look for when analysing skill levels or improvements. Experienced teachers or coaches can look briefly at a performance and isolate the priorities of remediation required. Sometimes the obvious error is the result of something happening elsewhere in the body or action. For example, a left leg emerging from the water in freestyle swimming might not just require an instruction to keep the foot under the water. It could be caused by the opposite hand veering out to the right before pulling and creating an equal and opposite reaction at the other end of the body. So, one learns to break down the overview into subsections very quickly to provide good feedback and assess skill level and improvements. Checklists and rubrics are helpful in fine-tuning.

Providing feedback

When learning a skill it is valuable to have an experienced and knowledgeable teacher or coach. Learning a skill correctly from the outset is desirable as 'nothing breeds success like success'. If one does not receive timely, appropriate and positive feedback, then learners develop poor habits and it makes correction harder. It is true that 'it is harder to teach an old dog new tricks'. Types of feedback are included in the ATAR Units 1 and 2 section of this chapter.

Providing safe learning environments

Knowledge of the area where the session takes place is very important. Are there any obstacles that someone could run into or trip over; is the ground surface rough, hard or slippery? The lesson plan could involve throwing a javelin or discus, making it imperative for that group to be strictly supervised. Avoid looking into the sun when demonstrating or during activities such as ball throwing. In addition, teachers or coaches should deliver instructions 'downwind', to ensure that the class can hear. A bland background behind the demostrater ensures learners are not distracted.

Leadership

A leader is an individual who significantly influences the thoughts, behaviours and feelings of others (Gardner 1995). The first goal of leadership is getting the very best out of the people in your organisation, whether they have talent to spare or are spare on talent (Wooden & Jamison 2005). The most powerful leadership tool is your own personal example. The following section describes the important qualities that good leaders display.

Text outcomes:
Define 'leadership' and the qualities of a good leader

- *Trustworthiness*
- *Enthusiasm*
- *Confidence*
- *Determination*
- *Ability to listen to others*
- *Honesty*
- *Responsibility*
- *Reliability*
- *Patience*
- *Decisiveness*
- *Loyalty*

Qualities of good leaders

Trustworthiness

Teachers or coaches must realise that trust is something they receive from their classes or squads and, once received, needs nurturing. Trust is fragile and can be easily broken. Teachers or coaches provide leadership by trusting their athletes and, in turn, athletes may give their trust to the teacher or coach. In order to maintain trust, a teacher or coach must remember to address the problems associated with the athlete's performance and not make negative comments about an athlete's character.

Enthusiasm

The teacher or coach's manner throughout each class or session can be infectious and affects the responses of the group. Therefore, a teacher or coach must display energy, passion, joy and love for the job of training their squads or athletes. The famous Australian painter, Arthur Streeton, summed it up nicely with '*paint what you love and love what you paint*'. Be aware that false or phony enthusiasm is easily identified by the participants and will cause the session to deteriorate quickly.

Confidence

It is important that a teacher or coach has the confidence to make decisions and to take responsibility for the outcome. It is equally important that a teacher or coach builds confidence in athletes by giving them decision-making responsibilities and supporting their efforts. Confidence comes from the group being as well prepared as is possible for the task ahead and making every effort to comprehensively develop skill, fitness and mental readiness. One must be careful that some early success does not turn confidence into arrogance or complacency, or all will be lost.

Ability to listen to others

Good leaders are able to suspend judgement while listening to others' ideas, as well as accept new ways of doing things thought up by someone else. Such openness builds mutual respect and trust, between teachers or coaches and classes or athletes. Embrace new ideas and try them; if they work, keep them. If new ideas don't work, drop them; but listen to others with different ideas because '*minds are like parachutes, they only work when open*'.

Honesty
It is important that a teacher or coach is honest with their athletes and demonstrates integrity, so that their actions are an honest reflection of what the teacher or coach values. Athletes will very quickly lose respect for a teacher or coach who is not dealing with them openly and honestly. Leaders must earn the trust of their followers and this is largely achieved by setting a good example in matters of honesty and integrity.

Responsibility
A good leader gives credit where credit is due but is also willing to take responsibility for his/her own failures. Players should also be responsible for their roles in the total class or team picture. Individual responsibility can take various forms. For example, in a rowing eight, if one oars-person does not attend training, the boat can't go in the water. If a substitute is used, the flow of the boat can be such that it does not work properly. This is detrimental to the whole crew and most of the training benefits are potentially lost. Hence, there is a great team orientation and responsibility to each other. As the adage goes, '*There is no "I" in team*'.

Reliability
A teacher or coach should demonstrate reliability at all times. These include always being there and in plenty of time to prepare for the session, whether it is for competition or training. Teachers or coaches must be reliable and consistent in the way they handle problems arising with learners or athletes and not show favouritism, irrespective of whether it is the star performer or fringe player.

Patience
Before someone can perform a skill, he/she must be taught how it is done and be provided with appropriate practice before expecting success in competition. Patience is most important when a team or athlete is performing poorly. John Wooden, a great American basketball coach, once wrote that patience is required when following the laws of teaching, which he states are the same as the laws of learning: explanation, demonstration, imitation, correction when necessary and then repetition. While it is important for a teacher or coach to know what changes to make to the team structure or training plan, it is equally important that they know when to make them and not impatiently rush ahead.

Decisiveness
A good teacher or coach is not afraid to make difficult or unpopular decisions because they have confidence in themselves and their abilities and when that it is in the best interests of the squad or team. Wondering out loud in front of a group sends a message that you are uncertain and don't know what you are doing. Classes or teams will then lose confidence in you and maybe take matters into their own hands, resulting in disordered chaos. The better prepared a coach is for any contingencies in training or competition, the more likely successful adjustments can be made with minimum destabilisation of the group.

Determination
Having the determination and dedication to spend whatever time or energy is necessary to accomplish the task at hand is a quality that a teacher or coach should possess. A leader can inspire determination in others by leading by example.

Loyalty
A teacher or coach can demonstrate loyalty through consistently supporting peers, team members and team affiliates. With a worthy

set of core values and self-discipline and genuine care for those you lead, one can look forward to having others return the same. People soon realise whether their leaders are genuinely caring about their personal welfare or not. It will soon be 'found out' if you only care about what they can do for you. But, leaders who are fair, considerate and live by high standards can expect to be rewarded with a group who will stay put if the going gets tough.

Leadership Styles

Text outcomes:
Identify the autocratic, democratic and laissez-faire styles of leadership, and their relationship to coaching models

Autocratic

An ***autocratic leader*** uses an authoritarian manner and dictates exactly what is going to occur in the training session without consulting with the learners or athletes or anyone else. Autocratic leaders are common and they plan the programs within the ramifications of time, equipment, weather and space that are available; that is, they make the decisions. There has been a shift towards modern teachers or coaches relying on greater inclusivity, athletes' views, assistant's input and they are open to alternatives. However, the autocratic teacher or coach ultimately makes the final decision and there are occasions when an autocratic style of leadership is necessary. This occurs when an immediate decision needs to be made, the decision is unlikely to change whether the athletes had input or not and the athletes will not lose motivation as a result of not being involved in the decision. An example might arise when a drawn soccer match requires an immediate list of five players to be presented to execute the penalty shoot-out. Clear-cut, decisive action is required so that players have no confusion as to their roles. The teacher or coach takes on that responsibility and allows players to concentrate on the task ahead.

Democratic

A ***democratic leader*** requires the group to be a part of any decision-making process. This style of leadership is characterised by a process of consultation between the teacher or coach and the athlete(s). The teacher or coach may ask questions or provide a number of alternatives, but he/she allows the team or athlete to make the decisions. This approach serves to empower the athletes and provides them with a sense of control over their current and future career. A teacher or coach also should be aware that a democratic style can have negative outcomes when there is no clear agreement within a group of athletes and should be prepared to cope with this situation. Appropriate courses of action could include a brief trial of the most popular choice, followed by practising the next most popular and so on. Then, the group might have another discussion as to which they now preferred. Or, alternatively, the teacher or coach might decide the course of action by a combination of choices or his/her own preference.

Laissez-faire

Laissez-faire is a French term that describes a leadership style where the teacher or coach will 'let people do as they choose'. In this style of leadership, the teacher or coach's role is minimised and he/she minimally

interferes in athlete or team decisions. The athlete or team will generally learn from their own mistakes. This approach is really only effective if the team or athlete is highly self-motivated, capable of making their own decisions and/or want to focus on participation, socialisation and enjoyment.

Types of Practice

It is one thing to suggest that practice is important for motor skill learning, but it is another thing to understand the best practice or teaching strategy to use in different circumstances.

Text outcomes:
Consolidate and extend skill development by using different teaching strategies

- *Whole and part practice*
- *Chaining and shaping practice*
- *Specific and variable practice*
- *Practice for accuracy or speed*
- *Mental or physical practice*

Whole and part practice

- ***Whole practice***–where the entire motor skill is rehearsed.
- ***Part practice***–where the motor skill is broken into parts that are rehearsed separately.

The decision about whether a motor skill should be practised as a whole or broken down into parts is based upon the complexity and organisation of the skill.

Complexity of a skill is defined as the number of its component parts and the amount of attention it requires to perform. The attention required is dictated by the amount of information to be processed and whether the task requires accuracy and needs to be performed quickly. Figure 5.1a & b show a simple skill of jumping into the air, which requires limited attention, accuracy and space and plenty of time is available. Figure 5.1c shows a complex skill of a netballer catching a pass when pressured by a defender and requires all four qualities for success.



Figure 5.1: *The simple skill of jumping into the air (a & b). A complex skill of catching a netball, while under pressure from a defender (c)*

Organisation of the skill: refers to the relationships among the component parts of a skill. A skill with a high level of organisation has component parts that are interdependent. Therefore, you usually cannot perform one part of the skill until the preceding part has been learned. For example, an important part of the basketball jump-shot requires the movement of the arms and the jump to be proficient first, because timing of the ball release must work in sync with all of the parts that preceded the ball release.

The general principle concerning whether to use part or whole practice states that:

- Motor skills that are high in complexity and low in organisation are best practised by the part method; that is, the skill can be broken down into components and each part can be practised separately and effectively (for example, Figure 5.2a, a volleyball spike).
- Motor skills that are low in complexity and high in organisation are best practised using the whole method, as breaking it down into parts might be detrimental to the performance of the skill. Hence, the whole skill should be practised with activities such as an Australian Rules football punt kick (Figure 5.2b).

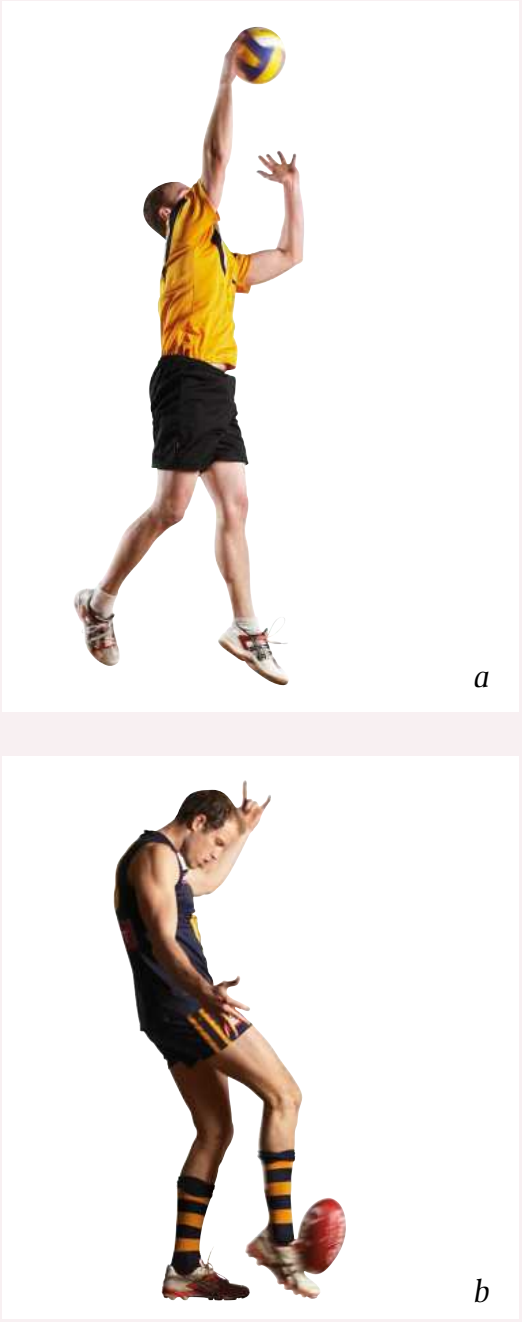


Figure 5.2: *Volleyball spike (high in complexity and low organisation) (a) and kicking a football (low in complexity and high in organisation) (b)*

Types of part practice

The three types of part practice are ***fractionisation***, ***segmentation*** (or progressive part practice) and ***simplification***.

Fractionisation

Fractionisation is a type of part practice where two or more components of a complex skill are practised separately. This is particularly useful for motor skills in which the limbs

move unevenly (asymmetrically), as in playing a musical instrument or serving in tennis. Generally, it is easier to move limbs symmetrically (for example, clapping your hands and stamping your feet together), so it can be beneficial to practise each limb separately. Fractionisation is common in swimming where kicking is practised separately from the arm movement.

Segmentation

Segmentation (progressive part method) is when the first component part of a skill can be practised independently until well learned, then a second part of the skill is practised, initially on its own and then together with the first part. If there is a third part to the skill, it is practised independently and then added to the first and second parts. For example, in a basketball lay-up shot, one can first practise dribbling the ball; then practise the two-step footwork as the second part; and finally add the release of the ball. Many motor skills fall somewhere in the middle along the complexity and organisation continuums and can be effectively practised using a ***progressive-part*** method. Thus, the whole skill is gradually built by subsequently adding each independent part.

Simplification

Simplification is a type of part practice in which the difficulty of some aspect of the motor skill is reduced. Two common ways of simplifying a motor skill are to reduce the difficulty of the objects used or to perform the skill in slow motion. Someone learning to juggle three balls may benefit from practising with silk scarves because they move more slowly through the air and do not bounce out of the hand. A child learning to hit a foam ball with an oversized plastic bat is also benefitting from the simplification method of part practice.

Chaining and shaping practice

The teaching methods of chaining and shaping motor skills are related to the idea of using part practice as described in the previous section.

Shaping

Shaping is when simplified or incomplete versions of a skill are rehearsed initially (to allow the performer to simply perform the skill) and then missing components are gradually added. Usually a teacher or coach will use the shaping method by demonstrating and explaining the skill, get the athlete to practise a simplified version of the task, make corrections and adjustments and then allow further practice before adding missing components, until the whole skill is rehearsed.

Chaining

Chaining is different from shaping because the skill is broken down into components that are rehearsed separately, as if they were isolated skills. The components of the skill are then put together to perform the whole skill. Similar to the principles outlined in the previous section, chaining is best used in sports that are easily broken down into component parts (see 'Whole and part practice' for information about when a skill can be broken down). Chaining can be executed in one of two ways, depending on the skill. In ***forward chaining*** the components of the skill are rehearsed in the order that the whole skill is performed (for example, starting with the first component of the skill). However, ***backward chaining*** is practised with the last component first and the whole skill is built by working backwards.

The main difference between the use of chaining and shaping is that the order of the skill is important in chaining, whereas the order is not as important for shaping the skill. When shaping a skill, a teacher or coach may choose

an aspect of the skill that does not exactly replicate an actual component of the skill. For example, you might practise an exaggerated version of the high elbow lift in freestyle swimming by trailing your thumb along your side during the initial part of the arm recovery. This clearly emphasises the importance of the high elbow recovery but, when other aspects of the skill are added to form the whole stroke, sliding the thumb along the rib cage is omitted.

Specific and variable practice

Specific practice is often called 'fixed' or 'constant' practice and occurs when a skill, or skill component, is rehearsed repeatedly without varying the skill itself or the performance context. ***Variable practice*** involves practising either variations of the same skill or variations of the environmental context in which the skill is performed.

The decision about whether to use specific or fixed practice depends largely upon whether skills are classified as open or closed (see 'Classification of motor skills' in Unit 1). A closed skill that is not affected by environmental factors outside the control of the performer (either for initiating or continuing the skill) can effectively be practised and consolidated by performing in a specific or fixed manner (for example, golf strokes, gymnastics, solo dance routines and springboard diving).

Many skills; however, need to be adjusted according to what is occurring in the environment. For example, the need to execute the same in-step soccer kick over a short distance or long distance depends on where your teammates are on the field. By practising variations of the skill, the performer learns how to adapt the same skill in accordance with the demands of the environment or particular performance or game context. Specific practice is well-suited to closed skills, while variable practice is preferred for open skills. This is because athletes need to be aware of teammates, opponents and other aspects of the environment (such as the goals and boundaries) and must respond accordingly.

Practice with an emphasis on accuracy or speed

One characteristic of human movement when performing any sporting task is the speed-accuracy trade-off (Fitts 1954). When performing a task in which you are instructed to move fast, accuracy will be decreased. In direct contrast, emphasising accuracy will decrease movement speed. Consider the difference in speed between a first and second serve in tennis. The first serve is generally a lot faster because the emphasis might be on speed, but accuracy becomes more of a priority for the second serve because it will be a double fault (and a point lost) if it is inaccurate.

In many tasks it is clear to the teacher or coach whether speed or accuracy should be emphasised during practice. For tasks where accuracy is the main goal, such as golf putting, then the instructions and feedback should emphasise accuracy. Diving off the blocks to start a 50 m freestyle swim is a task that requires movement speed and, therefore, speed should be emphasised at practice.



Figure 5.3: *Emphasising speed while practising the dive start*

However, many sport skills require a combination of speed and accuracy and it is important for a teacher or coach to know which to emphasise. Generally, it is accepted that it is best to emphasise accuracy first and gradually increase movement speed, while maintaining accuracy as individuals learn.

Mental and physical practice

Mental practice is rehearsal of the perceptual, cognitive and motor skills in the absence of any overt movement or gross muscular involvement. An individual engaged in mental practice can think about the sequences of steps involved in the performance of the skill and can practise the skill without making mistakes. A specific type of mental practice is ***mental imagery***. Here, individuals imagine themselves performing motor skills from either an internal perspective (for example, where the movement and the environment are experienced from the same view as when actually performing the skill), or from an external perspective (for example, where performers imagine watching themselves perform the skill, as if on video).

It is important to point out that, when considering mental or physical practice, physical practice is usually better for learning, but a combination of the two has been shown to be effective in many situations. Mental practice can also be used effectively in situations where an athlete is injured and unable to physically practise the skill.

Text outcomes: *Identify the relationship between feedback and skill development*

- *Briefing or frontloading*
- *Debriefing skills*

The Unit 2 content, presented in this chapter, details the types of feedback teachers or coaches use to enhance skill development in their athletes. However, teachers or coaches must consider both the content and timing of information they present to athletes. A teacher or coach can create effective learning environments by utilising briefing or frontloading and debriefing techniques.

Briefing or frontloading

As the name suggests, ***briefing*** or ***frontloading*** is information provided by the teacher or coach to athletes prior to practising activities, which can range from isolated skill practice through to game simulations. Frontloading aims to set up how you want a group to interpret an activity and serves to:

- review learning and commitments from previous activities
- review the aims of the activity and what can be learned
- encourage reflection on motivations
- anticipate what behaviours will result in success
- identify what behaviours will hinder success.

Debriefing skills

A ***debrief*** is a guided reflection of what happened during an activity or event, followed by an open sharing of these reflections. A teacher or coach should facilitate the debriefing process to ensure that the athletes understand the important aspects of the skill. Debriefing is particularly important when teachers or coaches are trying to develop the strategic and tactical knowledge of their athletes so they can execute the teacher or coach's 'game plan'.

A teacher or coach should facilitate the debriefing discussion of the activity by asking the following questions:

- What happened?
- So what? - Why did that happen?
- Now what?

Motor Learning and Coaching: ATAR Units 1 and 2

A similar approach is followed for each section of the ATAR Units 1 and 2 curriculum. Sections start with textbook-related learning outcome statements, followed by a dot-point box identifying the 'Content that follows' and the theory and application for each content area. Suggested class tasks and practical activities are embedded within the sections of the text. A 'Key point summary' box is presented at the end of each section.

Two practical investigations are included as Appendix B1 (Unit 1 content: Stages of learning–traffic light task) and Appendix B2 (Unit 2 content: Extrinsic (augmented) feedback–knowledge of results). A format for report writing can be located at the end of this chapter (Appendix A) to assist students with their preparation of a practical investigation. Marking matrices are also included in Appendices B1 and B2. Answers are provided for teachers only.

Revision questions (with answers) are included near the end of this chapter as Appendix C.

Following the revision questions is a 'Personalised project', which requires students to access knowledge and understanding from 'Sport Psychology and Motor Learning and Coaching' (Appendix D). Even if this task is not undertaken for assessment purposes, it provides a valuable tool for revision.

A 'Glossary of key terms' appears on the final pages of this chapter (Appendix E).

Content that follows: *Skill (Unit 1)*

- *Definitions of skill: Motor skill, cognitive skill and perceptual skill*
- *Learning versus performance*
- *The expert advantage*

Skill

A skill has a predetermined goal that performers attempt to achieve. Hence, we can assess how well a skill is being performed relative to that goal. A skill is learned and is improved through practice and experience. Specifically, a ***motor skill*** is the '*learned ability to bring about pre-determined results with maximum certainty, often with minimum outlay of time or energy or both*' (Guthrie 1952). If you were to compare the actions of highly skilled performers with those less competent, a number of differences can be observed:

- if speed is important, the highly skilled are faster (for example, 100 m sprint and downhill slalom skiing)
- where movement timing is important, the highly skilled have more consistent movement times (for example, synchronised swimming and baseball batting)
- where reproducing the same skill is important, the highly skilled have greater control and timing of their movements (for example, golf and gymnastics)

- Where energy expenditure is a consideration, the highly skilled are more efficient (for example, endurance running and swimming).
- Where athletes need to attend to situational demands and make appropriate decisions, the highly skilled are more effective (for example, netball and touch football).

Class task: *Analysing skilled performance*

Picture in your mind, or look at a video of, an elite performer. Discuss what makes the best players the best. How would you describe the performance of the best performers in the sport that you have chosen?

When a fullback in Australian Rules football successfully kicks the ball back into play after a point has been scored there are a number other skills being demonstrated (Figure 5.4). The observable motor skill is the technical execution of the kick. But, before the kick-in, the fullback must rely on visual information, seeing players up the ground, the wind direction and the wet and heavy ball. The fullback also relies on verbal information from his team, asking for the ball and directing him where to kick-in. The process of recognising and then interpreting this information (watching team-mates create space or listening to them provide instructions) from the environment is called the ***perceptual skill***. ***Cognitive skill***, which is strongly linked to the above two skills, includes problem solving, remembering and decision making. Table 5.3 lists a number of sports and provides examples of the motor, perceptual and cognitive skills involved.



Figure 5.4: *Australian Rules footballer kicking the ball back into play after a behind (one point) has been scored. What options are there for the fullback? What is the best option?*

Table 5.3: *Examples of motor, perceptual and cognitive skills performed in tennis, golf and soccer*

Sport	Motor skill	Perceptual skill	Cognitive skill
Tennis	Tennis serve aimed at the middle 'T' of the service box	Viewing and judging the width and depth of where my opponent is standing when returning my serve	Remembering that my opponent has trouble returning the ball when served to their backhand and deciding to serve to that side
Golf	2nd shot from the fairway to the green	Perceiving the distance to the pin and environmental factors, such as wind direction and strength and the slope of the ground	Deciding that the distance I usually hit my 5 iron will get me closest to the pin
Soccer	Goal-keeper trying to save a penalty kick	Keeping my visual gaze focused on the hips and trunk of the kicker	Deciding to dive to the right before the ball is kicked because of the angle of the hips and trunk

Perception is not just the sensation, but also the meaning we attach to the sensation. The meaning attached to any sensation is formed by previous experiences and the linking of sensory information from various sources. Two goalkeepers in soccer may have equal motor skill competency, yet the goalkeeper with superior perceptual skill will be more likely to stop the goal. This goalkeeper is able to respond as described in Table 5.3 and better predict where the ball will be kicked even before it leaves the boot.

Look at Figure 5.5 below. What did you see? A vase or two faces? Can you switch between seeing a vase and two faces? When you switch between the two images, you are demonstrating perceptual skill.

Class task:
Using your perceptual skills

Look at the image below and quickly determine what you see first.

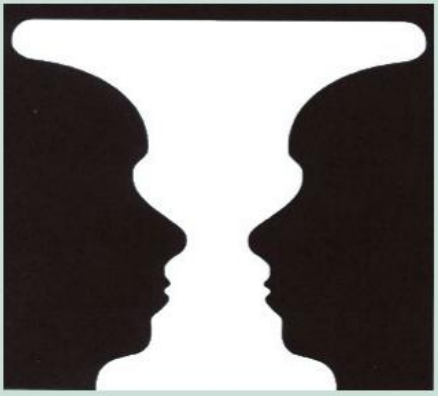


Figure 5.5: *A perceptual challenge*

Discussion question:
Why is it that two people can look at the same image (receiving exactly the same visual sensation) and see different things (a vase or two people)? Why might this be important for sport performance?

Learning versus performance

The terms learning and performance are used often in this chapter, so we should distinguish between the two terms. ***Performance*** is an observable behaviour (for example, a skill performed) at a specific time and location. ***Learning*** is the relatively permanent change in the capability to perform a skill (usually an improvement) as a result of practice or experience. If you were to have fifty practice attempts at juggling three balls, you might improve your performance by the fiftieth attempt. If you came back the next day and performed at the same level at which you started, then your improved performance (from the end of the previous day) was lost; it was temporary. Therefore, you cannot claim learning has occurred.



Figure 5.6: *Beginner (a) and expert juggler (b)*

In the previous section, we defined and gave examples of 'cognitive skill', 'perceptual skill' and 'motor skill', but the term 'skill' also has the connotation of describing a performance of a high standard. The three types of skill mentioned above can be performed poorly or at

a high level. In this section we have defined the characteristics of skilled or skilful performance.

The expert advantage

What sets Roger Federer apart from the world's twentieth ranked tennis player? There is nothing exceptional about his physical appearance (other players are taller, faster or stronger). Some argue that he is technically outstanding, but not by enough to explain his superiority on its own. So, what is the source of his true expert advantage?

Many researchers believe that the superior perceptual and cognitive skills of experts provide them with more time than lesser skilled opponents. As with the goalkeeper example previously discussed (Table 5.3) athletes will be advantaged if they have superior perceptual skill and can predict what will happen earlier. Also, superior cognitive skills enable them to make better decisions faster. If Roger Federer possesses both superior perceptual and cognitive skills, he will have more time to make the best decision and more time to execute the motor skill with precision.

UWA research snapshot:
The link between perceptual skill and knee injuries

Research in the School of Sport Science, Exercise and Health at The University of Western Australia is examining the perceptual skill of individuals when they react to a three-dimensional projection of a tackler coming towards them in Australian Rules football. We know that if a player has enough time then they can sidestep an opponent safely. Our research revealed that when there are several opponents and little time to read the play, only the highly skilled players could sidestep safely.

Key point summary:

- A motor skill is the 'learned ability to bring about pre-determined results with maximum certainty, often with minimum outlay of time or energy or both' (Guthrie 1952).
- In general, highly skilled performers are: faster, more consistent, able to display greater control and timing, more physiologically efficient and more efficient in decision making.
- Perceptual skill is the process of recognising and then interpreting information from the environment.
- Cognitive skill is the mental processing that incorporates problem solving, remembering and decision making.
- Motor learning is reflected by a relatively permanent change in motor skill capabilities that is associated with practice or experience.
- Motor performance is an observable behaviour at a specific time and location.
- The superior perceptual and cognitive skills of expert sportspeople often provide them with more time to execute motor skills than lesser skilled opponents.

Revision questions:

Test yourself on revision questions 1-3 located at the end of this chapter.

The Classification of Motor Skills

Classifying motor skills guides a teacher or coach as to the best way to introduce a skill. It also helps to identify the most important aspects of a skill, advance the difficulty of a skill or increase its similarity with the way it is performed in competition. For example, it is quite easy to pass a soccer ball to a teammate when the ball is stationary at your feet and your teammate is also standing still. But, when playing a game of soccer, usually you have to pass a moving ball to a moving teammate.

Any single motor skill can be classified within the classification categories outlined in this section; however, each skill may be best classified by using one. Once you understand the classification categories you can make this decision and understand the relevance for designing a practice session.

It should be noted that, although the classification systems are presented as ends of a continuum rather than distinct categories, most sport skills would fit somewhere along the continuum rather than at either end. The concept is similar to that of hot or cold, with varying temperatures in between.

The following section will present and discuss four categories used to classify motor skills. These are Closed–Open; Fine–Gross; Discrete–Serial–Continuous and Simple–Complex.

Text outcomes: *Motor skills (Unit 1)*

- *Describe the classification of motor skills.*

Content that follows: *Classification of motor skills (Unit 1)*

- *Closed versus Open motor skills*
- *Gross versus Fine motor skills*
- *Discrete, Serial, and Continuous motor skills*
- *Simple versus Complex motor skills*

Closed–Open skills

Two features of a motor skill determine whether it is open or closed: whether the timing of the skill is dictated by factors external to the performer and whether the environment is predictable and/or stable. Firstly, if the initiation of the skill is completely controlled by the performer, it can be classified towards the ***closed skill*** end of the continuum. On the other hand, if the performance of the motor skill is paced by something that occurs in the environment and outside the performer's control, it is classified near the ***open skill*** end of the continuum. Secondly, if the skill has commenced and the environment remains stable and doesn't affect the performance, or control the performance outcome, it is classified as a ***closed skill***. If the environment is unpredictable and constantly changing and the performer has to respond to those external factors, then the skill is classified as an ***open motor skill***.

Most sports are made up of a number of





Figure 5.7: *Photo of a tennis player serving–closed skill (a) and a player playing a ground stroke–open skill (b)*

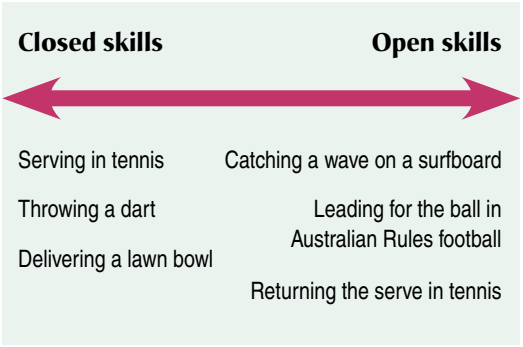


Figure 5.8: *The closed–open skill continuum*

motor skills. A good tennis player can execute forehand and backhand ground strokes, volley at the net, hit an overhead smash and can serve the ball well. All motor skills important in tennis can be classified along the closed–open motor skill continuum. For example, when serving (Figure 5.7a), performers can commence whenever they want to; at least until an umpire tells them to 'hurry up'. The tennis serve can be classified as a closed skill because the initiation of the skill is predominantly independent from what is occurring in the environment. Also, every time you serve the ball, features such as the net height and the size of the service box do not change. Based on these two aspects of the motor skill, the tennis serve is classified as a closed motor skill.

Other than serving, all strokes played in tennis are, in some way, externally paced in response to an opponent. The court geometry (for example, net height and court dimensions) does not change, but the ball location, speed, spin and height are unpredictable, change constantly and are externally paced by an opponent. Thus, the environment is unstable and these strokes are classified as open motor skills.

Gross–Fine skills

Another way to categorise motor skills is to examine the size of the muscles required to perform the skill. Common daily activities of walking and running use large muscles and are classified *as **gross motor skills***. Pulling the trigger in pistol shooting (Figure 5.9a) and writing your name with a pen require the well-controlled movement of smaller muscles and are classified as ***fine motor skills***. The punt kick in Australian Rules football (Figure 5.9b) comprises skill components that can be classified as gross (for example, the run-up and swing of the leg), while others can be classified as fine (for example, guiding the ball down to drop it onto the boot). If placing the punt kick along the fine–gross motor skill continuum, it would be nearer the gross motor skill end because the most important aspect of the kick is the leg movement. But, it is not purely a gross motor skill due to the fine motor skills required by the hands and fingers. Individuals who work in the broad field of rehabilitation often classify skills according to this continuum. Physiotherapists tend to deal with the rehabilitation of gross motor skills, whereas occupational therapists predominantly deal with fine motor skills.





Figure 5.9: *A pistol shooter–a fine skill (a) and a footballer kicking a ball–gross skill (b)*

Discrete–Serial–Continuous skills

Motor skills can also be classified according to whether there is an easily recognisable starting and finishing point. Many tennis motor skills in the ***open–closed*** classification system can also be classified along a ***discrete–continuous*** continuum. A ***discrete skill*** has an identifiable start and finish. The tennis serve is an example as it commences with the ball toss and finishes with the follow-through after the ball strike. When discrete skills are strung together to form more complicated skills, such as a dance or gymnastics routine, they are classified as ***serial skills***. That is, the discrete motor skills can be rehearsed in isolation, or be placed together and performed as an entire routine. The term ***serial*** suggests that the order of the discrete skills is crucial to successful performance.

Continuous skills have no distinct beginning and end points and performers could theoretically continue for as long as they wish. Continuous skills generally contain repetitive movements, with the end of one skill cycle often beginning the next. Running, cycling or swimming are common sporting examples of continuous skills, while steering a car is an everyday example.

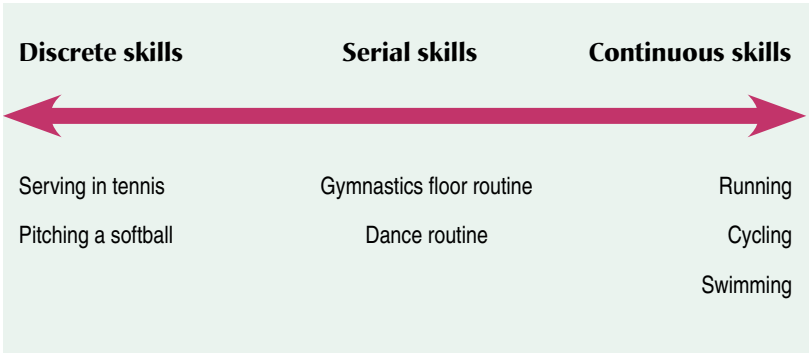


Figure 5.10: *The discrete–serial–continuous skill continuum*







Figure 5.11: *Pitching a softball–discrete skill (a), gymnast during a floor routine–serial skill (b), cyclist pedalling–continuous skill (c)*

Simple–Complex skills

A dance routine is not only a serial skill (as previously discussed) but if there are many components (discrete skills), it is also an example of a ***complex motor skill***. The complexity of a motor skill can be defined by a number of other factors, including:

- how much information needs to be processed
- the required level of movement precision or accuracy
- the time available to perform the perceptual and cognitive components of the skill.

If you perform an unfamiliar dance routine, it would require great concentration to first remember the components of the sequence and then perform them accurately and in time with the music.

The skills of shooting an arrow, picking up a cup or throwing a dart have few component parts, demand relatively limited attention and are classified as ***simple motor skills***. As learned in the other classification systems, they also share characteristics so could be considered closed, fine and discrete skills.

The Phases of Motor Learning section that follows in this chapter outlines how a complex skill becomes easier to perform as you become more proficient. However, the motor skill (for example, dance or gymnastics routine) remains classified as a complex skill because it still retains the characteristics described above. This is important for coaches and instructors because once certain aspects of a skill become easier, then other aspects of a skill can be practised. For example, one can add more steps to a complex dance routine; or the hand and arm movements, head position and posture can be refined. This increases the complexity of an already complex skill!

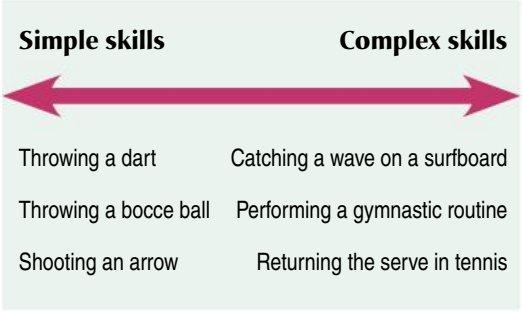


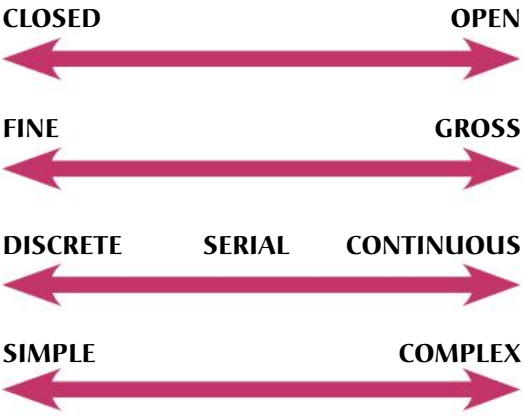
***Figure 5.12**: The simple–complex skill continuum*

Practical activity: *Classifying motor skills*

Different activities represent differing degrees of each of the motor skills classification systems. Draw four lines on a piece of paper, as done below, representing the four classification systems. From a sport, or sports, of your choice identify tasks that can be placed towards the end of the continuum for each classification system.

Equipment:

- Piece of paper and pen.



In summary, armed with the classification systems, a teacher or coach can better understand the ramifications of introducing each activity to a class. If teachers or coaches have a better awareness of the roles of environment, opponents, equipment and skill levels, then they can also bring about a more effective and efficient learning experience.

Key point summary:

- Closed skills are observed when the performer dictates the timing of the skill and when the environment is predictable or stable.
- Open skills are observed when the timing of the skill is dictated by factors external to the performer and when the environment is unpredictable or unstable.
- Fine motor skills use controlled movement of small muscles.
- Gross motor skills use large muscles.
- Discrete skills have an identifiable start and finish.
- Serial skills are defined by the linking of discrete skills together to form more complicated skills.
- Continuous skills have no distinct beginning and end points and contain repetitive movements.
- The complexity of a motor skill is defined by: the amount of information to be processed, the required level of movement precision or accuracy and the time available to perceptually and cognitively process information.

Revision questions:

Test yourself on revision questions 4–7 located at the end of this chapter.

Phases of Motor Learning

If you were coaching someone to perform a forward one-and-a-half somersault dive (Figure 5.13) from the 3 m high springboard, there are a number of things that need consideration before providing instruction or feedback. The level of proficiency or expertise of the performer is perhaps the most obvious. For instance, very different instructions are needed for someone attempting a forward somersault for the first time (Figure 5.13a) than the defending national champion who has performed the dive thousands of times before (Figure 5.13a). Fitts and Posner (1967) proposed the three phases of learning model. It outlines some key motor skill performance characteristics as learners progress from their first attempt to becoming an expert.

Text outcomes:
Learning a motor skill (Unit 1)

- *Describe the phases of motor learning and how they can be used to improve motor skills.*

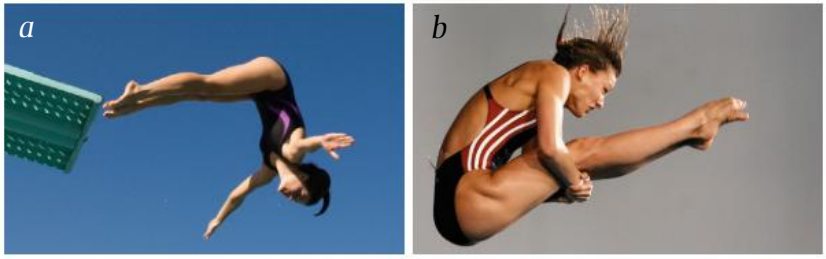


Figure 5.13: *A beginner diver (a) and an experienced springboard diver (b) performing a forward one-and-a-half somersault dive*

Content that follows:

Phases of motor learning (Unit 1)

- *Cognitive phase*
- *Associative phase*
- *Autonomous phase*
- *Using the phases of motor learning to develop or improve specific physical skills*

Cognitive (or early) phase of learning

Firstly, learners must have some level of cognitive understanding of the task they are trying to learn. When learning to hit a golf ball with a driver, someone at the early stage of learning may ask: 'Where do I stand? How do I hold the club? What is the goal of the task?' The learner needs a cognitive understanding of these fundamentals that an elite performer completes without having to think about them.

Performers at this early phase of learning commonly make a lot of errors and the errors tend to be relatively large in magnitude. They also display a lack of consistency from one practice attempt to the next. The performers may be aware that they are doing something wrong, but lack sufficient knowledge of the task or environment to be able to self-correct. Therefore, an important part of this phase of learning is the acquisition of knowledge or a cognitive understanding of the task.

We all remember scenarios when trying to learn a difficult task but without a teacher or coach available to provide the key points with which to get started. I remember, when learning how to surf, where the most frustrating thing was continually making the same mistake when trying to move from lying to standing. Unfortunately, I was unaware of how to change what I was doing. I needed some instruction and feedback from a teacher or coach to help understand the fundamental movements, such as positioning of the hands or feet. Luckily, a friend demonstrated the action from lying down to standing up while on the sand plus some key points on which to concentrate. While it still took many attempts before standing up properly on the surfboard, the demonstration and instruction gave me a cognitive understanding, or mental picture, of what I needed to do. With more practice I refined the cognitive understanding of the task sufficiently to perform the motor skill at a basic level until the mistakes gradually occurred less frequently and were smaller in magnitude.

At this stage of learning, a teacher or coach might simplify the skill by breaking it down into less complicated sub-movements. Skills can be simplified in many ways. For example, they can be slowed down, as when acquiring juggling skills and the balls are replaced with silk handkerchiefs. Alternatively, if a certain aspect of a motor skill is too difficult, that part could be practised in isolation. Perhaps you can recollect having practised a skill this way. It should be noted that many motor skills are best practised as a whole, with a teacher or coach directing learners to the part of the skill needing improvement.

Practical activity:
Simplifying a skill

Three-ball juggling: Use tennis balls and follow the sequence to commence a three-ball juggle. Repeat this procedure with handkerchiefs instead of tennis balls.

- Start with two balls in your right hand and one ball in your left.
- Toss one ball from the right hand into the air.

- While that ball is in the air, toss the single ball from your left hand into the air.
- Now toss the single ball in your right hand in the air before immediately catching the first ball that was thrown in your left hand.
- Catch the second ball in your right hand.
- Complete the cycle by catching the third ball thrown with your left hand.

Discuss the differences between juggling with tennis balls and juggling with handkerchiefs.

Equipment:

- Three handkerchiefs for each student (silk handkerchiefs work best).
- Three tennis balls for each student.

Key point summary:

- The cognitive phase of learning is characterised by:
  - the athlete tries to gain an understanding of 'what to do'
  - errors are large in number and magnitude
  - the athlete has little capacity to correct their own errors
  - instruction and feedback from a coach can be very beneficial.

Associative (or intermediate) phase of learning

Once a cognitive understanding of the task has been gained through practice and, as in the surfing example previously described, having received some instruction and feedback, the performer can move to the associative phase of learning. The performance of the motor skill at this phase is characterised by a lower number of errors that are smaller in magnitude. The basic movement pattern has been learned yet there remains much room for improvement.

An important improvement that occurs at this stage is that the performer becomes more aware of the environment in which they are performing their skills. Well-coordinated movement occurs when actions are performed proficiently and in accordance with environmental demands. When practising motor skills at the associative stage of learning, individuals need exposure to a variety of practice situations to ensure that they are practising well-coordinated movements and not simply a stereotyped action that cannot adjust to changing environmental demands. For example, when catching a fly ball in softball (Figure 5.14), it is important to practise catching balls hit at different heights, directions, speeds and distances from the catcher.

The associative stage of learning is often called the 'refining' stage because the skill is improving from one attempt to the next through practice. The skill becomes more consistent as learners develop the capability to identify and correct some of their own errors. Therefore, the teacher or coach should allow the learner to use their own feedback rather than a sole reliance on coach feedback. This important issue is detailed below when feedback is examined more closely.



Figure 5.14: *To improve catching a fly ball with a glove, use variety in the practice schedule*

Key point summary:

- The associative phase of learning is characterised by:
  - the athlete is able to perform the basic skill
  - the athlete is better able to adjust to the environment when performing the motor skill
  - errors become less in number and magnitude
  - the athlete begins to detect and correct their own errors
  - the athlete is encouraged to use their own feedback.

Autonomous (or final) phase of learning

After considerable practice, a motor skill can be performed automatically or performed easily, without having to consciously think about its execution. This has several advantages when performing motor skills under the pressure of competition. When the skill is automated, it gives the athlete greater opportunity to scan the environment and select the best option. Consider a basketball player running down the court dribbling the ball. If the motor skill of bouncing the ball is automated (without having to think about it) it enables the player to direct attention to other vital pieces of information (cues) in the environment (Figure 5.15). More objective assessment can be made regarding where teammates and opponents are positioned, to ensure that the next skill performed is effective and a good choice. Less conscious attention is required to perform motor skills at the autonomous stage of learning and the performances are characterised by low error and high consistency. Performers who attain this final stage of learning can detect their own errors and make corrections.



Figure 5.15: *A basketball player running and dribbling the ball, whilst attending to other cues*

Many sports, such as tennis, do not allow the teacher or coach to provide any information to the performer once the game or match has commenced. Even in team sports, the teacher or coach has limited opportunities to provide information and feedback to the team. Therefore, it becomes important for the teacher or coach to prepare athletes to recognise and cope with the errors they make. In elite sport, most athletes are at the autonomous phase of learning and errors may not be movement errors, but decision-making or tactical errors. A teacher or coach can prepare an athlete for dealing with errors related to technique, player positioning and movement patterns or even tactical errors by setting up

scenarios at training that replicate important events in a game. A teacher or coach may choose to recreate a scenario where the athlete failed to identify the errors that they were making in the past. Once again, a variety of scenarios for the athlete to problem solve tend to lead to the best learning outcomes.

Key point summary:

- The autonomous phase of learning is characterised by:
  - the athlete does not consciously think about the specific movement characteristics of the skill
  - the athlete can perform other tasks at the same time
  - low performance variability
  - the athlete can detect their own errors and make adjustments to correct them.

Revision questions:

Test yourself on revision questions 8–12 located at the end of this chapter.

Cues to Improve Performance

When individuals are learning a new skill, demonstrations, instructions and practice activities should provide clear information that assists learning of the skill. A range of guidance can be used to inform the learner of the key components of performance. This section considers visual, verbal and proprioceptive cues and how they can be implemented.

Text outcomes:
Improving performance (Unit 1)

- *Identify the types of cues used to improve performance.*

Content that follows: *Cues used to improve performance (Unit 1)*

- *Visual cues: Demonstration, visual aids and enhancing the visual environment*
- *Verbal cues*
- *Proprioceptive cues: Kinaesthesis*
- *Selecting appropriate cues for learners*

Visual cues

Visual cues give the learner an opportunity to see what the movement requires. Teachers or coaches often provide visual cues through the demonstration of a skill because they are more effective: '*a picture paints a thousand words*'. Graphs or charts can enrich the visual information available in the practice environment.

Demonstration

An accurate model or skill demonstration is a powerful visual cue to help the learner and present much information in a short time. The teacher or coach should focus the learner's attention on specific components of any demonstration but this

is a delicate balancing act. Too much talking by the teacher or coach can distract the learner, but too little instruction can lead the learner to view the skill as a whole but miss the specific aspects of the demonstration that will help them.

The teacher or coach should recognise that what learners are 'looking at' may not be what they 'see'. What we see and what we look at can be different! In other words, the learner could perceive information from the demonstration that may or may not be accurate. For example, if two learners watch a highly skilled hockey player demonstrate a hard hit (Figure 5.16), one may see the hit being the product of the intensive physical effort of the player, while the other may leave with the impression that the sequential actions of the legs, trunk and arms are the key. When practising the hockey hit in the future, both learners would approach the performance of the skill in different ways. Therefore, the coaches' instructions should ensure the right information is extracted from the demonstration.



Figure 5.16: *A demonstration of a hard hockey drive*

Visual aids

Graphs, flow charts, pictures and diagrams are all visual aids. The most commonly used aid is video, which can show images of a high-performance athlete or the learner performing the skill. Elite athletes and coaches also regularly use computer analysis programs to qualitatively (describe) and quantitatively (measure) analyse performances.

Enhancing the visual environment

To ensure the learner attends to important aspects of the display, the teacher or coach enhances the visual environment. For example, placing a target on a wall or floor at which learners can aim; placing chalk markings on the pitch for cricketers to bowl the ball in the desired area; positioning targets in the tennis service box to highlight the desired landing point of a service; and dance instructors outlining feet positions on the ground to represent a sequence of steps for beginners to follow.

Verbal cues

A ***verbal cue*** is a short, concise phrase that directs attention to the most important feature(s) in the environment, or prompts performers to attend to key components of the skill. When individuals are learning new skills, teaching or coaching instructions should clearly describe the movements or outcomes required. As noted above, novices in the cognitive phase of learning often have many questions concerning how to perform the basics of the skill. Verbal instructions have been shown to have powerful and lasting effects on learning new motor skills, but they need to be appropriate for the age, comprehension and experience level of the learner. For example, '*chin-over-knee and over-back-toe*', is a simple verbal cue that encourages the learner to position their body weight over their back foot whilst preparing to throw a ball or shot put. Complicated verbal cues can confuse the issue, so one needs to be succinct. Technical verbal cues also can be used to direct high-level performers in areas of already well-rehearsed motor skills that need some fine-tuning.

Teachers or coaches need to be aware that individuals can only absorb limited information.

You probably can remember a teacher or coach standing in front of a class or squad who listed far too many points on which you need to focus. Mostly, players end up forgetting half of the information and can only recall bits and pieces of the other half. If the expectation is that they remember everything, they commonly feel overwhelmed and don't know where to start. This problem is sometimes called 'paralysis by analysis.' Consider when the centipede was asked what the forty-fifth leg on the left was doing when the sixth leg on the right touched the ground, it became so confused and it fell into a ditch!! Instead of over-complicating the teaching or coaching point, brief verbal cues should be used to relay important information for performing a skill successfully.

Proprioceptive cues

Before considering proprioceptive cues, it is important to define proprioception and its relationship to kinaesthesis or kinaesthetic information. The prefix ***proprio -*** means ***from within the body***. Therefore, ***proprioception*** reflects our sensations and perceptions of body positions and movements in space. Information about limb movement, characteristics of position, direction and velocity, as well as a sense of effort are included (Magill 2006). Another type of information that comes from the body is termed ***kinaesthesis***, with the terms ***kines*** meaning movement and ***thesis*** meaning ***the sense of***. ***Kinaesthesis*** is our own awareness of joint movements and muscle-tension levels during motor activity (Schmidt & Wrisberg 2000). The terms kinaesthesis and proprioception are used interchangeably here, to refer to the collection of internal sensory information that informs us about our own joints, muscles and orientation of our bodies in space.

Therefore, proprioceptive feedback to an athlete often involves physically directing the athlete through the movement to know what a successful performance feels like. For example, when learning the breaststroke kick for the first time, swimmers lie on the side of the pool and replicate the desired action. The teacher or coach can provide proprioceptive cues by providing resistance and/or manoeuvring the swimmer's feet into the correct (toes-to-shins) position (Figure 5.17). They also can move the swimmer's legs through the full kicking action.



Figure 5.17: *A swimming teacher providing proprioceptive cues to improve the breaststroke kick*

Practical activity: *Using proprioceptive cues in the finger-nose-finger activity*

Stand facing a wall and, with your right arm stretched out, point your right index finger at a 90^0 angle towards the wall to your left. Start with your left index fingertip touching the tip of your nose, reach out and touch the tip of your right finger and then back again to the tip of your nose. Repeat this cycle (nose-finger-nose) five times. Now try the same task with your eyes closed. Were the contact points always fingertip to fingertip or fingertip to nose-tip? Why is it more difficult with eyes closed?

Equipment:

- None.

Selecting appropriate cues for learners

Cues are important for improving performance and skill development, but information and feedback are only effective if learners actually take notice, understand and apply these cues. Also, learners absorb information in different ways, which has lead to the idea of 'individual learning styles'.

Learners usually prefer to have information presented in one of four ways: visual, auditory, through reading or writing, and by feeling or doing. When a visual learner receives information visually, it is consistent with his/her preferred learning style, with the best outcomes for skill improvement. Conversely, when a visual learner is only ever told verbally how to perform or correct their skill performances, learning is unlikely to be maximised. Having knowledge of different learning styles will enable teachers or coaches to present the same piece of information in a number of ways to accommodate all the learning preferences of the different individuals in the group.

Class task: *Consideration of preferred learning styles*

Form small groups of two to three students. Discuss how you would teach a group of four swimmers to breaststroke, each of whom has a different preferred learning style. Start by establishing how you would introduce the swimmers to breaststroke for the first time. Make sure you consider how the presentation of the information would need to vary for each of the swimmers.

Key point summary:

- A visual cue includes a demonstration or piece of observable information that allows the learner to determine what the movement requires.
- A verbal cue is a concise phrase that directs attention to the most important feature(s) in the performance environment, or prompts performers to attend to the key components of the skill. They need to be appropriate for the learner.
- Kinaesthesis or proprioception provides internal sensory information about joints, muscles and the orientation of a body in space.
- Learners usually prefer to have information presented in one of four ways: visual, auditory, through reading or writing and by feeling or doing.

Practical investigation

Describe and discuss the characteristics of a skilled performance, Fitts and Posner's phases of motor learning and the visual and verbal cues that can enhance learning.

See Appendix B1 for a practical investigation, along with questions and report-writing format recommendations.

Revision questions:

Test yourself on revision questions 13–15 located at the end of this chapter.

Humans as Processors of Information

One interpretation of how humans interact with the world is based on the notion that we are processors of information. The term ***processor*** means that somehow we code the information and possibly change it from one form to another, or combine different types of information (integrate). Human information processing is similar to the way a computer 'takes in' information from outside sources (for example, an external hard drive), interprets that information and combines it with other information in the computer's memory. The way information is processed is limited by aspects of the computer, such as the size of the memory and speed of the processor. Some people have a terrific memory and can remember a long list of instructions from a teacher or coach, but many of us cannot. Finally, the computer output can be displayed in various formats such as the monitor, printer or be emailed. This could resemble the many different movement outputs made by humans, based on the information that enters the system and the way it is processed.

Text outcomes:
Information processing (Unit 1)

- *Know the phases of information processing during skill performance.*

Content that follows:
Phases of information processing and feedback (Unit 1)

- *Stimulus identification–Perception*
- *Response selection–Decision*
- *Response programming–Action*
- *Feedback*

Three Phases of Information Processing and Feedback

Firstly, an individual must sense that a stimulus is present and identify what that stimulus is, or stimuli are. This phase is called ***stimulus identification***. Secondly, after a stimulus has been identified, a decision as to whether you respond or not and how you respond, is made and this phase is called ***response selection***. After selecting the response, the individual needs to prepare and organise the motor system to produce the desired movement known as ***response programming***. After completing these three phases, a movement is initiated, which is depicted as the ***output*** in Figure 5.17. Finally, both during and after any movement, ***feedback*** from different sources provides information concerning its success or otherwise.

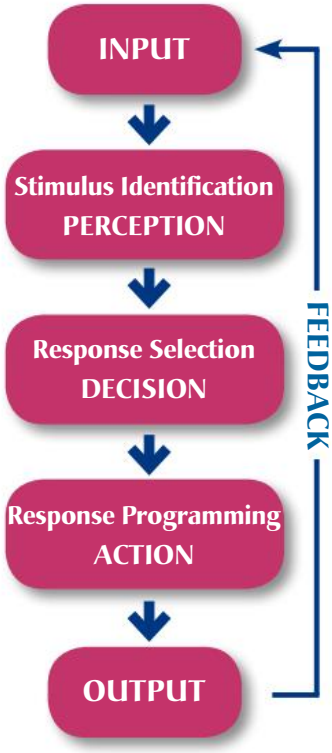


Figure 5.17: *The three-phase model of information processing with feedback loop*

Phase 1: Stimulus identification (perception)

The stimulus identification stage requires an environmental stimulus to be detected. For example, having reached the set position in readiness for a 100 m sprint, the gun goes off (stimulus) to signal that it is time to leave the blocks. Few team sports have such a single, distinct stimulus. Even the tip-off at the start of a game of basketball requires you to identify the stimulus of the ball going into the air, plus the actions of your direct opponent and the positions of your team and opposition.

There is much information via environmental stimuli that can be processed even when standing still in a room. But, we cannot direct our attention to all of it. At this first phase of information processing we ignore or filter some of what is less relevant and only identify information relevant to our goal. For example, when trying to catch a ball hit into the air, we must identify characteristics of the ball, such as how fast it is travelling, whether it is spinning, its size (to place hands at the right distance apart) and where it will land. Less attention would be directed to irrelevant visual information, such as the number and size of the clouds in the sky, the bird flying overhead or even the colour of the ball. The features of the environment, that are important for the execution of motor skills, are called ***regulatory features*** and the irrelevant features are ***non-regulatory features***.

In the brief outline of perceptual skills above, ***perception*** was described as not just the sensation, but also the meaning we attach to the sensation. That meaning is formed by previous experiences and the integration of sensory information from a number of sources. The stimuli in the information-processing model can be derived from any sensory input but visual, verbal and proprioceptive stimuli are the most relevant to motor learning and performance.

The sound of a tennis ball impacting on the racquet strings can provide a valuable auditory stimulus concerning how hard a stroke has been played. Some tennis players have been accused of masking important auditory cues by grunting at the same time as they strike the ball. Critics of grunting claim that the noise restricts receivers from reacting appropriately to the sound of the ball.

Class task: *Determining regulatory and non-regulatory features*

In pairs, choose a team sport and one important motor skill from that sport. Identify and discuss the stimuli that need to be identified (regulatory features) to perform the motor skill well. What are some examples of sensory information that can be ignored (non-regulatory features)?

In a previous section on expert advantage, one of the major differences identified between experts and novices across a number of sports was perceptual skill. Many fast-action sports require patterns to be recognised quickly and experts seem to recognise stimuli (patterns) that go almost unnoticed by novices. In looking at the same visual field, a highly skilled player can perceive very different information to that of a lesser skilled individual.

Phase 2: Response selection (decision)

Having interpreted the information that was sensed, a decision can be made about what to do next, known as the ***response selection*** phase. If a cricket ball is hit in the air towards a fielder, he/she must rapidly decide whether to attempt to catch the ball (if it is possible to get there), or

wait until the ball has bounced and stop the ball from reaching the boundary.

At this decision-making stage of information processing, the stimulus is compared with information stored in the memory of the performer. If the player has been in this situation before (for example, the teacher or coach may have trained him/her specifically with this stimulus) then there is a specific response he/she selects. For example, your volleyball coach has detected that you are often failing to block an opponent's spike. Consequently, your coach has encouraged you to rehearse defensive blocking skills. The result is that you can now more accurately and quickly decide when to block and when to hold your court position.

Researchers have also been interested in the many aspects of performance that can speed up or slow down the time it takes to process information in this decision stage. One of the most influential findings, known as ***Hick's Law***, demonstrated that, if there are a number of different potential stimuli in the environment, as opposed to only one, it takes more time to process the available information. Many sportspeople use Hick's Law to their advantage. If a tennis player served to the same location, with the same spin and velocity on every serve, it would soon become predictable and easy for the opponent to react quickly to the serve. However, the number of potential stimuli, in this case serve variations, is only limited by the number of serves that the player is able or willing to try. In assuming a more unpredictable serve strategy, the player would present the opponent with the greater challenge of selecting a response to a number of possible serves. Similarly, a common tactic in volleyball is for a number of players to jump into the air to fake a spike, creating uncertainty in the minds of their opposition, which, in turn, slows down the information processing (Figure 5.18).



Figure 5.18: *A volleyball team using fake spikers, when number 16 is preparing to actually spike the ball. An example of using Hick's Law to advantage*

Phase 3: Response programming (action)

Once a stimulus is identified and a response selected, athletes can organise and plan appropriate actions. In the ***response programming*** phase, the selected response is retrieved from the memory and the relevant muscles are readied to perform the task. Note that the action is only programmed here in the model (no movement occurs yet) and the 'output' in Figure 5.17 is the actual movement.

If the motor skill that you are preparing (programming) to perform is simple (see the definition of a simple skill in 'Classification of Skills' section), then the response programming stage is very quick (for example, the start of a 100 m sprint). Conversely, when performing a complex motor skill, it takes longer to program and prepare the muscles to complete the action. Furthermore, if the motor skill requires a high degree of accuracy (for example, trap or clay pigeon shooting), or takes a long time to perform, then information processing is also slowed at the response programming stage.

Feedback

Feedback on your performance is a vital component of the information-processing model of human movement. During and

following the execution of a motor skill, feedback from various sensory receptors can assist with improving performance. If an action is performed slowly, feedback can be used to achieve the task goal during the motor skill. For example, when you reach forward to pick up the cup before you take a drink, you use visual information to guide your hand to the correct location. If your hand is heading in the wrong direction, there is enough time to make corrections based on the visual feedback. Similarly, the backswing in golf is usually performed slowly enough, so as to obtain feedback from the muscles about the limb positions and whether they are where they should be. The downswing towards the ball, on the other hand, is normally performed so quickly that, once the downswing is started, there is not enough time to make any corrections...and you must wait until the next stroke to make any corrections. Tiger Woods is perhaps one of the most skilled golfers of all time and is renowned for the ability to stop his swing when he detects an error. By doing that, he is using ***proprioceptive feedback*** that informs him of the need to stop.

More specific to sport coaching is the feedback received after a skill is performed. Sometimes a teacher or coach provides feedback, which describes whether the goal of the task was achieved; for example, how far the discus travelled, or the time of a 50 m split section of a 400 m freestyle race. Or, a teacher or coach might provide feedback based on how the action was performed, or the technique that led to the discus travelling a certain distance. These two broad types of feedback are covered in more detail below. Regardless of the feedback type, it needs to be usable by the athlete to improve in the performances that follow.

Key point summary:

- Three phases of information processing includes:
  - stimulus identification–sensing and identifying a stimulus
  - response selection–deciding if to respond and what response to make
  - response programming–preparing and organising the desired movement.
- After completing information processing, a movement is initiated which is the output.
- Feedback, accessed during and after the performance, is used to improve subsequent performances.

Revision questions:

Test yourself on revision questions 16–19 located at the end of this chapter.

Feedback for Motor Learning

This section considers the feedback provided via the task performance itself (inherent feedback) and feedback additional to that provided by the execution of the task itself (extrinsic or augmented feedback). Figure 5.19 shows the feedback family tree.

Text outcomes:
Feedback (Unit 2)

- *Define the types of feedback.*

Content that follows:
Types of feedback (Unit 2)

- *Intrinsic (inherent) feedback*
- *Extrinsic (augmented) feedback: Knowledge of results (KR), knowledge of performance (KP), terminal, concurrent, verbal, and non-verbal*

Intrinsic (inherent) feedback

Sensory information that is a natural part of performing the skill is ***task-intrinsic*** or ***inherent feedback***. The terms ***intrinsic*** and ***inherent*** refer to the feedback that comes from within the task that is inherent or intrinsic to the task. Thus, visual feedback about by how much the golf ball missed the hole; auditory feedback from the sound of the ball going into the hole; and proprioceptive feedback from your arms swinging the putter are all intrinsic or inherent feedback. Almost every movement we make is associated with some form of inherent feedback to provide a means to evaluate the success of our movements.

In many situations, the inherent feedback requires almost no evaluation, is signalled immediately and can be clearly interpreted, such as when you fail to hit a ball with a bat. On other occasions, the inherent feedback is not so easily understood or recognised and the performer must learn how to interpret the inherent feedback. An example of this could be a dancer, learning to sense when the knee is at a particular angle as demanded in the routine. Initially, the dancer may have difficulty in accurately selecting the required position but, with practice, will learn a reference of correctness to accurately evaluate his/her own performance.

Extrinsic (augmented) feedback

Teachers or coaches watch athletes perform and usually provide information additional to the inherent feedback from the performance. This extra feedback augments and enhances the inherent feedback, is called ***extrinsic (augmented) feedback*** and is the best method to improve motor learning.

In many situations, extrinsic feedback enhances the task-intrinsic feedback already available to the athlete. For example, a tennis coach could direct a player to adjust the racquet grip to gain more topspin during a forehand, even though the task-intrinsic, proprioceptive feedback could have informed the individual of the incorrect grip. It is common for beginners, particularly at the cognitive stage of learning, to require extrinsic feedback.

In other sport and everyday situations, task-intrinsic feedback is either not available or is difficult for the performer to understand. A situation when important task-intrinsic feedback is unavailable occurs when a golf instructor directs a golfer not to lift the head during or after a golf swing. This advice often is given to golfers to prevent the common mistake of lifting the head prior to hitting the ball. However, as the golfer concentrated on keeping the head still, he/she would not see where the ball had gone and the coach provides extrinsic feedback about the result of the performance.

There are two categories of extrinsic (augmented) feedback: ***knowledge of results (KR)*** and ***knowledge of performance (KP)***.

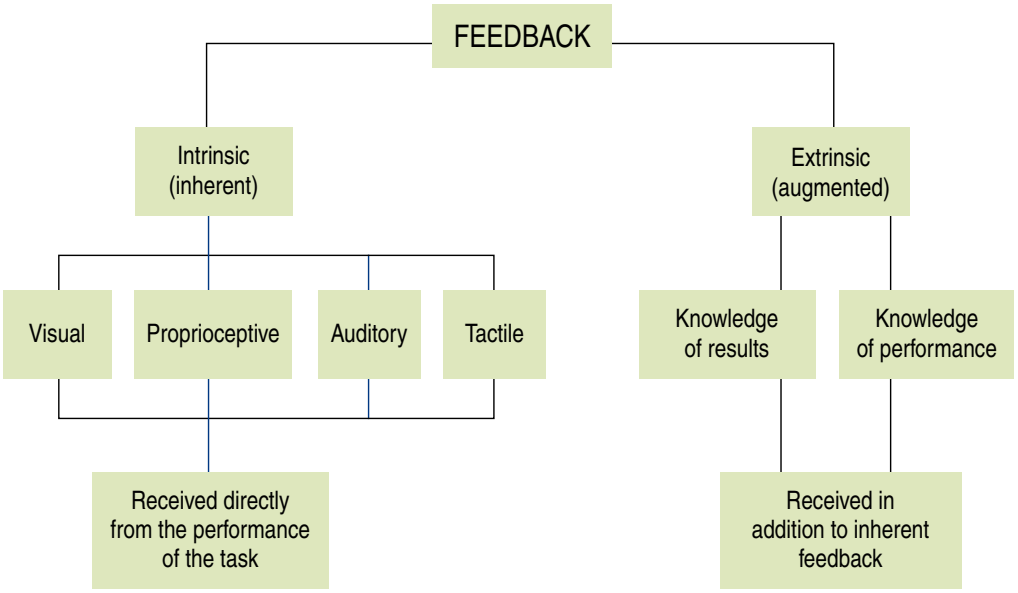


Figure 5.19:
The feedback family tree

Both KR and KP can be present at various times, during and after performances and by different means, including verbal and non-verbal communication. The following section examines KR and KP and a subsequent section outlines ways of presenting extrinsic feedback.

Types of extrinsic (augmented) feedback

Knowledge of results (KR)

Knowledge of results (KR) is feedback about the movement outcome, relative to the task goal. Note that KR is not feedback about the movement itself or how the task was performed. A swimming coach calling out the times, as swimmers are finishing 100 m freestyle is an example of KR. This is because it informs swimmers of the outcome of their swims, but does not provide information about their technique or other information that contributed to achieving that time. Knowledge of results can be highly specific (such as an exact distance from a target); or very general, such as 'well done' or 'very good'.

Knowledge of performance (KP)

The second category of feedback information concerns the movement pattern produced by the performer to achieve the outcome and is called ***knowledge of performance (KP)***. The crucial point here is how KP differs from KR. Using the swimming coach example provided above, to provide KP, the times for the 100 m freestyle would not be called out (as in the KR example); but feedback related to the technique that produced the time would be provided (for example, 'your elbow needs to be higher during recovery'; 'your stroke became too short at the end of the 100 m as you tired').

Knowledge of performance (KP) is related to the type of extrinsic feedback that teachers or coaches give students or athletes during a normal practice or training session. By providing KP, learners' attention can be directed to parts of movement patterns to be changed for improved performance outcomes.

Table 5.4: *Dimensions of knowledge of results and knowledge of performance (adapted from Schmidt & Lee 2005)*

Concurrent: presented during the performance	**Terminal:** presented after the performance
Immediate: presented immediately after the performance	**Delayed:** delayed presentation after the performance
Verbal: presented in a form that is spoken or capable of being spoken	**Non-verbal:** presented in a form that is not capable of being spoken

Much research has examined the effects of the various dimensions of KR and KP seen in Table 5.4. The two questions related to *when* best to provide extrinsic (augmented) feedback and *what* type of information should be provided, are important for teachers or coaches.

Timing of extrinsic (augmented) feedback

Picture a rowing coach in a powerboat, travelling alongside a single scull rower. If the coach wanted to provide feedback, when is the best time to do so? You can provide extrinsic feedback while the rower is actually sculling ***(concurrent feedback)***; or you can wait until returning to dry land before providing feedback ***(terminal feedback).*** If you choose to provide the feedback after training, how soon after completing the session should you provide the feedback? Also, how often should you provide the feedback? This section examines the 'timing of extrinsic (augmented) feedback'.

As suggested in Table 5.4, ***concurrent, extrinsic (augmented) feedback*** relates to information that is presented while the task is being performed. ***Terminal, extrinsic (augmented) feedback*** is information that is presented upon completion of the performance and can take the form of KR or KP. There is little evidence to suggest whether concurrent or terminal feedback is better but, in general, it is suggested that terminal feedback is effective in almost all learning situations.

Using terminal, extrinsic (augmented) feedback

For feedback to be effective, it should be provided when the athlete is ready and able to absorb the information. Terminal, extrinsic (augmented) feedback is effective because teachers or coaches can ensure that they have the athlete's attention. In many sport skills, feedback should not be provided during the execution of the skill. It is unrealistic for a golf coach to try and correct a swing fault during the execution of the stroke because the relatively little time taken to swing the golf club prevents the golfer from incorporating the feedback offered during the swing. Furthermore, if golfers take heed of the instructions, they will be distracted from executing the skill properly. The golf coach should provide terminal, extrinsic feedback after the swing is completed so that the golfer can devote full attention to the feedback.

Using concurrent, extrinsic (augmented) feedback

A teacher or coach can provide concurrent, extrinsic (augmented) feedback to players during the execution of a drill that is designed

to improve a particular tactical scenario. For example, if a basketball coach was trying to ensure that players were in the correct formation for a 'zone' defence, then he/she can constantly provide verbal information to the players and ensure this occurs. Continuous motor skills such as running, cycling and rowing provide an appropriate opportunity for the teacher or coach to provide concurrent, extrinsic feedback. When performing continuous skills, the athlete is better placed to hear or see the teacher or coach and incorporate this feedback.

Concurrent, extrinsic feedback can be useful where an individual is in rehabilitation from an injury and the proprioceptive feedback concerning joint position may be absent or difficult for the person to interpret. Technology such as goniometers could be used to provide joint angle information and provide feedback about the joint ranges of movement during the action.

Immediate and delayed, terminal, extrinsic (augmented) feedback

Providing feedback as soon as the skill is completed is ***immediate, terminal, extrinsic (augmented) feedback***. However, if you wait for a period of time, you are presenting ***delayed, terminal, extrinsic (augmented) feedback***. This section addresses the question raised above, concerning how long after the performance of the skill should the extrinsic feedback be provided.

Coaching manuals regularly suggest that immediate, terminal, extrinsic feedback provides the best learning effects. It is claimed that any delay results in performers forgetting precisely what they did during their performances. Unfortunately, it is not quite that simple as some research has shown that delaying the presentation of feedback following the performance does not negatively affect learning. For example, if learners are encouraged to think about and evaluate their own performances before any coach feedback, then the delay can have a positive effect on learning. However, individuals in the early stages of learning (cognitive stage) might be unable to accurately evaluate their own performances and any delay in providing feedback may negatively impact on learning.

Both immediate and delayed, terminal, extrinsic feedback achieve the best learning outcomes when learners are encouraged to self-reflect (task-intrinsic feedback) either before or after the teacher or coach provides feedback.

How often should extrinsic (augmented) feedback be provided?

When parents pay coaches to improve their children's sport skills, they usually want the coach to provide plenty of feedback to the child, or 'value for money'. However, there is much evidence warning teachers or coaches not to provide feedback after every single practice trial. When extrinsic feedback is provided after every trial, the learner develops a dependence on the feedback. If learners get into situations where the coach is not present to provide extrinsic feedback, their performances will suffer. Some sports have rules preventing coaches from providing pupils with feedback during competition, for example, tennis. If the athlete has been trained by having feedback after every single practice attempt, then he/she may not be prepared to utilise intrinsic (inherent) feedback. Without the ability to use intrinsic (inherent) feedback, the player's performance will suffer.

Verbal, extrinsic (augmented) feedback

General coaching guidelines suggest that feedback should be constructive and assist in either skill learning and/or to motivate

the performer to keep trying. Therefore, constructive feedback will be positive, informative, concise and direct learners' attention to important characteristics of the skill.

The content of the coach's verbal feedback is largely determined by the purpose of the feedback (for information, reinforcement or motivation) or the skill level of the performer.

Extrinsic (augmented) feedback about errors or correct characteristics of performance

If you want to improve the performance of a motor skill, it is better to provide information about the errors in the performance. The error information directs the athlete to change the incorrect aspects of performance, whereas feedback concerning correct performance encourages the athlete to continue performing in that manner. Therefore, a teacher or coach first relays information about some correct aspects of performances to serve as a motivator. Then, one can add that it would be even better if a certain fault was adjusted. Teachers or coaches must ensure that they are not just grumpy critics of their athletes' performances, all of the time. One coaching adage is that 'I am often pleased but never satisfied'.

Qualitative or quantitative extrinsic (augmented) feedback

Teachers or coaches sometimes provide ***quantitative feedback*** that is very specific and involves providing a numerical value related to the magnitude of some aspect of the skill such as, 'that ball landed 10 cm past the tennis court baseline' or 'you were three seconds slower on that lap than the previous one'. Other times, the feedback might be ***qualitative*** and refer only to the quality of performance without regard to numerical values (for example, 'your ball toss was too high for that serve' or 'you need to straighten your right arm').

Individuals at the cognitive stage of learning give more attention to qualitative feedback, even when both qualitative and quantitative feedback is provided. Early learners concentrate on performing an action that includes the basic movements, but advanced performers (autonomous stages of learning) prefer to utilise quantitative feedback because it enables them to refine the performance characteristics in greater detail.

Descriptive or prescriptive, extrinsic (augmented) feedback

Descriptive, extrinsic (augmented) feedback simply describes the characteristics of performance that were incorrect or require improvement. If you were providing descriptive feedback to an Australian Rules footballer, practising their goal kicking, you might tell them 'you dropped the ball from too high'. ***Prescriptive*** augmented feedback not only describes the errors but also suggests a means to correct the problem. If you were providing prescriptive feedback to the footballer you would say not only, 'you dropped the ball from too high' but also add, 'concentrate on guiding the ball onto your foot'. Beginners usually require more prescriptive feedback because they are unaware of how to correct their mistakes, whereas more advanced performers may only require descriptive feedback because they have sufficient knowledge of the skill to correct themselves. A description of the error may also be preferable with advanced athletes, as they will be forced to try to solve the mistake themselves. This will have the positive outcome of empowering the athlete to solve their problems independent of the teacher or coach. This is especially important in sports, like tennis, where the rules prevent the coach from providing their pupil with feedback.

Non-verbal extrinsic (augmented) feedback

Technological advances have allowed coaches to quickly and easily provide non-verbal feedback to their athletes. Real-time cameras, some operating at high speeds, can be rewound and provide visual feedback of the last throw, last swim, last serve or kick, for example. In some institutes of sport or university departments of sport science, extra information of velocity, limb sequential movements and distances achieved are immediately available. Some swimming pools have mirrors on the ceiling for backstroke swimmers and on the bottom of the pool for the other strokes so that swimmers can watch themselves as they swim. Hence, they can examine for themselves whether they are following the technique instructions issued by the teacher or coach before (and during) their swims.

Video feedback

The first time athletes view themselves performing a motor skill from video replay, they often comment that it is the first time they understand precisely what the teacher or coach had been demanding them to do. Video feedback can be useful for performers at all stages of learning. Viewing your own performance on video is also an effective way to develop the capacity to correct your own errors.

While video feedback is an excellent example of non-verbal feedback, it is important to note that the best learning occurs when the viewing of the video is accompanied by verbal extrinsic feedback, as the teacher or coach directs the learner's attention to important characteristics of the performance.

Biofeedback

Biofeedback refers to information related to physiological processes, such as heart rate, the electrical activity in the muscles, blood pressure or blood glucose levels. Heart rate feedback is common in sport and can be used effectively by a teacher or coach to ensure that the athlete is working at the correct intensity during a drill or performance. Athletes can wear small telemetry receivers and be Wi-Fi connected to record heart rates during training. A new swimsuit is being developed, with a tiny microchip in the fabric, so that swimmers can be wired for heart rate, without needing to wear any other apparatus. New technologies such as continuous glucose monitoring systems (CGMS) allow diabetics to be confident that their blood sugar levels are at safe levels during and after a training session.

UWA research snapshot: *Diabetes Research Group*

Previously, to assess their blood glucose (BG) levels, diabetics would take finger-stick blood samples at regular intervals throughout the day. This has the obvious drawback of not knowing your BG levels in between. A recent advance in technology has seen the development of continuous glucose monitoring systems (CGMS) to provide real-time feedback concerning blood sugar levels to diabetic individuals. Current research at the School of Sport Science, Exercise and Health at The University of Western Australia is investigating the use of CGMS for use throughout the day and also during exercise. The CGMS have an LCD that can be viewed at any time and an audible alarm that alerts you to when your BG levels go outside a safe range.

The Purpose of Feedback in Motor Learning

Text outcomes:
The purpose of feedback (Unit 2)

- *Identify the purpose of feedback.*

Content that follows:
The purpose of feedback (Unit 2)

- *Information and reinforcement*
- *Motivation*

Feedback for information and reinforcement

Extrinsic feedback from a teacher or coach assists learning by providing information about what was incorrect about the previous attempt and advice on how to improve the next performance. Extrinsic (augmented) feedback can also provide information about the success of the skill just performed (or currently being performed). The learner can use that information to judge the reliability of their own inherent (task-intrinsic) feedback.

It is generally accepted that the amount of information provided will change as a learner progresses through the stages of learning. At the early (cognitive) stage of learning, feedback is usually provided more frequently to assist the learner to understand the link between the movement performed and the outcome of that movement. It is also provided more immediately because they have not developed the capacity to interpret the task-intrinsic (inherent) feedback.

Particularly in the early stages of learning, it is important that the link between the movement performed and the outcome of that movement is reinforced. With practice, the learner can develop and strengthen the relationship between what the limbs were 'programmed to do' and what they 'actually did'.

Feedback for motivation

While extrinsic (augmented) feedback has been shown to have a long-lasting effect on the learning of motor skills, it also has an important function to serve in the short term to motivate learners. Research into learning environments where feedback is provided, when compared to no feedback, has demonstrated that learners:

- put more effort into practice
- persist longer at practice
- are more interested and involved in the practice session.

Outside learning motor skills, feedback has been shown to influence whether individuals will adhere to a training program, a rehabilitation program or school studies. Related to providing feedback for motivation is the idea that feedback from a teacher or coach affects learners' perceptions of their own abilities, which, in turn, can influence their confidence.

When learning or practising, providing feedback for motivation is important and this is something that all teachers and coaches should understand and apply. Positive, constructive feedback that encourages athletes to continue striving towards a goal is as important as providing information to correct errors.

Key point summary:

- Intrinsic (inherent) feedback is sensory information that is a natural part of performing the skill and includes visual, proprioceptive and auditory information.
- Extrinsic (augmented) feedback is extra information that is not inherent to the task and includes:
  - Knowledge of results (KR)—information about the movement outcome relative to the task goal.
  - Knowledge of performance (KP)—information about the nature of the movement pattern.
  - Terminal feedback—information presented after the performance that can be delayed or presented immediately after the performance is completed.
  - Concurrent feedback—information presented during the performance.
  - Verbal feedback serves to inform and reinforce or motivate and includes:
    - qualitative—best used for the early phase of learning
    - quantitative—best used for the later phase of learning
    - descriptive—identifies the errors
    - prescriptive—identifies the errors and a means to correct them.
  - Non-verbal feedback can be sourced from real-time cameras, mirrors, video and biofeedback.
- During the early phase of learning, extrinsic feedback should be provided consistently and immediately after the performance is completed.
- When learners are able, extrinsic feedback should not be presented continuously, such that it creates learner dependence. Learners should be encouraged, through delaying extrinsic feedback, to self-evaluate performance using intrinsic feedback.

Practical investigation

Describe and discuss the importance of intrinsic and extrinsic feedback to learning motor skills.

See Appendix B2 for a practical investigation, along with questions and report-writing format recommendations.

Revision questions:

Test yourself on revision questions 20–23 located at the end of this chapter.

Skill Learning and Individual Differences

Most of what has been presented in this chapter can be applied to everybody, as they learn or refine their motor skills. However, every learner presents with unique characteristics, based on factors such as age, cultural and environmental differences, previous sport experiences and physical and emotional status that need to be identified and catered for to maximise learning outcomes.

One approach to examining individual differences within skill-learning settings is to consider:

- the characteristics of the individual learning the skill (age, skill level, fitness level and injury)
- the characteristics of the task that is being practised (type of activity)
- the environment in which the task is being performed (level of competition).

This section examines some of these characteristics and considers how tasks and the environment might be manipulated to improve motor skill learning and the subsequent enjoyment of participants.

Text outcomes:
Skill learning and individual differences (Unit 2)

- *Identify the relationship between skill learning processes and individual differences.*

Content that follows:
Skill learning and individual differences related to (Unit 2)

- *Age: children and older adults*
- *Skill level*
- *Fitness level*
- *Injury*
- *Level of competition*
- *Type of activity*

Age

Coaching children

Huge physical and maturational changes occur during childhood, which presents many challenges when teaching or coaching groups of children. To facilitate children's motor learning, one recommendation is to use scaled-down adult equipment. This can include using lighter tennis racquets or cricket and baseball bats, smaller footballs and basketballs, or smaller court, pitch or field sizes. Also, it should be recognised that children 'soak up' motor skills between the ages of four and fourteen years and that these are the critical years for them to gain skills in a wide variety of physical activities, such as running and jumping, hitting and kicking, throwing and catching, swimming, gymnastics and dance.

When teaching or coaching children, classes or training sessions should focus on:

- maximising participation and activity levels
- enjoyment and engagement
- skill learning and development
- respect for self and others
- interpersonal skills.

Children between four and fourteen years of age instinctively enjoy learning and especially learning by doing–'getting some muscle into their learning'. Hence, these are the years in which to place the major emphasis on skill acquisition over a wide range of activities as suggested above. As adolescence approaches, issues of growth spurts, sexual maturation and hormone elevations can bring challenges for teachers or coaches. This is especially so in issues of gender interactions, self-consciousness and large maturation variations. It can be frustrating to find steadily improving students or athletes encountering extended performance plateaus and, sometimes, even performance that goes backwards. Growth spurts can disrupt coordination and teachers or coaches must realise that sport skill learning is still taking place, despite a lack of any improvements in performance. It could well be something beyond the teacher or coach's control that needs rectification before the skill improves.

Coordination difficulties during a growth spurt result from the longer limb levers needing the muscles to catch up with strength; and the hand–eye, leg–eye distances adjust. For example, a tennis coach might try to increase the pupil's serving speed. The actual increase in the ball velocity may take a long time because important components of lever length, speed and strength take different time periods to develop. However, a coach can still focus on the tennis serving technique and, once the levers, muscles, power and skill are in sync, a fairly rapid performance improvement will occur.

Coaching older people and veterans

While it is important to encourage older people to live an active lifestyle, teachers or coaches should recognise that a general decline takes place in most physical activities with 'normal' ageing. Older people need to ease into an activity program during two to three months. One should follow the precept that it is better to finish a session feeling that it has hardly been worthwhile getting changed and having done too little rather than too much, for the first two to three months. Special concern should be shown for older adults, particularly those who are ex-athletes, who have good memories and can remember what they used to be able to do, even though they have not done it for more than twenty years! The use of appropriate footwear and soft playing surfaces, equipment that is light and can be handled with ease (for example, light resistance or weights that can be lifted for ~20 repetitions) and taking care in hot and cold conditions can be monitored to help ensure safe training practices by older people. Older people need to communicate with the teacher or coach and self-monitor physical exertion to work within safe levels. The coach needs to understand that, even in an older training group he/she will be catering to a variety of different motor ability and fitness levels.

Compared to younger individuals, older adults demonstrate:

- slowing of both motor and sensory pathways
- musculoskeletal decline (muscular and bone strength)
- reduced strength
- reduced postural control (or balance)
- reduced fine motor control
- reduced respiratory and cardiovascular capacities.

The loss of these functional capacities can be much delayed with lifelong physical activity and can be well regained with a carefully, progressively overloaded, well-supervised program via an experienced exercise scientist. The slowing down of motor and sensory pathways results in slower reactions to important events occurring in the environment. Older people are likely to slip and fall in everyday life; teachers or coaches must cater for these limitations when setting goals for the exercise sessions.

Skill level

The 'Phases of Motor Learning' section in this chapter has already considered characteristics of performers when moving through the cognitive, associative and autonomous stages of learning. A teacher or coach should understand the stages of learning and provide the best instructions and feedback for individuals to progress optimally through each of these phases. The section examining extrinsic (augmented) feedback provided some guidelines for presenting feedback for individuals at different skill levels.

In general, the higher the skill level, the more specific the feedback (to refine the existing skill) and athletes should be more involved in solving the problems identified by the teacher or coach. At lower skill levels, more frequent feedback may be required to ensure that bad habits are not developed and the feedback is more prescriptive because they don't know how to correct their own mistakes. More advanced performers have sufficient knowledge of the skill to self-correct, so they should be encouraged to do so. They may only require descriptive feedback from the teacher or coach to fine-tune some aspect.

Fitness level

A teacher or coach must adjust the intensity, frequency and duration of a training session to reflect the needs of the sport and also the readiness and needs of each individual. Objective measures should be used to determine initial fitness levels prior to program entry and followed up at regular intervals. Less fit participants must not be fatigued to a level that prevents full concentration on skill development. A balance is required between the physiological and skill training demands of the sport.

Injury

It is often tempting to encourage players to 'push through the pain barrier'; 'no gain without pain' and continue training or playing with an injury. Therefore, teachers or coaches need some knowledge of the type and nature of injuries common to the sport, and how to avoid harming athletes. The level of competition usually dictates the level of medical and paramedical support to which players have access. But, at any level, players should be carefully monitored to avert further damage by encouraging a complete and as rapid-as-possible rehabilitation. The adage, 'Prevention is better than cure' is certainly true. Many injured athletes have a tough time coping with absence from the team and competition, so they need tasks to help improve other aspects of their game. For example, a lower limb injury provides an opportunity to work on increasing upper body strength. In many team sports, players need to keep abreast of new strategies and tactics. Thus, an injury might enable development of game knowledge through video-based perceptual training. Injured AFL players regularly sit inside the coach's box on game day to gain insight into what happens and how various strategies and

tactics are discussed and implemented by the coaches.

Kobie McGurk represented Australia in hockey at the Beijing Olympics, but suffered a serious knee injury in 2009, which required reconstructive surgery. Being a highly motivated and dedicated athlete, Kobie found the experience of sitting on the sidelines very challenging. She tried to use this time to make herself better, describing it as, 'working on areas that I am not so good at, the left side of my body which is weaker and team leadership'. Kobie continued to attend all training sessions in addition to her rehabilitation requirements. She acknowledged that early on in her recovery it was too dangerous to undertake stick-work and Kobie would watch the games on television. She explained, 'I play all of the games or strategies in my mind.' She also sat in the coach's box and learned from that experience.

Level of competition

Within any level of competition there can be a wide range of skill levels between performers. For example, a highly skilled performer may have finished a professional career but wants to continue playing at a social level. Or a mediocre athlete who came to the sport as an adult might want to train full-on for Masters Games, which are held in many sports. As teachers or coaches play a role in maintaining an athlete's motivation, they should ensure that the training session reflects the current level(s) of competition, or the level of competition to which the athlete or team is striving. If coaching a lower level (or grade) team motivated to participate by the social interaction it offers, there is little point in training them like an A-grade team. The athletes will likely lose motivation and leave.

Type of activity

The types of activities implemented during training sessions need to take account of the individual difference categories covered in this section. The ages, skill levels, group experiences and goals, whether an ex-athlete resuming or novice adult, injured participants, individual or team activities and water or land-based are just some of the considerations for a teacher or coach to manage. To that one can add psychological factors of personality, motivation, group dynamics and a host of squad-interpersonal relationship issues. There is always someone returning from holidays, illness or a long lay-off and space is often limited for heterogeneous groups within the main group.

Despite the many complexities that interact with the teaching or coaching process, working with others to realise educational outcomes is very rewarding. Teachers or coach's find it gratifying when athletes achieve their personal goals, enhance their self-esteem and confidence and when they improve their skills and competitive performances.

Key point summary:

- When designing skill learning programs, teachers or coaches need to consider:
  - The characteristics of the individual:
    - age
      - ◊ respect and accommodate the limitations of growth and age

Key point summary (continued):

- ◊ modify equipment, activities, conditioning and teaching to maximise safety and learning
- skill level
  - ◊ provide activities, instructions and feedback to progress optimally through each phase of learning
- fitness level
  - ◊ matching training to the individual's readiness and needs of the sport
- injury
  - ◊ provide athlete support, preventing further damage and facilitating rehabilitation.

- The characteristics of the task that is being practised:
  - type of activity, which is impacted by all of the individual difference variables
    - ◊ physical: age, skill level, fitness level and injury
    - ◊ psychological: motivation, confidence, arousal, anxiety, concentration, personality, group dynamics and inter-personal relationships.
- The environment in which the task is being performed:
  - level of competition
    - ◊ matching training to the needs and aspirations of the individual.

Revision questions:

Test yourself on revision question 24 located at the end of this chapter.

References

Fitts PM 1954, 'The information capacity of the human motor system in controlling the amplitude of movement', *Journal of Experimental Psychology*, vol. *47*, pp. 381–391.

Gardner H 1995, Leading minds: *An anatomy of leadership*, Basic Books, New York.

Guthrie ER 1935, *The psychology of learning*, Harper, New York.

Magill RA 2006, *Motor learning and control: Concepts and Applications*, 8th edn, McGraw-Hill, Boston.

Schmidt RA & Wrisberg CA 2000, *Motor learning and performance: A situation-based learning approach*, 2nd edn, Human Kinetics, Champaign IL.

Wooden J & Jamison S 2005, *Wooden on Leadership*, McGraw Hill, New York, p. 289.

Appendix A:

Writing the practical investigation report

Writing a report

If you are required to write a report as part of your practical investigation, you may choose to use the following format:

Title: Title of the practical investigation.

Aim: State what you hope to achieve in the experiments (~30–50 words).

Introduction: Define and discuss the sport science principles being investigated (~200 words).

Hypotheses: Identify the expected results or anticipated outcomes (statements).

Method: Identify the steps taken to complete the experiments (~100 words).

Results: Present the data and findings in the appropriate format (for example, graphs, diagrams and tables).

Response to the questions: Write the questions out and respond.

Discussion: Provide a detailed discussion of the results. Apply the sport science principles under investigation to other sporting contexts (~400 words).

Conclusion: Summarise the discoveries made. Make links to each hypothesis and include limitations of the experiment (~100 words).

Appendix B1

Practical Investigation and Report: Motor Learning and Coaching
Stages of learning–Traffic light task

Weighting: Unit 1

Type: Investigation

Content:
Describe and discuss:

- the characteristics of performance
- the cognitive processes that are evident during Fitts and Posner's phases of motor learning
- the visual and verbal cues that a coach can use to enhance practice.

Task outline
By completing the task below you will enhance your understanding of the three phases of motor learning (the cognitive phase, the associative phase and the autonomous phase). Furthermore, you will investigate different ways that a teacher or coach could enhance motor skill learning.
Total marks = /30

Experiment
Task one (Condition A)
Method

1. Work in groups of eight to nine students.
2. Each group requires nine witch's hats (markers) or square mats that are to be setup according to Figure 5.20.
3. Eight students will stand next to the witch's hats (markers) or on square mats (all facing the middle with no one on the centre position).
4. Begin the task when all participants are familiar with the rules (see below). It is important that participants only move according to the rules of the task that are outlined.
5. The task finishes when all four participants from one end of the line end up at the other end of the line (Figure 5.21).
6. Allocate someone to be the master timer, who will use a stopwatch to time how long it takes to solve the problem, completing the task once.
7. If the group has nine individuals, the ninth person is to fulfil the role of coach and/or the master timer.



Figure 5.20: *The nine witch's hats (markers) or square mats should be set out in a straight line as above. Eight participants will stand next to the witch's hats or on the square mats (all facing the middle with no one next to the centre hat).*

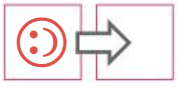


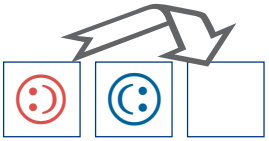
Figure 5.21: *The game finishes when all eight participants are at opposite end of the line from where they started.*

Rules of the game:

1. You can only move ***forward*** and in the following ways.

   i. If there is a space in front of you, then you can move into it.





ii. If you are directly facing someone facing in the opposite direction and there is a space behind them, then you can move into the spare position behind them.

2. You cannot move backwards.
3. You cannot turn and face the other direction.

Task one (Condition B)
Method

1. Repeat the task as previously completed in Condition A, ensuring that all participants begin in their original positions.
2. The aim is to achieve and record a time of less than 20 seconds to complete the task from beginning to end.
3. Two timekeepers will be required. One, to record the time taken for each attempt and a second, the master timer, to record the overall time taken to complete Condition B.

Task one (Condition C)
Method

1. Repeat the task as previously completed in Conditions A and B, ensuring that all participants adopt a ***new*** starting position.
2. Again, the aim is to achieve and record a time of less than 20 seconds to complete the task from beginning to end.
3. Two timekeepers will be required. One, to record the time taken for each attempt and a second, the master timer, to record the overall time taken to complete Condition C.

Questions
In presenting your findings respond to the following:

a. Using Fitts and Posner's phases of motor learning, describe the performance of the group in completing the task for the first time (Task one, Condition A). Consider the players' understanding of the game, the number of errors made and whether any of the players were able to correct these errors (3 marks).

b. After the task was completed for the first time (Task one, Condition A), how long did it take to be able to complete the task in less than 20 seconds (Task one, Condition B)? Describe the changes that occurred in the team's performance during this time (3 marks).

c. When the players' starting positions were changed in Task one, Condition C, what happened to the time required to complete the task? Explain why this occurred (2 marks).

d. Identify and explain any visual or verbal cues that a coach could use to enhance performance, that is, decrease the time it took to complete the task (2 marks).

e. Using a sport of your choice that is classified as 'open' and another that is classified as 'closed', explain how the characteristics of an autonomous performer differ between the two (5 marks).

Equipment

- Nine witch's hats (markers) or square mats for each group.
- Stopwatch–two for each group.

Task: Stages of learning–Traffic light task: 30 marks

Components and Performance Standards	Marks
Hypotheses (2 marks)	
Provides simple statements of the expected results or anticipated outcomes in relation to skilled performance, Fitts and Posner's phases of learning and using visual and verbal cues.	**1 mark**
Provides clear statements of the expected results or anticipated outcomes in relation to the characteristics of skilled performance, Fitts and Posner's phases of learning and, using visual and verbal cues, to enhance learning.	**2 marks**
Introduction (3 marks)	
Identifies and defines the variables associated with skilled performance, phases of learning and cues to enhance learning.	**1 mark**
Shows an understanding of the characteristics of skilled performance. Identifies Fitts and Posner's phases of learning and how visual and verbal cues can be used to enhance learning.	**2 marks**
Shows a comprehensive understanding of the characteristics of skilled performance. Discusses Fitts and Posner's phases of learning and how visual and verbal cues can be used to enhance learning.	**3 marks**
Results (2 marks)	
Satisfactory presentation of data.	**1 mark**
Accurate and relevant presentation of data.	**2 marks**
Response to Questions (15 marks)	
Questions a and b: *3 marks for each correct answer (6 marks).* ***Questions c and d:*** *2 marks for each correct answer (4 marks).* ***Question e:*** *5 marks.*	
Discussion (6 marks)	
Shows little comprehension of the variables associated with the activities undertaken.	**1 mark**
Limited discussion of the results found and few links made to the variables associated with the phases of learning and cues used when teaching/coaching.	**2 marks**
Uses other sporting contexts to discuss the results found and identifies skilled performance. Discusses other sporting examples in relation to Fitts and Posner's phases of learning. Identifies visual and verbal cues used when teaching/coaching.	**3 marks**
Uses other sporting contexts to discuss the results found and identifies and defines most of the variables associated with skilled performance. Discusses other sporting examples in relation to Fitts and Posner's phases of learning and how visual and verbal cues can be used to enhance learning.	**4 marks**
Uses other sporting contexts to show an understanding of the results found and discusses these in reference to the characteristics of skilled performance. Discusses other sporting examples in relation to Fitts and Posner's phases of learning and how visual and verbal cues can be used to enhance learning for each phase.	**5 marks**
Uses other sporting contexts to show a comprehensive understanding of the results found and discusses these in application to the characteristics of skilled performance. Discusses other sporting examples in relation to Fitts and Posner's phases of learning and how visual and verbal cues can be used to enhance learning for each phase.	**6 marks**
Conclusion (2 marks)	
Summarises some of the factors associated with performance, learning and cues used when teaching/coaching in relation to the hypotheses.	**1 mark**
Fully summarises the impact of the factors affecting skilled performance, phases of learning and visual and verbal cues in relation to the hypotheses. Limitations discussed.	**2 marks**
Comment:	**Total** **/30**

Appendix B1.1 – Answers

Practical Investigation and Report: Motor Learning and Coaching

Stages of learning–Traffic light task

a. Using Fitts and Posner's phases of motor learning, describe the performance of the group in completing the task for the first time (Task one, Condition A). Consider the players' understanding of the game, the number of errors made and whether any of the players were able to correct these errors (3 marks).

Answer

Performance was initially characterised by the players trying to gain an understanding of the rules; where to stand and how to move.

During the initial attempts, participants were unable to progress very far into the task. Participants found it difficult to move within the rules and as a consequence had to start again.

Participants may have become frustrated as a result trying to work out how to solve the task but not knowing how or whether they were correct in their approach. Participants may also have repeated the same mistakes and not progressed, that is, reaching the same point during each attempt to complete the task.

Feedback regarding the group's performance and how to correct errors is important for improvement and progression into the next phase of learning.

b. After the task was completed for the first time (Task one, Condition A), how long did it take to be able to complete the task in less than 20 seconds (Task one, Condition B)? Describe the changes that occurred in the team's performance during this time (3 marks).

Answer

Responses need to reflect upon the differences/progression between the cognitive and the associative stage. This may include the following performance characteristics:

- able to perform the basic skill
- improved ability to adjust to the environment in performing the motor skill
- errors become less in number and magnitude
- less variation between performances
- the learner begins to detect and correct their own errors
- the performer is encouraged to utilise their own feedback

c. When the players' starting positions were changed in Task one, Condition C, what happened to the time required to complete the task? Explain why this occurred (2 marks).

Answer

Increased Time: Identifying a form of regression in understanding, either a regression to the cognitive phase or early associative phase.

Decreases Time: Practicing allows participants to quickly re-establish their understanding of the task and improve performance. This further assists them to access a higher level of understanding required to be classified in the autonomous phase.

d. Identify and explain any visual or verbal cues that a coach could use to enhance performance, that is, decrease the time it took to complete the task (2 marks).

Answer

Visual cues:

- A demonstration
- A visual aid – set of instructions or diagrams
- Enhancing the visual aid – number the mats and the participants. This will facilitate the coach's instructions and demonstrations.

Verbal cues:

- Short concise phrases that draw attention to the most important components of the skill
- Presentation of the verbal cues is sequential, such that the highest priority instructions are delivered first.

e. Using one sport of your own choice that is classified as 'open' and another that is classified as 'closed', explain how the characteristics of an autonomous performer differ between the two (5 marks).

Answer

- Understanding
  - Open skill – broad understanding of not only their own role in the sport, but the role of other performers
  - Closed skill – excellent capacity to self-coach themselves because of their ability to correct their own errors
- Behavioural performance
  - Open skill – performance of skill is well-coordinated within the limbs, and also attuned to the requirements of the environment. Players' repertoire of positional play and adaptability/flexibility within the team is well developed. They are able to predict patterns of play relative to their own teammates and the opposition.
  - Closed skill – performance is highly consistent from trial to trial
- Information processing
  - Open skill – the performer is required to scan the environment quickly to select the best option
  - Close skill – they can narrow their focus to concentrate purely on the technical execution to ensure low error and high consistency levels.

Appendix B1.2 Practical Investigation Preparation: Motor Learning and Coaching

Stages of learning –Traffic light task

Unit 1:

Type: Investigation

Outcome 4: Knowledge and understanding of sport psychology concepts for physical activity.

Content:
Describe and discuss:

- the characteristics of performance
- the cognitive processes that are evident during Fitts and Posner's phases of motor learning
- the visual and verbal cues that a coach can use to enhance practice.

Task outline
By completing the task you will enhance your understanding of the three phases of motor learning (the cognitive phase, the associative phase and the autonomous phase). Furthermore, you will investigate different ways that a teacher or coach could enhance motor skill learning.

Equipment
- Nine witch's hats (markers) or square mats for each group.
- Stopwatch—two for each group.

Once the experiment is completed you need to:
1. Compose an accurate and relevant presentation of the results. (Bring with you and submit at the completion of the In-Class Assessment Task.)
2. Answer all of the questions outlined. Some of these questions, along with additional questions will appear in the In-Class Assessment Task.
3. Develop a comprehensive understanding of the characteristics of skilled performance. Discuss Fitts and Posner's phases of learning and how visual and verbal cues can be used to enhance learning.
4. Through research, use other sporting contexts to show a comprehensive understanding of the results found and discuss these in application to the characteristics of skilled performance. Discuss other sporting examples in relation to Fitts and Posner's phases of learning and how visual and verbal cues can be used to enhance learning for each phase.
5. Discuss the limitations of this experiment.

Experiment
Task one (Condition A)
Method
1. Work in groups of eight to nine students.
2. Each group requires nine witch's hats (markers) or square mats that are to be setup according to Figure 5.20.



Figure 5.20: *The nine witch's hats (markers) or square mats should be set out in a straight line as above. Eight participants will stand next to the witch's hats or on the square mats (all facing the middle with no one next to the centre hat).*

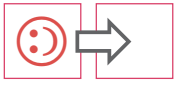


Figure 5.21: *The game finishes when all eight participants are at opposite end of the line from where they started.*

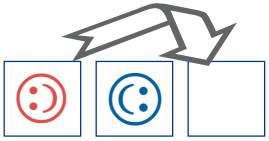
3. Eight students will stand next to the witch's hats (markers) or on square mats (all facing the middle with no one on the centre position).
4. Begin the task when all participants are familiar with the rules (see below). It is important that participants only move according to the rules of the task that are outlined.
5. The task finishes when all four participants from one end of the line end up at the other end of the line (Figure 5.21).
6. Allocate someone to be the master timer, who will use a stopwatch to time how long it takes to solve the problem, completing the task once.
7. If the group has nine individuals, the ninth person is to fulfil the role of coach and/or the master timer.

Rules of the game:

1. You can only move ***forward*** and in the following ways.
   i. If there is a space in front of you, then you can move into it.



   ii. If you are directly facing someone facing in the opposite direction and there is a space behind them, then you can move into the spare position behind them.



2. You cannot move backwards.
3. You cannot turn and face the other direction.

Task one (Condition B)

Method

1. Repeat the task as previously completed in Condition A, ensuring that all participants begin in their original positions.
2. The aim is to achieve and record a time of less than 20 seconds to complete the task from beginning to end.
3. Two timekeepers will be required. One, to record the time taken for each attempt and a second, the master timer, to record the overall time taken to complete Condition B.

Task one (Condition C)
Method

1. Repeat the task as previously completed in Condition B, ensuring that all participants adopt a ***new*** starting position.
2. Again, the aim is to achieve and record a time of less than 20 seconds to complete the task from beginning to end.
3. Two timekeepers will be required. One, to record the time taken for each attempt and a second, the master timer, to record the overall time taken to complete Condition C.

Questions

a. Using Fitts and Posner's phases of motor learning, describe the performance of the group in completing the task for the first time (Task one, Condition A). Consider the players' understanding of the game, the number of errors made and whether any of the players were able to correct these errors.
b. After the task was completed for the first time (Task one, Condition A), how long did it take to be able to complete the task in less than 20 seconds (Task one, Condition B)? Describe the changes that occurred in the team's performance during this time.
c. When the players' starting positions were changed in Task one, Condition C, what happened to the time required to complete the task? Explain why this occurred.
d. Identify and explain any visual or verbal cues that a coach could use to enhance performance, that is, decrease the time it took to complete the task.
e. Using a sport of your choice that is classified as 'open' and another that is classified as 'closed', explain how the characteristics of an autonomous performer differ between the two.

Appendix B1.3

Practical Investigation Assessment Task: Motor Learning and Coaching

Stages of learning –Traffic light task

Name: _____

Unit 1

Type: Investigation

Outcome 4: Knowledge and understanding of sport psychology concepts for physical activity.

Content: Describe and discuss: the characteristics of performance, the cognitive processes that are evident during Fitts and Posner's phases of motor learning and the visual and verbal cues that a coach can use to enhance practice.



Total: _____ / 40 marks

Having completed the stages of learning experiment you are required to address the questions outlined.

An outline of the task has been provided to you.

Experiment
Task one (Condition A)
Method

1. Work in groups of eight to nine students.
2. Each group requires nine witch's hats (markers) or square mats that are to be setup according to Figure 5.20.
3. Eight students will stand next to the witch's hats (markers) or on square mats (all facing the middle with no one on the centre position).
4. Begin the task when all participants are familiar with the rules (see below). It is important that participants only move according to the rules of the task that are outlined.
5. The task finishes when all four participants from one end of the line end up at the other end of the line (Figure 5.21).
6. Allocate someone to be the master timer, who will use a stopwatch to time how long it takes to solve the problem, completing the task once.
7. If the group has nine individuals, the ninth person is to fulfil the role of coach and/or the master timer.



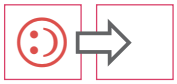
Figure 5.20: *The nine witch's hats (markers) or square mats should be set out in a straight line as above. Eight participants will stand next to the witch's hats or on the square mats (all facing the middle with no one next to the centre hat).*



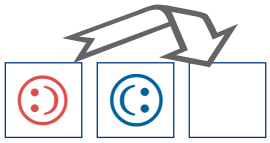
Figure 5.21: *The game finishes when all eight participants are at opposite end of the line from where they started.*

Rules of the game:

1. You can only move ***forward*** and in the following ways.
   i. If there is a space in front of you, then you can move into it.



   ii. If you are directly facing someone facing in the opposite direction and there is a space behind them, then you can move into the spare position behind them.



2. You cannot move backwards.
3. You cannot turn and face the other direction.

Task one (Condition B)
Method

1. Repeat the task as previously completed in Condition A, ensuring that all participants begin in their original positions.
2. The aim is to achieve and record a time of less than 20 seconds to complete the task from beginning to end.
3. Two timekeepers will be required. One, to record the time taken for each attempt and a second, the master timer, to record the overall time taken to complete Condition B.

Task one (Condition C)
Method

1. Repeat the task as previously completed in Condition B, ensuring that all participants adopt a ***new*** starting position.
2. Again, the aim is to achieve and record a time of less than 20 seconds to complete the task from beginning to end.
3. Two timekeepers will be required. One, to record the time taken for each attempt and a second, the master timer, to record the overall time taken to complete Condition C.

Section One – Results

1. Using Fitts and Posner's phases of motor learning, describe the performance of the group in completing the task for the first time (Task one, Condition A). Consider the players' understanding of the game, the number of errors made and whether any of the players were able to correct these errors.

(3 marks)

2. After the task was completed for the first time (Task one, Condition A), how long did it take to be able to complete the task in less than 20 seconds (Task one, Condition B)? Describe the changes that occurred in the team's performance during this time.

(3 marks)

3. When the players' starting positions were changed in Task one, Condition C, what happened to the time required to complete the task? Explain why this occurred.

_____

_____

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_____

_____

_____

(2 marks)

4. Outline two limitations of the experiment and how they may be overcome. You may wish to include any potential limitations that may not have been observed.

_____

_____

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_____

_____

_____

(2 marks)

5. Presentation of results (teacher to indicate).
   - Accurate and relevant presentation of data. (2 marks)
     OR
   - Satisfactory presentation of data. (1 mark)

Section Two – Application

6. Clearly define and outline in detail visual and verbal cues which are used to enhance performance.

(6 marks)

7. Identify a clear example of a visual and verbal cue that a coach could use to enhance performance, that is, decrease the time it took to complete the task.

(2 marks)

8. Clearly define Motor Performance.

_____

_____

_____

_____

_____

(3 marks)

9. Describe the key characteristics of an athlete in the autonomous phase of motor learning.

_____

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_____

_____

_____

(4 marks)

Section Three – Extension

10. What aspects of catching a wave on a surfboard make it an open skill?

_____

_____

(1 mark)

11. Using the open and closed skill classifications system, describe a situation where throwing a ball in softball could meet the criterion that defines a closed skill. Describe a second situation where a throw in softball could be defined as an open skill.

_____

_____

_____

_____

_____

(2 marks)

12. Using the example of a vault in gymnastics, define this activity using the motor skill classification systems identified below. Justify your answer.

    i. Is it a fine or gross skill?

_____

_____

_____

(2 marks)

    ii. Is it a discrete, serial or continuous skill?

_____

_____

_____

(2 marks)

    iii. Based on the skills visual and perceptual needs, is it a simple or complex skill?

_____

_____

_____

(2 marks)

13. Describe how a coach, when designing practice activities, could assist a performer in the associative phase of learning to transition to the autonomous phase.

_____

_____

(1 mark)

14. Describe how a coach can assist an autonomous performer to improve their error detection and correction.

_____

_____

_____

_____

_____

_____

(3 marks)

Teachers – maintain the security of these documents. Do not provide them to students.

Appendix B1.4

Practical Investigation Marking Key: Motor Learning and Coaching

Stages of learning –Traffic light task

Unit 1

Type: Investigation

Outcome 4: Knowledge and understanding of sport psychology concepts for physical activity.

Content: Describe and discuss: the characteristics of performance, the cognitive processes that are evident during Fitts and Posner's phases of motor learning and the visual and verbal cues that a coach can use to enhance practice.



Having completed the stages of learning experiment you are required to address the questions outlined below.

An outline of the task has been provided to you.

Experiment
Task one (Condition A)
Method

1. Work in groups of eight to nine students.
2. Each group requires nine witch's hats (markers) or square mats that are to be setup according to Figure 5.20.
3. Eight students will stand next to the witch's hats (markers) or on square mats (all facing the middle with no one on the centre position).
4. Begin the task when all participants are familiar with the rules (see below). It is important that participants only move according to the rules of the task that are outlined.



Figure 5.20: *The nine witch's hats (markers) or square mats should be set out in a straight line as above. Eight participants will stand next to the witch's hats or on the square mats (all facing the middle with no one next to the centre hat).*

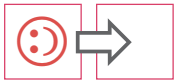


Figure 5.21: *The game finishes when all eight participants are at opposite end of the line from where they started.*

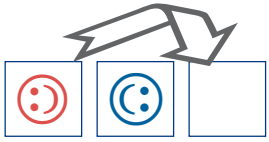
5. The task finishes when all four participants from one end of the line end up at the other end of the line (Figure 5.21).
6. Allocate someone to be the master timer, who will use a stopwatch to time how long it takes to solve the problem, completing the task once.
7. If the group has nine individuals, the ninth person is to fulfil the role of coach and/or the master timer.

Rules of the game:

1. You can only move ***forward*** and in the following ways.
   i. If there is a space in front of you, then you can move into it.



   ii. If you are directly facing someone facing in the opposite direction and there is a space behind them, then you can move into the spare position behind them.



2. You cannot move backwards.
3. You cannot turn and face the other direction.

Task one (Condition B)

Method

1. Repeat the task as previously completed in Condition A, ensuring that all participants begin in their original positions.
2. The aim is to achieve and record a time of less than 20 seconds to complete the task from beginning to end.
3. Two timekeepers will be required. One, to record the time taken for each attempt and a second, the master timer, to record the overall time taken to complete Condition B.

Task one (Condition C)

Method

1. Repeat the task as previously completed in Condition B, ensuring that all participants adopt a ***new*** starting position.
2. Again, the aim is to achieve and record a time of less than 20 seconds to complete the task from beginning to end.
3. Two timekeepers will be required. One, to record the time taken for each attempt and a second, the master timer, to record the overall time taken to complete Condition C.

Section One – Results

1. Using Fitts and Posner's phases of motor learning, describe the performance of the group in completing the task for the first time (Task one, Condition A). Consider the players' understanding of the game, the number of errors made and whether any of the players were able to correct these errors.
   - **Performance was initially characterised by the players trying to gain an understanding of the rules; where to stand and how to move.**
   - **During the initial attempts, participants were unable to progress very far into the task.**
   - **Participants found it difficult to move within the rules and as a consequence had to start again.**
   - **Participants may have become frustrated as a result of trying to work out how to solve the task but not knowing how or whether they were correct in their approach.**

- **Participants may also have repeated the same mistakes and not progressed, that is, reaching the same point during each attempt to complete the task.**
- **Feedback regarding the group's performance and how to correct errors is important for improvement and progression into the next phase of learning.**

(3 marks)

2. After the task was completed for the first time (Task one, Condition A), how long did it take to be able to complete the task in less than 20 seconds (Task one, Condition B)? Describe the changes that occurred in the team's performance during this time.

   Responses need to reflect upon the differences/progression between the cognitive and associative stages. This may include the following performance characteristics:
   - **Able to perform the basic skill**
   - **Improved ability to adjust to the environment in performing the motor skill**
   - **Errors become less in number and magnitude**
   - **Less variation between performances**
   - **The learner begins to detect and correct their own errors**
   - **The performer is encouraged to utilise their own feedback.**

   (3 marks)

3. When the players' starting positions were changed in Task one, Condition C, what happened to the time required to complete the task? Explain why this occurred.
   - **Increased Time: Identifying a form of regression in understanding. Either a regression to the cognitive phase or early associative phase.**
   - **Decreased Time: Practicing allows participants to quickly re-establish their understanding required to be classified in the autonomous phase.**

   (2 marks)

4. Outline two limitations of the experiment and how they may be overcome. You may wish to include any potential limitations that may not have been observed.
   - **Some students may already be familiar with the task prior to the experiment.**
   - **Students may not display appropriate interpersonal/ leadership skills.**
   - **Single data sample.**
   - **Recording of the results.**

   (2 marks)

5. Presentation of results (teacher to indicate).
   - Accurate and relevant presentation of data.

   (2 marks)

   OR
   - Satisfactory presentation of data.

   (1 mark)

Section Two – Application

6. Clearly define and outline in detail visual and verbal cues which are used to enhance performance.

   Verbal Cue
   - **A verbal cue** is a short, concise phrase that directs attention to the most important feature(s) in the environment, or prompts performers to attend to key components of the skill.
   - **When individuals are learning new skills, teaching or coaching**

instructions should clearly describe the movements or outcomes required.

Visual Cues

- **Visual cues give the learner an opportunity to see what the movement requires.**
- **Demonstration:** An accurate model or skill demonstration is a powerful visual cue to help the learner and present much information in a short time. The teacher or coach should focus the learner's attention on specific components of any demonstration but this is a delicate balancing act.
- **Visual aids:** Graphs, flow charts, pictures and diagrams are all visual aids. The most commonly used aid is video, which can show images of a high-performance athlete or the learner performing the skill.
- **Enhancing the visual environment:** to ensure the learner attends to important aspects of the display, the teacher or coach enhances the visual environment. For example, placing a target on a wall or floor at which learners can aim; placing chalk markings on the pitch for cricketers to bowl the ball in the desired area; positioning targets in the tennis service box to highlight the desired landing point of a service; and dance instructors outlining feet positions on the ground to represent a sequence of steps for beginners to follow.

(6 marks)

7. Identify a clear example of a visual and verbal cue that a coach could use to enhance performance, that is, decrease the time it took to complete the task.

Visual Cues

- **A demonstration.**
- **A visual aid i.e. a set of instructions or diagrams.**
- **Enhancing the visual environment i.e. number the mats and the participants. This will facilitate the coach's instructions and demonstration.**

Verbal Cues

- **Short concise phrases that draws attention to the most important components of the skill.**
- **Presentation of the verbal cues is sequential, such that the highest priority instructions are delivered first.**
- **For example using the name or number of a participant followed by the desired action i.e. Sarah Forward**

(2 marks)

8. Clearly define Motor Performance.
   - **An observable behaviour at a specific time and location.**
   - **It is temporary.**
   - **May not be due to practice.**

   (3 marks)

9. Describe the key characteristics of an athlete in the autonomous phase of motor learning.
   - **The athlete does not consciously think about the specific movement characteristics of the skill.**
   - **The athlete can perform other tasks at the same time.**
   - **Low performance variability.**
   - **The athlete can detect their own errors and make adjustments to correct them.**

   (4 marks)

Section Three – Extension

10. What aspects of catching a wave on a surfboard make it an open skill?
    - **It is externally paced. That is, the surfer is responding to the motion of the wave.**
    - **In addition, the waves are dissimilar for size, speed, shape, point of breaking and the optimum point of for take-off.**
    - **Therefore, the surfer is required, each time they try and catch a wave, to respond to these changing environmental variables**

    (1 mark)

11. Using the open and closed skill classifications system, describe a situation where throwing a ball in softball could meet the criterion that defines a closed skill. Describe a second situation where a throw in softball could be defined as an open skill.
    - **A softball throw defined as a closed skill is the pitch.**
    - **A softball throw defined as an open skill would be a short-stop running to stop a ground ball, picking up the ball on the run and at the same time deciding who they are more likely to throw out, the batter running to first or the runner moving from first to second and then throwing the ball to the base of choice.**

    (2 marks)

12. Using the example of a vault in gymnastics, define this activity using the motor skill classification systems identified below. Justify your answer.

    i. Is it a fine or gross skill?
    - **Gross skill. The activity requires large muscle actions.**

    (2 marks)

    ii. Is it a discrete, serial or continuous skill?
    - **Serial skill. Executing a vault links together the skills of the run-up, the take-off, the in-flight actions and the landing.**

    (2 marks)

    iii. Based on the skills visual and perceptual needs, is it a simple or complex skill?
    - **Simple skill. A vault does not require perceptual or cognitive processing of environmental information.**

    (2 marks)

13. Describe how a coach, when designing practice activities, could assist a performer in the associative phase of learning to transition to the autonomous phase.
    - **The coach could provide a variety of practice situations.**

    (1 mark)

14. Describe how a coach can assist an autonomous performer to improve their error detection and correction.
    - **A coach can create game-like scenarios at training that replicate important events.**
    - **These scenarios could be similar to those that the athlete failed to identify in the past.**
    - **The can also allow time for the performer to analyse their own feedback.**

    (3 marks)

Appendix B2

Practical Investigation and Report: Motor Learning and Coaching
Extrinsic (augmented) feedback—Knowledge of results

Weighting: Unit 2

Type: Investigation

Content:
Describe and discuss the importance of:

- intrinsic (task inherent) feedback to motor learning
- extrinsic (augmented) feedback to motor learning.

Task outline
By completing the experiment outlined below you are to observe and measure performance and gain and understanding of:

- the difference between intrinsic (inherent) and extrinsic (augmented) feedback
- the effect of varying schedules of knowledge of results (KR) on motor learning
- the roles of feedback in motor learning.

Total marks = /30

Experiment
Task one
Divide the class into three groups:

- Group one will complete Condition A
- Group two will complete Condition B
- Group three will complete Condition C.

Condition A: 100% quantitative KR schedule
Method

- Work in groups of 3, with each individual assuming the role of either:
  i. experimenter
  ii. assistant
  iii. golfer.
- Set up the putting course (Figure 5.22):
  i. Place a line of masking tape on the carpeted floor to indicate the putting line where the golfer stands ready to execute a golf putt.
  ii. Place a line of masking tape on the floor at a distance of approximately 3 m from the putting line to indicate the target.

3. The putter is to be used in the opposite stance to what the golfer would normally prefer (a right-handed golfer will hold the putter as a left-handed golfer would– with the right foot closest to the target). Set the golfer up at the putting line and blindfold the golfer.
4. Place the ball on the putting line, while the assistant places the golfer's golf club head directly behind and just touching the ball.
5. Instruct the golfer to perform a putt towards the target line (approximately 3 m away).
6. The experimenter will measure and

record the error from the target line for each putt. Record the distance that the ball finishes from the target line, for example, if the ball finishes 10 cm too far or 10 cm too short of the target line, the same distance will be recorded; an error of 10 cm. Do ***not*** record how far the ball was from the target line in the sideways direction; only record the error in the direction of the putt.

7. The golfer will receive extrinsic (augmented) feedback from the experimenter in accordance with a 100% quantitative KR schedule, that is, the experimenter will inform the golfer of how far they overshot or undershot the target after every single golf putt.
8. The assistant will return the golf ball to the starting position and place the golfer's golf club head directly behind and touching the ball.
9. ***Practice phase:*** The golfer is to repeat the task of putting in the following format:
   i. Twelve putts with a blindfold on, with the distance from the target line for each putt recorded.
   ii. Receive extrinsic (augmented) feedback after every putt.
   iii. One minute's rest after the set of twelve putts are completed and measured. The blindfold can be removed during the rest period.
   iv. Repeat this process until three sets (thirty-six putts) are completed and measured.
10. Following the three blocks of twelve putts that constitute the 'Practice phase', participants will have a five-minute (approximately) break before performing the 'Retention Phase'.
11. ***Retention phase:*** This will include one set of twelve putts with ***no feedback***. That is, twelve putts, where the distance from the target line will be recorded but ***no verbal feedback*** will be provided by the experimenter or the assistant. The blindfold is to be worn.

Condition B: 33% quantitative KR schedule
Method

1. Work in groups of three, with each individual assuming the role of either:
   i. experimenter
   ii. assistant
   iii. golfer.
2. Set up the putting course (Figure 5.22):
   i. Place a line of masking tape on the carpeted floor to indicate the putting line where the golfer stands ready to execute a golf putt.
   i. Place a line of masking tape on the floor at a distance of approximately 3 m from the putting line to indicate the target.
3. The putter is to be used in the opposite stance to what the golfer would normally prefer (a right-handed golfer will hold the putter as a left-handed golfer would– with the right foot closest to the target). Set the golfer up at the putting line and blindfold the golfer.
4. Place the ball on the putting line, while the assistant places the golfer's golf club head directly behind and just touching the ball.
5. Instruct the golfer to perform a putt towards the target line (approximately 3 m away).
6. The experimenter will measure and record the error from the target line for each putt. Record the distance that the ball finishes from the target line, for example, if the ball finishes 10 cm

too far or 10 cm too short of the target line, the same distance or error will be recorded; an error of 10 cm. Do ***not*** record how far the ball was from the target line in the sideways direction; only record the error in the direction of the putt.

7. The golfer will receive extrinsic (augmented) feedback from the experimenter in accordance with a 33% quantitative KR schedule, that is, the experimenter will inform the golfer of how far they overshot or undershot the target after every third putt (no feedback will be provided about the first, second, fourth, fifth, seventh, eighth, tenth, nor the eleventh putt).
8. The assistant will return the golf ball to the starting position and place the golfer's golf club head directly behind and touching the ball.
9. ***Practice phase:*** The golfer is to repeat the task of putting in the following format:
   i. Twelve putts with a blindfold on, with the distance from the target line for each putt recorded.
   ii. Receive extrinsic (augmented) feedback only on the third, sixth, ninth and twelfth putt.
   iii. One minute's rest after the set of twelve putts are completed and measured. The blindfold can be removed during the rest period.
   iv. Repeat this process until three sets (thirty-six putts) are completed and measured.
10. Following the three blocks of twelve putts that constitute the 'Practice phase', participants will have a five-minute (approximately) break before performing the 'Retention phase'.
11. ***Retention phase:*** This will include one set of twelve putts with ***no feedback***. That is, twelve putts, where the distance from the target line will be recorded but ***no verbal feedback*** will be provided by the experimenter or the assistant. The blindfold is to be worn.

Condition C: 33% KR schedule of qualitative feedback and encouragement

Method

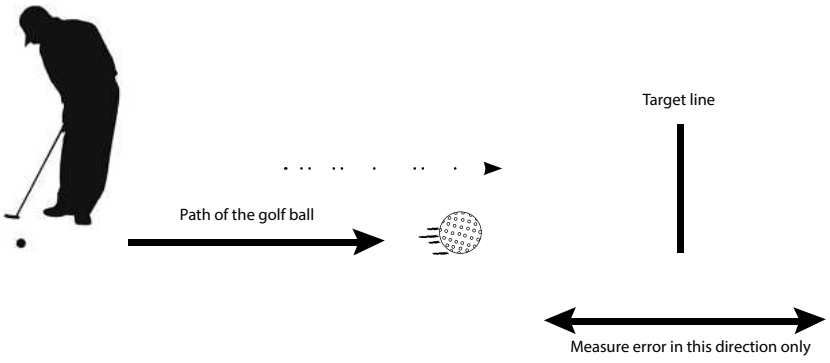
1. Work in groups of three, with each individual assuming the role of either:
   a. experimenter
   b. assistant
   c. golfer.
2. Set up the putting course (Figure 5.22):
   i. Place a line of masking tape on the carpeted floor to indicate the putting line where the golfer stands ready to execute a golf putt.
   ii. Place a line of masking tape on the floor at a distance of approximately 3 m from the putting line to indicate the target.
3. The putter is to be used in the opposite stance to what the golfer would normally prefer (a right-handed golfer will hold the putter as a left-handed golfer would– with the right foot closest to the target). Set the golfer up at the putting line and blindfold the golfer.
4. Place the ball on the putting line while the assistant places the golfer's golf club head directly behind and just touching the ball.
5. Instruct the golfer to perform a putt towards the target line (approximately 3 m away).
6. The experimenter will measure and record the error from the target line

for each putt. Record the distance that the ball finishes from the target line, for example, if the ball finishes 10 cm too far or 10 cm too short of the target line, the same distance or error will be recorded; an error of 10 cm. Do ***not*** record how far the ball was from the target line in the sideways direction; only record the error in the direction of the putt.

7. Feedback will be provided in accordance with a 33% qualitative KR schedule, that is, after every third putt (no feedback will be provided about the first, second, fourth, fifth, seventh, eighth, tenth nor the eleventh putt). The golfer will ***not*** receive any feedback about how far the golf ball finished from the target; rather, the feedback will be qualitative and in the form of the following phrases:
   a. 'doing better'–when the golfer is getting closer to the target line
   b. 'doing worse'–when the golfer is getting further away.

   If, for example, the golfer's first and second putts were short of the target by 30 cm and 25 cm respectively and then the third putt (requiring feedback) was only 20 cm short of the target, the following feedback should be provided after the third putt: 'doing better (qualitative KR), keep trying to improve (encouragement)'. The experimenter can construct forms of encouragement, but it is important not to give the golfer information about the result of the performance.
8. The assistant will return the golf ball to the starting position and place the golfer's golf club head directly behind and touching the ball.
9. ***Practice phase:*** The golfer is to repeat the task of putting in the following format:
   a. Twelve putts with a blindfold on, with the distance from the target line for each putt recorded.
   b. Receive extrinsic (augmented) feedback only on the third, sixth, ninth and twelfth putt.
   c. One minute's rest after the set of twelve putts are completed and measured. The blindfold can be removed during the rest period.
   d. Repeat this process until three sets (thirty-six putts) are completed and measured.
10. ***Retention phase:*** Following the three blocks of twelve putts that constitute the 'Practice phase', participants will have a five-minute (approximately) break before performing the 'Retention phase'. This will include one set of twelve putts with ***no feedback***. That is, twelve putts, where the distance from the target line will be recorded but ***no verbal feedback*** will be provided by the experimenter or the assistant. The blindfold is to be worn.

Figure 5.22: *The experimental set-up*



Results

Tables, as drawn below, will need to be completed with your group's data and the data from the other groups that performed the two alternate conditions.

Condition A: 100% quantitative KR													
Set	1	2	3	4	5	6	7	8	9	10	11	12	Avg.
1													
2													
3													
5-min break													
Retention													

Condition B: 33% quantitative KR													
Set	1	2	3	4	5	6	7	8	9	10	11	12	Avg.
1													
2													
3													
5-min break													
Retention													

Condition C: 33% qualitative KR and encouragement													
Set	1	2	3	4	5	6	7	8	9	10	11	12	Avg.
1													
2													
3													
5-min break													
Retention													

Questions

In presenting your findings respond to the following:

a. Identify the intrinsic (inherent) feedback and the extrinsic (augmented) feedback used in this golf putting task and explain where these types of feedback come from (2 marks).

b. Which feedback schedule resulted in the lowest average error in the 'retention' block? Discuss why these results occurred (2 marks).

c. There are two purposes for feedback; one is for information and reinforcement and the second is for motivation. Explain how both of these purposes were accessed by the golfer in the three different practice schedules (3 marks).

d. Take on the role of a golf coach about to provide feedback to a golfer following the execution of a fairway stroke using a 3 iron.

   i. How would you provide KR augmented feedback as compared to KP augmented feedback for a golf swing? (2 marks)

   ii. Explain whether you would most likely use terminal feedback or concurrent feedback for a golf stroke (2 marks).

   iii. Identify and explain verbal and non-verbal forms of feedback that you could use to improve your athlete's golf swing (2 marks).

e. Now consider coaching a high-level (expert) golfer and a beginner golfer. Compare and contrast the amount of extrinsic (augmented) feedback and whether the feedback should be descriptive or prescriptive for both of the golfers (2 marks).

Equipment

- Carpet floor.
- Masking tape.
- Tape measure–one for each group of three students.
- Golf putter–one for each group of three students.
- Golf balls.
- Blindfold–one for each group of three students.

Task: Extrinsic (augmented feedback)—Knowledge of results: 30 marks

Components and Performance Standards	Marks
Hypotheses (2 marks)	
Provides simple statements of the expected results or anticipated outcomes in relation to intrinsic and extrinsic feedback, knowledge of results and the roles of feedback.	**1 mark**
Provides clear statements of the expected results or anticipated outcomes in relation to using intrinsic and extrinsic feedback when learning, the use of knowledge of results when learning and the two key roles of feedback.	**2 marks**
Introduction (3 marks)	
Identifies and defines intrinsic and extrinsic feedback, knowledge of results and the roles of feedback.	**1 mark**
Shows an understanding of intrinsic and extrinsic feedback, knowledge of results and the roles of feedback.	**2 marks**
Shows a comprehensive understanding of intrinsic and extrinsic feedback, knowledge of results, impact of feedback on learning skills and the roles of feedback during the learning process.	**3 marks**
Results (2 marks)	
Satisfactory presentation of data.	**1 mark**
Accurate and relevant presentation of data.	**2 marks**
Response to Questions (15 marks)	
Questions a and b: *2 marks (4 marks).* ***Question c:*** *3 marks.* ***Question d:*** *i 2 marks, ii 2 marks, iii 2 marks (6 marks).* ***Question e:*** *2 marks.*	
Discussion (6 marks)	
Shows little comprehension of the variables associated with the activities undertaken.	**1 mark**
Limited discussion of the results found and few links made to the variables associated with providing feedback and learning.	**2 marks**
Uses other sporting contexts to discuss the results found and identifies some of the variables associated with feedback, knowledge of results and the roles of feedback.	**3 marks**
Uses other sporting contexts to discuss the results found and identifies and defines most of the variables associated with providing intrinsic and extrinsic feedback, knowledge of results and the roles of feedback during the learning process.	**4 marks**
Uses other sporting contexts to show an understanding of the results found and discusses these in reference to providing intrinsic and extrinsic feedback, knowledge of results and the roles of feedback during the learning process.	**5 marks**
Uses other sporting contexts to show a comprehensive understanding of the results found and discusses these in application to providing intrinsic and extrinsic feedback, knowledge of results and the roles of feedback during the learning process.	**6 marks**
Conclusion (2 marks)	
Summarises some of the factors associated with learning and feedback in relation to the hypotheses.	**1 mark**
Fully summarises the impact of the factors affecting learning in relation to feedback and the hypotheses. Limitations discussed.	**2 marks**
Comment:	**Total** **/30**

Appendix B2.1 – Answers

Practical Investigation and Report: Motor Learning and Coaching

Extrinsic (augmented) feedback–Knowledge of results

a. Identify the intrinsic (inherent) feedback and the extrinsic (augmented) feedback used in this golf putting task and explain where the types of feedback come from (2 marks).

Answer

Intrinsic (inherent) Feedback

- Proprioceptive feedback from your arms swinging the putter.
- Proprioceptive and auditory feedback from the putter making contact with the ball.
- No visual intrinsic feedback in this task because of the blindfold.

Extrinsic (augmented) Feedback

- Provided by the experimenter in the form of KR or encouragement, depending on which experimental group.

b. Which feedback schedule resulted in the lowest average error in the 'retention' block? Discuss why these results occurred (2 marks).\

Answer

There are 2 potential outcomes here.

1) The 100% KR schedule records the lowest average. In general, when individuals first practice a task they require a lot of feedback to ensure that they are performing the skill correctly and do not develop bad habits. The golfer who received 100% KR was able to use the KR after every putt to ensure that they were performing accurately and this lead to the best retention of the skill even when there was no feedback provided in the 'retention' block.

2) The 33% KR schedule records the lowest average. Receiving feedback after every third putt was enough to ensure that the golfer was "staying on track" and not making large mistakes. Furthermore, an important aspect of learning the skill is to be able to effectively use the intrinsic feedback. Reducing the frequency of feedback affords the learner the opportunity to use the intrinsic feedback and the augmented KR feedback every 3rd putt was used to check that the intrinsic feedback was correct. When the feedback was removed completely as in the 'retention' block, the golfer who had practised with 33% KR was able to rely only on their intrinsic feedback to accurately putt the golf ball.

NOTE: It is very unlikely that the 3rd group would perform best, if this is the case see 2) and also suggest the qualitative comments were sufficient to allow the golfer to hone in on the target line.

c. There are two purposes for feedback; one is for information and reinforcement and the second is for motivation. Explain how both of these purposes were accessed by the golfer in the three different practice schedules (3 marks).

Answer

100% and 33% KR schedules:

Feedback for information and reinforcement: the error information provided by the KR was used to improve the next performance. The

feedback was used to develop and strengthen the relationship between what the limbs were 'programmed to do' and what they 'actually did'.
Feedback for motivation: The golfers in these practice schedules would also have used feedback in the short-term to motivate themselves to keep getting closer to the target. Feedback has been shown to motivate learners to put more effort into practice, persist longer at practice and maintain interest in the practice session.

33% Qualitative KR and Encouragement:
Feedback for information and reinforcement: One of the main differences between this practice condition and the other two was that the information provided in the KR was not as accurate. The KR in the 100% Quantitative KR and the 33% Quantitative KR conditions provided information about precisely how far away from the target the golf ball finished. This condition, however, only provided information relative to previous performance but it is likely that the golfer was unaware of precisely how close they were putting to the target.
Feedback for motivation: the imprecise nature of the feedback may have lead the golfer to lose some motivation, however, they were also encouraged by the experimenter to "keep trying to improve". Positive, constructive feedback that encourages athletes to continue striving towards a goal is important for motivation.

d. Take on the role of a golf coach about to provide feedback to golfer following the execution of a fairway stroke using a 3 iron.
   i. How would you provide KR augmented feedback as compared to KP augmented feedback for a golf swing? (2 marks)
   ii. Explain whether you would most likely use terminal feedback or concurrent feedback for a golf stroke (2 marks).
   iii. Identify and explain verbal and non-verbal forms of feedback that you could use to improve your athlete's golf swing (2 marks).

Answer

i. ***KR for golf*** – feedback concerning where the ball landed is the most obvious. KR for golf could also include information about the trajectory of the ball, for example a chip shot that needed a high trajectory so that the ball did not roll too far after bouncing.
KP for golf – would be feedback focusing on the movement technique that produced the stroke, for example if the golfer raised his/her head during the swing of the club, then appropriate KP would inform the golfer that they moved their head and should "keep their head down".

ii. It is unrealistic for a golf coach to try and correct a swing fault during the execution of the stroke because the relatively little time taken to swing the golf club prevents the golfer from presenting concurrent feedback during the swing. Furthermore, if golfers take heed of the instructions, they will be distracted from executing the skill properly. The golf coach should provide terminal extrinsic feedback after the swing is completed so that the golfer can devote full attention to the feedback.

iii. ***Verbal feedback for golf*** – whether KR or KP, a coach should first relay information about some correct aspects of performances to serve as a motivator. Then, one can add that it would be even better if a certain fault was adjusted.
Non-verbal feedback for golf – video feedback: showing the golfer their own performance on video is an effective way to develop the capacity of the golfer to their own errors. While video feedback is an excellent example of non-verbal feedback, it is important to note that the best learning occurs when the viewing of the video is accompanied by a coach directing (verbal extrinsic feedback) the learner's attention to important characteristics of the performance

d. Now consider coaching a high-level (expert) golfer and a beginner golfer. Compare and contrast the amount of extrinsic (augmented) feedback and whether the feedback should be descriptive or prescriptive for both of the golfers (2 marks).
Answer
High-level golfer – In general, the higher the skill level the lower the frequency of feedback and the more specific and **quantitative** the feedback should be (to refine the existing skill). The athlete should also be more involved in solving the problems identified by the coach and therefore may only require **descriptive** feedback because they not only have sufficient knowledge of the skill to correct themselves. Descriptive feedback is when the coach provides a description of the error but does not provide a way to correct the error. Descriptive and quantitative feedback could be specific information about the angle of the wrist being 5 degrees too flexed and the coach then leaves the golfer to attempt to correct the wrist angle on the next swing.
Beginner golfer – At lower skill levels, more frequent feedback may be required to ensure that bad habits are not developed and the feedback should generally be more prescriptive because they are unaware of how to correct their mistakes. Prescriptive feedback not only informs the golfer that an error was made, but also suggests a means to correct the problem.

Appendix C (I)

Revision questions

1. Motor performance is an observable behaviour, while motor learning is best reflected by which one of the following statements.
   a. Processing and interpreting information
   b. Problem solving
   c. A relatively permanent change in motor performance that is associated with practice
   d. A relatively permanent change in motor performance that is associated with the expert athlete
2. Differentiate between perceptual skills and cognitive skills?
3. Superior perceptual and cognitive skills are identified as the source of the expert advantage. What advantage do they provide?
4. What aspects of catching a wave on a surfboard make it an open skill
5. Using the open and closed skill classifications system, describe a situation where throwing a ball in softball could meet the criterion that defines a closed skill.Describe a second situation where a throw in softball could be defined as an open skill.
6. Shooting a free throw in basketball is a relatively discrete skill. Which one of the following statements best characterises a serial skill?
   a. The linking of discrete skills to form more complicated skills
   b. Two free throw shots
   c. Repetitive movements with no distinct start or finish
   d. Pitching in softball
7. Using the athletics example of a long jump, define this activity using the motor skill classification systems identified below:
   i. Is it a fine or gross skill?
   ii. Is it a discrete, serial or continuous skill?
   iii. Is it a simple or complex skill?
8. Identify two ways a coach could simplify a skill for a learner who is in the cognitive phase of learning?
9. A learner in the associative phase of learning is characterised by
   a. the learner having no capacity to correct their own errors.
   b. trying to gain an understanding of what to do.
   c. the learning beginning to detect and correct their own errors.
   d. the learner does not have to think about specific movements.
10. Describe the differences between how an individual in the associative phase of learning is able to detect and correct errors when compared with an autonomous performer.
11. Describe how a coach, when designing practice activities, could assist a performer in the associative phase of learning to transition to the autonomous phase.
12. Describe how a coach can assist an autonomous performer to improve their error detection and correction.
13. List three important features of a good verbal cue.
14. Without looking, and assuming that you are sitting at a table, determine what position both of your feet are in. Explain the process by which you were able to do this.
15. If an athlete prefers to receive learning cues in the form of a demonstration, which of the learning styles do they favour?
16. The first phase of information processing involves perception. Which one of the following statements best describes the perception process in motors skills?

a. The decision we make in response to environmental cues
b. Focusing on non-regulatory features
c. Response programming
d. The sensation we get from the environment and also the meaning we attach to the sensation

17. List and describe the regulatory features from a sport or sporting situation (for example, a rebound in basketball) of your choice.
18. During the second phase of information processing, the response selection phase (decision), what does the athlete compare the stimulus with?
19. Explain, using motor learning and coaching principles, the theory behind the statement 'mixing or changing it up' in a sporting situation.
20. Explain how extrinsic feedback differs from intrinsic feedback.
21. Explain why feedback for an individual in the early phase of learning motor skills (cognitive) is generally best presented as: 'extrinsic, immediate, qualitative, prescriptive, knowledge of performance (KP)'.
22. Why might a coach resist from providing feedback consistently and choose to wait before discussing the performance with an athlete?
23. When coaching a child who is in the cognitive and/or early associative phases of learning, it is generally best to
    a. provide minimal and delayed feedback so they can work it out for themselves.
    b. focus on skill learning and participation levels.
    c. use adult sized equipment so they get used to it for the years to come.
    d. maximise the verbal description of the proprioceptive aspects of the task and minimise demonstrations of the skills required to save time.
24. Explain how an elite coach of professional athletes might not be the most appropriate, or attain the best learning outcomes, for junior or veteran performers.

Appendix C (II)

Revision answers

1. c. A relatively permanent change in motor performance that is associated with practice.
2. Perceptual skills involve the process of recognising and then interpreting information from the environment. Cognitive skills require using the perceptual information to problem solve, remember and make decisions.
3. Superior perceptual and cognitive skills provide the athlete with more time. Expert athletes are able to predict what will happen earlier, leading to the making of better decisions earlier and more time to execute the motor skill with precision.
4. It is externally paced. That is, the surfer is responding to the motion of the wave. In addition, the waves are dissimilar for size, speed, shape, point of breaking and the optimum point for take-off. Therefore the surfer is required, each time they try and catch a wave, to respond to these changing environmental variables.
5. A softball throw defined as a closed skill is the pitch. A softball throw defined as an open skill would be a short-stop running to stop a ground ball, picking up the ball on the run and at the same time deciding who they are more likely to throw out, the batter running to first or the runner moving from first to second and then throwing the ball to the base of choice.
6. a. The linking of discrete skills to form more complicated skills
7. i. Gross skill–as the long jump requires large muscle action.
   ii. Serial skill–executing long jump links together with the skills of the run-up, the take-off, the in-flight actions and the landing.
   iii. Simple skill–a long jump does not require perceptual or cognitive processing of environmental information.
8. One simplification could be to break the skill down into less complicated sub-movements, then practise part of the skill in isolation. A second simplification could be to slow the skill down.
9. c. The learning beginning to detect and correct their own errors.
10. In the associative phase of learning, the individual begins to detect and correct some errors. In the autonomous phase, the performer is able to detect errors when made and correct them often without external assistence.
11. The coach could provide a variety of practice situations.
12. A coach can create game-like scenarios at training that replicate important events. These scenarios could be similar to those that the athlete failed to identify in the past. The can also allow time for the performer to analyse their own feedback.
13. Short and concise, directs the learner's attention to the most important features of the performance environment or the action itself and the cue needs to be appropriate for the learner's age, comprehension and experience level.
14. Kinaesthesis and proprioception provides the internal sensory information about the joints, muscles and the orientation of our body and its parts in space. In this case, the proprioceptors in the lower limbs provided the information related to foot pressure on the ground, angle of the foot at the ankle and leg position and

pressure of legs crossing over with another leg and so on.

15. Visual learning cues.
16. d. The sensation we get from the environment and also the meaning we attach to the sensation
17. Regulatory features are the important pieces of information that are presented in the performance environment. The list should include only the cues that assist the performer to perceptually process the information and to successfully choose and respond with an action. The list should not include non-regulatory features or irrelevant information.
18. The athlete compares the stimulus with information that is collected from previous experiences and stored in memory.
19. Hick's law confirms that if there are a number for different potential stimuli in the environment, as opposed to only one, it takes more time to process the information. That is, the more possibilities or options to consider, the longer it takes to process the information and make a possible response. 'Mixing or changing it up', impacts by slowing the opponent's information processing and, therefore, their response time.
20. Extrinsic feedback is information that is in addition to that attained by the performer as a consequence of doing the task–intrinsically. Extrinsic feedback generally enhances intrinsic feedback. For the purposes of learning, extrinsic feedback is best for the initial stages of learning motor skills.
21. In many sports, task-intrinsic feedback is not available or the learner finds it difficult to understand and benefit from this information. Extrinsic feedback also serves to inform and reinforce and maintain the learner's motivation. Immediate feedback, rather than delayed feedback, ensures that their performance is fresh in their mind. With learners unable to interpret intrinsic feedback, the delay may not serve a purpose. Qualitative information serves to describe what has happened and, combined with prescriptive feedback, assists the learner to focus on what actions to do next time to correct the errors in performance. Extrinsic feedback in the form of KP, providing the teacher or coach provides accurate feedback appropriate for the learner's needs, facilitates more efficient performance actions, success and learning outcomes.
22. The coach is encouraging the athlete to access intrinsic feedback and, in doing so, trying to avoid learner dependence on the coach. This will assist the athlete to understand their own performance and better prepare then to detect and correct their own errors.
23. b. Focus on skill learning and participation levels.
24. Junior and veteran athletes may require modification of the equipment, playing environment and learning or training activities from that undertaken by elite professional athletes. If the elite coach is unwilling or unable to match the individual differences and needs of the non-professional performers, they may restrict motor skill learning and negatively impact on the athletes' enjoyment and health when compared with a developmentally focused and experienced teacher or coach. That is, what works for elite professional athletes will not necessarily work for others, who have different characteristics (age, skill level, fitness level) and different goals.

Appendix D

Personalised project – Units 1 and 2: Teaching or coaching a new complex skill(s)

This assessment task is framed by the principles of the Bloom's taxonomy. The mark allocations respect the level of complexity of individual task requirements. The following table differentiates for the complexity of each task, beginning with Level 1 (for example, label) to Level 6 (for example, create) (adapted from O'Brien & White 2001).

This project would be best initiated at the end of the sport psychology unit, before commencing the motor learning and coaching unit.

Weighting:

- Unit 1–25 marks
- Unit 2–25 marks

Type: Investigation

Content:

- Sport Psychology
- Motor Learning and Coaching

1	2	3	4	5	6
REMEMBERING	**UNDERSTANDING**	**APPLYING**	**ANALYSING**	**EVALUATING**	**CREATING**
Label	Classify	Measure	Identify	Justify	Create
Describe		Undertake	Analyse	Evaluate	Predict
		Compile	Compare & contrast		
			Discuss		

Total marks = /50

Instruction

Choose a complex skill or series of skills that you will teach or coach to another person (learner) who currently cannot successfully complete the task(s). The activity and the learner may be linked to your Physical Education Studies course (a classmate), or the skill and the learner may be independent of your current studies (for example, three-ball juggling or controlling a hacky-sack and a family member or younger student). The learner must be prepared to practise this activity for a minimum of three times per week (minimum of twenty minutes per session), during a period of three weeks.

Content

1. *Compile* a list of the critical elements (regulatory features) that define the new skill(s) (Unit 1: 2 marks).
2. *Create* and write a performance assessment tool (criteria and rubric) for the chosen skill(s) (0 marks).
3. Base-line data collection and performance (pre-intervention phase). Without having practised the skill(s), have the learner, as best they can, perform the skill(s) in front of you. Use the performance assessment tool that you created. Collect this information. An additional option is to video-record this performance. Repeat this process after one week (mid-intervention phase) of practice and at the end of the three weeks (post-intervention phase) (0 marks).
4. Use the base-line data collection performance as evidence to *analyse and classify* the learner's initial

(pre-intervention) phase of learning (Unit 1: 2 marks).

5. Using all of the classification of motor skills systems (closed–open; fine–gross; discrete–serial –continuous; simple–complex) *classify* the chosen skill(s) (Unit 1: 4 marks).
6. *Create and justify* practice activities, teaching or coaching strategies and psychological considerations to enhance the learner's outcomes for a three-week schedule (minimum three times per week) (minimum twenty minutes per session) and a mid-intervention and post-intervention learning and performance evaluation.

   Review and record any modifications to the initial teaching and learning plan that were implemented during the intervention.

   Use the following headings to record your initial program and any program modifications made during the intervention.

   - Motor learning and coaching principles:
     a. *Describe* the practice activities and any considerations for meeting the needs of the learner, which are designed to accommodate individual differences and the activity undertaken (Unit 2: 4 marks).
     b. *Identify* the cues that will be used to enhance learning and performance, including visual, verbal and proprioceptive (Unit 1: 3 marks).
     c. *Identify* a feedback schedule (types, frequency and timing) to enhance learning and performance (Unit 2: 6 marks).
     d. *Discuss* the purpose of the feedback provided (Unit 2: 2 marks).
   - Sport psychology principles:
     e. Using an interview *create* personal goals appropriate for the learner using the SMARTS method (Unit 2: 3 marks).
     f. *Discuss* the optimum psychological state (zone) for the learner and *identify and justify* strategies to enhance learning and performance with reference to:
        - Motivation (Units 1 and 2: 4 marks).
        - Self-confidence (Unit 1: 2 marks).
        - Stress management (Unit 1: 2 marks).
        - Concentration (Units 1 and 2: 4 marks).
        - Arousal and anxiety levels (Units 1 and 2: 4 marks).
7. *Evaluate and discuss* the intervention outcomes. In doing so, consider the impact of sport psychology and motor learning and coaching principles on the learning outcomes and the learner's performance (Units 1 and 2: 8 marks).

Process or support

- Beginner and improved performance evaluation assisted by the teacher.
- Review texts or scientific journals and, in a small group, hold a teacher-facilitated debate and discussion of the evidence at hand.
- Review video material.

Product or outcome

Verbal or written explanation

- Variables that contribute to or impact on learning and performance.

Written

- Variables that contribute to or impact on a personal performance.
- Qualitative and quantitative evaluation.
- Create a training program.
- Analyse and evaluate the impact of training adaptations on learning and performance.

Tabulate or graph

- Diagrams and label.
- Measure and record personal performance.
- Tabulate and identify the differences between initial, mid-intervention and post-intervention performance.

Appendix E

Glossary of key terms

Associative phase of learning: Second phase of learning that involves practice and refining of the skill.

Autonomous phase of learning: Third and final phase of learning where the performer is able to execute the skill with little or no direct cognitive attention.

Closed skill: When the performer dictates the timing of the skill and when the environment is predictable or stable.

Cognitive phase of learning: First phase of learning where a mental picture of the skill is formed.

Cognitive skill: The mental processing that incorporates problem solving, remembering and decision making.

Complex motor skills: Motor tasks that have a large number of component parts and demand high levels of attention.

Concurrent feedback: Information presented during the performance.

Continuous skills: Motor skills that have no distinct beginning and end points and contain repetitive movements.

Descriptive feedback: Describes the characteristics of performance that were incorrect or require improvement.

Discrete skills: Have an identifiable start and finish.

Extrinsic (augmented) feedback: Extra feedback to augment and enhance inherent feedback.

Fine motor skills: Motor activities that use controlled movement of small muscles.

Gross motor skills: Motor activities that use large muscles.

Intrinsic (inherent) feedback: Sensory information that is a natural part of performing the skill and is inherent to the task.

Kinaesthesis: Awareness of joint movements and muscle–tension levels during motor activity (Schmidt & Wrisberg 2000).

Knowledge of performance (KP): Information about the nature of the movement pattern.

Knowledge of results (KR): Information about the movement outcome relative to the task goal.

Motor learning: The relatively permanent change in motor skill capabilities that is associated with practice or experience.

Motor performance: An observable behaviour at a specific time and location.

Motor skill: The 'learned ability to bring about pre-determined results with maximum certainty, often with minimum outlay of time or energy or both' (Guthrie 1952).

Open skill: When the timing of the skill is dictated by factors external to the performer and when the environment is unpredictable or unstable.

Perceptual skill: The process of recognising and then interpreting information from the environment.

Prescriptive feedback: Describes the errors and a means to correct the problem.

Proprioception: The sensations and perceptions of body positions and movements in space.

Qualitative feedback: Information about the quality of a performance.

Quantitative feedback: Numerical information.

Regulatory features: Cues in the performance environment that are important for the successful execution of motor skills.

Serial skills: The linking of discrete skills together to form more complicated skills.

Simple motor skills: Motor tasks that have few component parts and demand relatively limited attention.

Terminal feedback: Information presented after the performance.

Verbal cue: Short, concise phrase that directs attention to the most important feature(s) in the performance environment, or prompts performers to attend to the key components of the skill.

Visual cue: A demonstration or piece of observable information that allows the learner to determine what the movement requires.

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Unit 1 and 2 Background Information: Exercise Physiology – Sports Injury and Rehabilitation

On-line Research Task

Content	Website	Student Findings (Type here)
Preventing Sport Injuries		
Preventing injuries	http://sportsmedicine.about.com/cs/injuryprevention/a/aa101801a.htm http://www.elastoplastsport.com.au/Common/Pdf/ClinicalPlaySafeChecklist.pdf http://kidshealth.org/parent/nutrition_fit/fitness/sports_safety.html http://kidshealth.org/kid/watch/out/sport_safety.html http://www.acc.co.nz/preventing-injuries/playing-sport/index.htm	
Protective equipment	http://www.smartplay.com.au/ImageLibraryAssets/resources/national/gear-up-brochure-nat.pdf	
Effective warm up Cool down	http://www.smartplay.com.au/ImageLibraryAssets/Resources/National/general-sports-safety-2008-warm-up-poster-nat.pdf http://www.sportsinjuryclinic.net/cybertherapist/stretching/allstretches.php	
Safe playing environment	http://www.smartplay.com.au/ImageLibraryAssets/Resources/VIC/training-2008-how-to-become-a-smartplay-club-booklet-vic.pdf	

Unit 1 and 2 Background Information: Exercise Physiology – Sports Injury and Rehabilitation

On-line Research Task

Content	Website	Student Findings (Type here)
Understand the immediate care used for sporting injuries including		
TOTAPS	http://www.elastoplastsport.com.au/Common/Pdf/Lesson3_notes.pdf http://intranet.pmreg.lism.catholic.edu.au/_AAATEACHER_WEB/PEClasses/Documents/injury_management.pdf	
RICER	http://www.elastoplastsport.com.au/Common/Pdf/Lesson3_notes.pdf http://intranet.pmreg.lism.catholic.edu.au/_AAATEACHER_WEB/PEClasses/Documents/injury_management.pdf http://www.elastoplastsport.com.au/Injury/Ricer.aspx http://www.smasa.asn.au/smartplay/ouch/injury_manage/injury_info.html	
HARM	http://www.elastoplastsport.com.au/Common/Pdf/Lesson3_notes.pdf http://intranet.pmreg.lism.catholic.edu.au/_AAATEACHER_WEB/PEClasses/Documents/injury_management.pdf http://www.smasa.asn.au/smartplay/ouch/injury_manage/injury_info.html	

Unit 1 and 2 Background Information: Exercise Physiology – Sports Injury and Rehabilitation

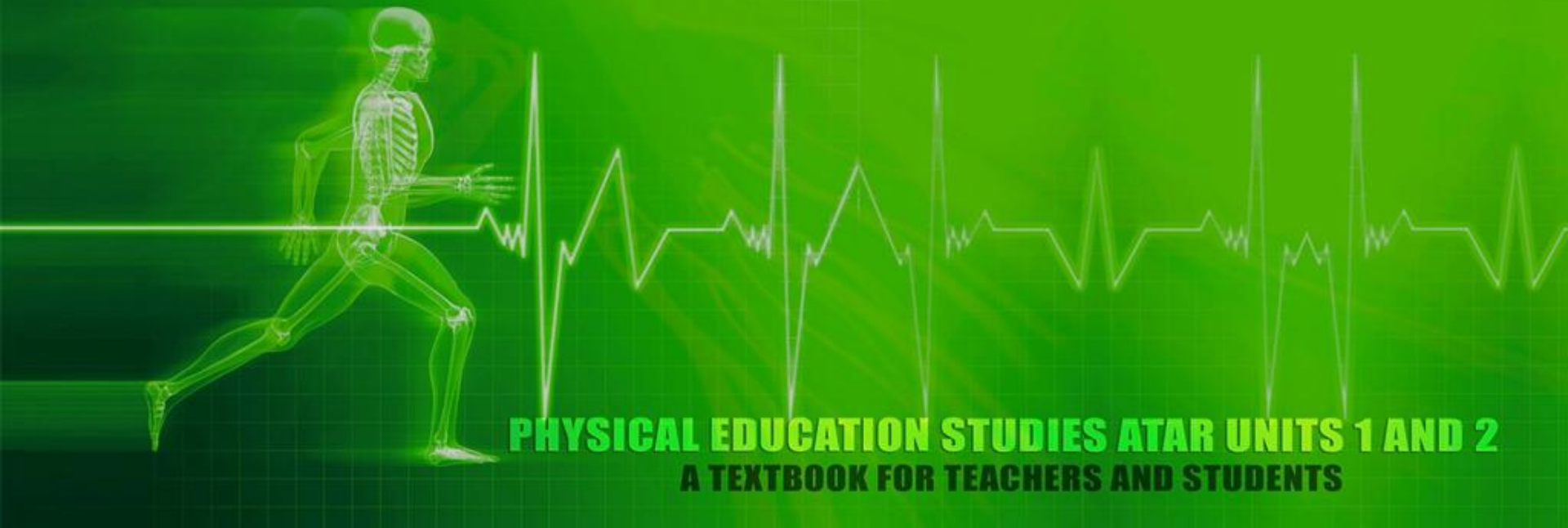
On-line Research Task

Content	Website	Student Findings (Type here)
Understand the extended care and rehabilitation of the injured athlete		
Support for injury – strapping, braces	http://www.physioroom.com/prevention/taping_guide/index.php http://www.sportstek.net/ankle_taping.htm http://www.sportsinjuryclinic.net/strapping-and-taping.php	
Goals for rehabilitation – restore range of motion, regain muscular strength, power, regain postural stability and balance, maintain CR fitness	http://www.pponline.co.uk/encyc/0181.htm http://www.smawa.asn.au/_uploads/res/120_838.pdf http://www.smawa.asn.au/_uploads/res/120_699.pdf http://www.angelfire.com/pa2/thermod/strength.html http://www.angelfire.com/pa2/thermod/rom.html http://www.angelfire.com/pa2/thermod/jointmobs.html	
Physical therapy rehabilitation strategies • Ultrasound	http://www.sportsinjuryclinic.net/cybertherapist/general/ultrasound.html	
• Heat/cold	http://www.sportsinjuryclinic.net/cybertherapist/general/heat_therapy.php http://www.sportsinjuryclinic.net/cold_therapy/cold_therapy.php http://www.sportsinjuryclinic.net/cold_therapy/coldtherapy_effects.php	
• Massage	http://www.sportsinjuryclinic.net/sports_massage/index.php	
• Exercise	http://www.sportsinjuryclinic.net/strengthening/resistancebands.php	

THE UNIVERSITY OF WESTERN AUSTRALIA

BIOMECHANICS

Prof Bruce Elliott
Dr Jacqueline Alderson
Dr Peter Whipp



PHYSICAL EDUCATION STUDIES ATAR UNITS 1 AND 2
A TEXTBOOK FOR TEACHERS AND STUDENTS

Introduction

What is biomechanics?

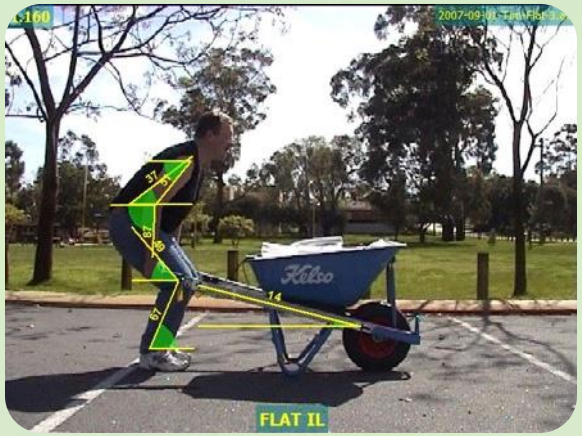
Simply put, ***biomechanics*** is: 'a study of movement using applied physics (mechanics section) and anatomy'. It is involved in sport, clinical application and everyday life (occupational biomechanics).



Sport biomechanics



Clinical biomechanics



Occupational biomechanics

Introduction

Sport biomechanics



Improve performance: Increase ball speed



Reduce the likelihood of knee injuries

Introduction

Clinical biomechanics



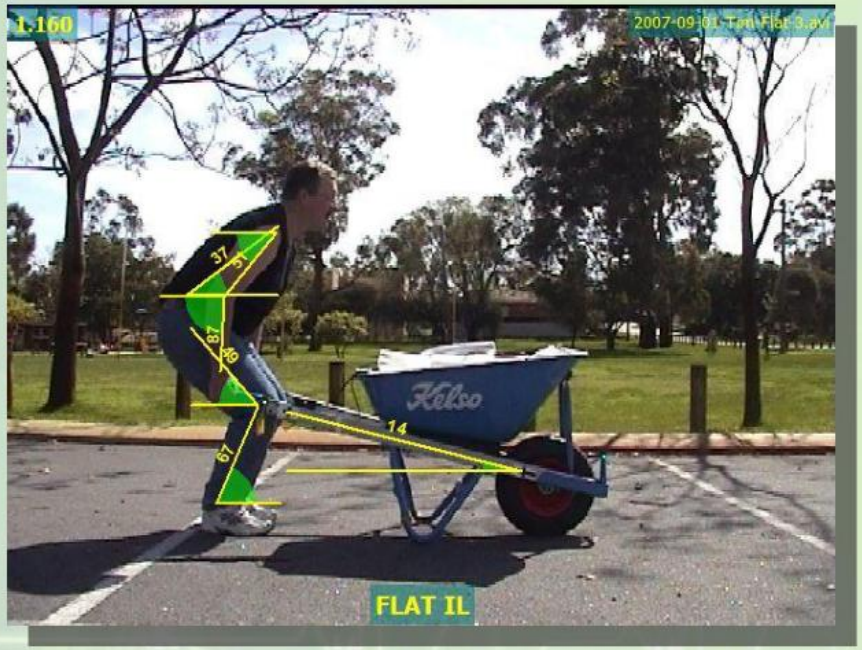
Analyse movement in a clinical setting



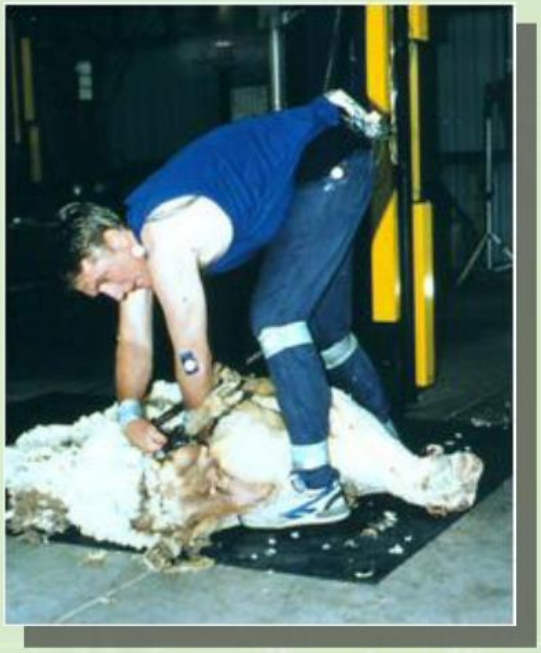
Assess how force plays a role in injuries

Introduction

Occupational/everyday biomechanics

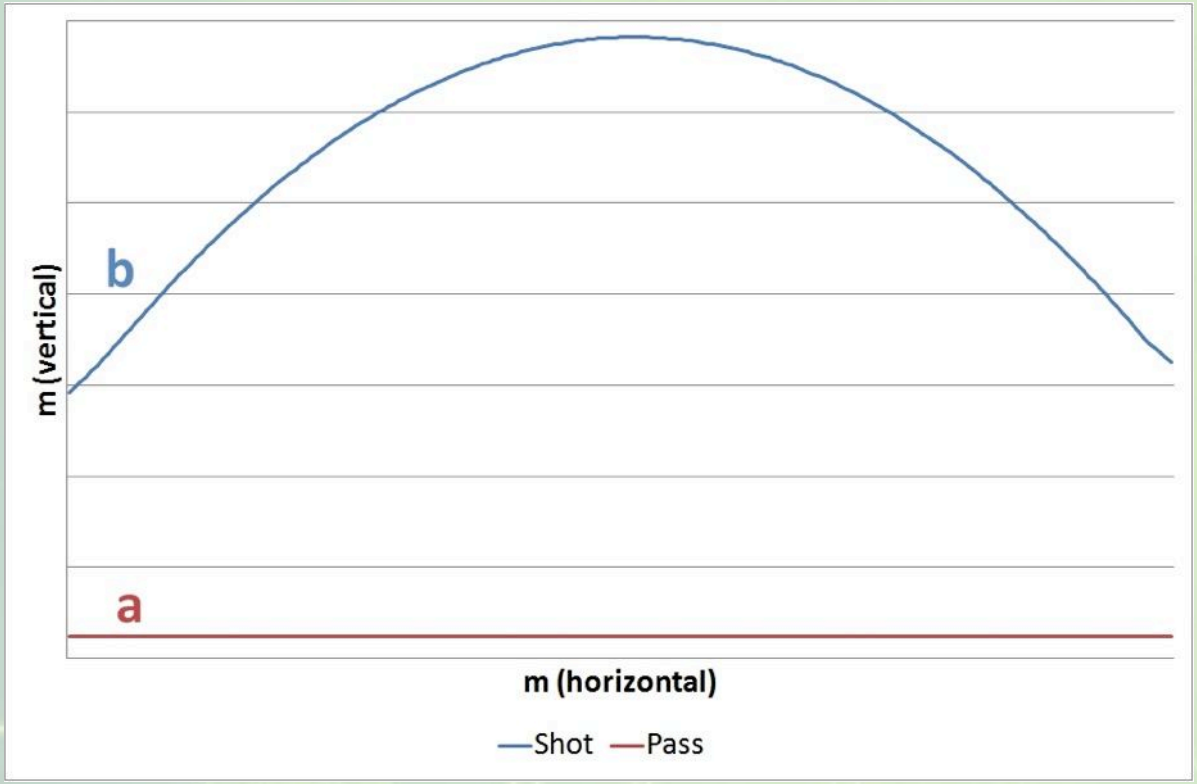


Forces associated with lifting – in this case a wheelbarrow



Back forces associated with shearing

Introduction



Compare the trajectories of the ball in a netball pass (a) and the shot for goal (b).

Linear = a

Curvilinear = b

Introduction

Angular motion

Rotation of the stick in this hockey drive is an example of ***angular motion***.



Introduction

General motion

Angular rotation of the 'legs' in cycling creates ***linear*** motion of the bike and rider.

General motion is therefore the linking of angular motion that creates linear movement of the body.

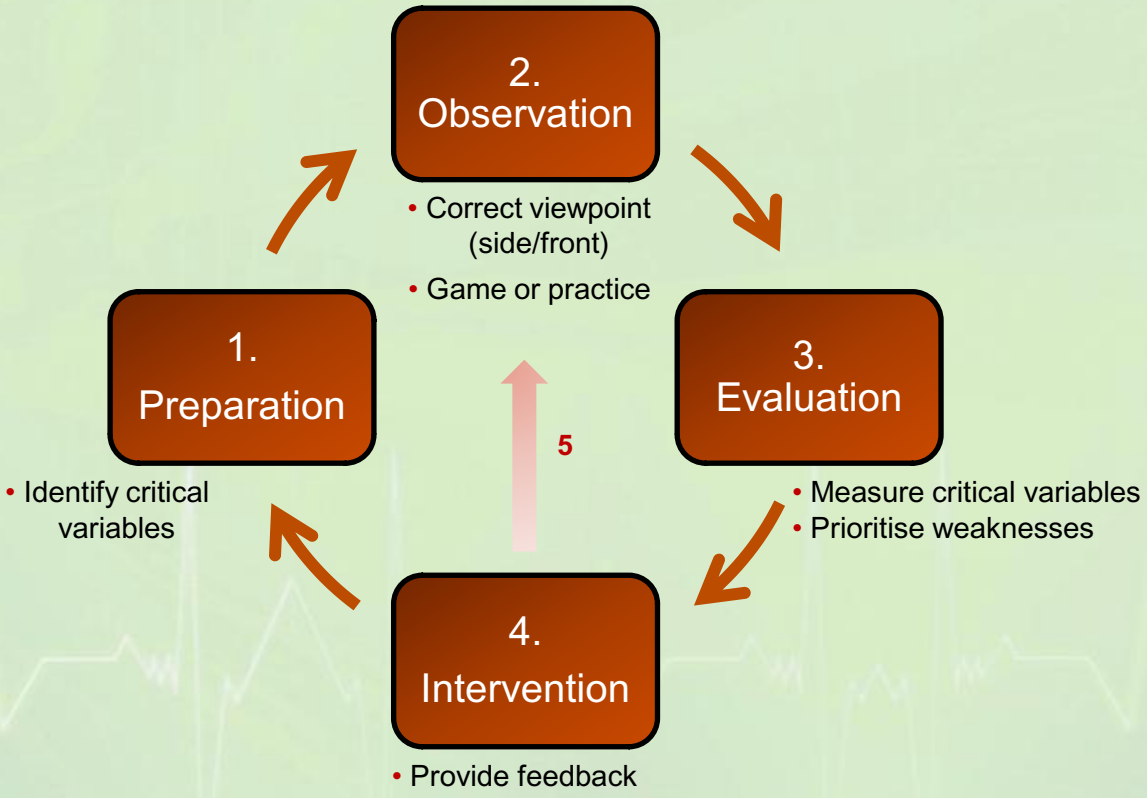


Introduction

Motion analysis: ➲ 5 stage process

Qualitative analysis involves assessment without measurement, whereas in ***quantitative analysis*** you measure a variable to assist your analysis (e.g. angle or velocity).

While there are classically 4 stages of analysis; you must re-assess your intervention (step 5) to complete the analysis process.



Introduction

Motion analysis

What mechanical features do you think are important in the development of ball velocity during the backswing (Figure 1), forwardswing (Figures 2 & 3) and follow through (Figure 4) phases of the tennis serve?









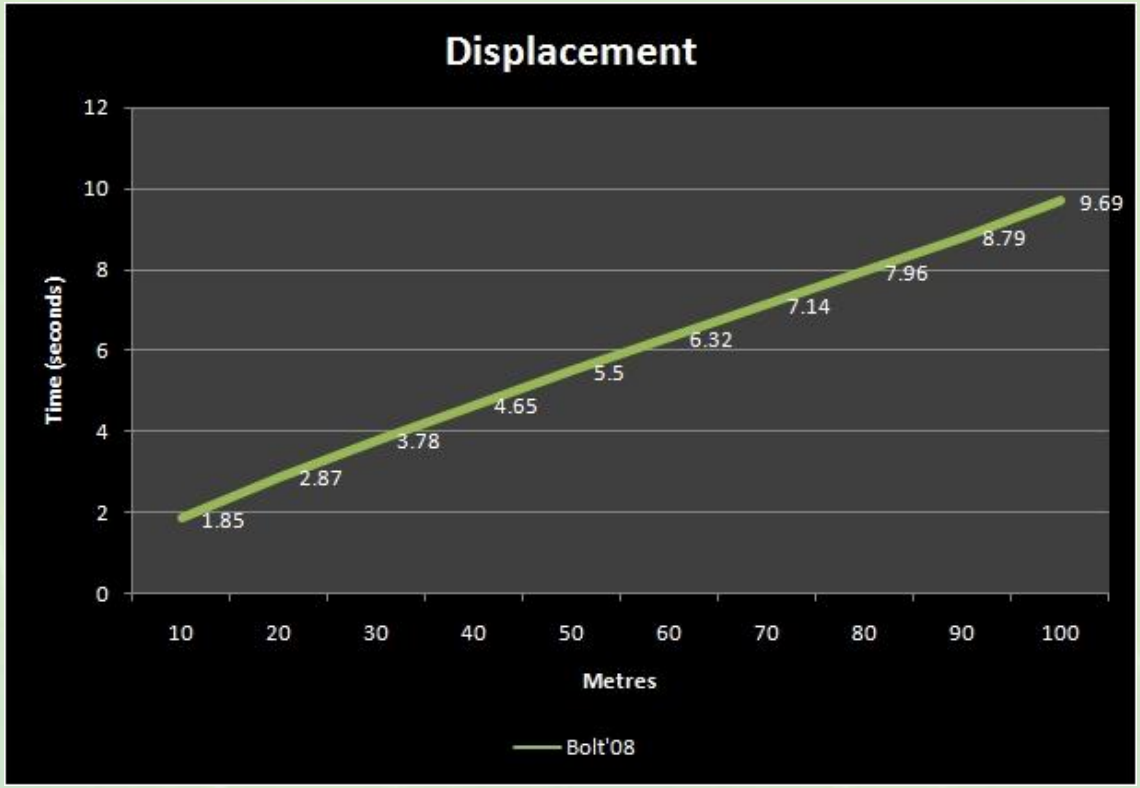
Pictures published with the permission of the International Tennis Federation

Units 1 & 2: Displacement vs Distance

Usain Bolt at the Beijing Olympics completed the 100 m sprint in 9.69 s.

That is, he was displaced by 100 m from the start line.

In this case his displacement and distance covered are the same.

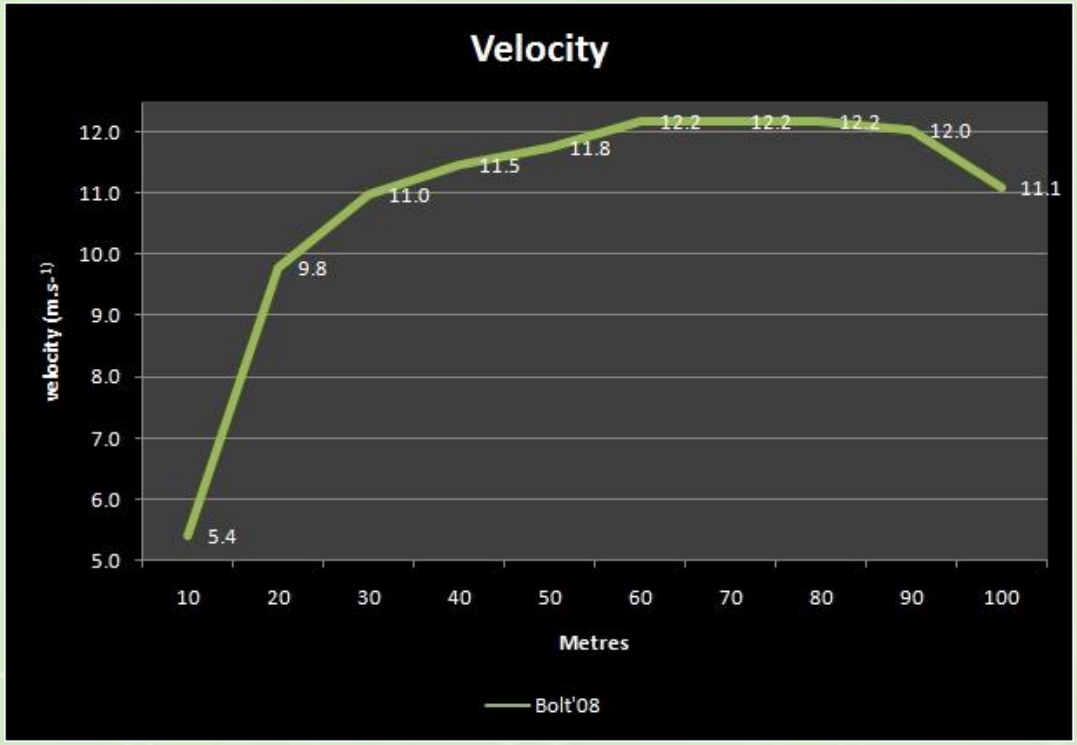


Units 1 & 2 : Velocity (instantaneous vs mean)

Usain Bolt at the Beijing Olympics completed the 100 m sprint in 9.69 s.

This is the velocity curve from the previous displacement graph.

The ***instantaneous velocity*** is the value at any point in time (12.2 m/s peak), whereas the ***average velocity*** would be the displacement (100 m) divided by the total time taken (9.69 s) - that is 10.3 m/s.



These are horizontal velocity measures (vector; size & direction), whereas speed does not take direction into account.

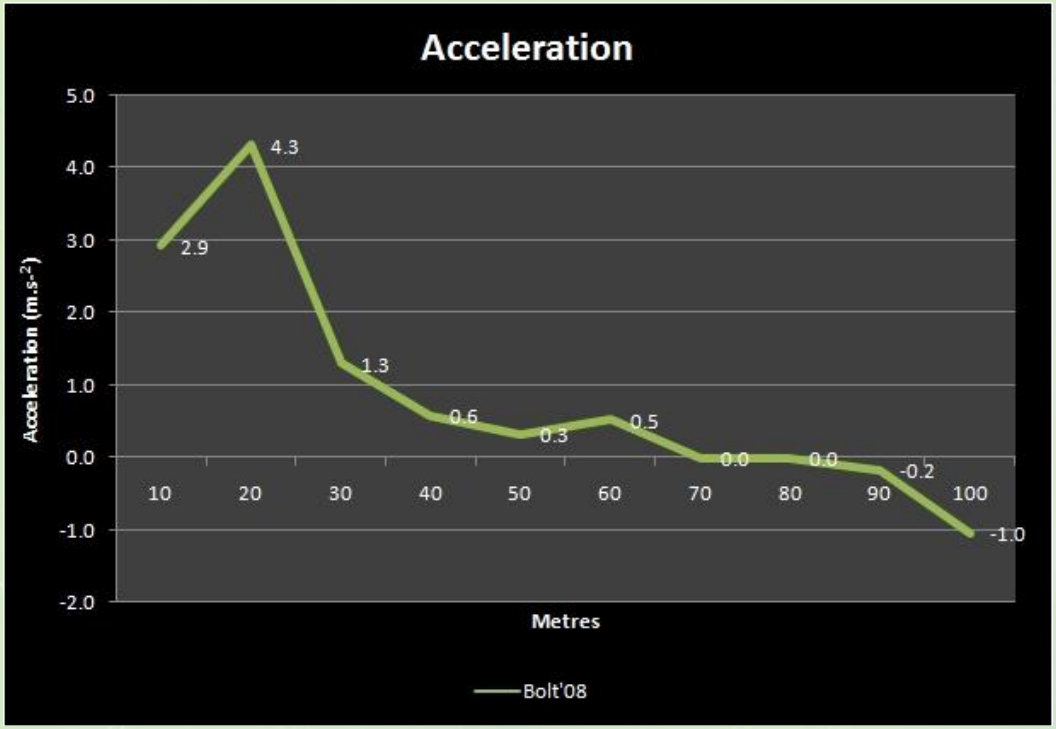
Units 1 & 2: Acceleration

Usain Bolt at the Beijing Olympics completed the 100 m sprint in 9.69 s.

Acceleration is the change in velocity over time.

The incredible thing about Usain Bolt is that he continues to accelerate (+ve value) throughout most of the race.

Only at about the 90 m mark does he start to slow down (-ve).



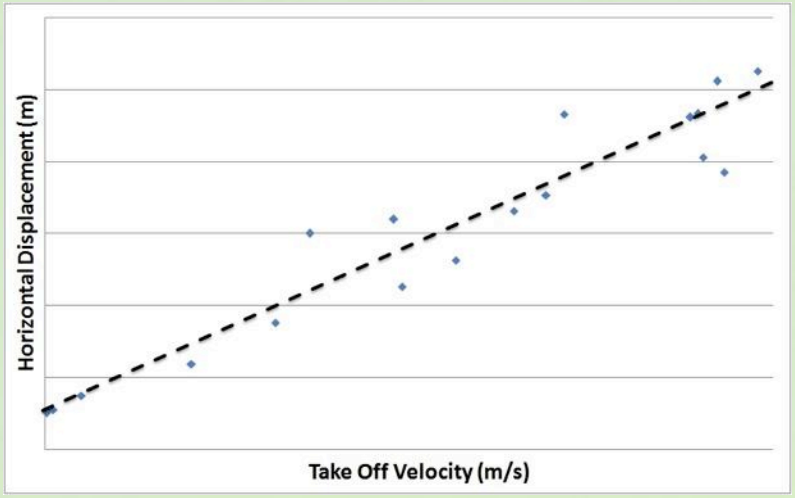
Units 1 & 2: Projectile Motion

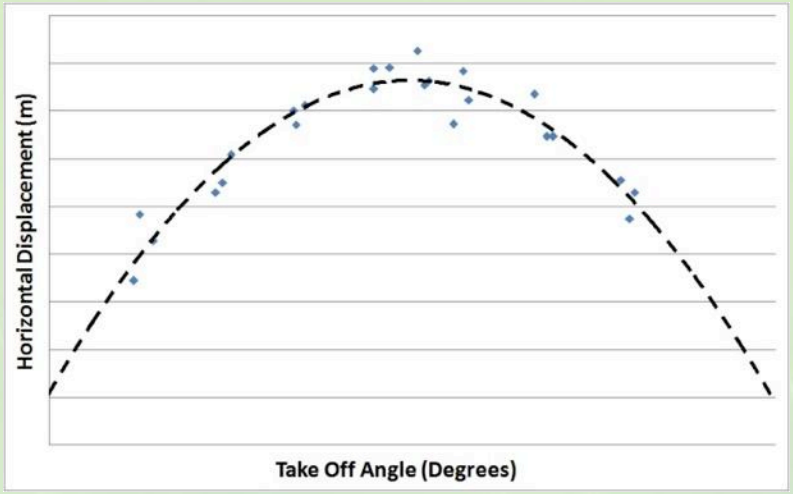
Horizontal emphasis

Take-off velocity, angle and height of centre of gravity (C of G) are all related to the skill being analysed.

Horizontal displacement increases with take-off velocity and a take-off angle of 45° produces the greatest distance, at least theoretically.

However, in the long jump take-off angles are approximately 20° as athletes can not jump at 45° and still retain a high horizontal running velocity.





Units 1 & 2: Projectile Motion

Vertical emphasis

Take-off velocity, angle and height of C of G are all related to the skill being analysed.

An emphasis on vertical displacement requires an increase in the take-off angle (~60° greater vertical velocity compared with long jump) with a reduction in the approach horizontal velocity (can not jump at this angle with the same velocity as in the long jump).

What horizontal velocity would you need to perform a vertical jump for a spike in volleyball?



Height of take-off must be considered for both sporting actions with an emphasis on horizontal or vertical displacement (consider the position of the centre of gravity at take-off).

Units 1 & 2: Projectile Motion

Exam style question

Explain the most important mechanical factors associated with projectile motion in the high jump?

(6 marks)



Units 1 & 2: Projectile Motion

Answer



What are the most important biomechanical factors associated with projectile motion in the high jump? (6 marks)

Three biomechanical factors should be considered:

1. Height of release (1 mark): The higher the start height of the C of G the less it will need to be raised to 'clear the bar'. (1 mark)

2. Angle of release (1 mark): The take-off angle needs to be appropriate to the skill. That is it should be greater than 45˚ (approximately 60˚) as the bar is higher than the point of take-off. (1 mark)

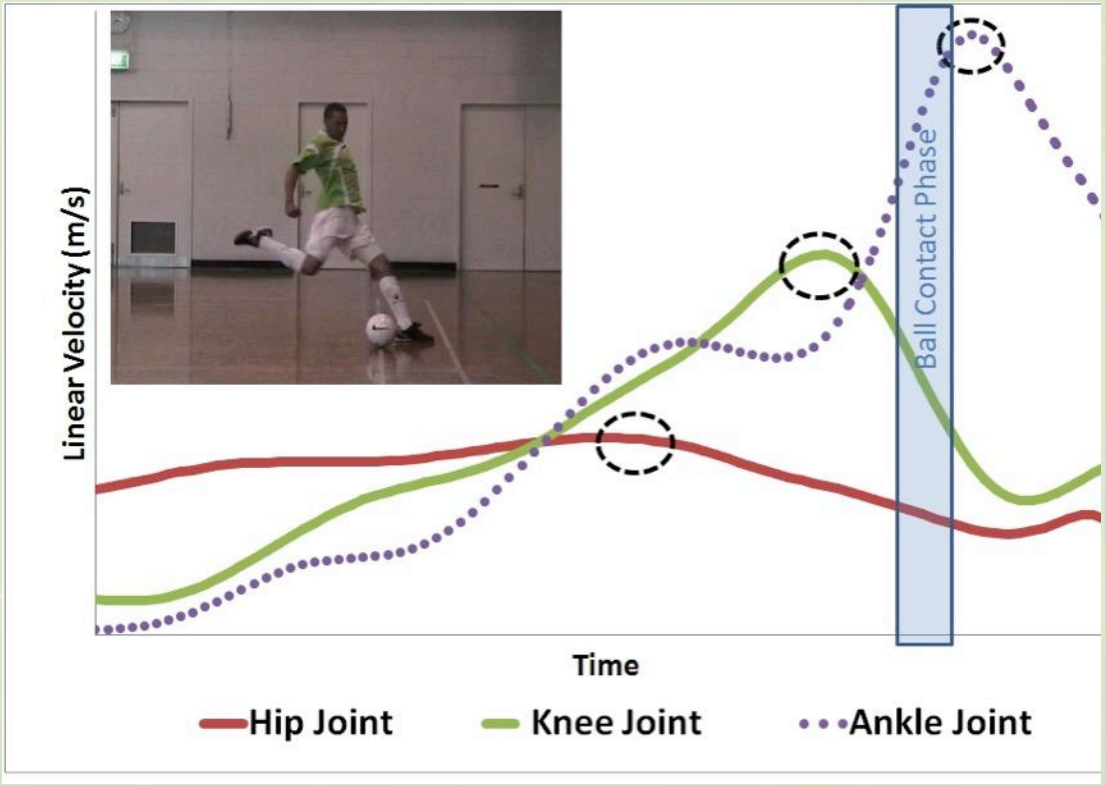
3. Velocity of release (1 mark): The horizontal run-up velocity needs to be converted into vertical velocity to drive the C of G vertically. (1 mark) However, some horizontal velocity is needed to permit the jumper to land on the mats.

Units 1 & 2: Linking Linear and Angular Motion

In a kick, angular motions are combined in the development of the foot velocity for impact.

Foot velocity produced by:

- run-up velocity (created kicking-hip linear velocity
- trunk rotation increases kicking-hip linear velocity
- The number of body parts that contribute
- thigh and leg rotations further increase the velocity of the foot

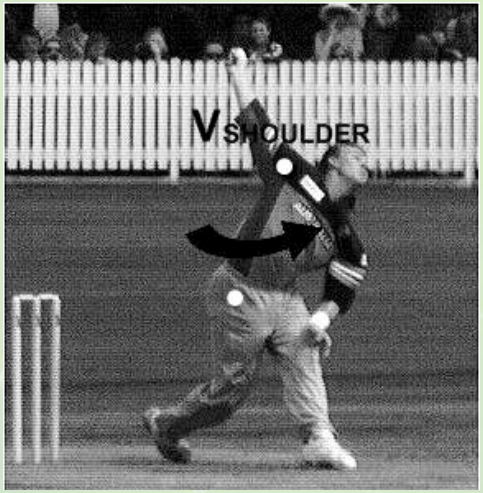


Units 1 & 2: Linking Linear and Angular Motion



Linear motion created by the run-up adds to the velocity of the ball.

Angular rotation of the trunk increases the linear velocity of the shoulder, which together with run-up velocity helps create release velocity.





Rotation of the upper limb combined with the length of the limb creates release velocity.

Units 1 & 2: Linear Kinetics - Weight

Body weight is a combination of body mass (does not change) and the force of gravity (small changes depending on location).

The rhino has a great weight because of its very high body mass.



Units 1 & 2: Linking Kinetics - Centre of Gravity (C of G)

The ***C of G*** represents the weight centre of the body. It does not have to be in the body:

- Donut - centre of hole
- High jumper - under her hips - that is the C of G does not have to be lifted over the bar using this technique





Units 1 & 2: Linking Kinetics - Balance

A number of factors influence balance:

- Mass; larger more stable
- Base of support; feet shoulder width apart for optimal balance. Narrow base reduces balance and wide stance makes movement difficult
- Line of the C of G; central for optimal balance, at the edge for quick movement



Hockey player with dynamic balance - C of G low, feet aligned with direction of travel and line of C of G near edge of base of support.

Units 1 & 2: Linking Kinetics - Balance

Two types of balance

Static balance: In sports such as archery, pistol shooting, darts and weight lifting:

- The C of G is central to the base of support
- The feet approximately shoulder width apart, aligned with direction of performance
- Knees slightly flexed or fully extended



Dynamic balance: In team sports, squash and tennis, athletes typically require:

- Lower C of G
- C of G line more at the edge of the base of support, as with the tennis player (weight on toes)
- In collision sports the feet are more aligned with the direction of the opposing tackle



Units 1 & 2: Balance

Exam style question

What biomechanical considerations does this boy need to consider to stay balanced?

(6 marks)



Units 1 & 2: Balance

Answer

What biomechanical considerations does this boy need to consider, to stay balanced? (6 marks)



To retain balance the boy must consider:

1. The width of the base of support (1 mark), with a little larger than shoulder width optimal (1 mark)

2. The height of his C of G (1 mark) – the longer the stilts the more unstable the boy would become (1 mark)

3. The line of C of G (1 mark). Ensure the line of C of G is within the base of support and where possible towards the middle of the base of support (1 mark)

Units 1 & 2: Newton's 1st Law

A body continues in its state of rest or uniform motion in a straight line, unless it is acted on by another force.

There are 2 parts to the law:

1. Start or alter movement. Such as would occur to move the club from Figure 1 to 2.

2. Change the state of a ball sitting on the ground, as would occur in Figure 3.



1 2 3

Units 1 & 2: Newton's 2nd Law

Force production: F = m x a

If you want to hit the ball with greater acceleration (hence velocity), then you need to apply more force, as the ball has a constant mass.



Units 1 & 2: Newton's 2nd Law

Force production:
F = m x a

If force production is the product of mass (m) multiplied by acceleration (a), then the development of strength/power are important ingredients in producing force.



Rafael Nadal has clearly benefited from long hours on the court and in the gymnasium.

Units 1 & 2: Newton's 2nd Law

Force absorption

F = m(v2 – v1)/t
a = (v2 – v1)/t
v2 = Final velocity
v1 = Initial velocity
t = Time from v1 to v2



The netballer landing with her leg away from the body must flex her knee to absorb the momentum at impact (mv2). That is, momentum is stopped over as large a time period as is tactically acceptable (increase value of t).

Units 1 & 2: Newton's 2nd Law

Force absorption

Large forces must be absorbed by the body on landing following a catch (netball or football).

It is therefore important to absorb these forces in the most appropriate way when landing - flex at the knee and wear shoes that assist in this process.



Units 1 & 2: Newton's 3rd Law

To every action there is an equal and opposite reaction

As the foot pushes against the ground in a side-step, the ground pushes back with an equal and opposite force (shown by the arrow).



Units 1 & 2: Newton's Laws

Exam style question

How do Newton's 1st and 2nd laws relate to the volleyball spike?

(4 marks)



Units 1 & 2: Newton's Laws

Answer

How do Newton's 1st and 2nd laws relate to the volleyball spike? (4 marks)

1st Law: Define (1 mark)
The movement of the ball, although influenced by gravity and air resistance during flight will be reversed following impact with the hand. (1 mark)

2nd Law: Define (1 mark)
Force application - The acceleration of the ball, after impact will be determined by the level of the force applied by the hand to the ball F = ma. (1 mark)

OR

Force absorption - The player on landing should flex his knees to stop the downward momentum (mv) of his body over an extended period (increase t). (1 mark)

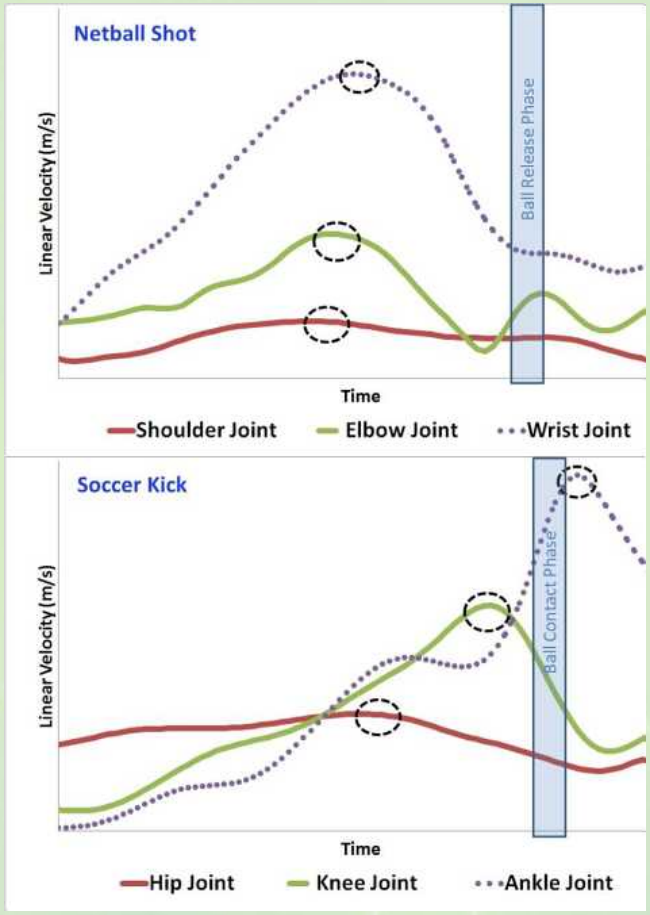


Units 1 & 2: Coordinated Movement

Movement sequencing generally will take one of two forms

1. ***Accuracy-based sports*** (netball shooting). Segments act as a unit, with the peak velocities occurring at the same time - see Figure for netball shot of upper limb vertical velocities. Body segments are added ***simultaneously***.

2. ***Velocity-based*** sports (distance/power throwing and hitting). Segments summate such that the more distal segment is added to the more proximal when peak velocity recorded - see Figure of soccer kick of lower limb horizontal velocities. Body segments are added ***sequentially***.



Units 1 & 2: Coordinated Movement

Exam style question

(a) The tennis serve is an example of what type of coordinated movement sequence? Define and explain.

(2 marks)

(a) With respect to coordinated movement, how is maximum velocity of the racquet achieved for impact?

(1 mark)



Units 1 & 2: Coordinated Movement

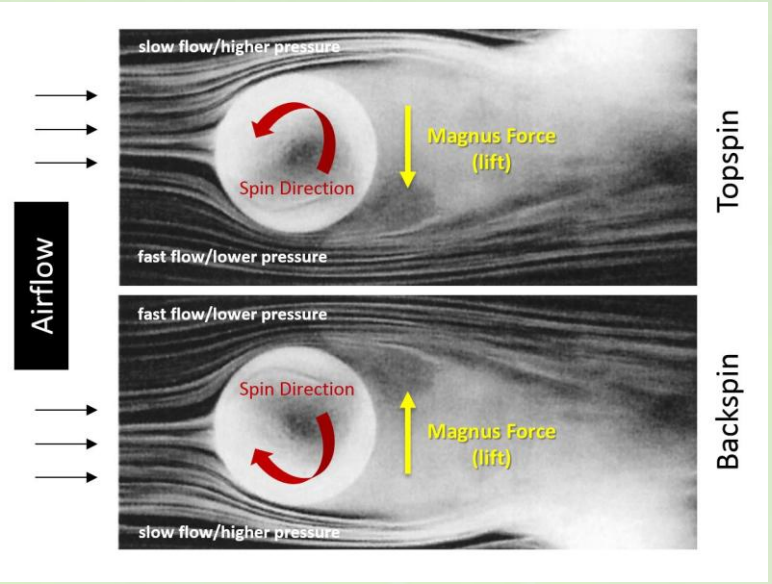
Answer

(a) The tennis serve is an example of what type of coordinated movement sequence? Define and explain. (2 marks)

(b) With respect to coordinated movement, how is maximum velocity of the racquet achieved for impact? (1 mark)

(a) The serve is an example of a 'velocity-based' coordinated sequence or sequential summation of velocity (1 mark), where the more distal segment is added to the more proximal at the point where its maximum velocity has been reached (1 mark).

(b) Trunk rotation followed by rotations of the upper limb and finally the racquet all contribute to the final velocity of the racquet. (1 mark)



Topspin (top) and backspin (bottom) air pressure differentials and resultant Magnus force (lift) effects.
Images courtesy of NASA.

Units 1 & 2: Coordinated Movement

Exam style question

Describe the optimal sequencing of body parts involved in a well coordinated golf swing. Integrate the biomechanical principles into optimal sequencing to support your answer.

(6 marks)



Units 1 & 2: Coordinated Movement



Answer

Describe the optimal sequencing of body parts involved in a well coordinated golf swing. Integrate the biomechanical principles into optimal sequencing to support your answer. (6 marks)

Backswing - the upper body and hips are rotated away from the target (1 mark) – increases distance of the club head from impact and the most body parts are incorporated. (1 mark)

Forward swing: Body segments are added sequentially. The initiation of the downswing is made with the lower body – these being the larger or stronger lower body parts (1 mark). These have the greatest mass and are harder to accelerate. He rotates around the front leg – enables forces to be generated around the stable leg (1 mark). The upper limb and hands rotations utilise the velocity generated in the preceding segment(s) - sequence of movements, added when previous at its maximum velocity. (1 mark)

Follow through - to ensure there is no deceleration before impact and the body segments gradually slow under control – reduce the potential for injury. (1 mark)

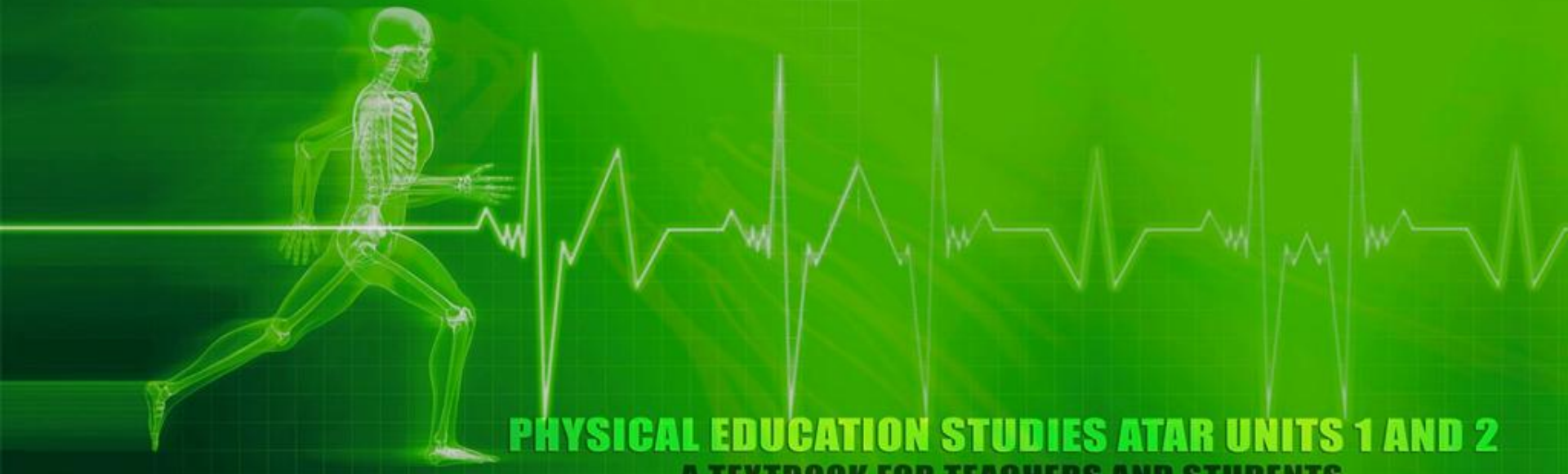
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FUNCTIONAL ANATOMY

Dr Grant Landers

Dr Peter Whipp

Dr Kym Guelfi



PHYSICAL EDUCATION STUDIES ATAR UNITS 1 AND 2

A TEXTBOOK FOR TEACHERS AND STUDENTS

Introduction

Anatomy

Our anatomy interacts with our environment:

- flexibility (gymnastics vs AFL)
- height (horse racing vs basketball)









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Introduction

Somatotype

Describes the shape of a person: 3 components

- endomorphy ~ adiposity or body fat
- mesomorphy ~ robustness
- ectomorphy ~ linearity

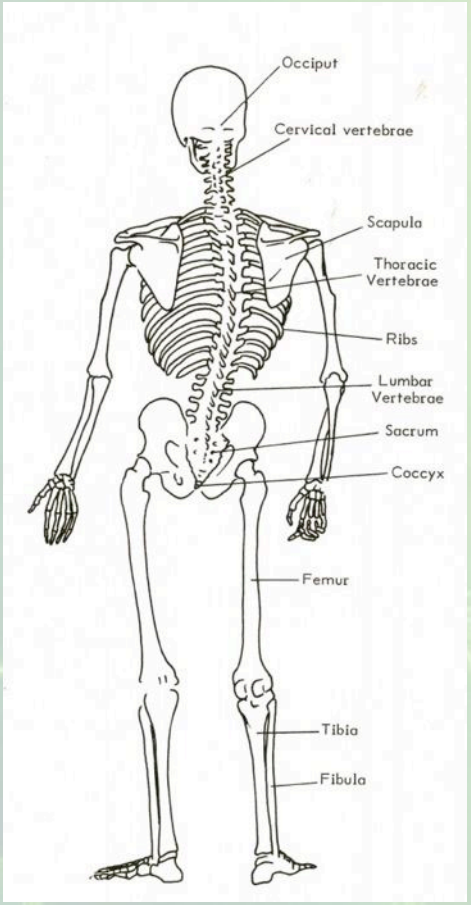




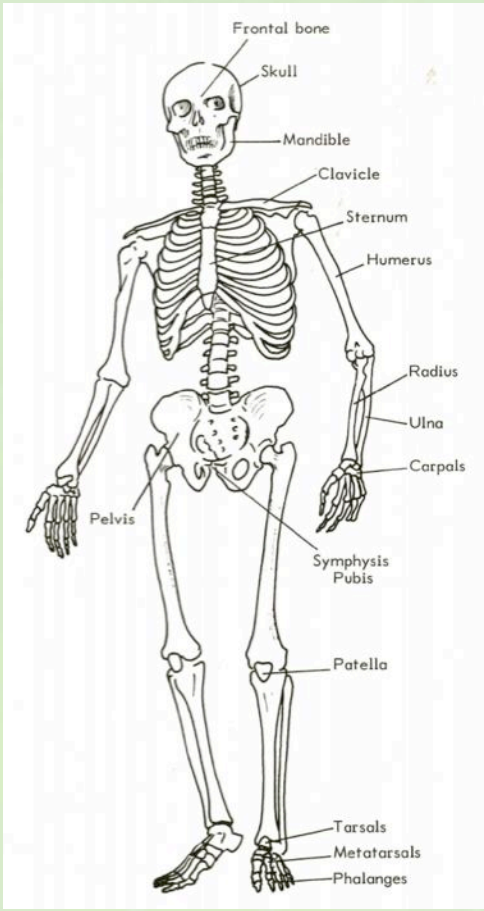


Introduction

Skeletal function



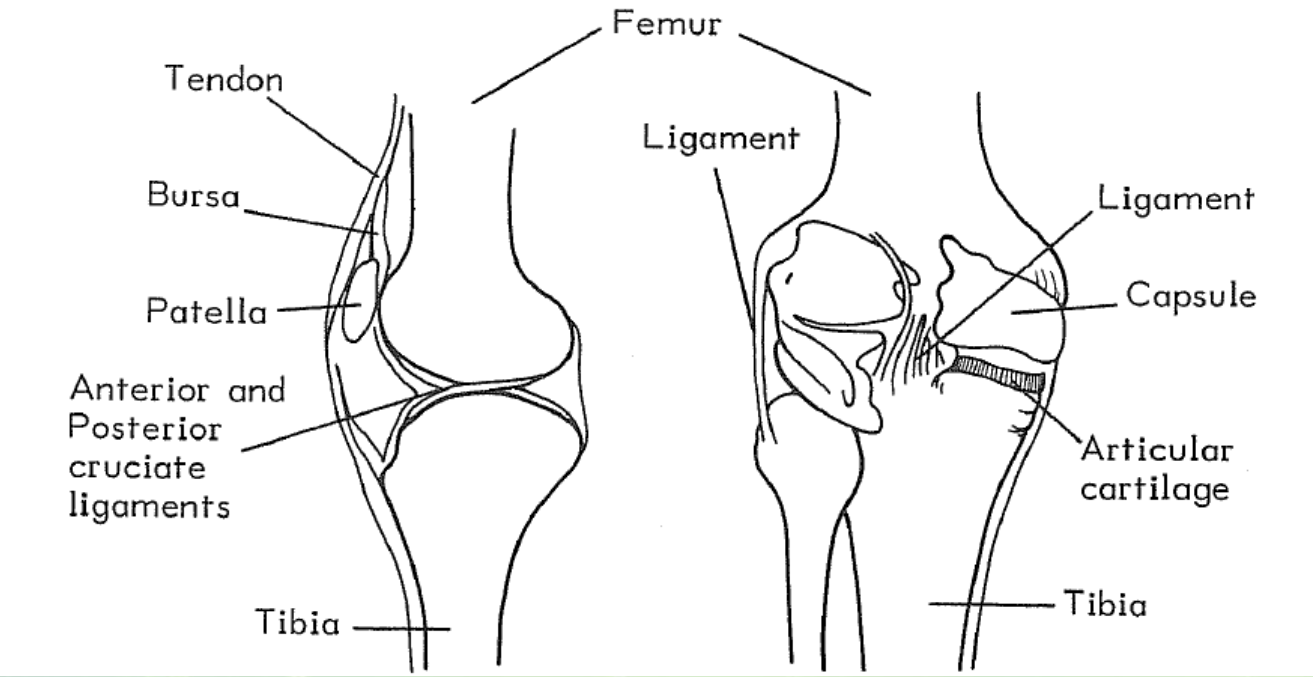
1. Support
2. Protect
3. Red blood cell development
4. Nutrient storage
5. Frame for movement



Introduction

Support

- Skeleton provides a frame work for movement
- Ligaments hold bones together



Introduction

Protection

Different body shapes provide differing levels of protection to internal organs





Introduction

Framework for movement

Movement results from muscles contracting against the rigid skeletal structure

Movement is determined by:

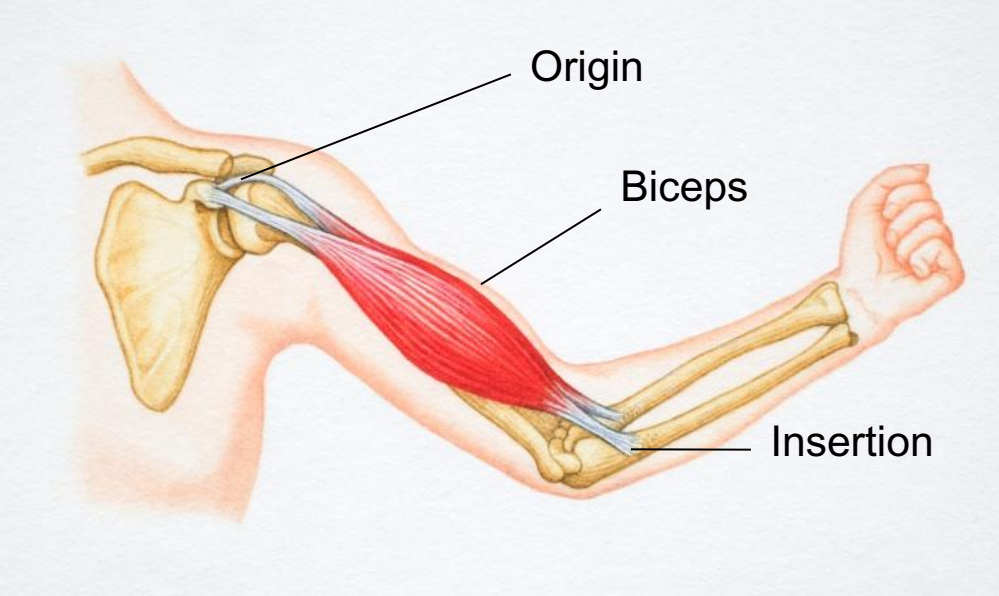
- Structure of bones
- Placement of ligaments
- Attachment points of muscles (origin & insertion)
- Muscle flexibility
- Size of the bone

Introduction

Origin & insertion

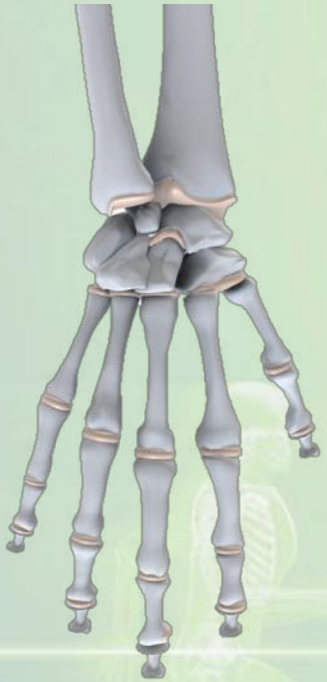
The muscle's ***origin*** is attached to the more stable bone

The ***insertion*** of the muscle attaches to the bone that moves when the muscle contracts

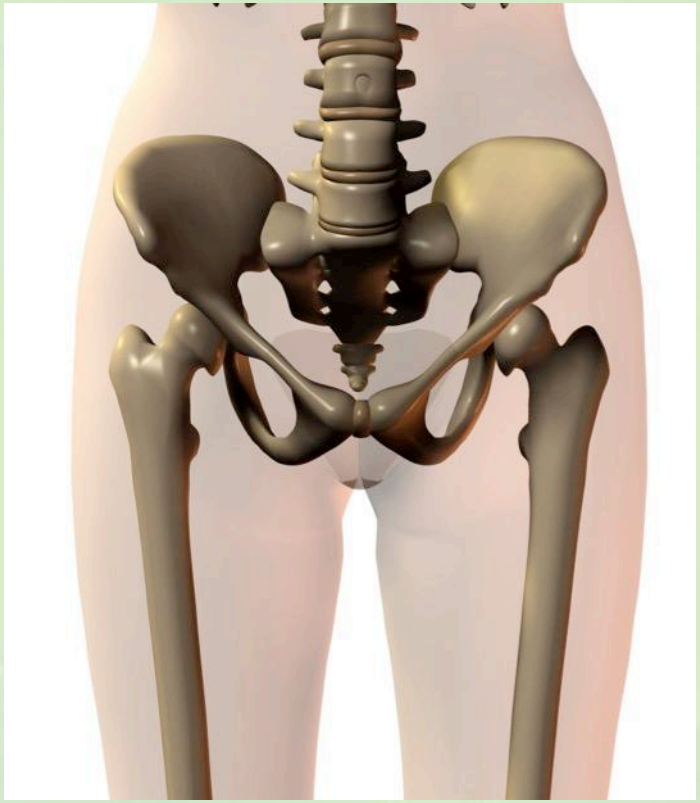


Introduction

Bone classification

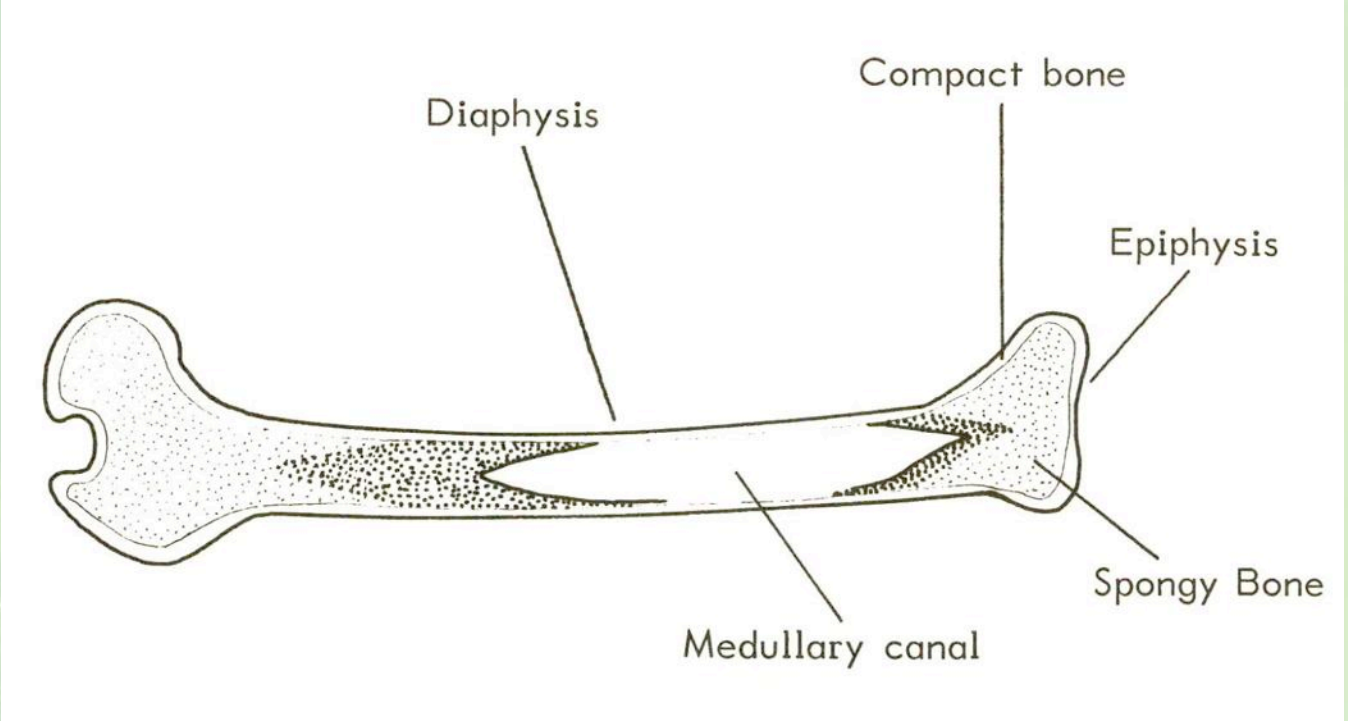


1. Flat bones
2. Long bones
3. Short bones
4. Irregular bones



Introduction

Long bones



Introduction

Range of movement (ROM)

Joints between bones allow movement

Range of motion (ROM) of these joints may be reduced or enhanced by:

- Structure of the bone
- Type of joint it forms
- Muscle attachment points
- Muscle size
- Flexibility

Introduction

Movement & joints: Structure of the bone



Minimal bone allowing hyperextension of the elbow

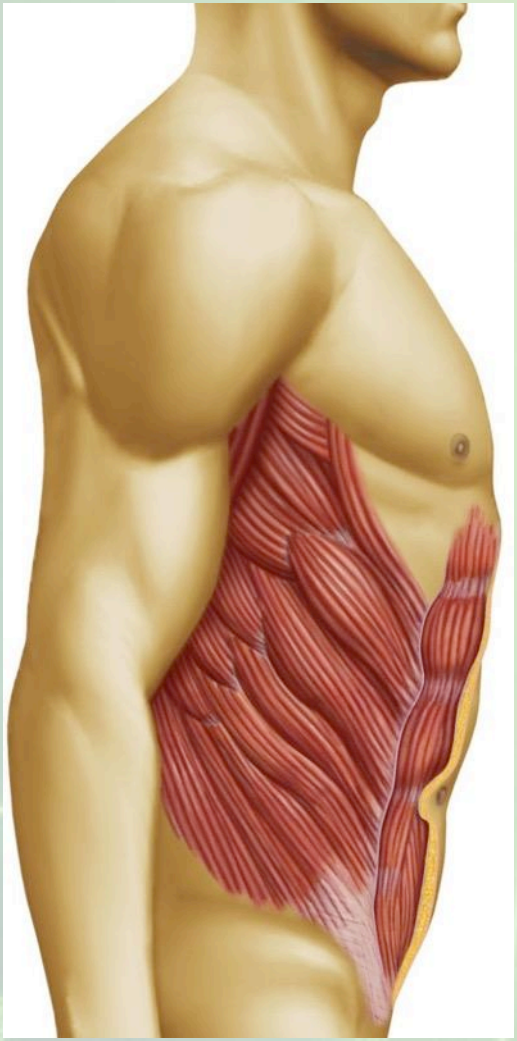
Introduction



Movement & joints: Joint type

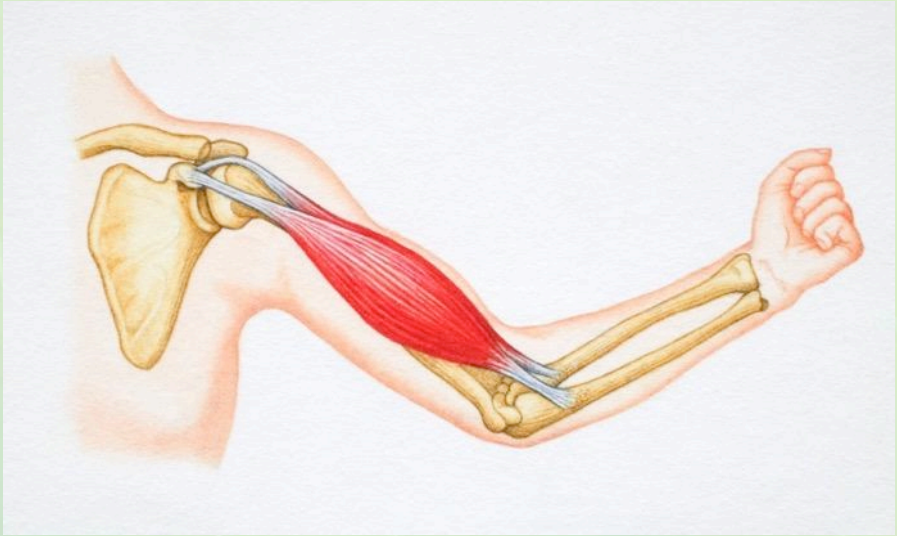
Compare the different movements available at the wrist, hand and fingers.

Introduction



Movement & joints: Muscle attachment point

Compare the different movements available when you try to contract the muscles attached to the side of your ribs and that of the biceps brachii.



Introduction

Movements & joints: Muscle size

Influencing joint range of motion

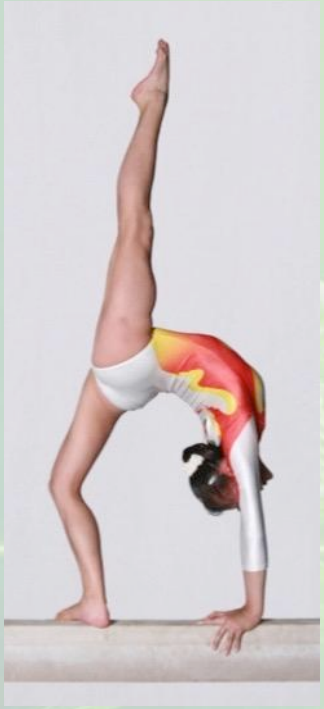




Introduction

Movement & joints: Flexibility

Different athletes require different levels of flexibility and range of movement to excel in their sport





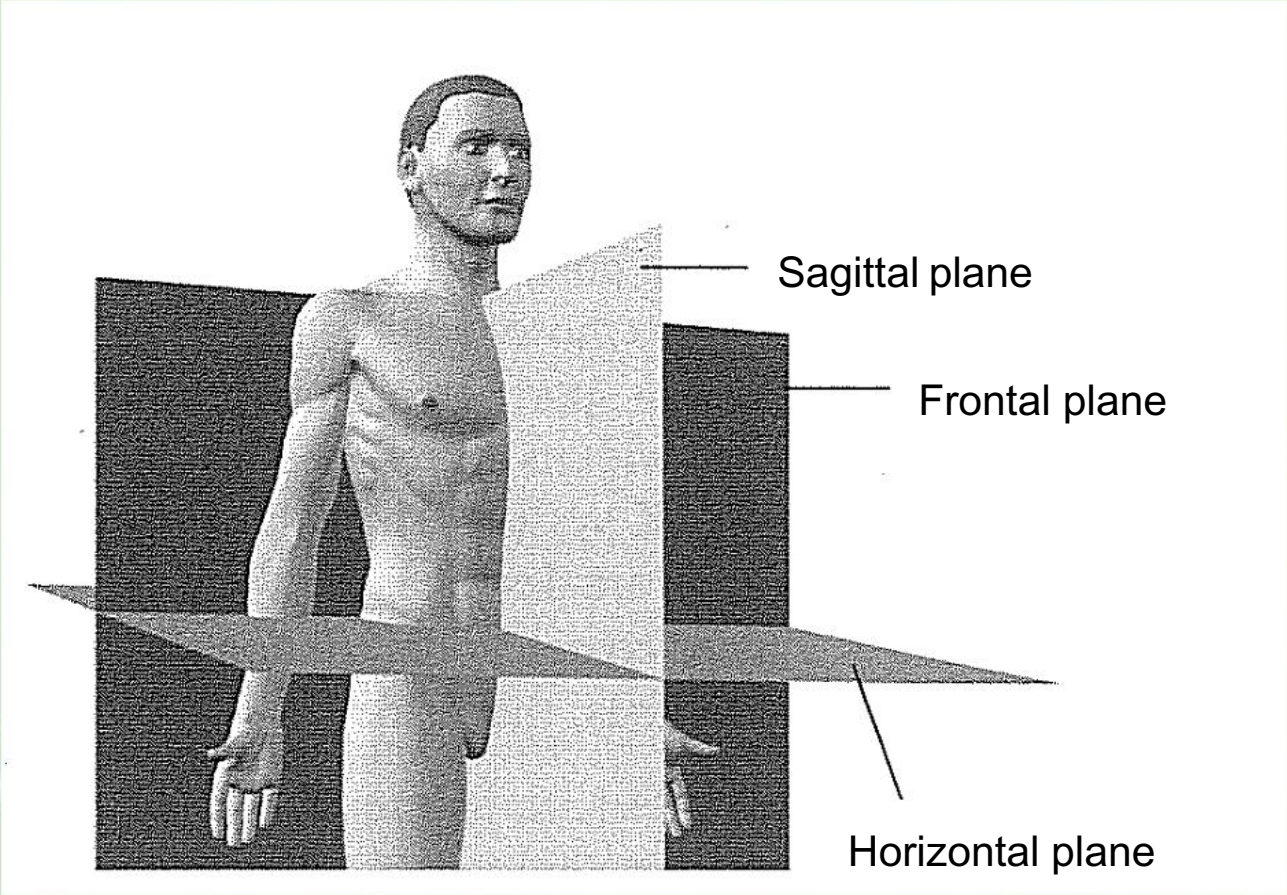




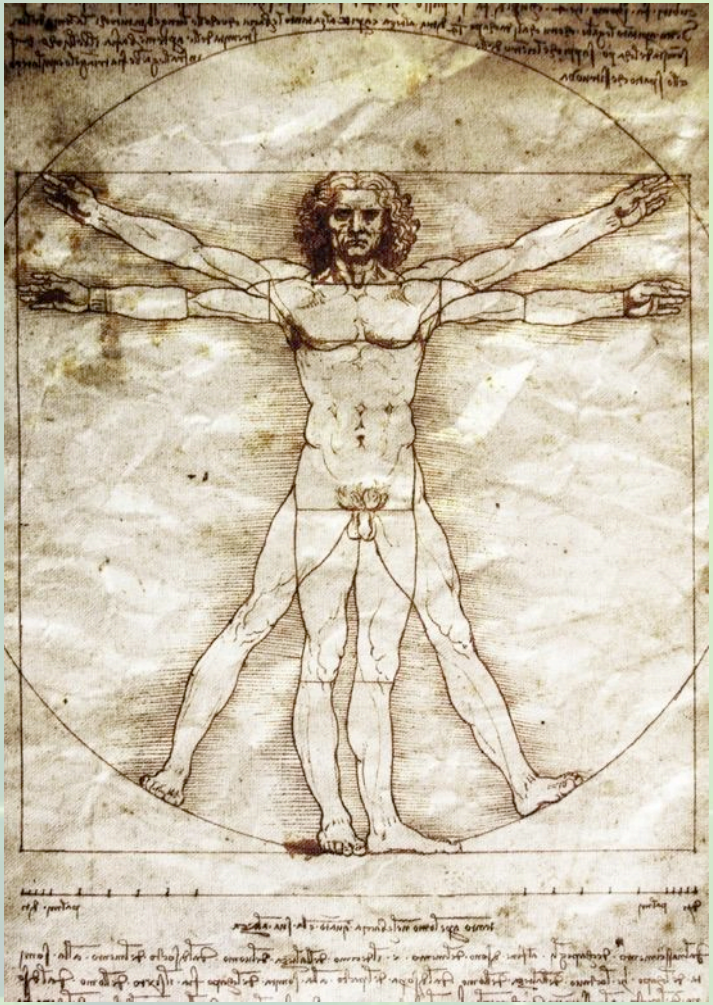


Introduction

Anatomical planes



Introduction



Actions

Flexion & extension

Abduction & adduction

Introduction

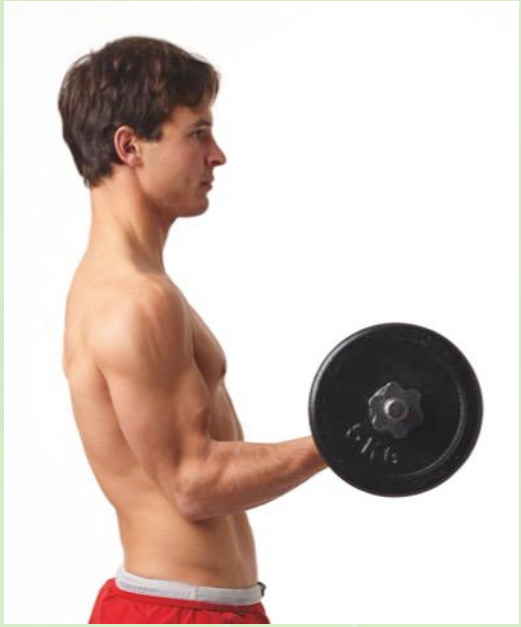
Muscle characteristics

Contractile
- Shortens when developing tension

Extensibility
- Being able to stretch a muscle beyond its normal resting length

Excitability
- Ability to receive and respond to stimuli

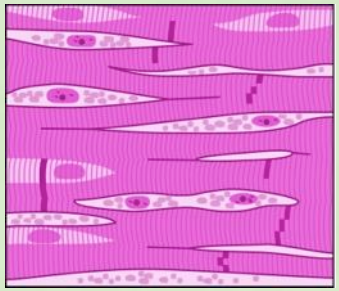
Elasticity
- Ability to return to its original shape after being stretched





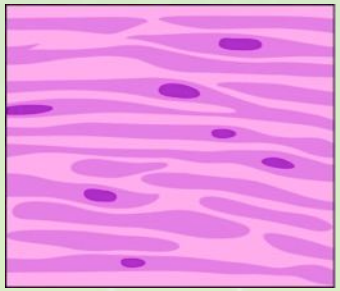
Introduction

Muscle types



Cardiac

- Muscles of the heart

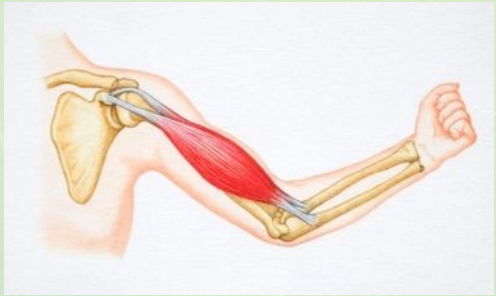


Smooth

- Digestive system & blood vessels

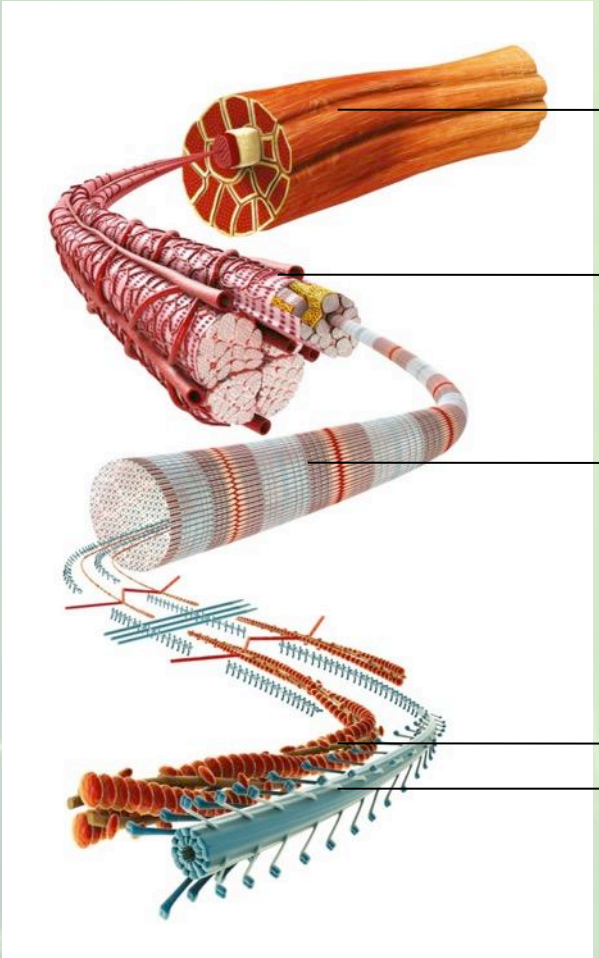
Skeletal

- Connected to bones and cause movement when contracted



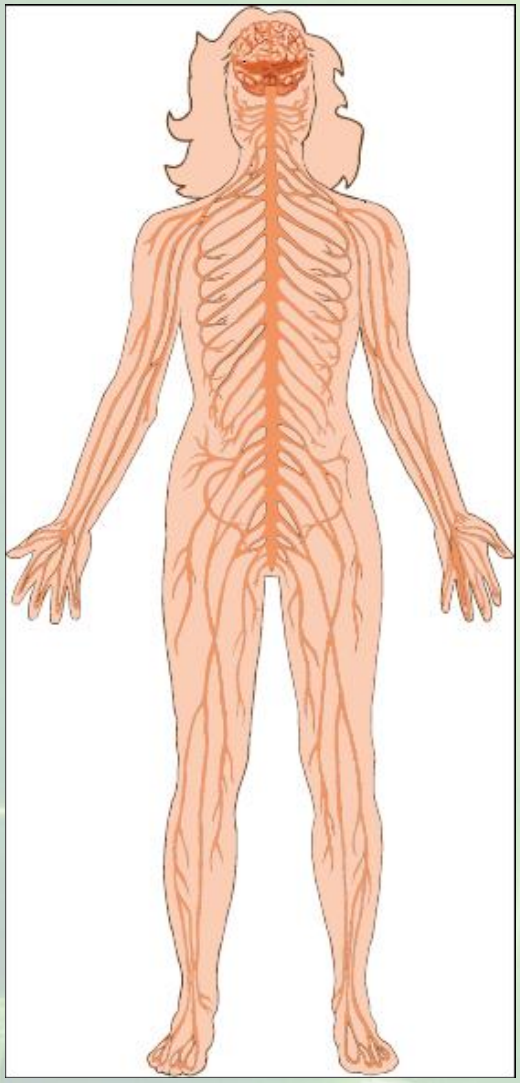
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Introduction



Skeletal muscle structure

Introduction



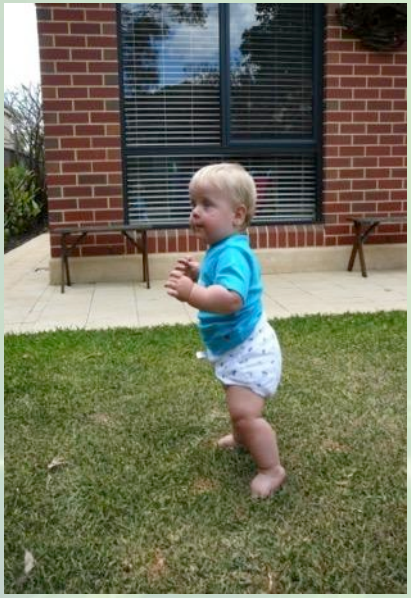
Neural pathways

Information sent from the brain down the spinal cord to the target muscle for muscle contraction & movement to occur

Introduction

Movement patterns

Movement patterns are developed at a young age and then become automated with practice



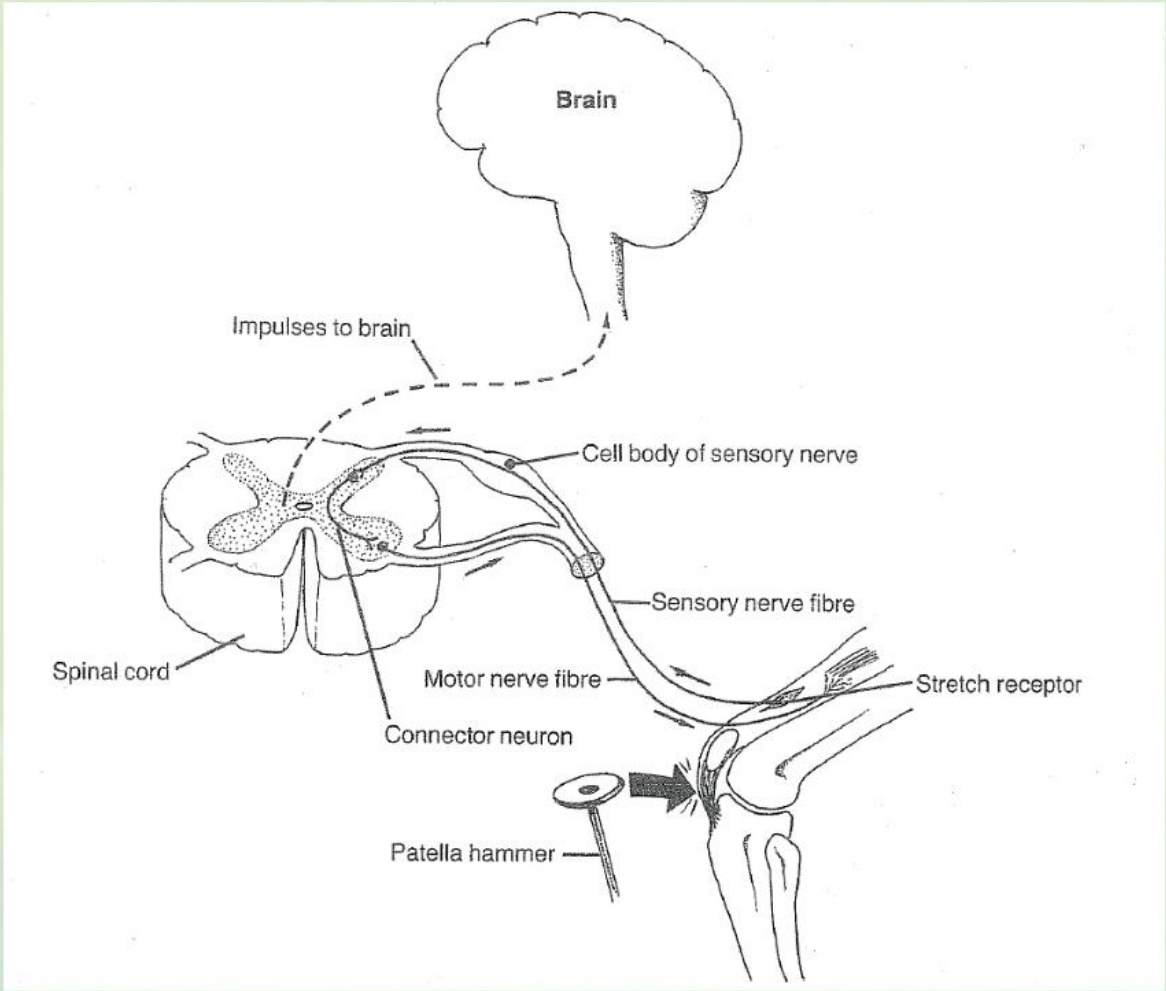


Introduction

Reflex actions

Protect the body from harm

Do not require input from the brain for skeletal muscles to contract



Introduction





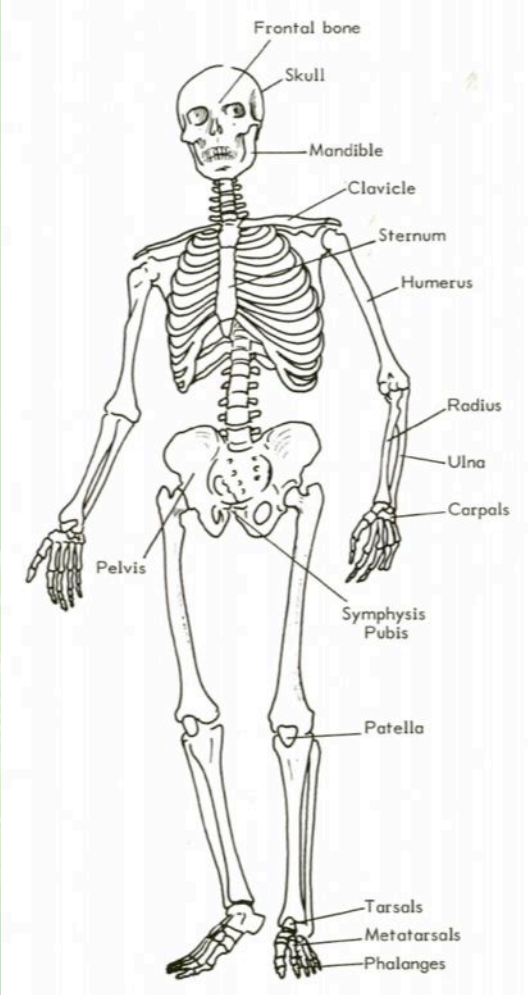
Muscle fibre types

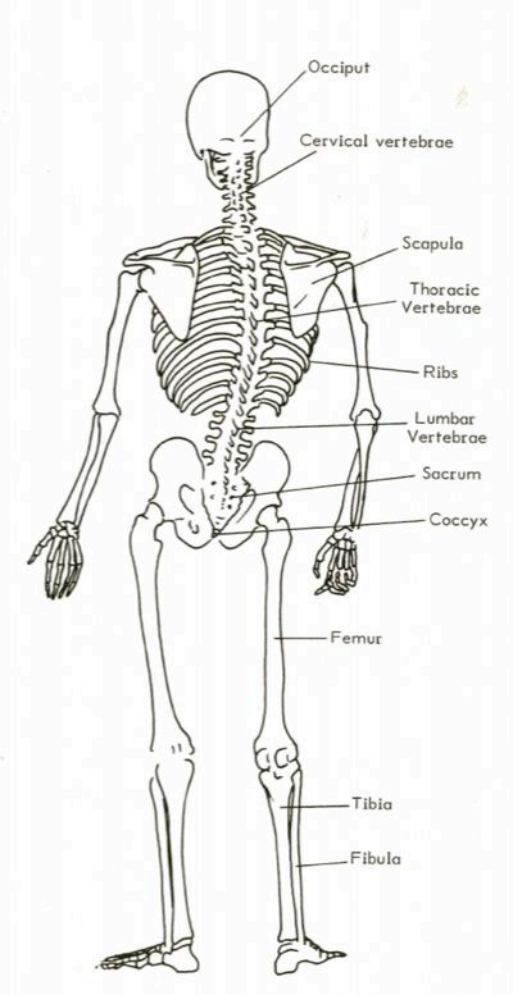
Fast-twitch fibres (Type II)
Muscles involved in quick or explosive movements.

Slow-twitch muscle fibres (Type I)
More fatigue resistant.
Found in endurance events athletes.

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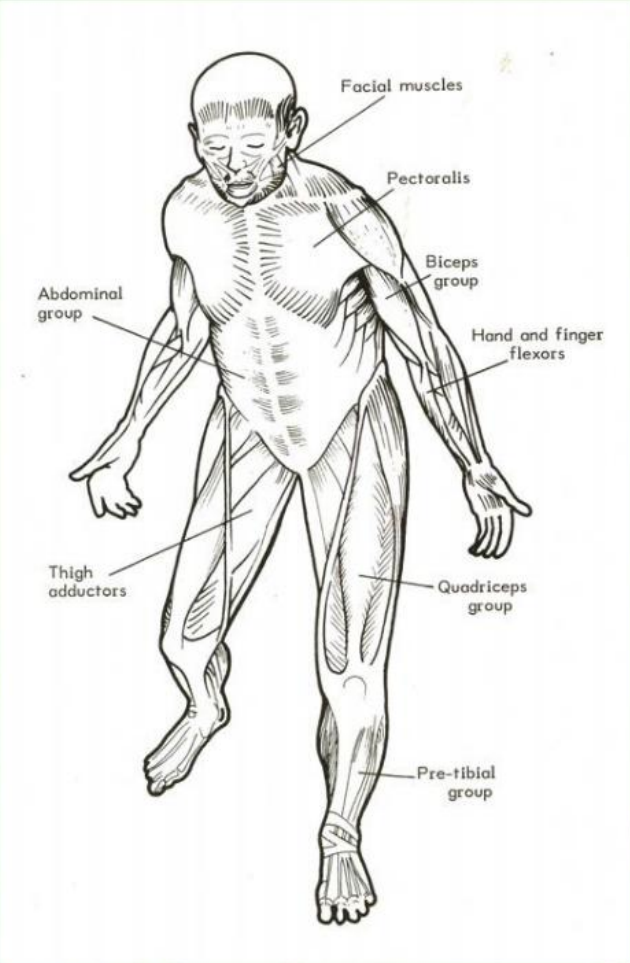
Units 1 & 2: Human Skeleton

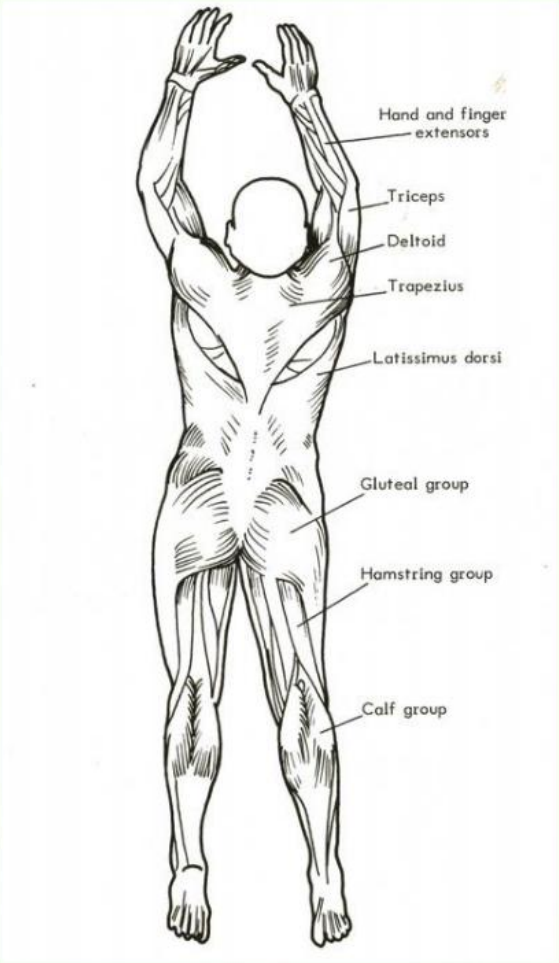




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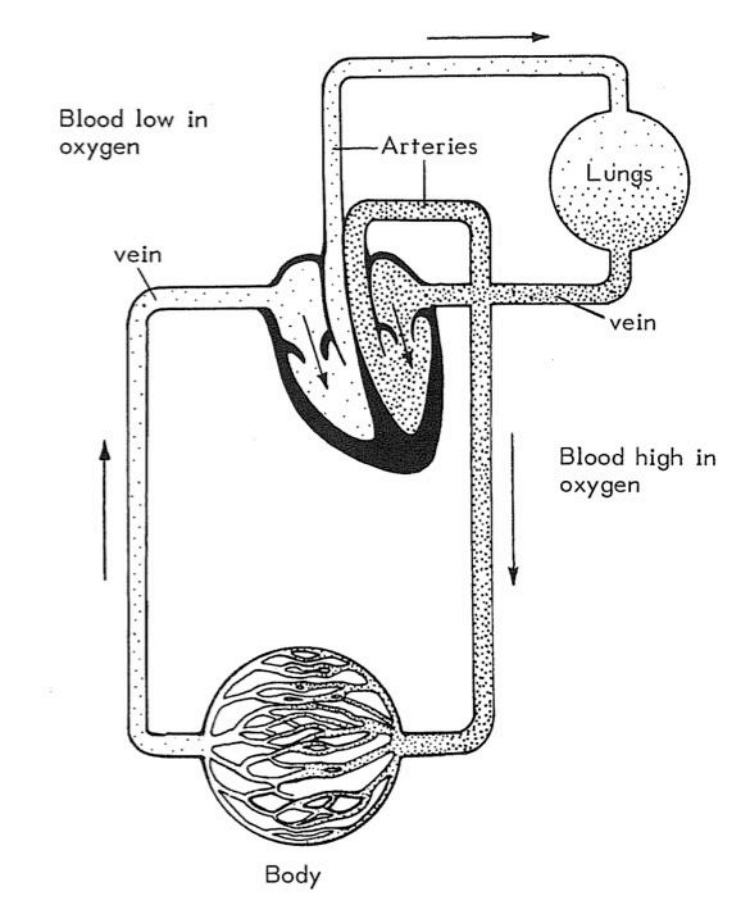
Units 1 & 2: Human Skeleton





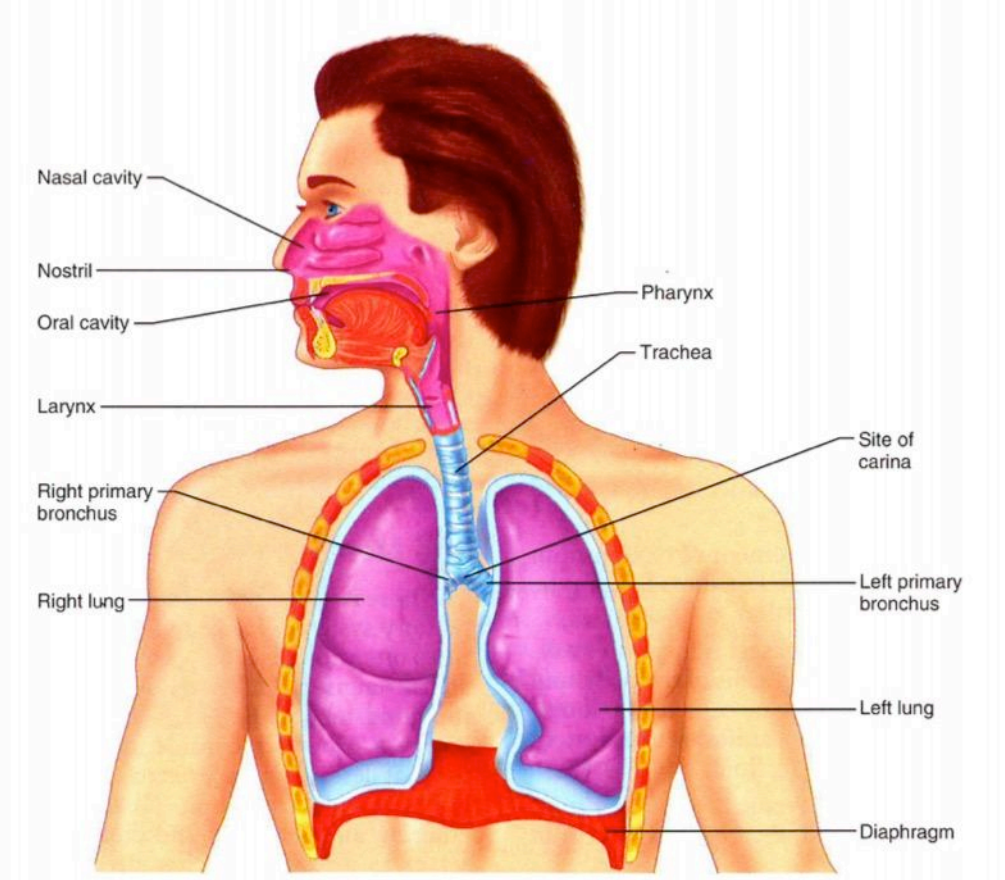
Units 1 & 2: Supporting the Aerobic Energy System

The respiratory and cardiovascular systems work together to provide oxygen the working muscles



Units 1 & 2: Respiratory System

The respiratory system transports oxygen from our external surroundings into the lungs to the site of gas exchange (the alveoli)

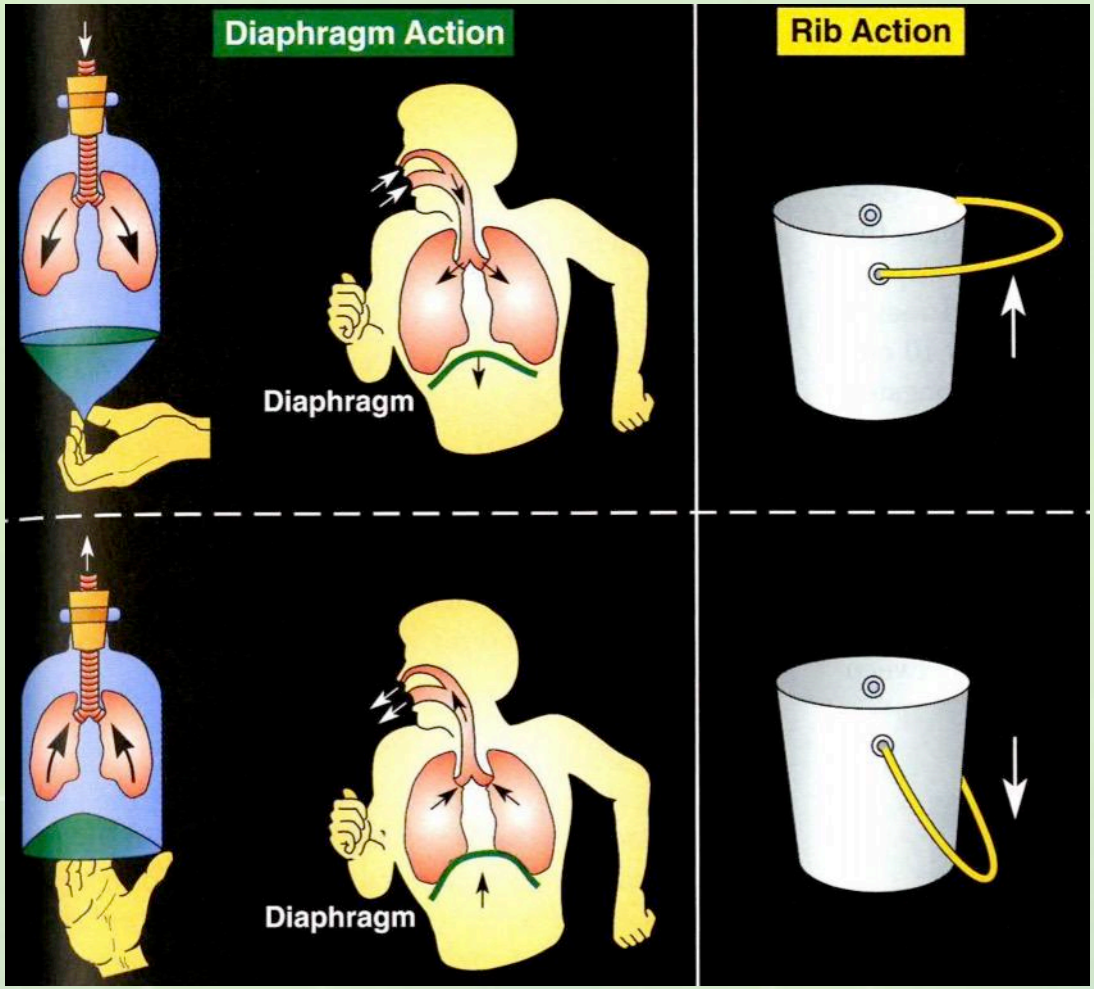


Units 1 & 2: Respiratory System

Mechanics of breathing

Inspiration

Expiration



Units 1 & 2: Respiratory System

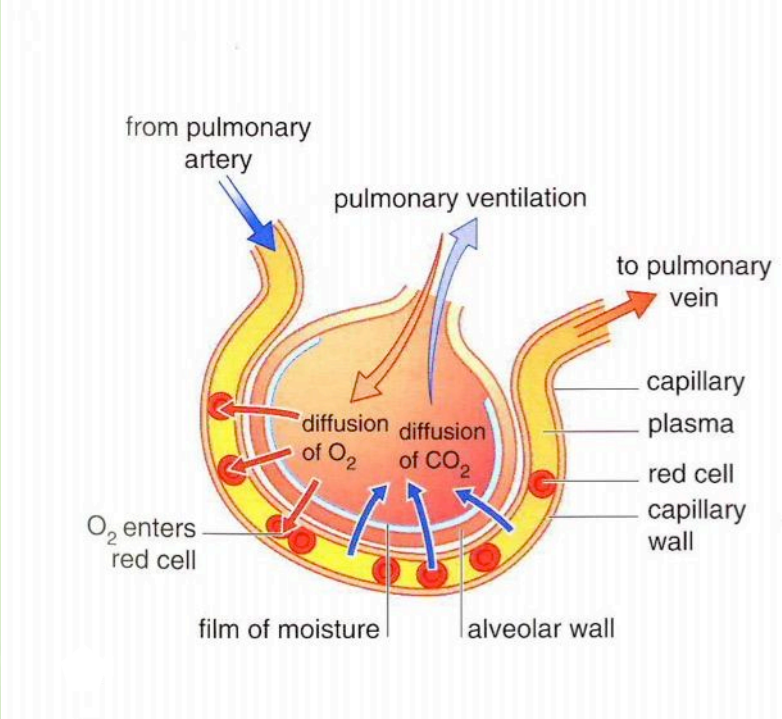
The amount of air we inspire (***minute ventilation***) is determined by the amount of air inspired with each breath (***tidal volume***) and the frequency of breaths each minute.

e.g. at rest:

- Tidal volume x breathing rate = minute ventilation
- 500 mL x 12 breaths per minute = 6 L per minute

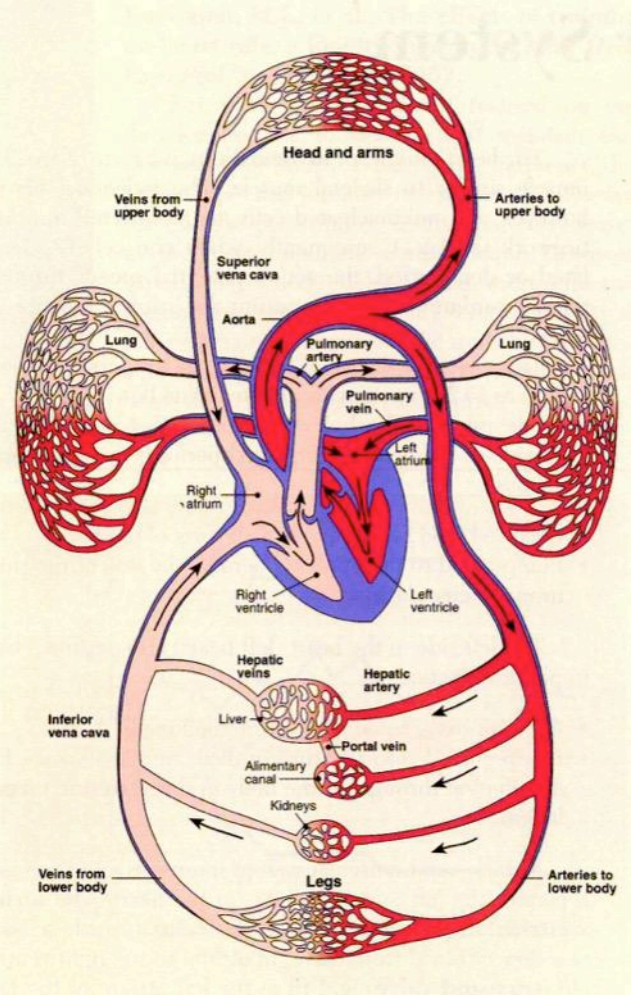
Units 1 & 2: Respiratory System

At the alveoli, passive diffusion occurs where oxygen moves from the alveoli (high concentration) into the bloodstream (low concentration), while carbon dioxide moves from the blood (high concentration) into the alveoli (low concentration) to be expelled from the body upon expiration.



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Units 1 & 2: Cardiovascular System

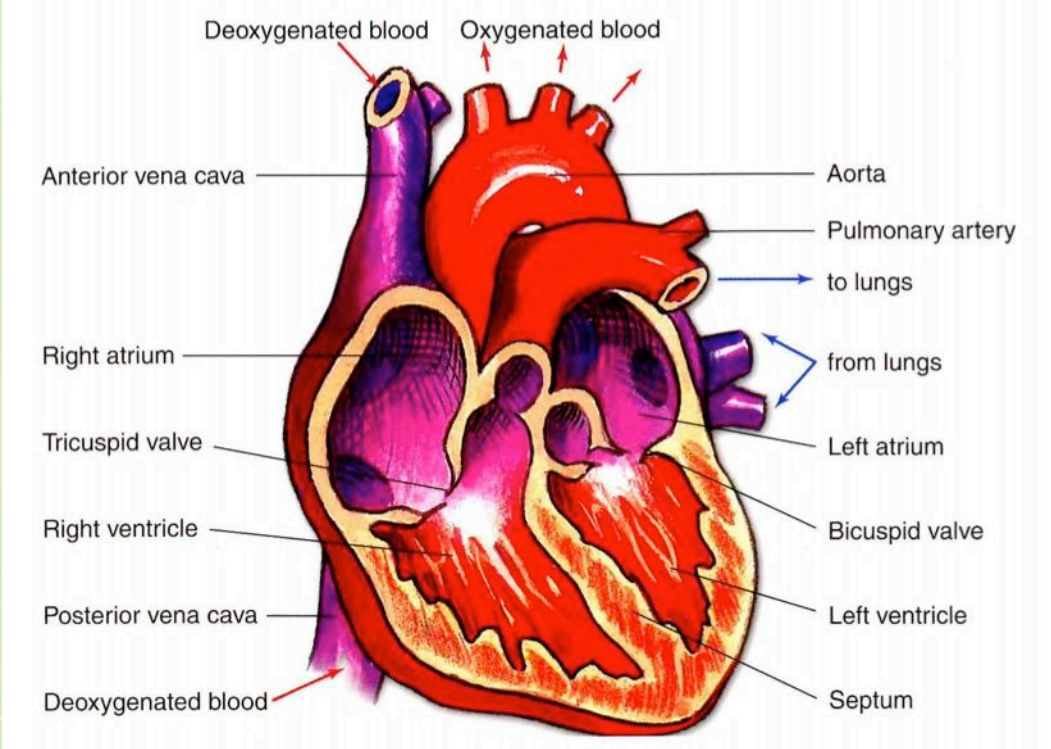


The cardiovascular system transports oxygen to the level of the working muscle

Units 1 & 2: Cardiovascular System

Pulmonary circulation - circulation of blood between the heart and lungs

Systemic circulation - circulation of blood between the heart and body tissues



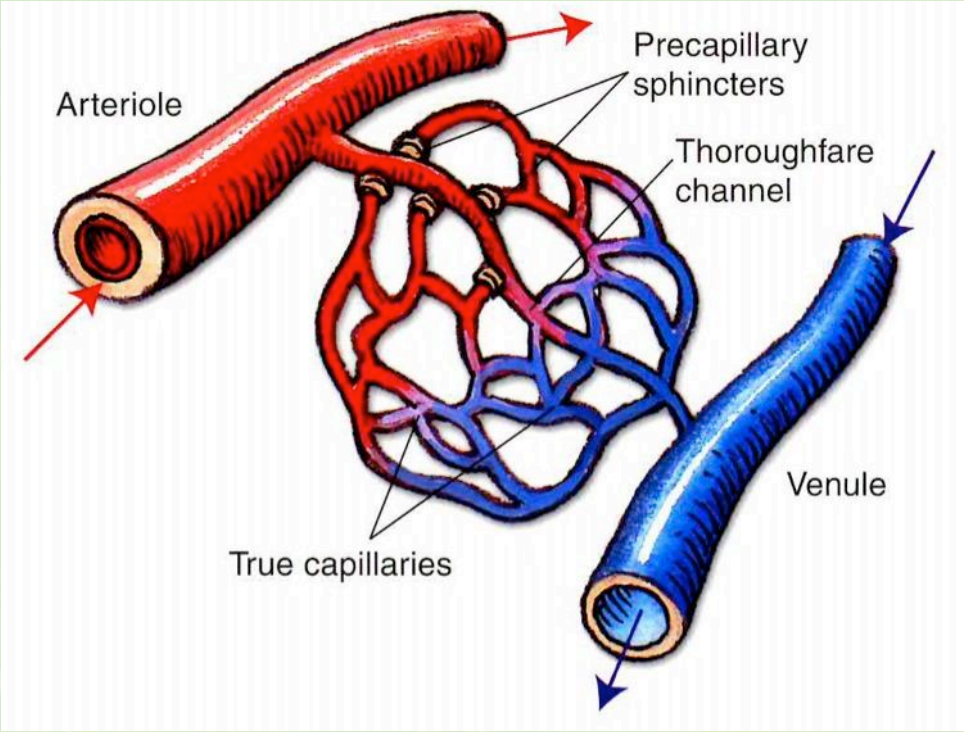
The heart

Units 1 & 2: Cardiovascular System

Arteries transport blood away from the heart

Capillaries are the site of gas exchange with the body tissues

Veins transport blood back to the heart



Units 1 & 2: Cardiovascular System

The amount of blood pumped around the body each minute (***cardiac output***) is determined by the volume of blood pumped with each beat of the heart (***stroke volume***) and the number of beats per minute (***heart rate***)

e.g. at rest:

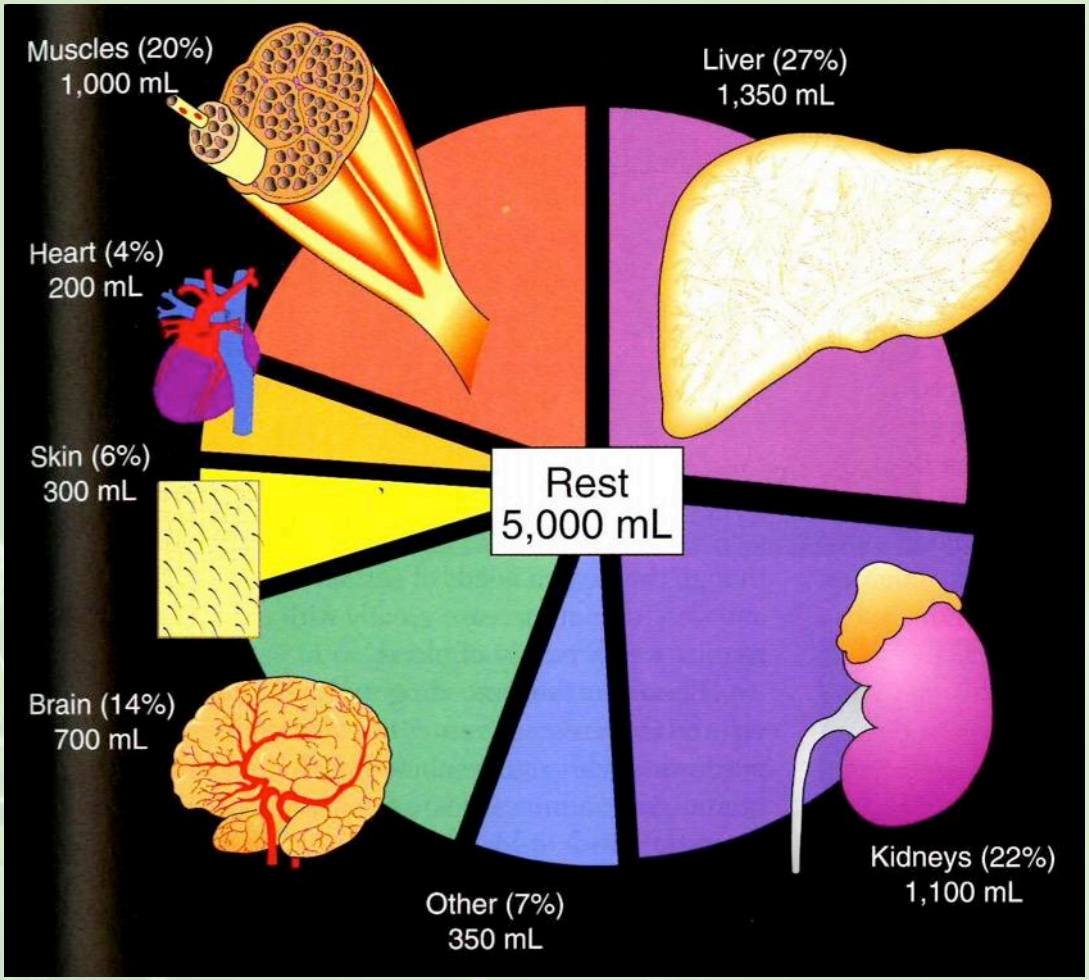
- Heart rate x stroke volume = cardiac output
- 77 bpm x 70 mL per beat = 5.4 L per minute

Units 1 & 2: Cardiovascular System

Systolic blood pressure represents the highest pressure in the arteries resulting from the contraction of the heart, while ***diastolic blood pressure*** occurs when the heart relaxes

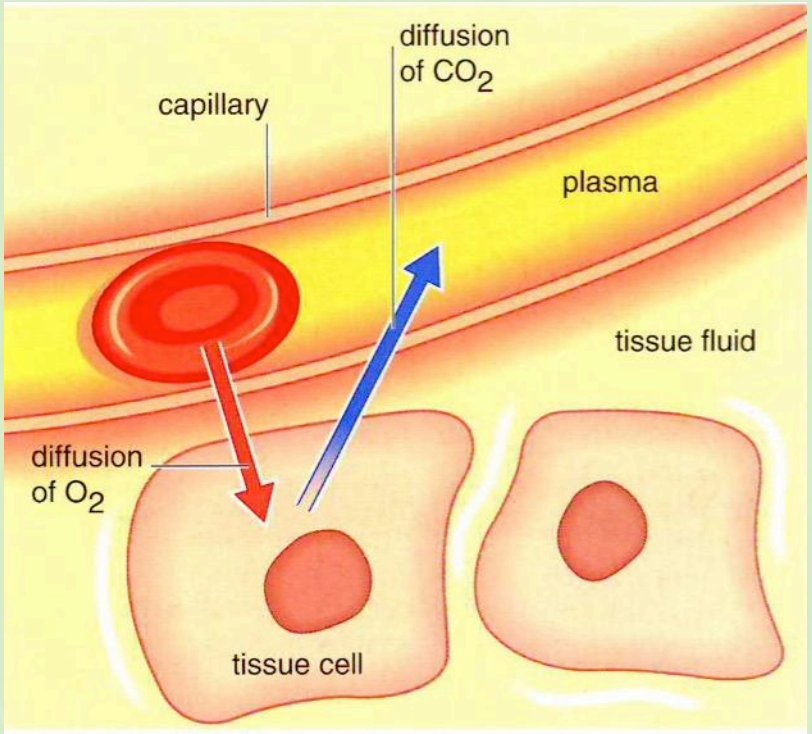


Units 1 & 2: Blood Flow Distribution at Rest



Units 1 & 2: Cardiovascular System

- The majority of oxygen is transported in the blood in combination with haemoglobin in red blood cells.
- The majority of carbon dioxide is transported in the blood as bicarbonate after combining with water.
- Oxygen and carbon dioxide are exchanged at the site of the tissues.



Units 1 & 2: Oxygen Consumption

- The volume of oxygen consumption (VO2) represents the volume of oxygen actually used by the body.
- This is the product of the amount of blood being transported around the body (cardiac output) and the amount of oxygen extracted from this blood (***the a-vO2 difference***).

Units 1 & 2: Crossover Dribble in Hockey

Pivot joint – radius & ulna

Right arm supinated



Right arm pronated



Units 1 & 2: Crossover Dribble in Hockey

Pivot joint – radius & ulna

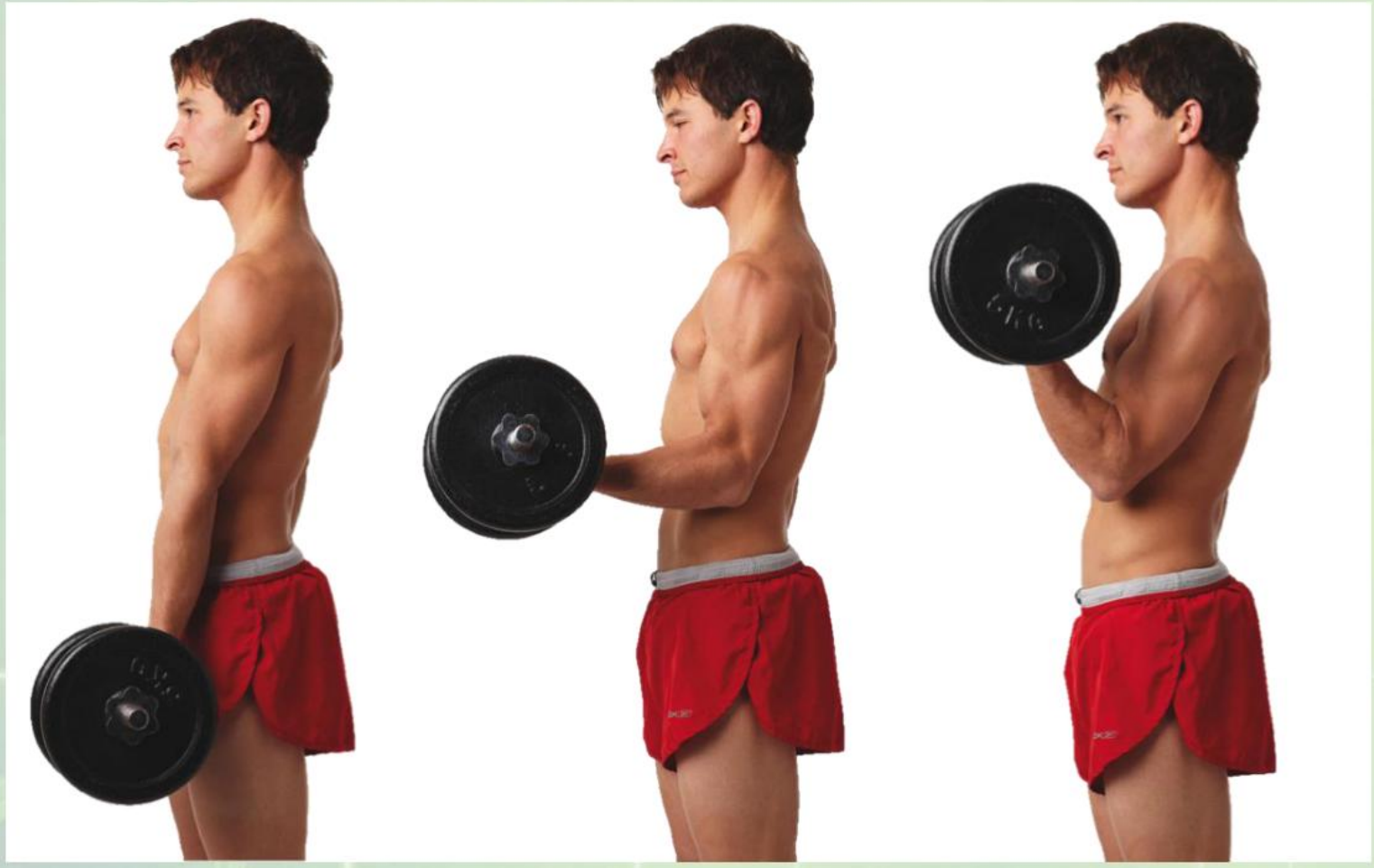
Bones:	radius & ulna
Joint type:	pivot joint
Muscles:	pronators & supinators
Action:	pronation & supination

Pronation:	occurs when the radius & ulna cross over (palm down)
Supination:	occurs when the radius & ulna are parallel (palm up)
Origin:	muscle attachment site (tendon) at the static end
Insertion:	muscle attachment site (tendon) closest to the end that moves

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Units 1 & 2: Bicep Curl

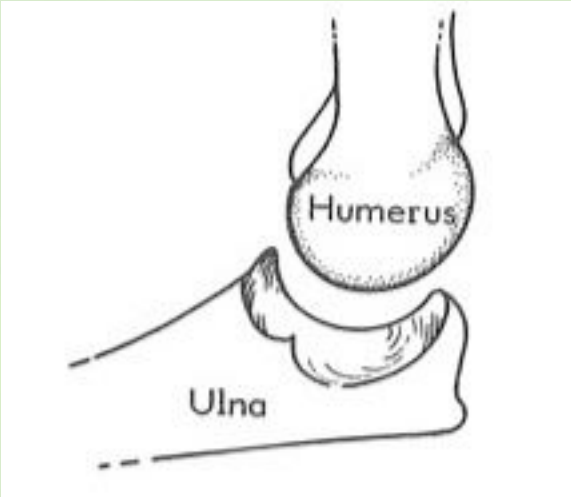
Hinge joint – elbow



Units 1 & 2: Bicep Curl

Hinge joint – elbow

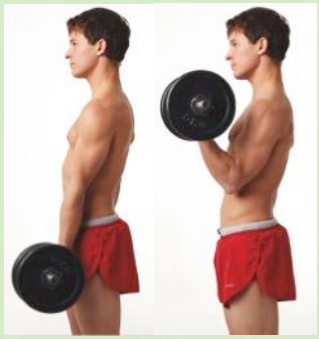
Bones:	Humerus, radius, & ulna
Joint type:	Hinge joint
Muscles:	Biceps (agonist) & triceps (antagonist)
Action:	Flexion & extension
Flexion:	Joint angle is decreased & limbs move closer together
Extension:	Joint angle is increased & limbs move further apart



Units 1 & 2: Muscle Contractions

Concentric muscle contraction:

- Muscle shortens when tension is developing



Eccentric muscle contraction:

- Muscle lengthens when tension is developed



Isometric contraction:

- no change in length when tension is developed





Units 1 & 2: Muscle Contractions

Exam style question

Muscles create movement by:

A) Both pushing & pulling on bones

B) Pulling on bones

C) Contracting the ligament attached to a bone

D) Contracting pairs of muscles

(1 mark)

Units 1 & 2: Muscle Contractions

Answer

Muscles create movement by:

A) Both pushing & pulling on bones

B) Pulling on bones

C) Contracting the ligament attached to a bone

D) Contracting pairs of muscles

(1 mark)

Answer = B

Muscles can only pull on bones. Ligaments do not contract, and they attach bone to bone. As one muscle contracts the reciprocal muscle relaxes.

Units 1 & 2: Muscle Contractions

Exam style question

When your gastrocnemius contracts concentrically, what are you likely to be doing?

(1 Mark)

Units 1 & 2: Muscle Contractions

Answer

When your gastrocnemius contracts concentrically, what are you likely to be doing? (1 mark)

Pointing your toe (1 mark)

OR

moving from a normal flat-foot standing position to standing on your toes (1 mark)

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Units 1 & 2: Swinging a Softball Bat

Gliding joints – vertebrae



Units 1 & 2: Swinging a Softball Bat

Gliding joints – vertebrae

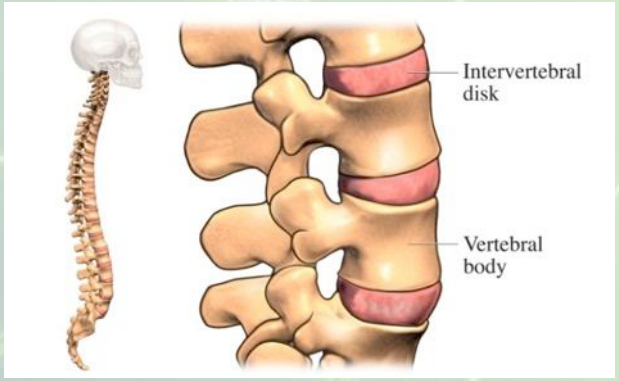
Bones: Vertebrae

Joint type: Gliding joint

Muscles: Abdominal muscles create trunk rotation

- Left- side abdominals (agonist)
- Right-side abdominals (antagonist)

Action: Rotation





Units 1 & 2: Kicking a Football

Gliding joint & hinge joint – knee



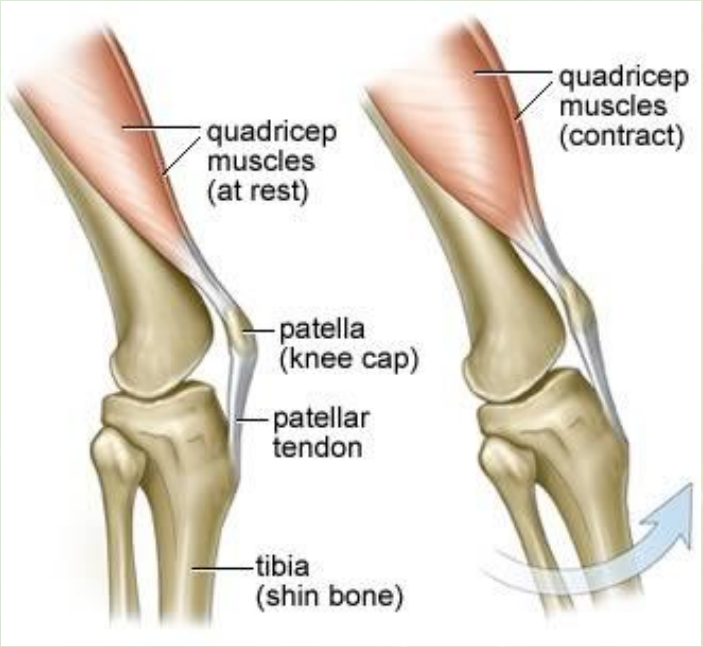
Units 1 & 2: Kicking a Football

Gliding joint & hinge joint – knee

Bones:	Femur, patella, tibia & fibula
Joint type:	Hinge & gliding joint
Muscles:	Quadriceps (agonist) & hamstrings (antagonist)
Action:	Extension

The patella gives the knee joint a mechanical advantage.

Because the hamstrings are contracting eccentrically at the end of the kicking phase they are subjected to large or fast forces that can lead to injury.



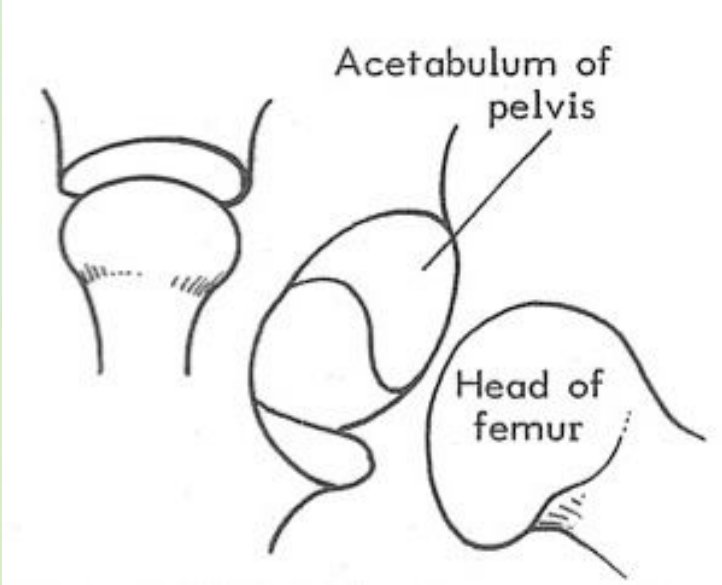
Units 1 & 2: The Splits

Ball & socket joint – hip



Units 1 & 2: The Splits

Ball & socket joint – hip



Bones: Pelvis & femur

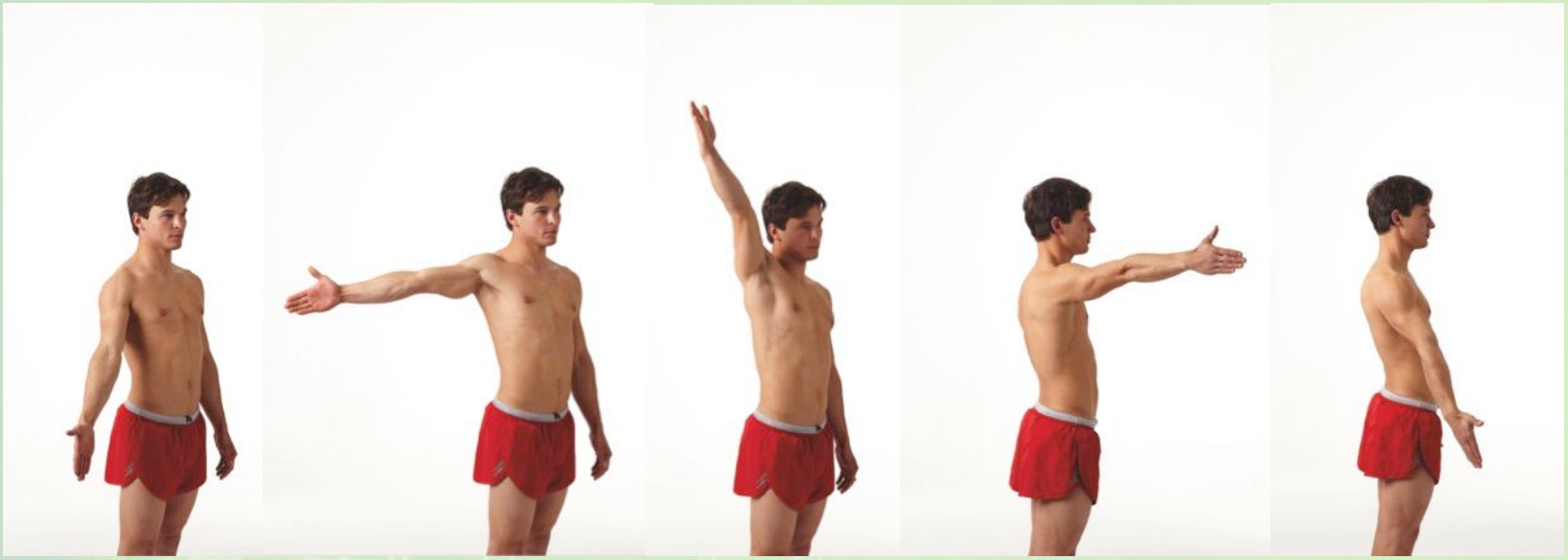
Joint type: Ball & socket joint

Muscles: Hip adductors (antagonist) & abductors (agonist)

Action: Abduction

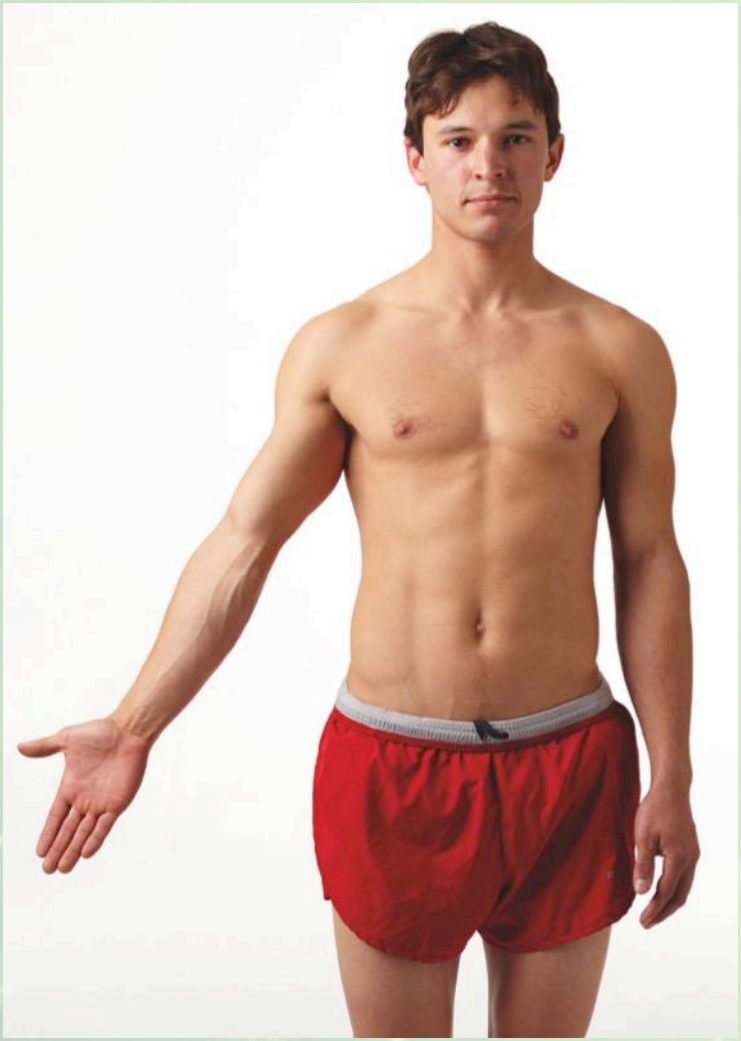
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Units 1 & 2: Circumduction



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Units 1 & 2: Rotation





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Units 1 & 2: Softball Pitch

Ball & socket joint – shoulder



Units 1 & 2: Softball Pitch

Ball & socket joint – shoulder

Bones: Humerus, scapula & clavicle

Joint type: Ball & socket joint

Muscles & Actions

At the initiation of the delivery stride:

Shoulder muscles - pectoralis major & deltoid (agonist)

& latissimus dorsi (antagonist)

Action: shoulder flexion



As the arm begins to move upward and outward:

Shoulder and back muscles - latissimus dorsi (agonist)

& pectoralis major (antagonist)

Action: shoulder extension



At the ball delivery towards the batter:

Contraction of the shoulder muscles - pectoralis major & deltoid (agonist)

& latissimus dorsi (antagonist)

Action: shoulder flexion



Units 1 & 2: Actions

Exam style question

You raise your arm to toss the ball in the air in preparation for a tennis serve.

What is the action created at the shoulder?

(1 mark)

Units 1 & 2: Actions

Answer

You raise your arm to toss the ball in the air in preparation for a tennis serve.

What is the action created at the shoulder? (1 mark)

Flexion



Units 1 & 2: Gripping a Hockey Stick

Saddle joint – thumb



Units 1 & 2: Gripping a Hockey Stick

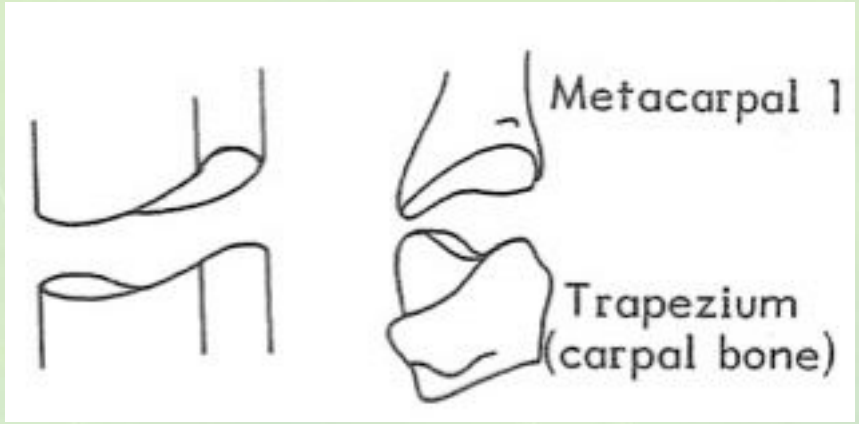
Saddle joint – thumb

Bones: Thumb, carpals & metacarpal.

Joint type: Saddle joint.

Action: Flexion, extension, abduction, adduction & circumduction.





Units 1 & 2: Dribbling with a Hockey Stick

Saddle joint – thumb

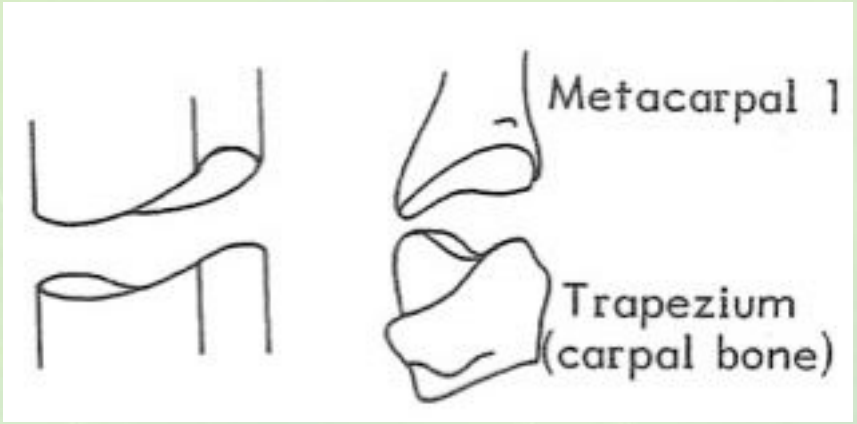
Bones: Thumb, carpals & metacarpal.

Joint type: Saddle joint.

Muscles: Wrist flexors & extensors.

Action: Flexion & extension.





Units 1 & 2: Breaststroke Kick



Putting it all together

- Ball & socket joint – hip
- Hinge joint – knee & ankle
- Gliding joint – tarsals & metatarsals
- 5 phases

Units 1 & 2: Breaststroke Kick

Phase 1

Bones: Tibia, fibula & tarsals

Joint type: Hinge

Muscles: Gastrocnemius

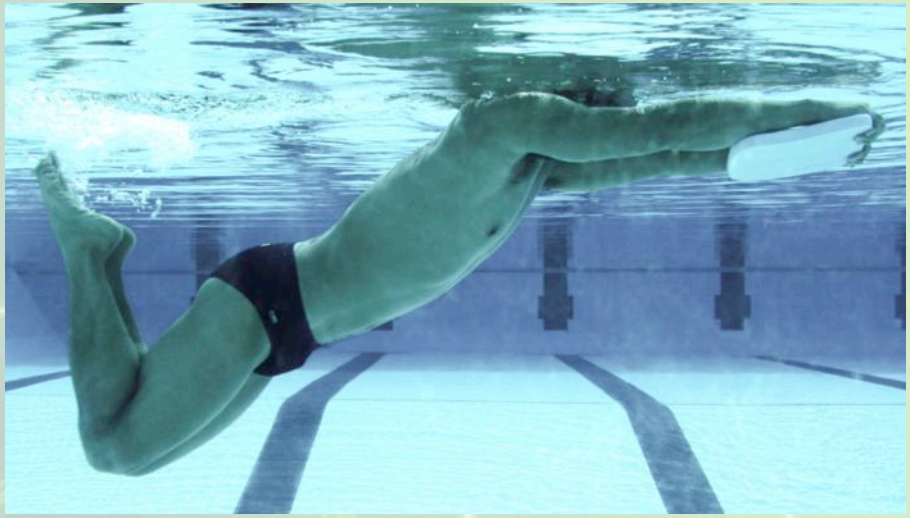
Action: Plantar flexion



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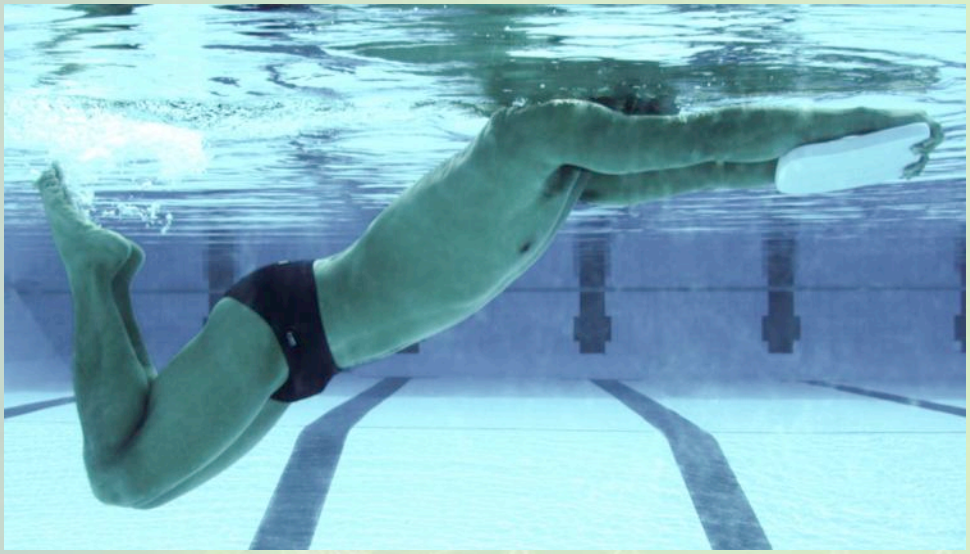
Units 1 & 2: Breaststroke Kick

Phase 2





Units 1 & 2: Breaststroke Kick



Phase 2

Bones: Femur & tibia

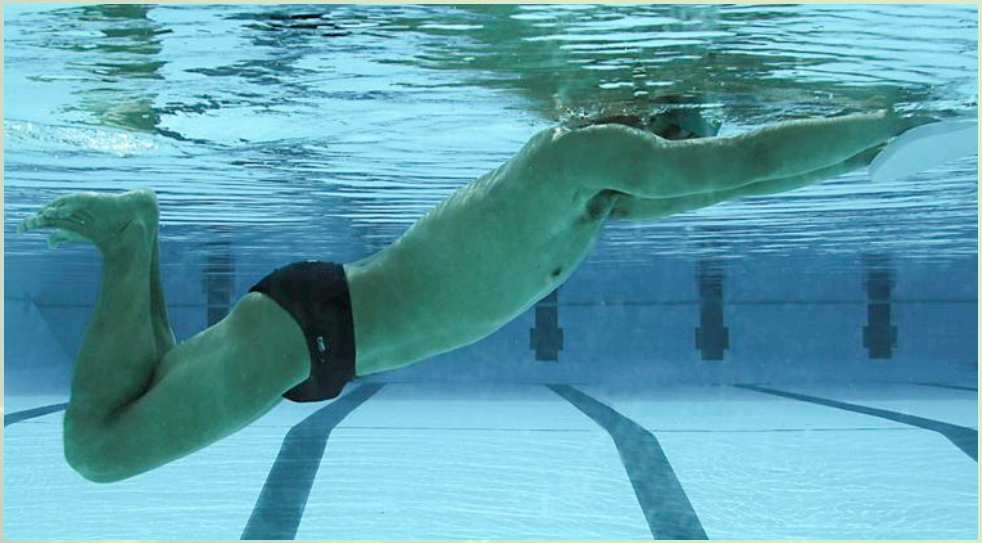
Joint type: Hinge

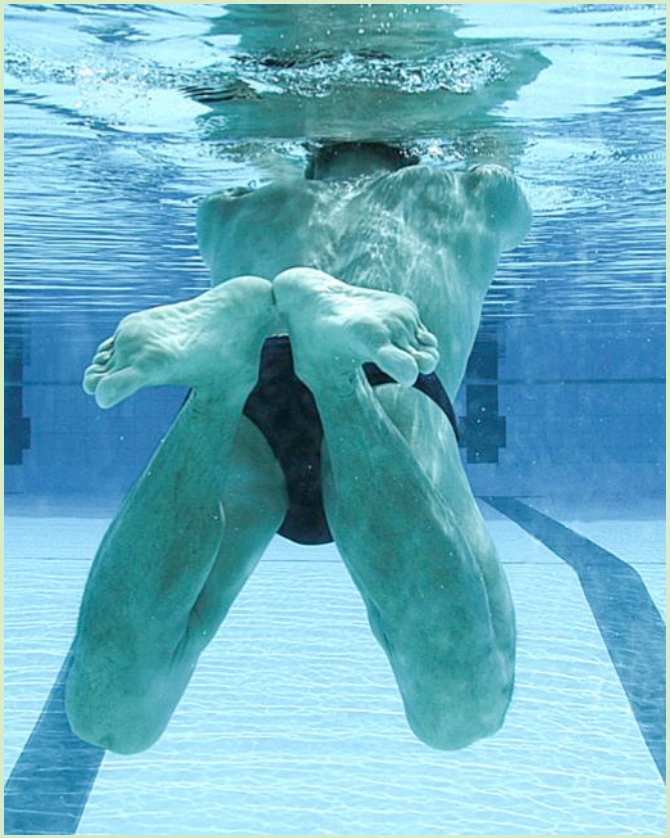
Muscles: Hamstrings

Action Flexion at the knee

Units 1 & 2: Breaststroke Kick

Phase 3





Units 1 & 2: Breaststroke Kick

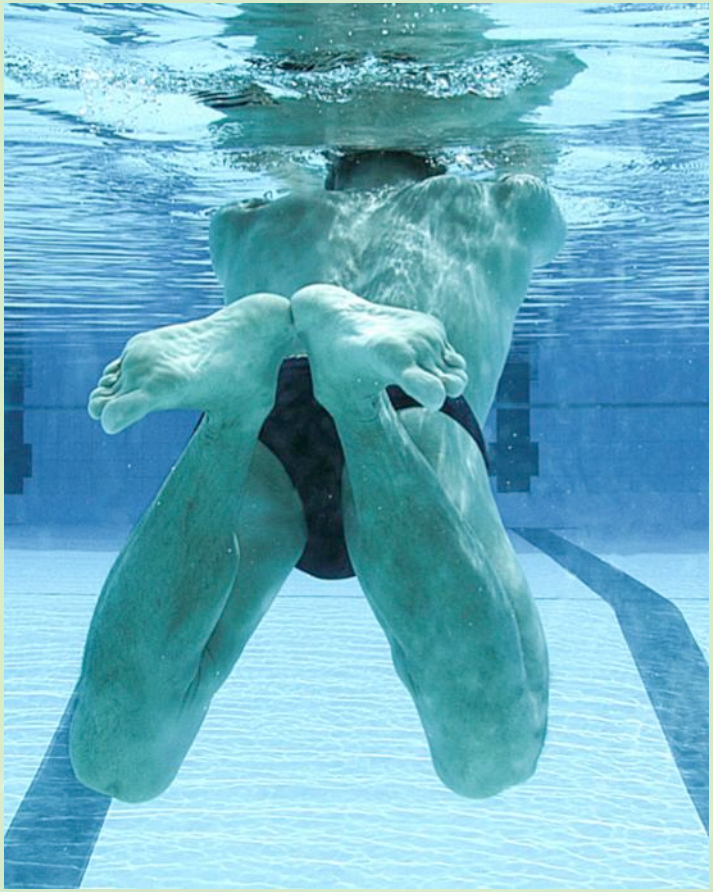
Phase 3

Bones: Tibia, fibula & tarsals

Joint type: Gliding & hinge joints

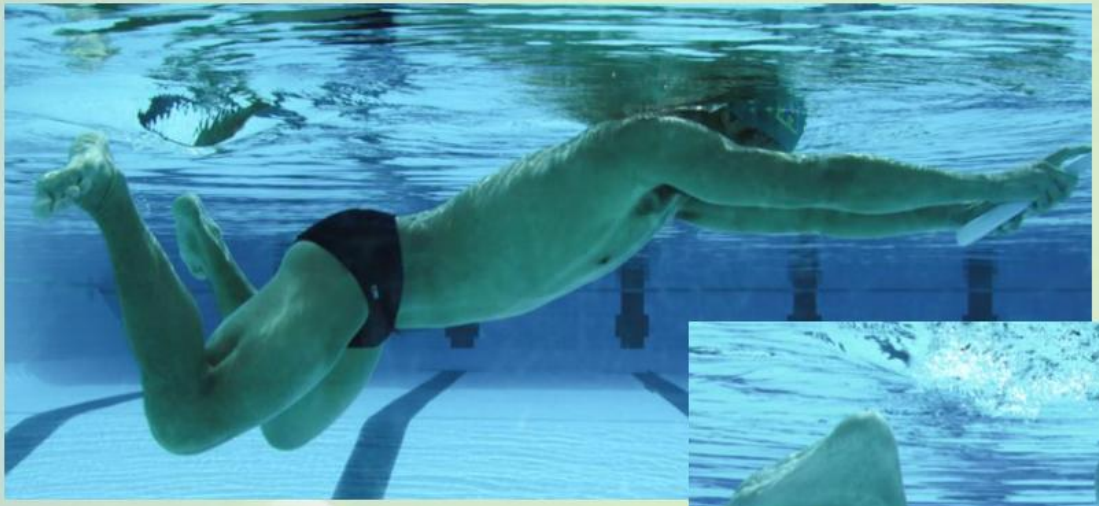
Muscles: Tibialis anterior

Action: Dorsi flexion & eversion



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Units 1 & 2: Breaststroke Kick





Phase 4

Units 1 & 2: Breaststroke Kick

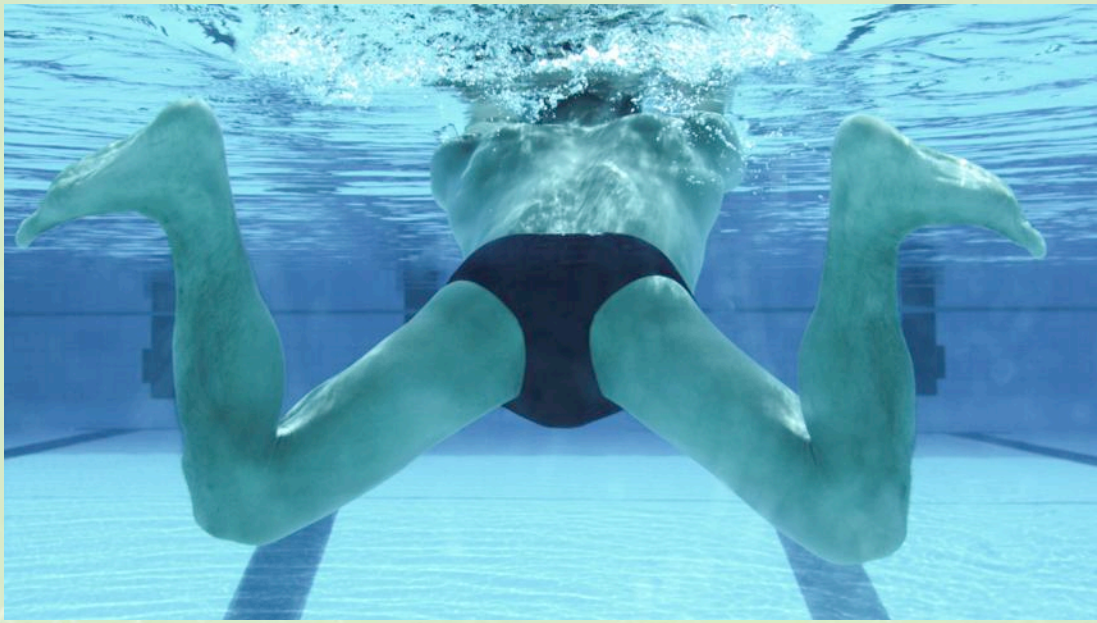
Phase 4

Bones: Pelvis & femur

Joint type: Ball & socket

Muscles: Adductors

Action: Adduction



Bones: Femur & tibia

Joint type: Hinge joint

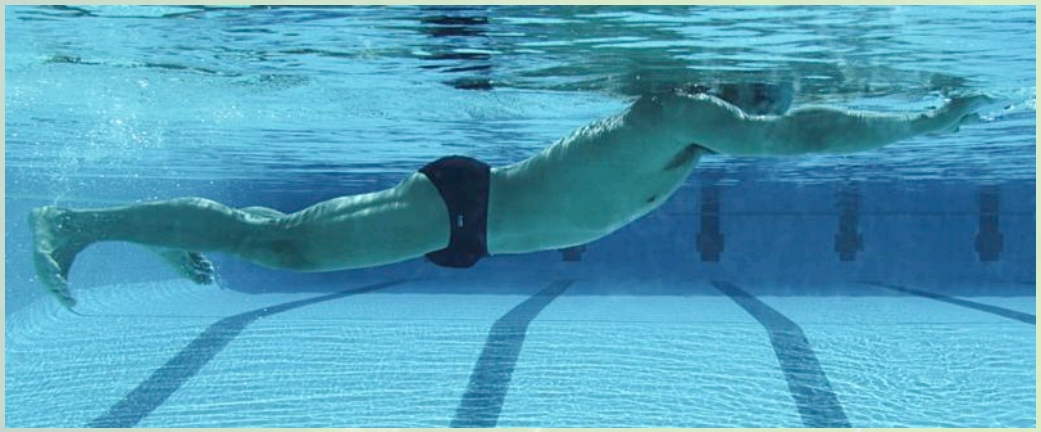
Muscles: Quadriceps

Action: Extension

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Units 1 & 2: Breaststroke Kick

Phase 5



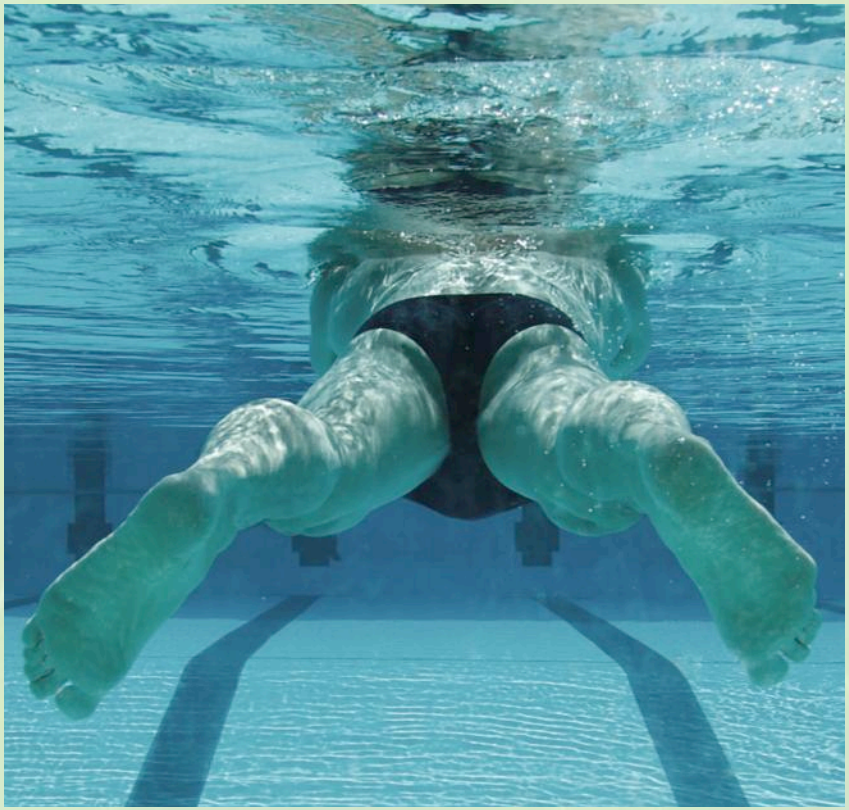


Units 1 & 2: Breaststroke Kick

Phase 5

Bones:	Pelvis & femur
Joint type:	Ball & socket
Muscles:	Adductors
Action:	Adduction

Bones:	Femur & tibia
Joint type:	Hinge joint
Muscles:	Quadriceps
Action:	Extension



Units 1 & 2: Actions

Exam style question

Adduction will result in the legs moving further apart or closer together?

(1 mark)

Units 1 & 2: Actions

Answer

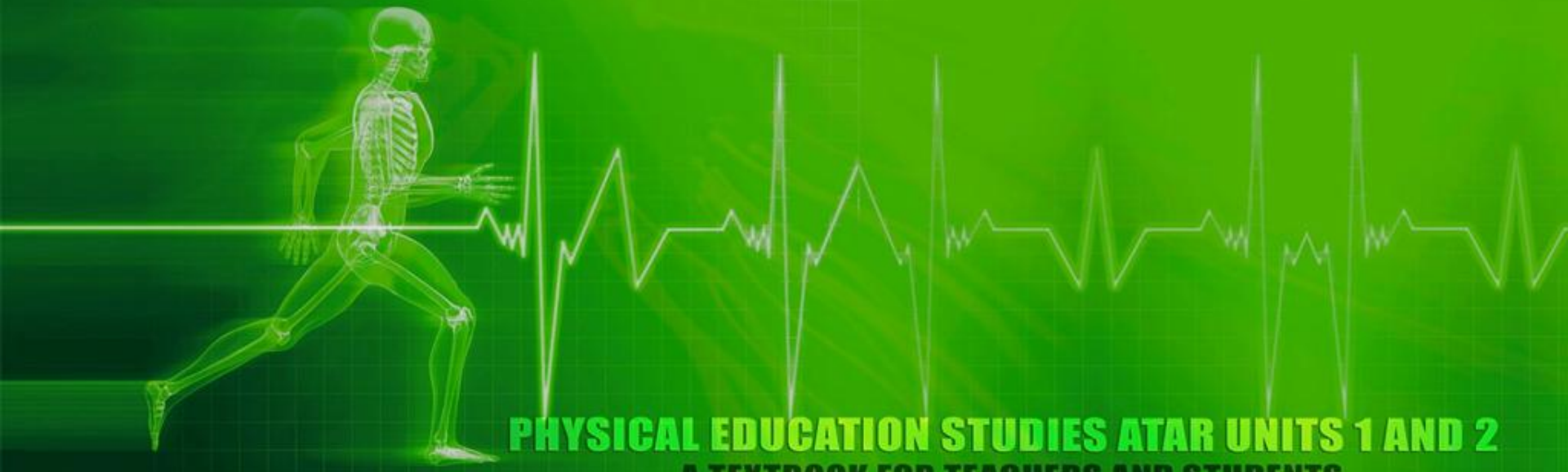
Adduction will result in the legs moving further apart or closer together? (1 mark)

Closer together

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EXERCISE PHYSIOLOGY

Dr Kym Guelfi
Dr Peter Whipp
Dr Peter Peeling

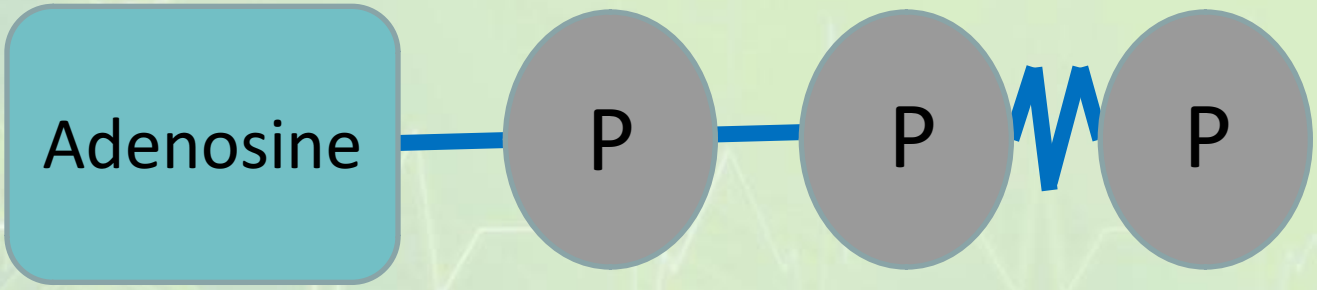


PHYSICAL EDUCATION STUDIES ATAR UNITS 1 AND 2
A TEXTBOOK FOR TEACHERS AND STUDENTS

Units 1 & 2: Energy for Physical Activity

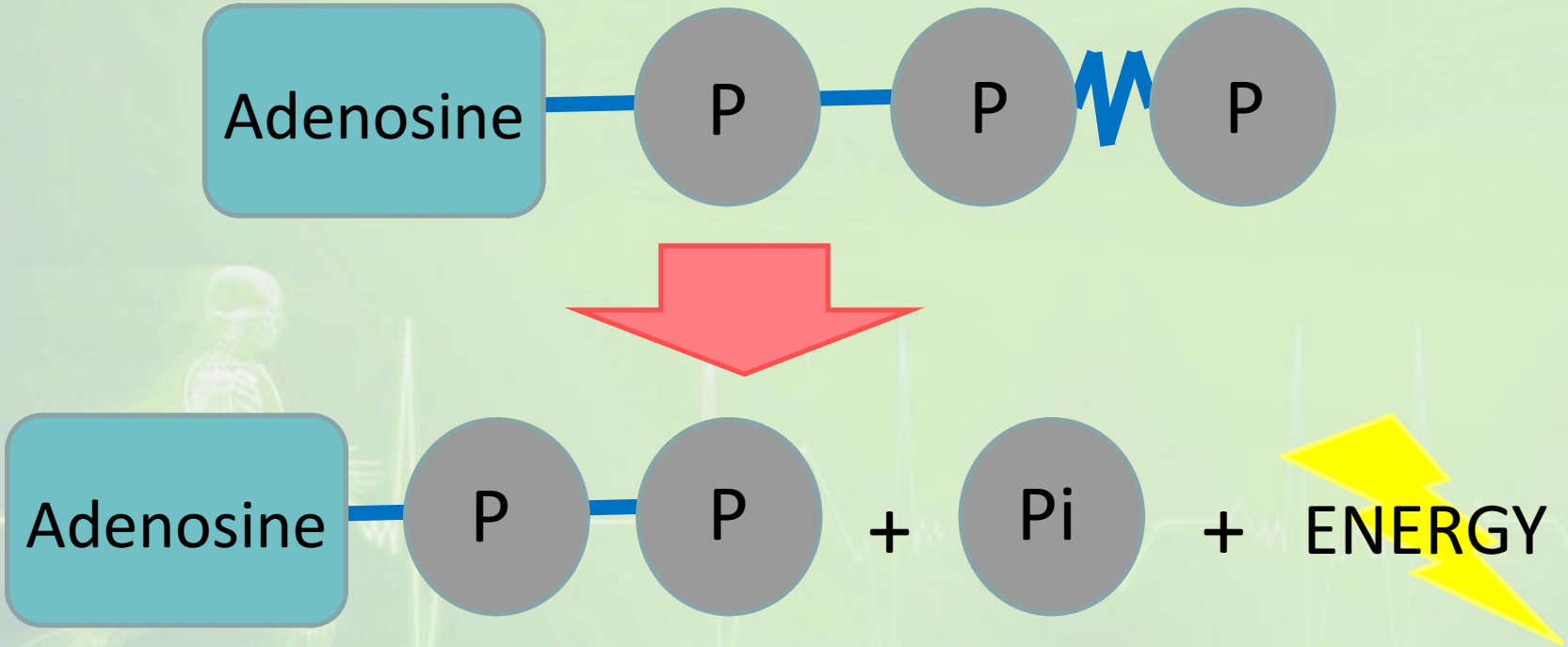
ATP is the basic unit of energy that fuels all of the activities that we participate in throughout the day

A molecule of ATP consists of one adenosine component attached to three phosphate groups



Units 1 & 2: Energy Release from ATP

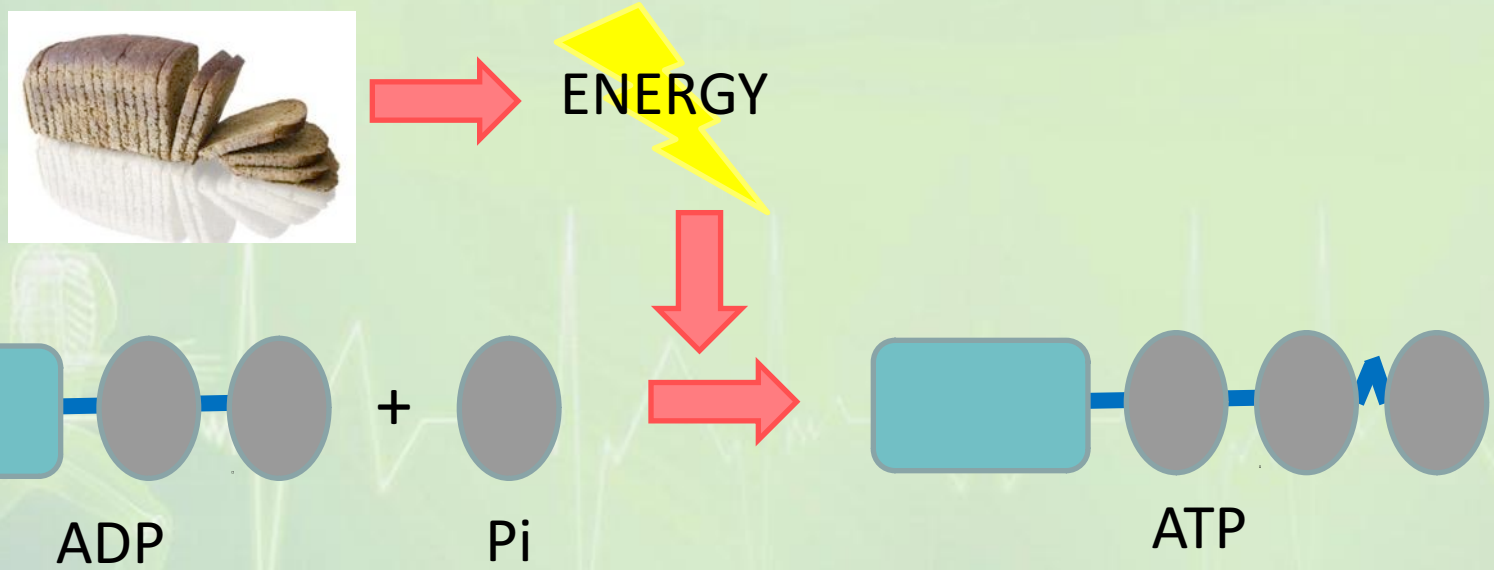
Energy is released from ATP when the high-energy bond linking the outermost phosphate group to the rest of the molecule is broken to liberate ADP and Pi



Units 1 & 2: ATP Replenishment

A limited amount of ATP is stored in the body

ATP must be continuously replenished so that our stores never run out. This is achieved by rejoining ADP and Pi using chemical energy derived from the food we eat.



Units 1 & 2: Energy Sources for Exercise

The food (& drink) we consume contains three macronutrients:

Carbohydrate



Fat

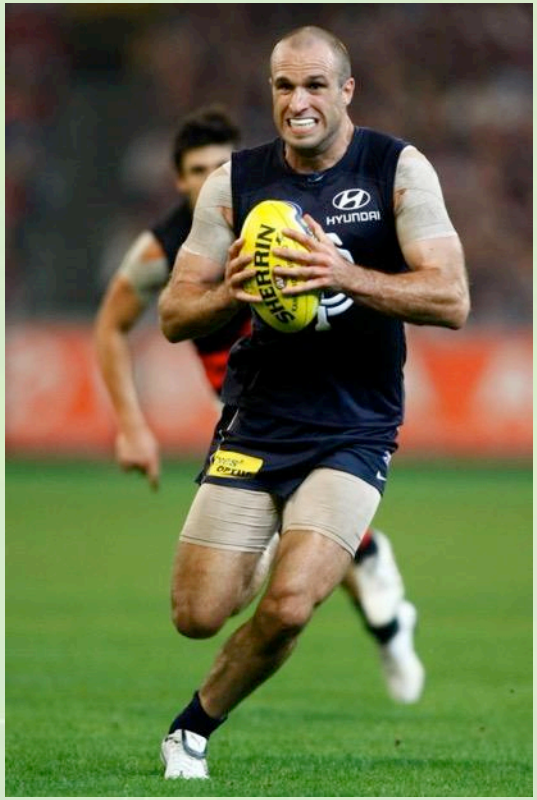


Protein



Units 1 & 2: Energy Requirements for Exercise

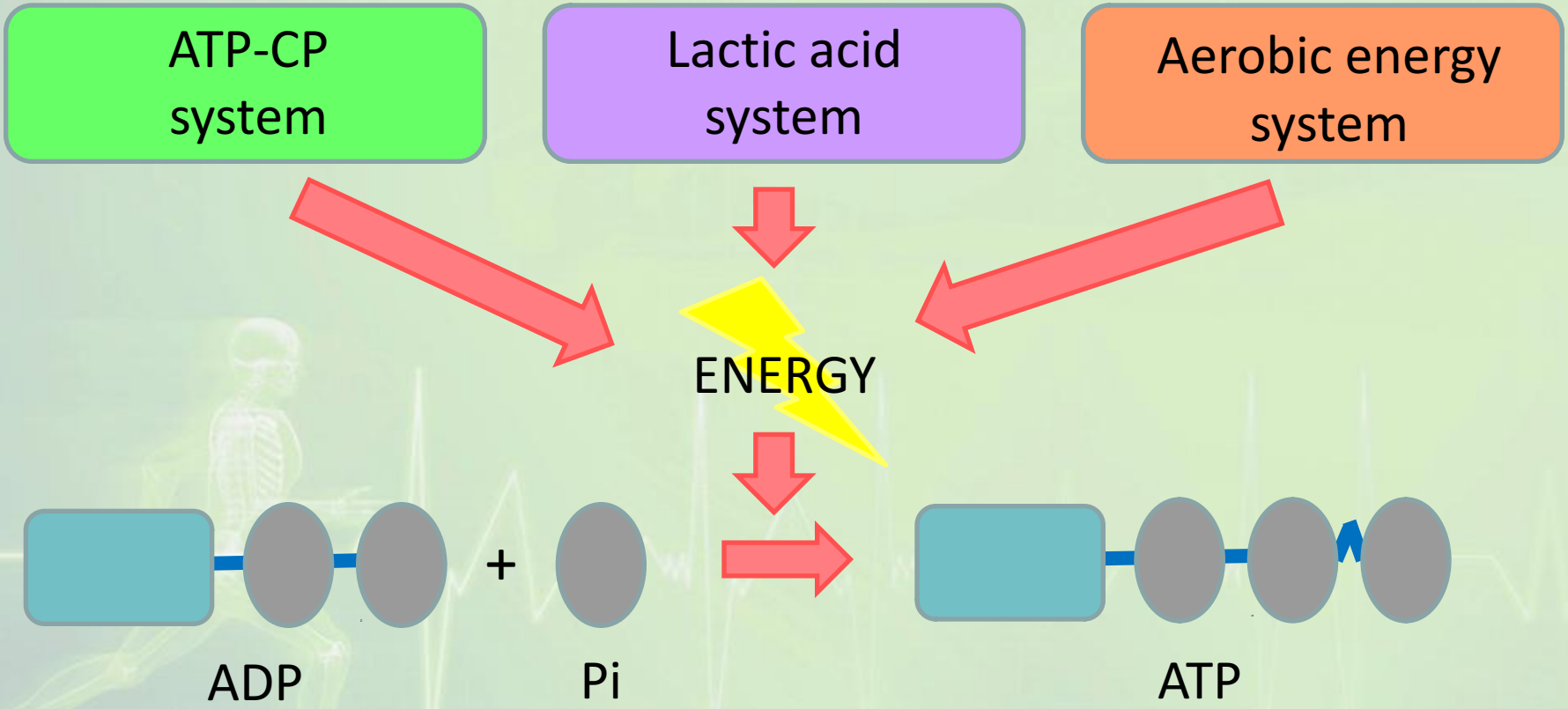
The amount of each macronutrient required in the diet varies, depending on the physical activity level of the individual and specific sport played





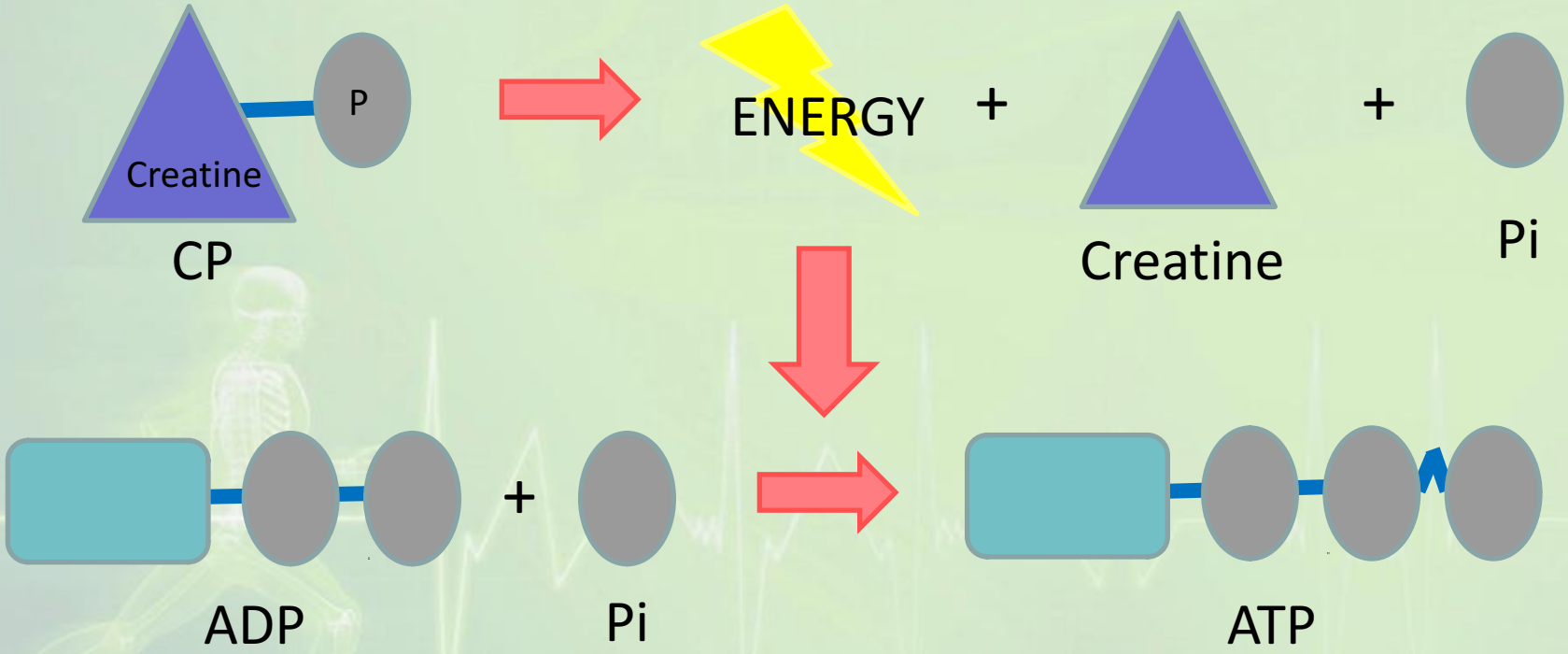
Units 1 & 2: Pathways of Energy Release from Food

There are three ways in which ATP can be replenished:



Units 1 & 2: ATP-CP System

The ATP-CP system replenishes ATP using energy from the breakdown of creatine phosphate (CP) to creatine and Pi



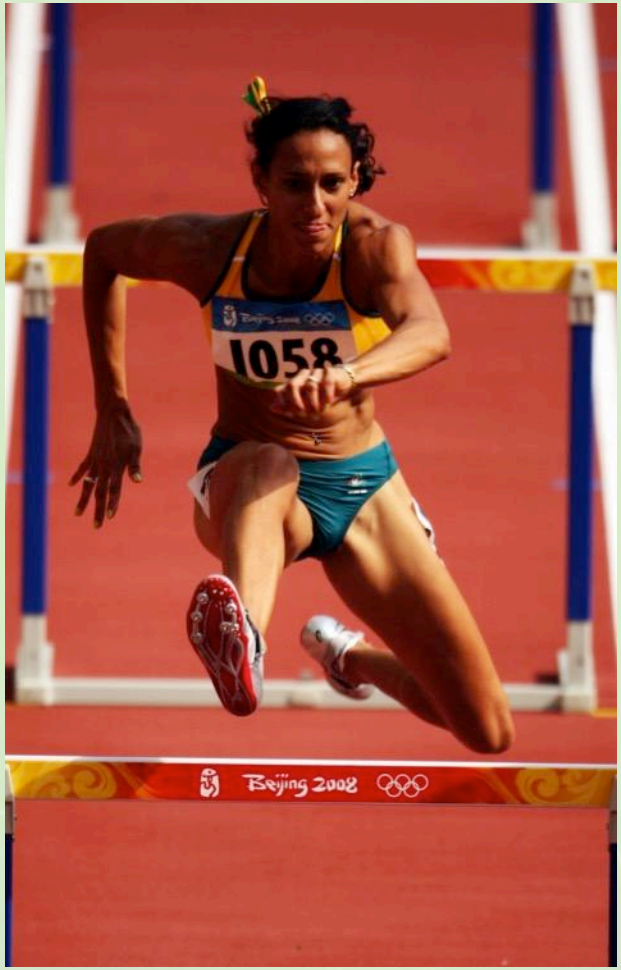
Units 1 & 2: ATP-CP System

- The ATP-CP system does not use oxygen (an anaerobic pathway)
- The ATP-CP system allows for the most immediate (quickest) replenishment of ATP
- We only store enough CP to power about eight seconds of intense activity

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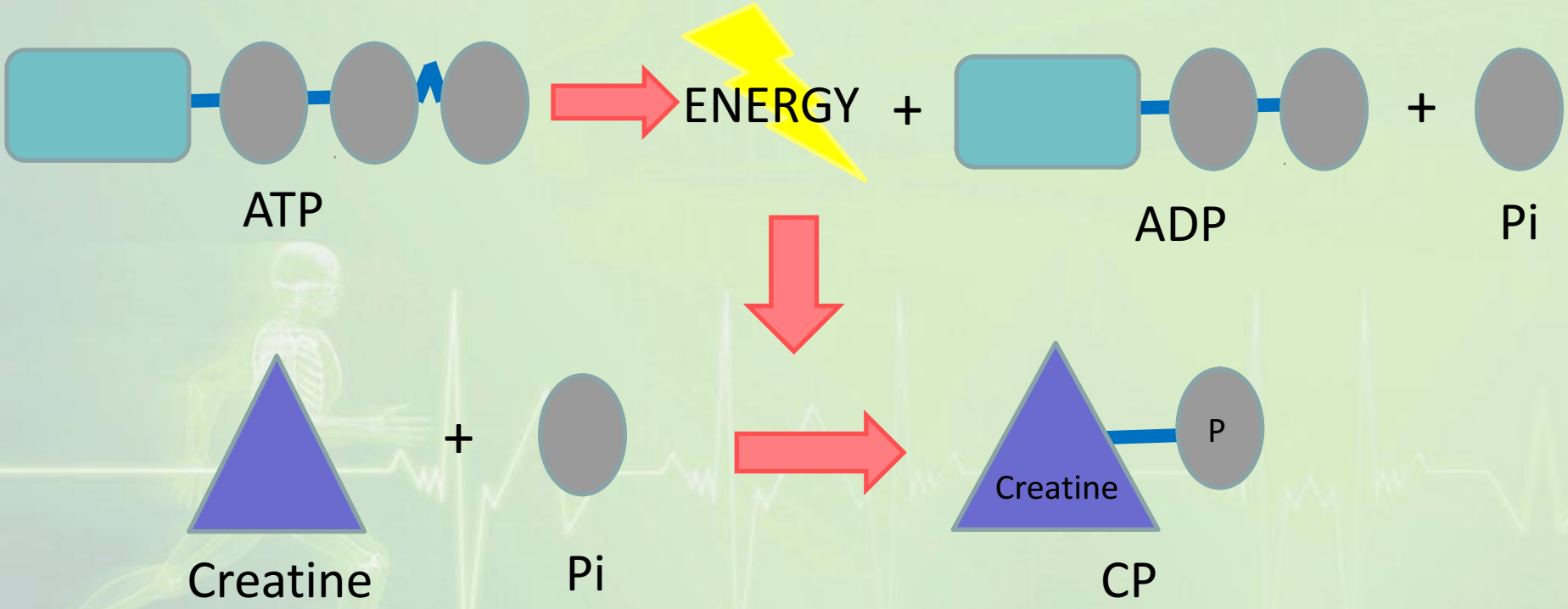
Units 1 & 2: ATP-CP System

The ATP-CP system is the dominant source of energy production during short sprint activities like the 100 m hurdles



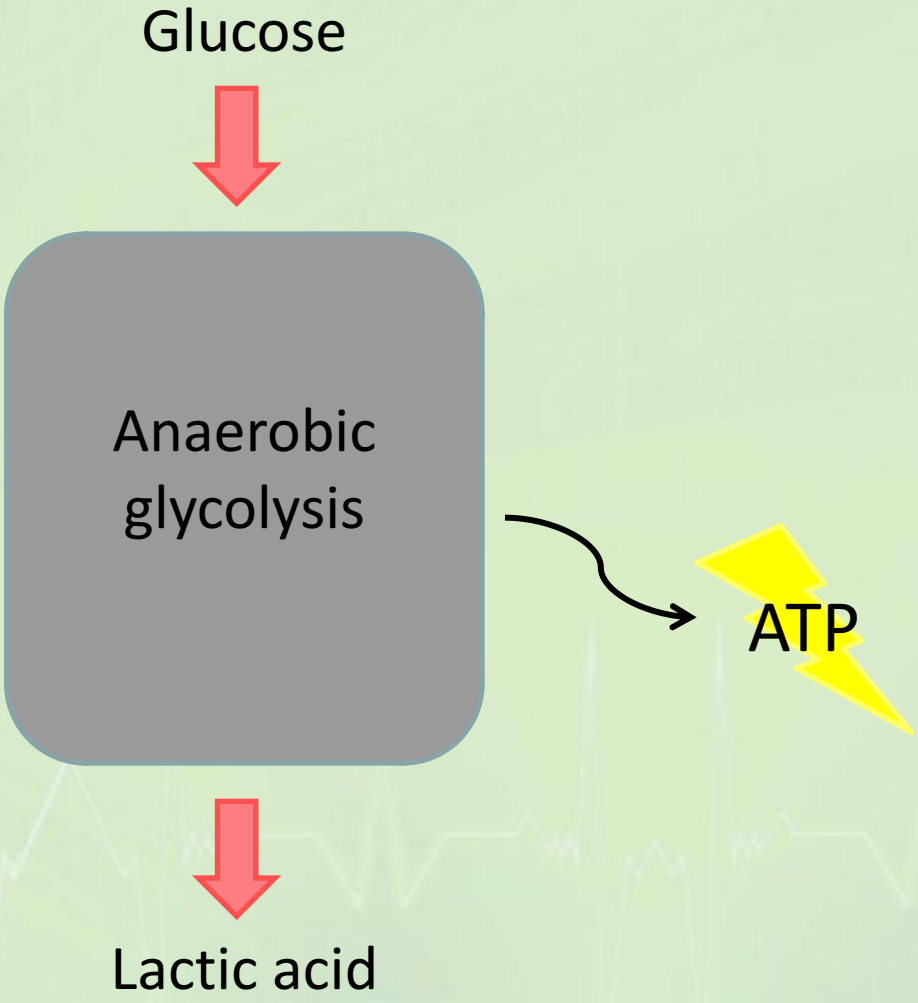
Units 1 & 2: ATP-CP System

CP stores are replenished during recovery from exercise using energy from ATP when adequate oxygen becomes available



Units 1 & 2: Lactic Acid System

The lactic acid system (anaerobic glycolysis) involves the partial breakdown of carbohydrate to lactic acid, which releases energy to make ATP



Units 1 & 2: Lactic Acid System

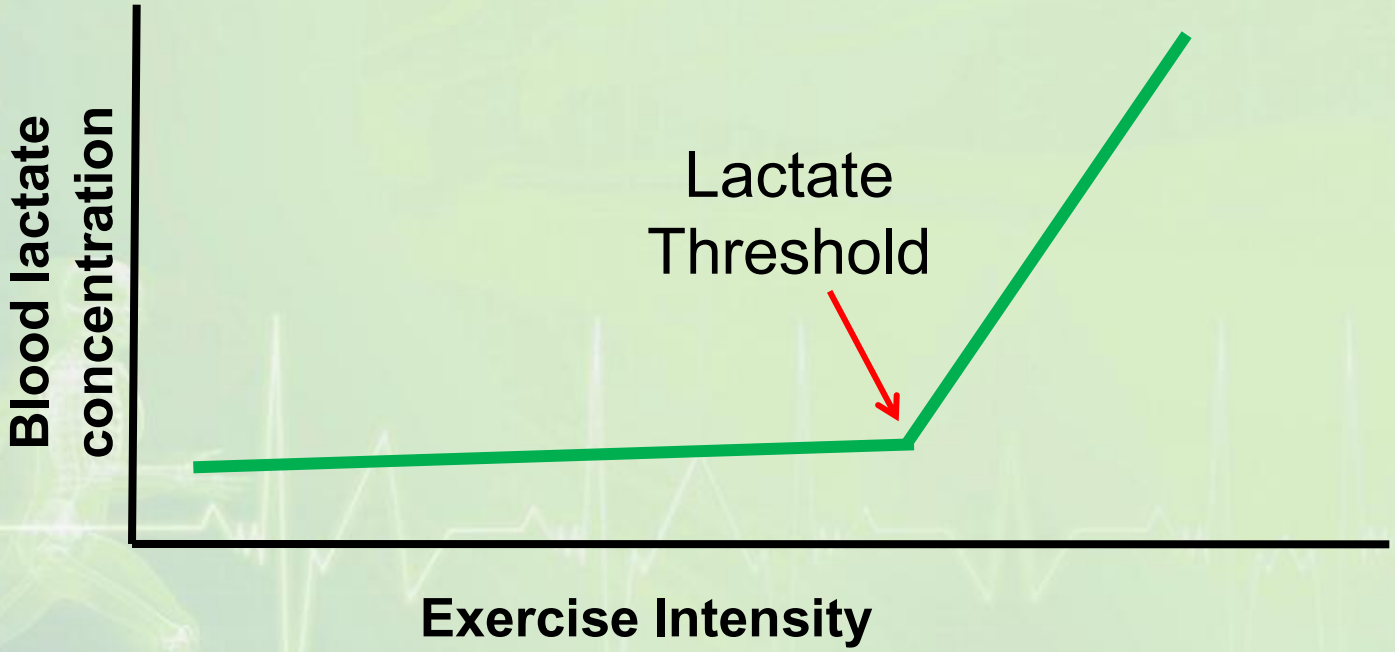


The lactic acid system does not require oxygen
(an anaerobic pathway)

The lactic acid system is the dominant source of ATP production during high-intensity activities lasting thirty to sixty seconds like the 400 m sprint

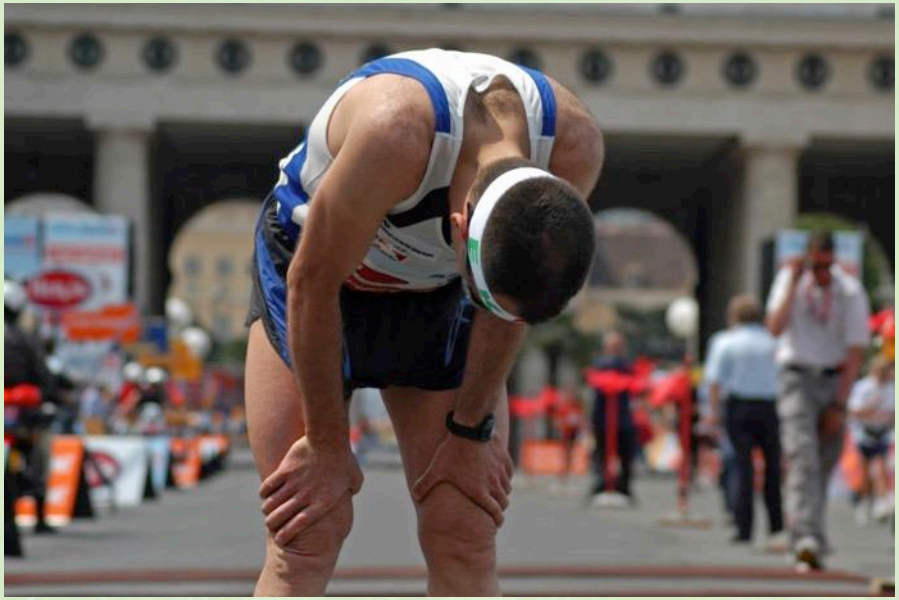
Units 1 & 2: Lactic Acid System

Lactic acid accumulates in the muscle when exercising at an intensity level higher than the lactate threshold, eventually resulting in fatigue



Units 1 & 2: Lactic Acid System

Lactic acid is removed during recovery from exercise as adequate oxygen becomes available

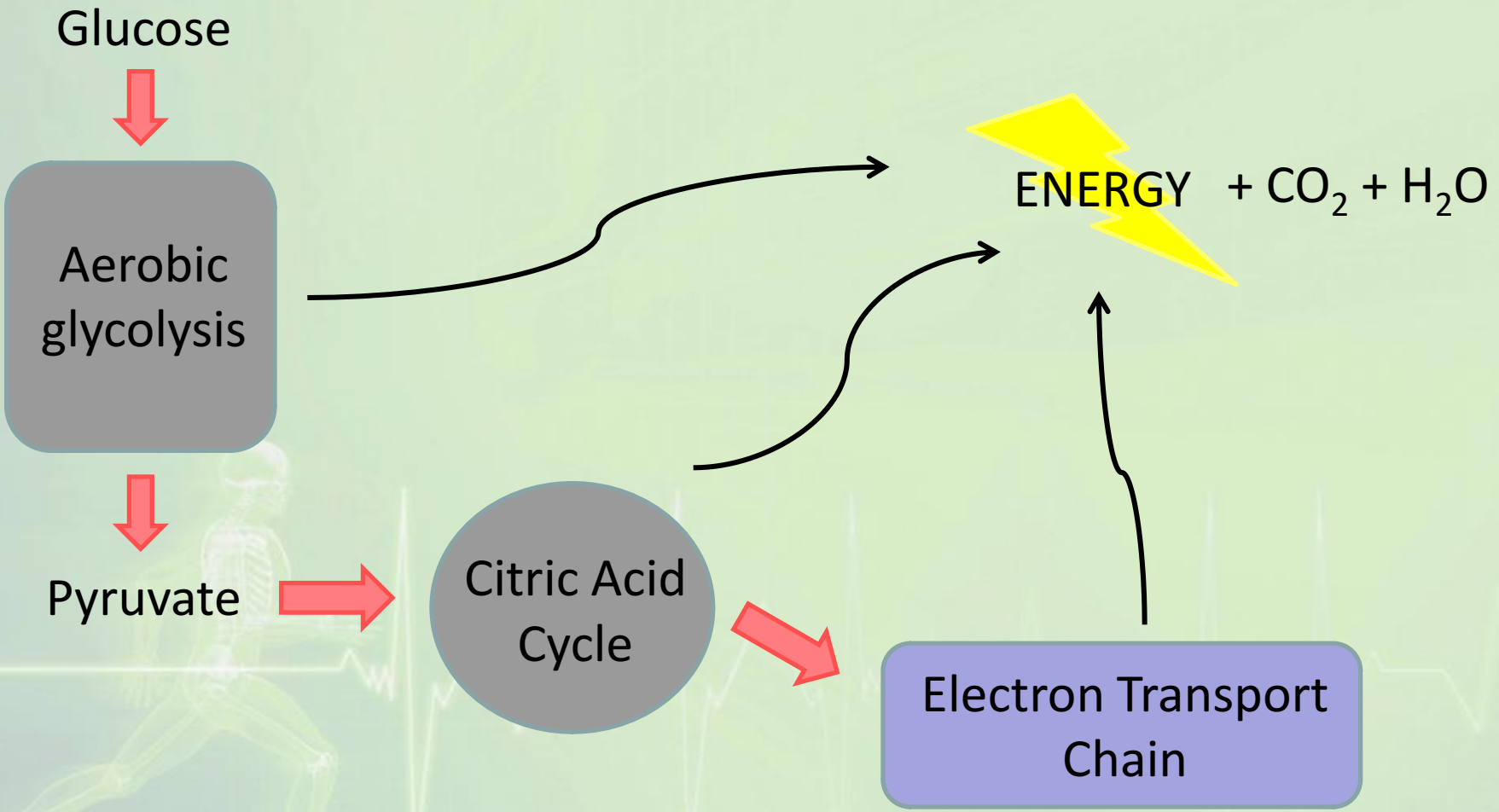


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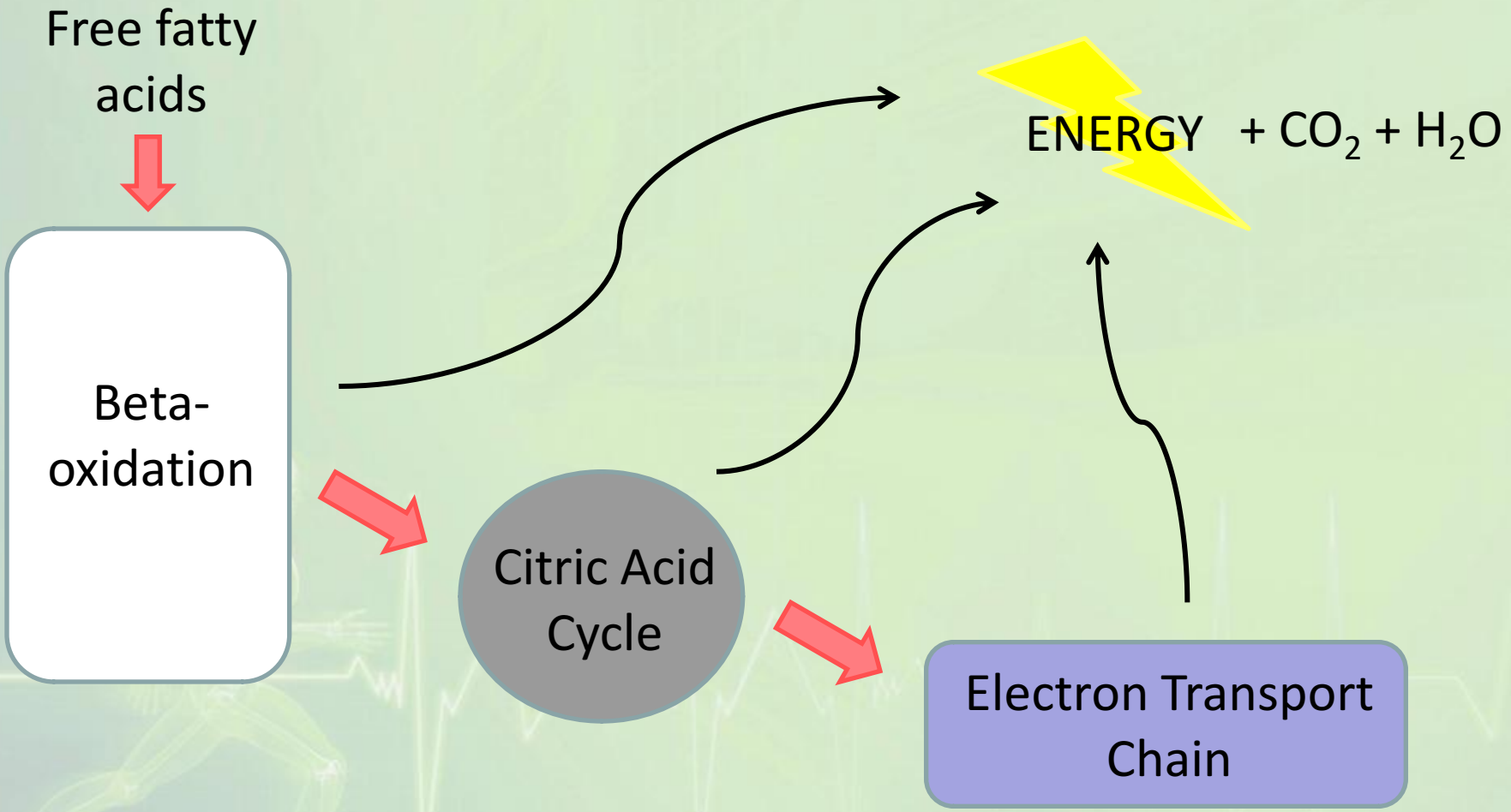
Units 1 & 2: Aerobic Energy System

- The production of ATP via the aerobic energy system requires oxygen
- The aerobic system is capable of producing the largest amount of ATP
- Both carbohydrate and fat can be used as fuels in the aerobic energy system
- The specific series of chemical reactions involved in the breakdown of fat and carbohydrate via the aerobic energy system differ

Units 1 & 2: Aerobic Metabolism Of Carbohydrate



Units 1 & 2: Aerobic Metabolism of Fat



Units 1 & 2: Aerobic Energy System

- The aerobic system is the dominant source of ATP production at rest and during moderate intensity or prolonged exercise
- Aerobic metabolism of carbohydrate produces ATP at a faster rate than fat
- We only store enough carbohydrate to fuel ~2 hrs of moderate intensity exercise

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Units 1 & 2: Comparing the Energy Systems

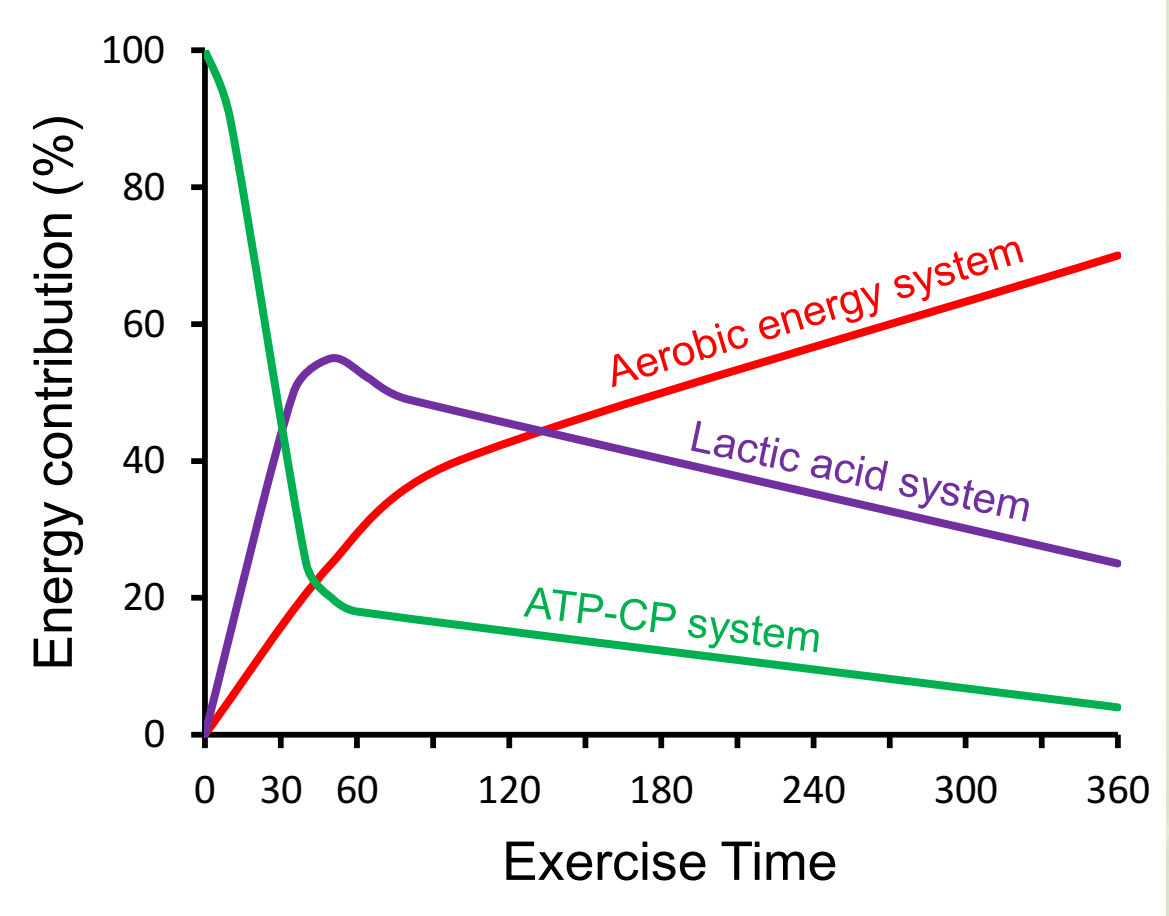
	ATP-CP system	Lactic acid system	Aerobic system
Fuel source	CP	Carbohydrate	Carbohydrate & Fat *(& Protein)*
O_2 required	No	No	Yes
Speed of energy supply	Most rapid	Rapid	Slow
Limitation / cause of fatigue	Limited stores of CP	Lactic acid production	Unlimited
Duration	~8 sec	~30–60 sec	~1.5–3 hrs
Type of activity	Sprint / power activities	Sprint endurance activities	Long duration endurance
Examples	Long jump, sprint for ball in soccer	400 m sprint, 100 m freestyle race	Marathon, triathlon

Units 1 & 2: Comparing the Energy Systems

- The ATP-CP system provides the most rapid source of ATP, but is limited in the amount of ATP that be produced
- The lactic acid system also provides a rapid source of ATP production, but is not as fast as the ATP-CP system
- The lactic acid system provides a larger amount of ATP than the ATP-CP system, but is ultimately limited by the production of lactic acid
- The aerobic system can supply an unlimited total amount of ATP, but the rate of production is relatively slow

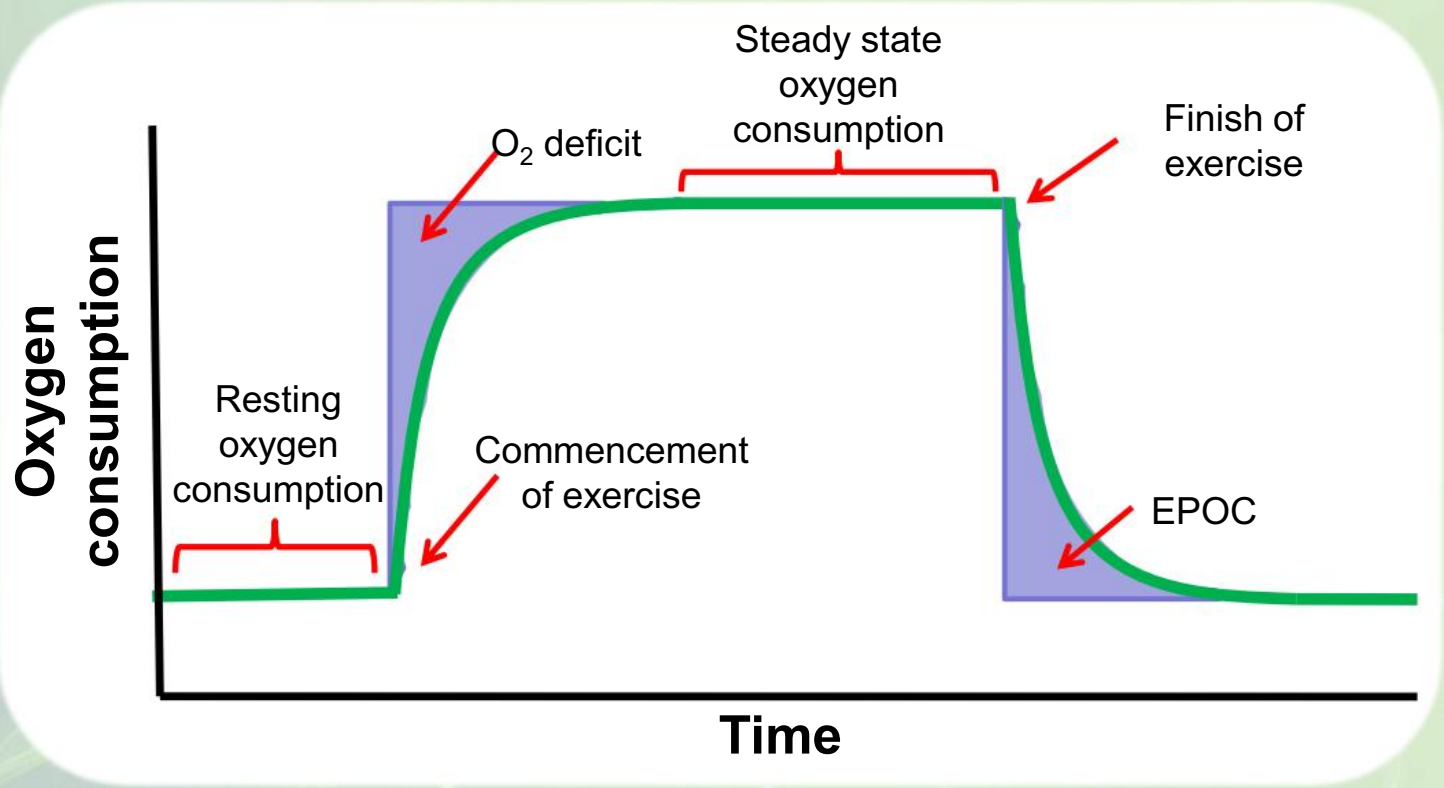
Units 1 & 2: The Energy System Continuum

The three energy systems all operate at once, with the intensity and duration of the activity determining the percentage contribution of each different system



Units 1 & 2: The Energy System Continuum

When commencing exercise, it takes time for oxygen consumption to increase, resulting in an oxygen deficit that must be repaid post-exercise



Units 1 & 2: Energy Systems

Exam style question

List (*i.*) the predominant energy system and (*ii.*) the main fuel source at each of the following points in a 5000 m track race.

(6 marks)

a) As the athletes stand on the start line.

b) As the athletes run the first 400 m.

c) From the 1000 m mark to the 4000 m mark of the race.

2A-2B: Energy Systems

Answer

List (i.) the predominant energy system and (ii.) the main fuel source at each of the following points in a 5000 m track race. (6 marks)

a) As the athletes stand on the start line.
   - *i. Aerobic energy system (1 mark)*
   - *ii. Fat (1 mark)*

b) As the athletes run the first 400 m.
   - *i. Lactic acid system (1 mark)*
   - *ii. Carbohydrate (1 mark)*

c) From the 1000 m mark to the 4000 m mark of the race.
   - *i. Aerobic energy system (1 mark)*
   - *ii. Carbohydrate (1 mark)*

Units 1 & 2: Energy Systems

Exam style question

Athletes competing in team sports such as hockey and netball are required to perform repeated short (~3 sec) maximal efforts with limited time (> 30 sec) in between for recovery.

List three changes within the muscle of an elite hockey player following an intense 15 min period of play.

(3 marks)

Units 1 & 2: Energy Systems

Answer

Athletes competing in team sports such as hockey and netball are required to perform repeated short (~3 sec) maximal efforts with limited time (> 30 sec) in between for recovery.

List three changes within the muscle of an elite hockey player following an intense 15 min period of play. (3 marks)

i. Decreased levels of CP (1 mark)
ii. Increased levels of lactic acid (1 mark)
iii. Decreased levels of stored carbohydrate (glycogen) (1 mark)

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Units 1 & 2: Acute Responses to Exercise

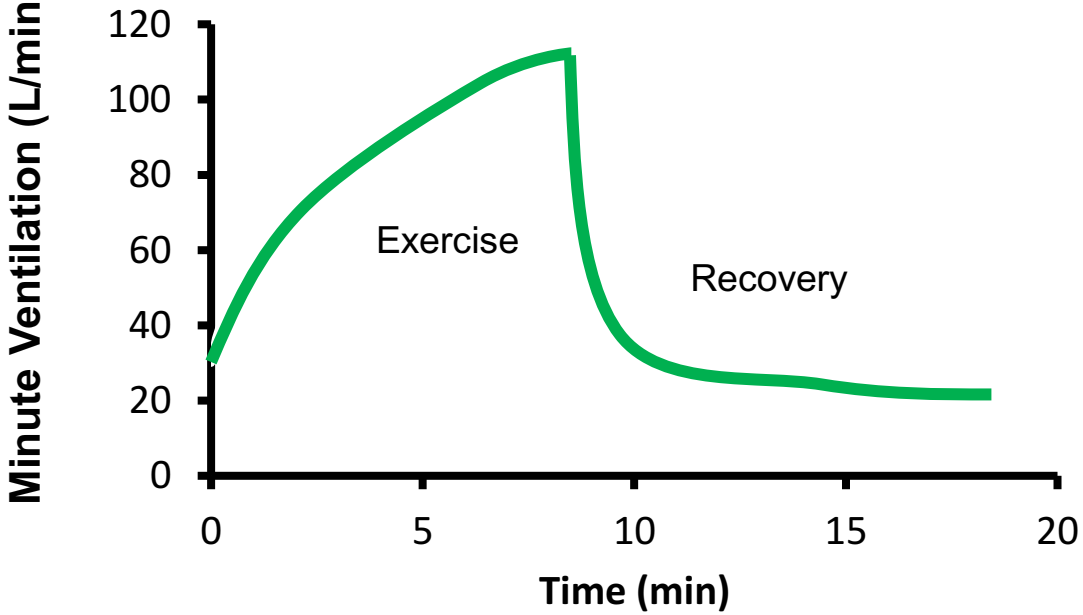
The body responds to the commencement of exercise by increasing all the processes involved in transporting oxygen to the working muscle



Units 1 & 2: Acute Responses to Exercise

Increased minute ventilation

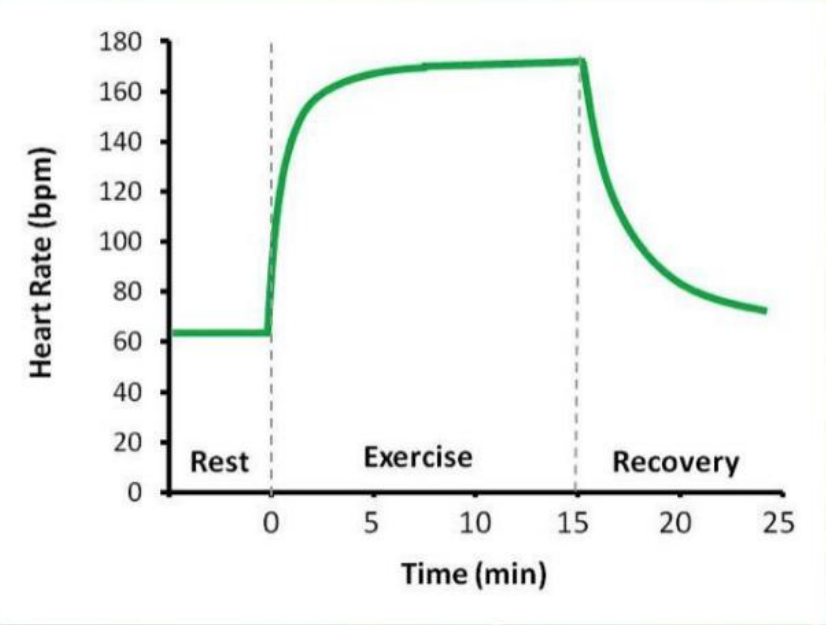
- due to an increase in both ***tidal volume*** and the number of ***breaths per minute***

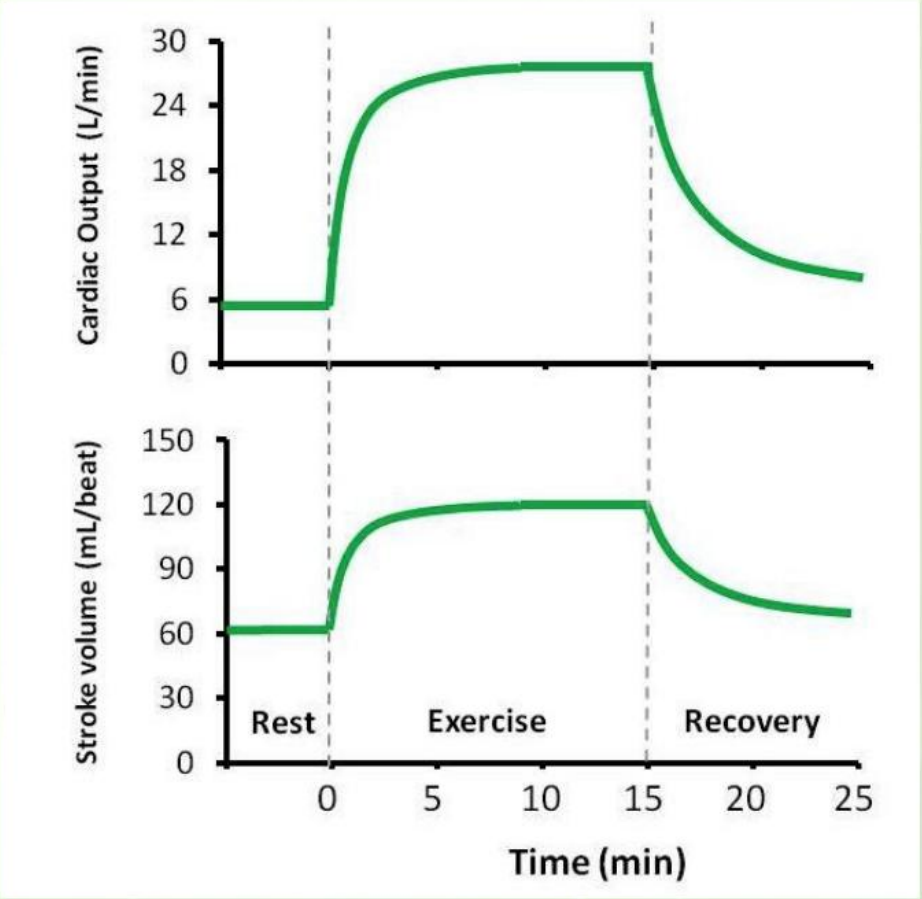


Units 1 & 2: Acute Responses to Exercise

Increased cardiac output

- due to an increase in both ***heart rate*** and ***stroke volume***

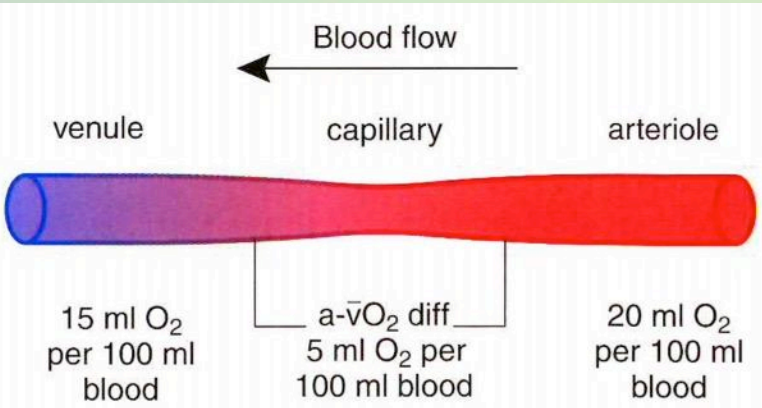




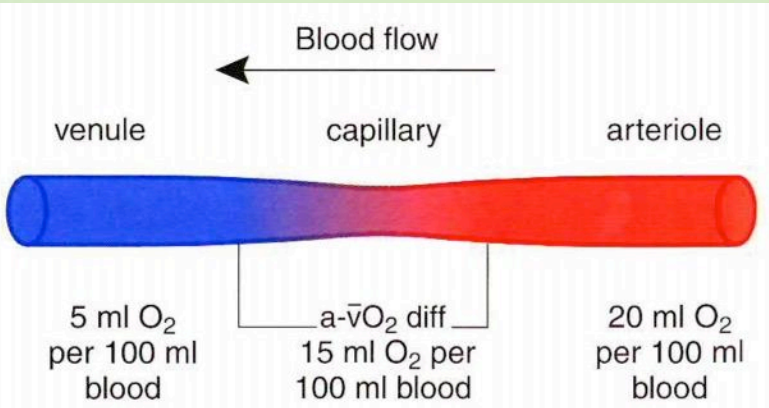
Units 1 & 2: Acute Responses to Exercise

Increased oxygen exchange at the tissues

Rest



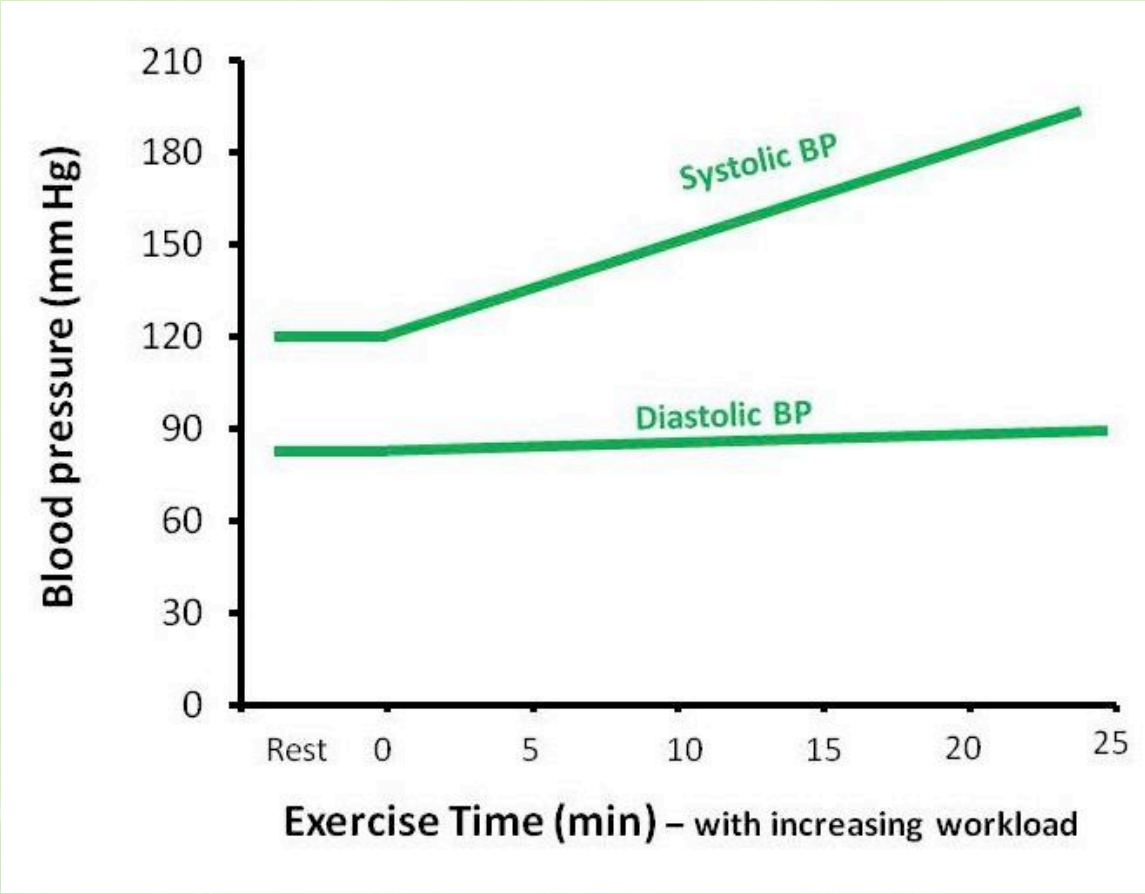
Exercise



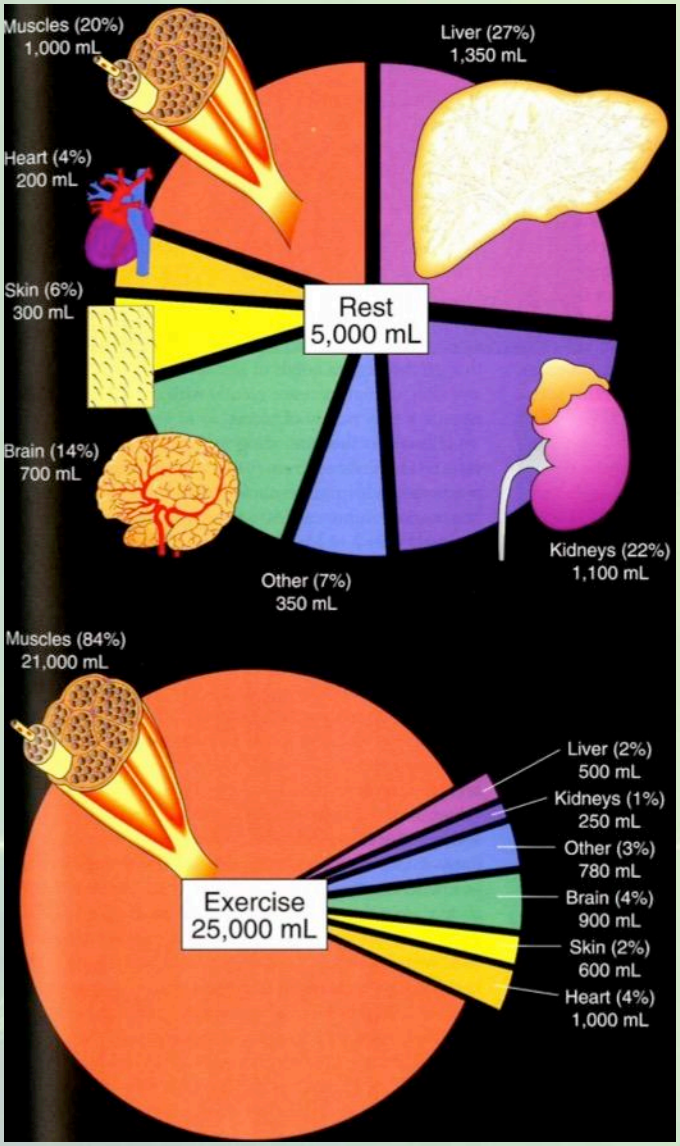
Units 1 & 2: Acute Responses to Exercise

Increased systolic blood pressure in direct proportion to exercise intensity.

Diastolic blood pressure remains relatively stable.



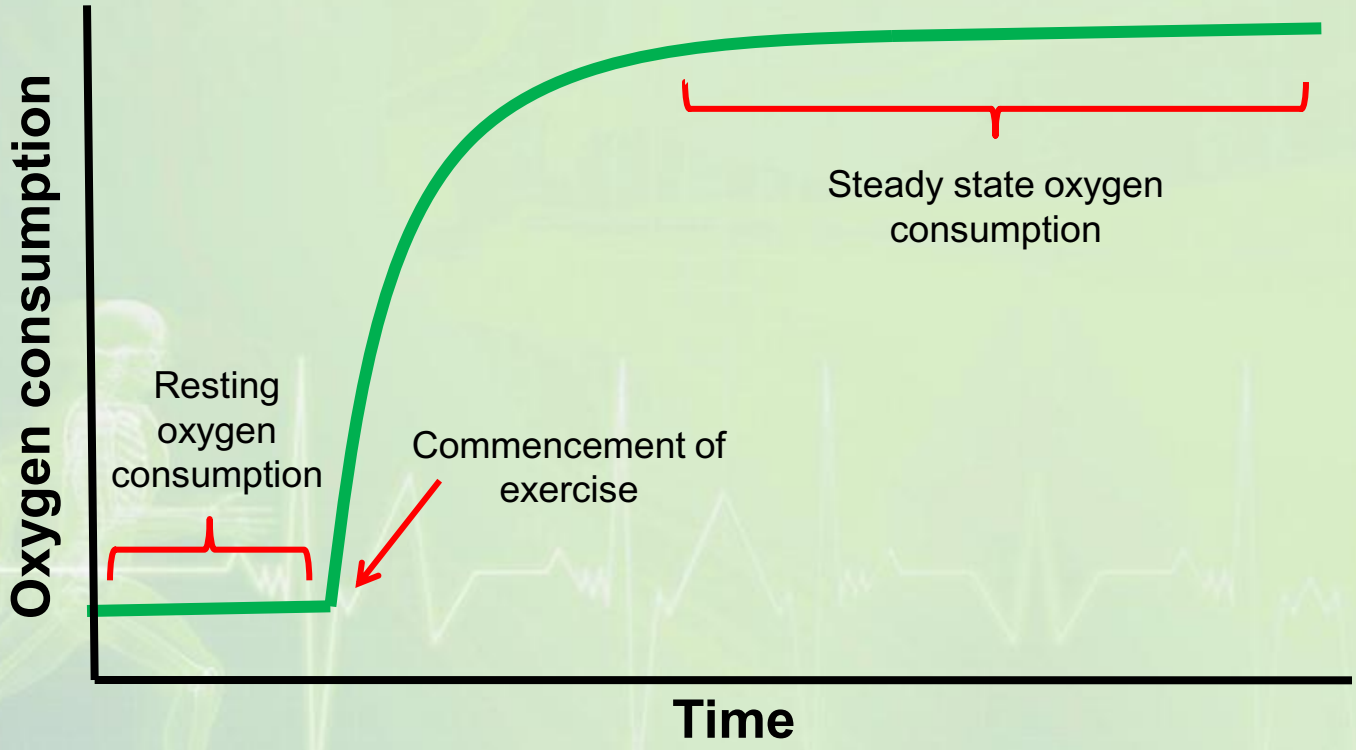
Units 1 & 2: Acute Responses to Exercise



Blood is rapidly redistributed to the working muscles with the onset of exercise

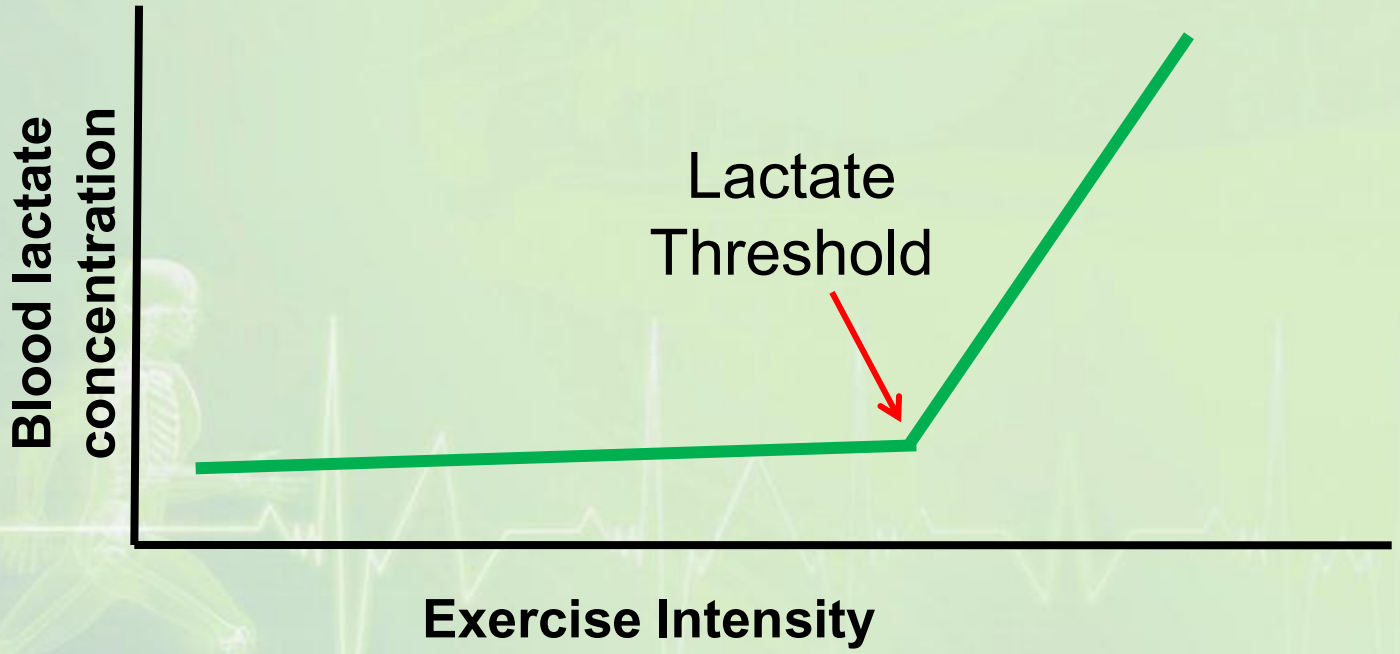
Units 1 & 2: Acute Responses to Exercise

Oxygen consumption (VO_2) increases in direct proportion to exercise intensity, until a maximum is reached



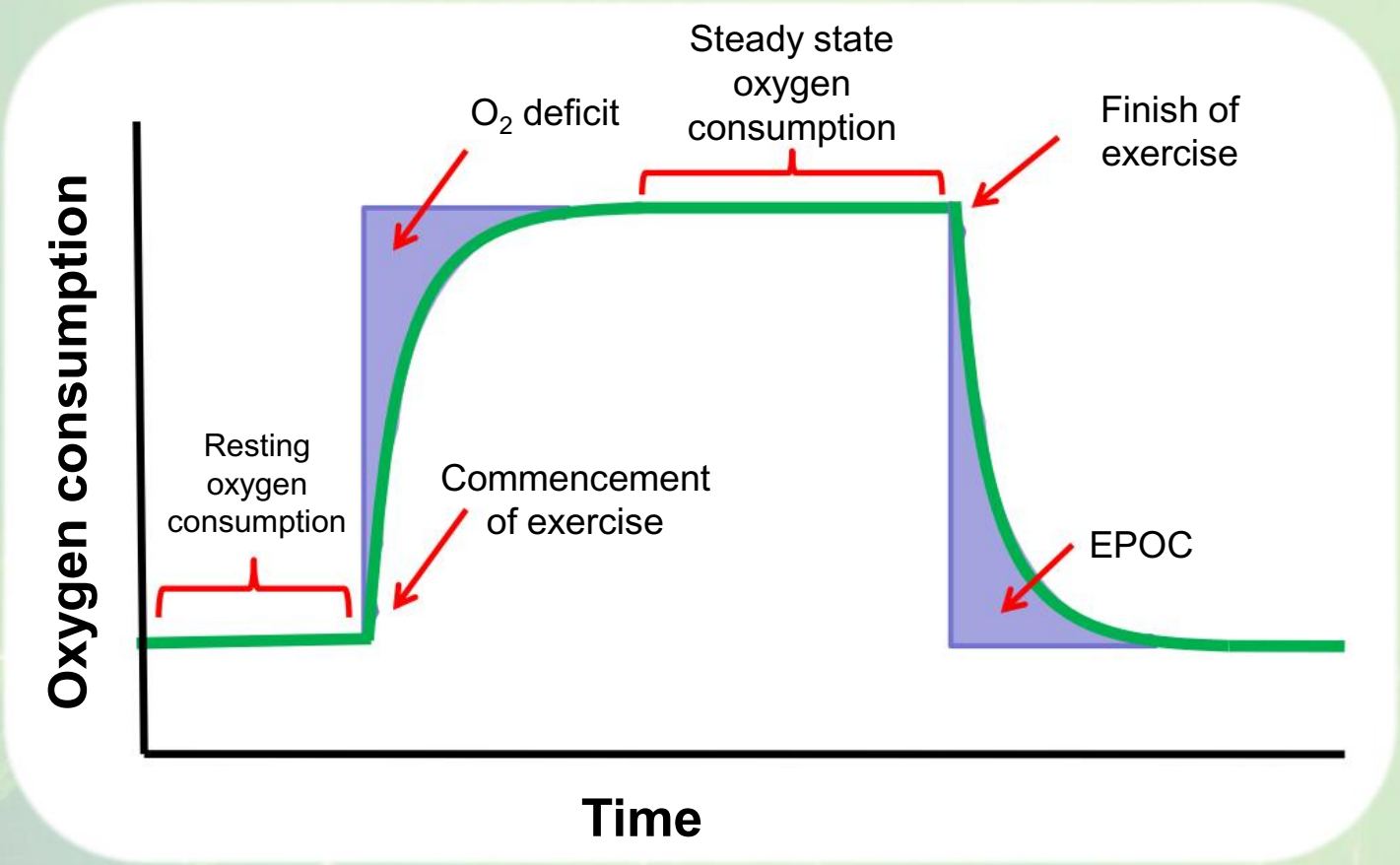
Units 1 & 2: Lactate Threshold

The lactate threshold is the exercise intensity at which lactic acid begins to accumulate in the blood

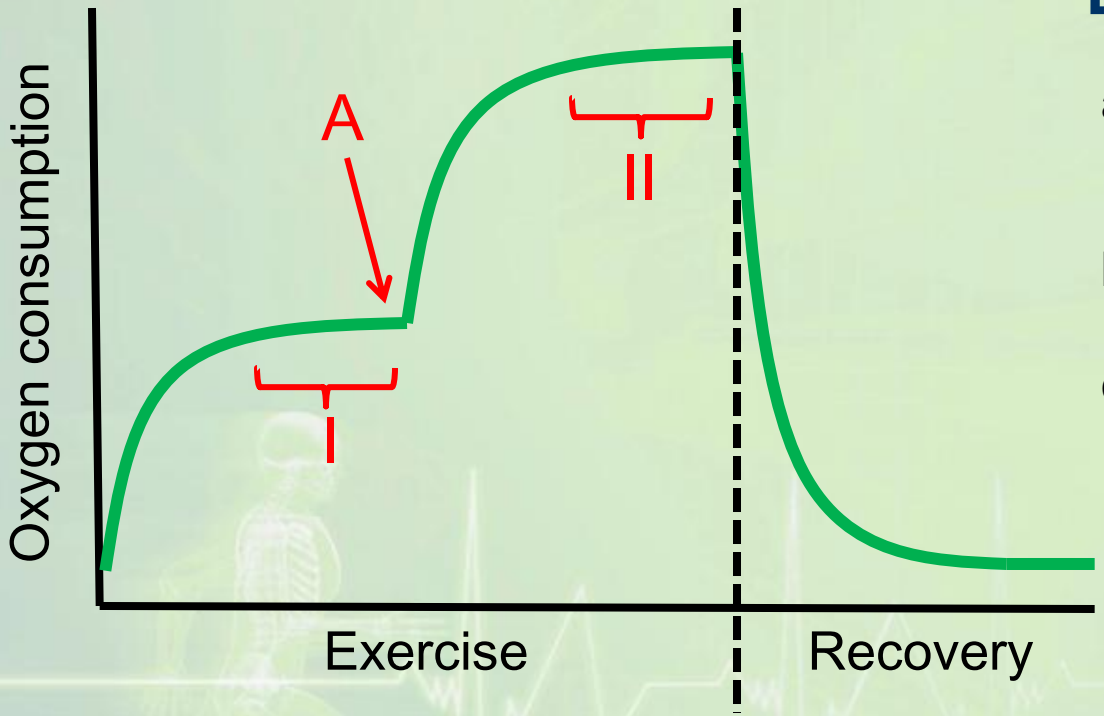


Units 1 & 2: Acute Responses to Exercise

Oxygen consumption may remain elevated for hours after exercise



Units 1 & 2: Acute Responses to Exercise



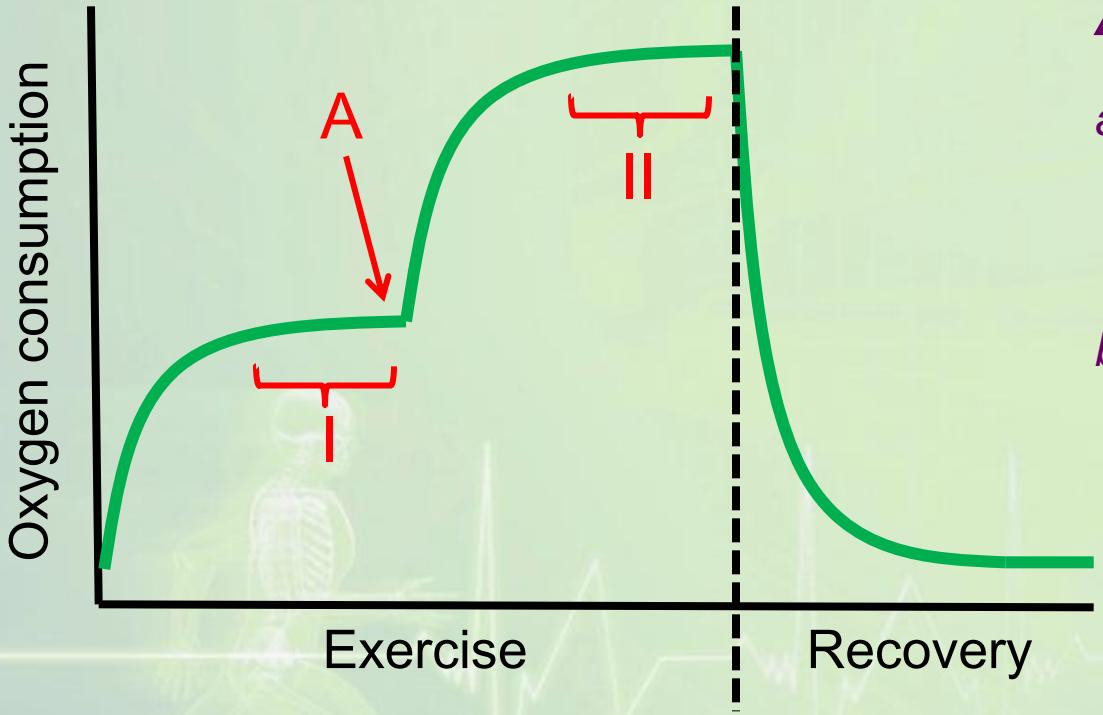
Exam style question

a) State what the red lines marked I and II signify. (1 mark)

b) State what occurred at point A. (1 mark)

c) Explain why the rate of oxygen consumption remains above resting levels during the recovery phase. (2 marks)

Units 1 & 2: Acute Responses to Exercise

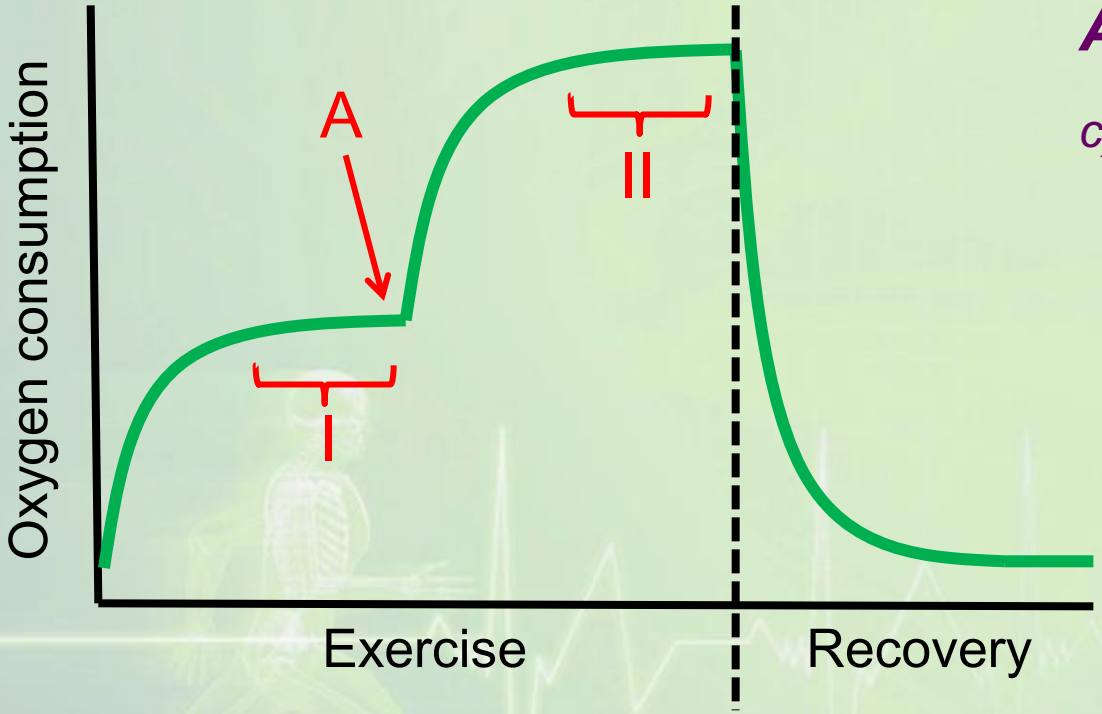


Answer

a) Lines I and II signify the achievement of a steady rate of oxygen consumption. (1 mark)

b) Point A represents an increase in exercise intensity which results in a subsequent increase in O_2 consumption. (1 mark)

2A-2B: Acute Responses to Exercise



Answer

c) The rate of O_2 consumption remains above resting levels during the recovery phase to allow for the replenishment of the anaerobic energy stores used during exercise (i.e. to replenish ATP and CP) (1 mark), and to remove lactic acid. (1 mark)

Units 1 & 2: Chronic Adaptations to Training

Regular exercise training results in cardiorespiratory adaptations that improve exercise performance

These adaptation can be:

- ***central*** – within the cardiorespiratory systems
- ***peripheral*** – within the muscle itself

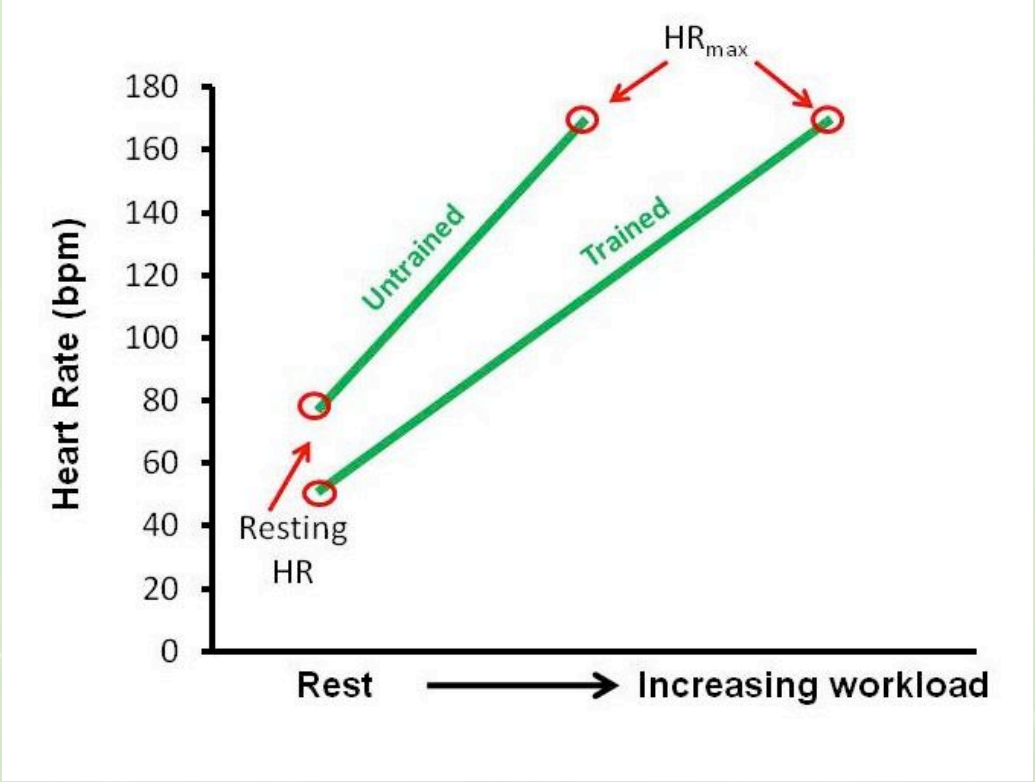
Units 1 & 2: Respiratory Adaptations to Training

- Minimal effect of lung structure and function
- More efficient respiration
- Higher maximal minute ventilation as a result of increased breathing frequency and maximal tidal volume
- Increased rate of oxygen exchange at the lungs

Units 1 & 2: Cardiovascular Adaptations to Training

Heart rate

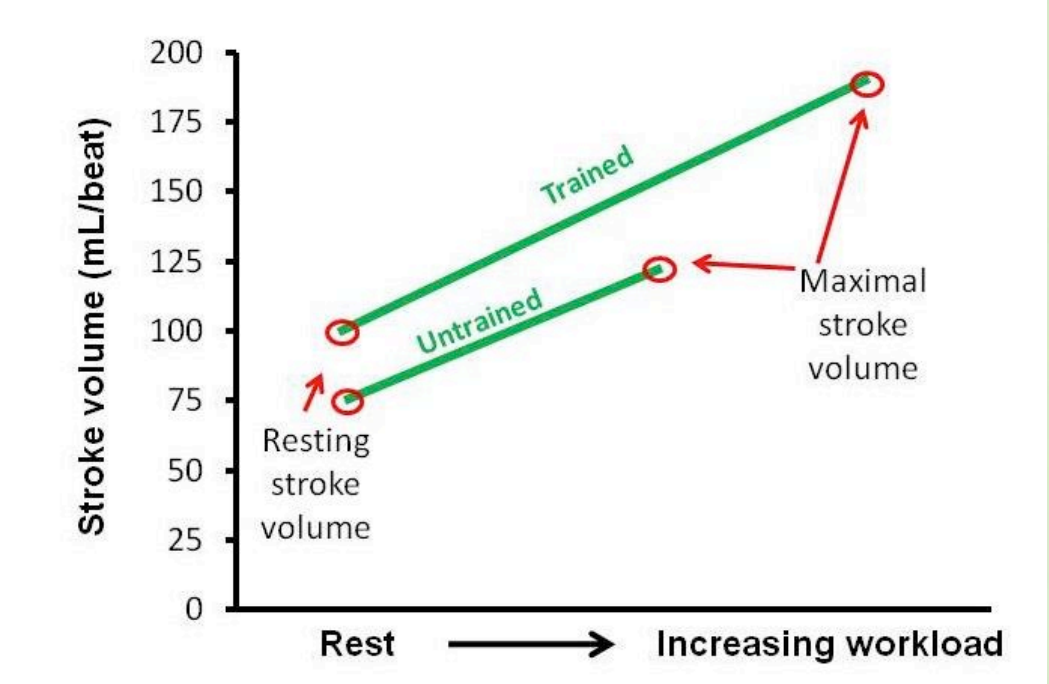
- Lower resting heart rate
- Lower heart rate response to submaximal exercise
- No effect on maximal heart rate



Units 1 & 2: Cardiovascular Adaptations to Training

Stroke volume

- Increased resting stroke volume
- Increased stroke volume during exercise



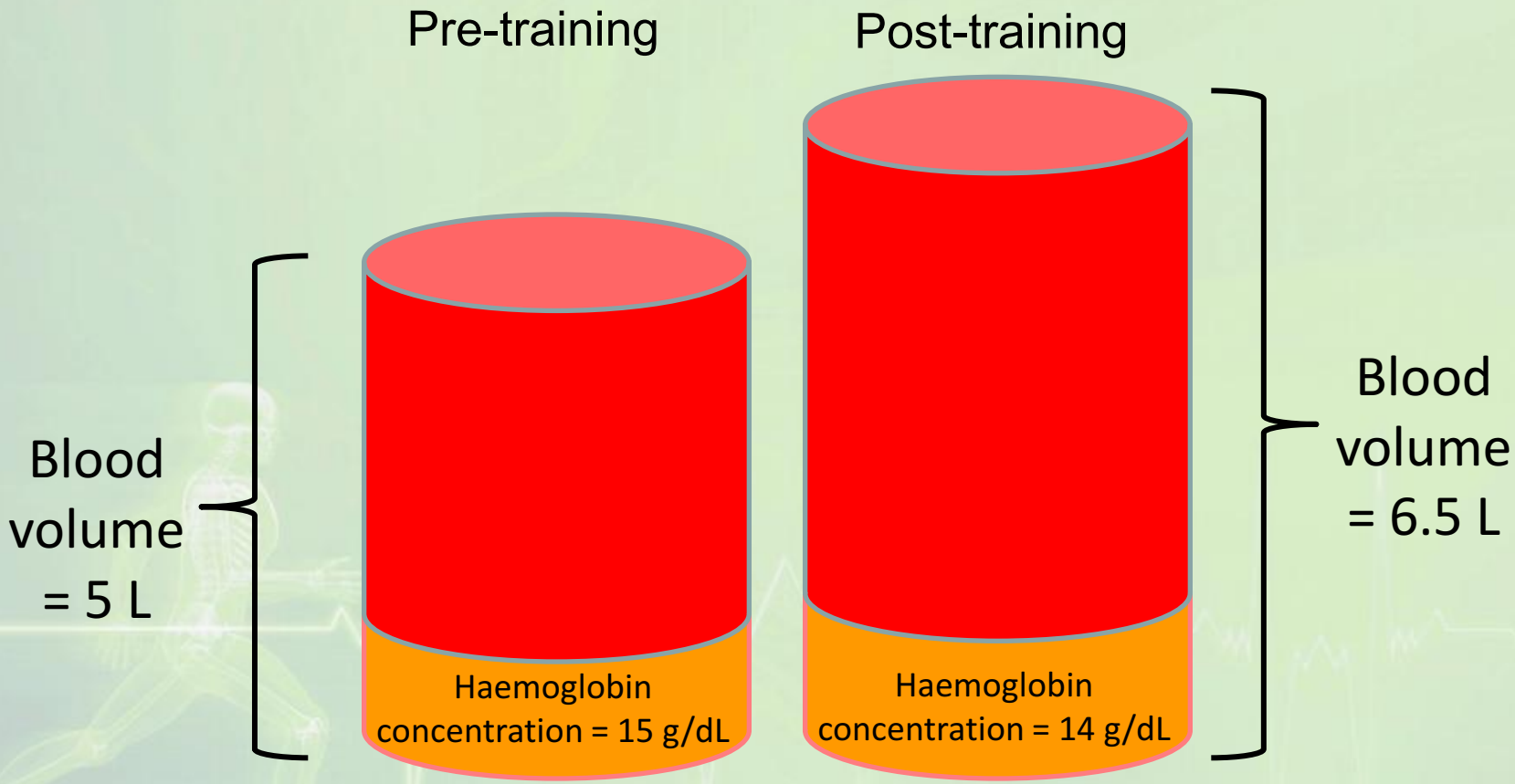
Units 1 & 2: Cardiovascular Adaptations to Training

Cardiac Output

- Unchanged at rest (due to higher stroke volume but lower resting heart rate)
- Increased during maximal exercise (due to higher stroke volume but same maximal heart rate)

Units 1 & 2: Cardiovascular Adaptations to Training

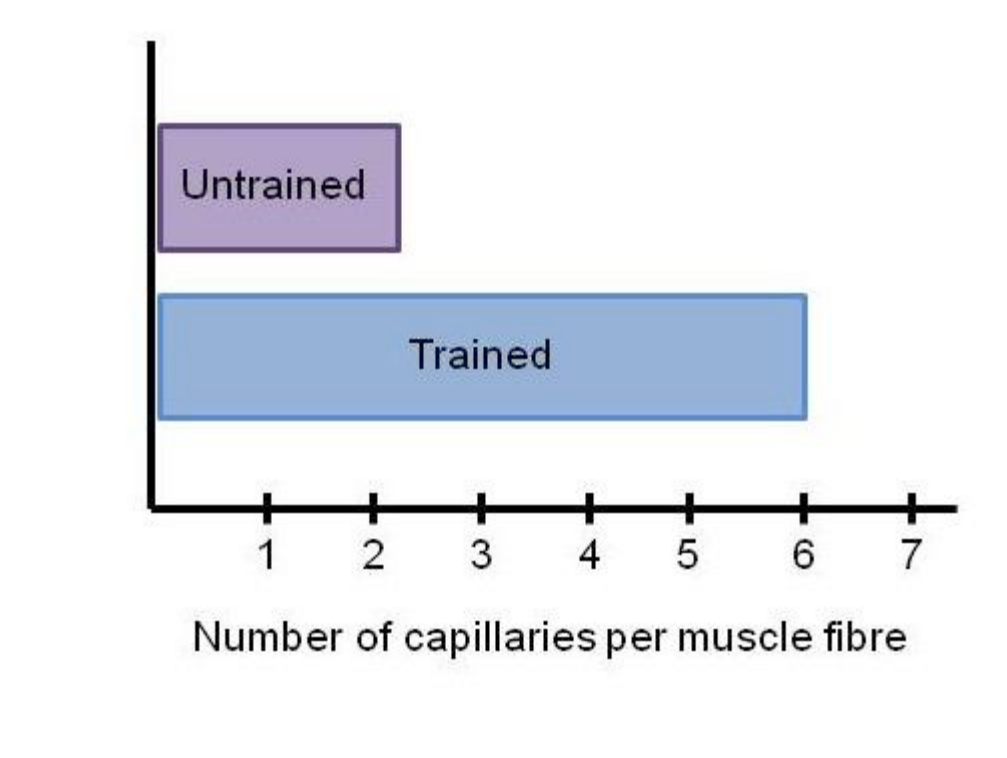
Increased total blood volume & haemoglobin (to a lesser extent)



Units 1 & 2: Cardiovascular Adaptations to Training

Gas exchange at the tissues

- Improved oxygen exchange at the tissues (a-vO_2diff) due to increased capillarisation



Units 1 & 2: Cardiovascular Adaptations to Training

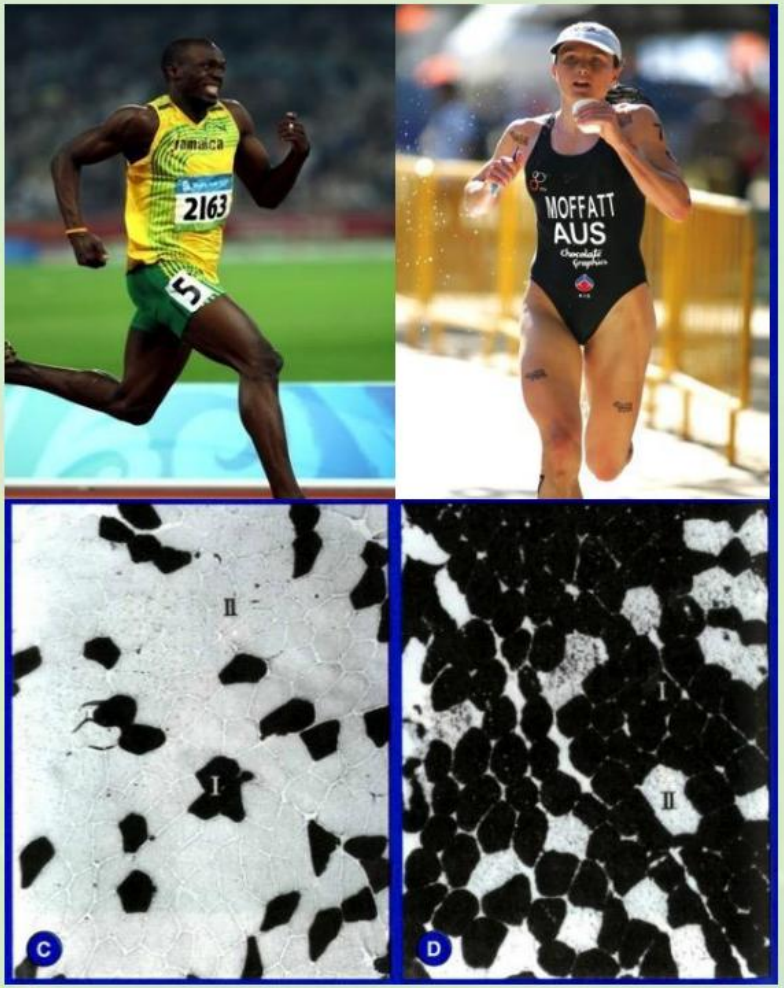
Oxygen consumption

- Quicker attainment of steady state oxygen consumption (and therefore a smaller oxygen deficit)
- Increased maximal oxygen consumption



Units 1 & 2: Cardiovascular Adaptations to Training

Hypertrophy of selective muscle fibres (Type I or II depending on the type of training)



Units 1 & 2: Metabolic Adaptations to Training

- Increased fuel storage within the muscle
- Increased number and size of mitochondria for the aerobic energy system
- Increased levels of the enzymes involved in the production of ATP

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Units 1 & 2: Chronic Adaptations to Training

	Pre-training	Post-training	Elite athlete
Ventilation at rest	6 L/min	6 L/min	6 L/min
Ventilation during maximal exercise	100 L/min	140 L/min	190 L/min
Resting heart rate	77 bpm	59 bpm	40 bpm
Heart rate during submaximal exercise	154 bpm	121 bpm	100 bpm
Heart rate at O_2max	190 bpm	189 bpm	187 bpm
Stroke volume at rest	68 mL	85 mL	110 mL
Stroke volume during maximal exercise	110 mL	130 mL	190 mL
Blood volume	5 L	5.5 L	6.5 L
Cardiac output at rest	5 L/min	5 L/min	5 L/min
Cardiac output during maximal exercise	22 L/min	26 L/min	35 L/min
O_2 at rest	300 mL/min	300 mL/min	300 mL/min
O_2 during maximal exercise	46 mL/kg/min	54 mL/kg/min	78 mL/kg/min

Units 1 & 2: Chronic Adaptations to Training

The central and peripheral adaptations to training result in improved exercise performance as a result of enhanced:

- ***Aerobic capacity***
  - Highest amount of ATP that can be produced by the aerobic energy system
- ***Anaerobic capacity***
  - Highest amount of ATP that can be produced by anaerobic pathways
- A combination of both aerobic and anaerobic capacity

Units 1 & 2: Improved Aerobic Capacity

- Cardiovascular and respiratory adaptations:
  - ↑ maximal cardiac output (due to ↑ maximal stroke volume)
  - ↑ plasma volume and haemoglobin
  - ↑ gas exchange at the lungs and at the muscles
- Muscular changes:
  - hypertrophy of Type I fibres
  - ↑ aerobic ability of Type I and II muscle fibres
- Metabolic adaptations:
  - ↑ aerobic fuel (fat and carbohydrate) storage within muscle
  - ↑ mitochondria
  - ↑ aerobic enzymes

Units 1 & 2: Improved Anaerobic Capacity

Due to:

- ↑ anaerobic fuel (ATP, CP, glycogen) storage within the muscle
- ↑ anaerobic enzymes
- hypertrophy of Type II fibres

Units 1 & 2: Chronic Adaptations to Training

Exam style question

A soccer team begins an 8 week pre-season training program. The training program will produce both acute (immediate responses) and chronic (long-term) adaptations. List one adaption for each of the following:

(4 marks)

a) Acute respiratory adaptation

b) Acute cardiovascular adaptation

c) Chronic cardiovascular adaptation

d) Chronic muscular adaptation

Units 1 & 2: Chronic Adaptations to Training

Answer

a) Acute respiratory adaptation (any one for 1 mark)
- *↑ minute ventilation (↑ tidal volume and breathing frequency)*
- *↑ gas exchange at lungs*

b) Acute cardiovascular adaptation (any one for 1 mark)
- *↑ cardiac output (↑ heart rate and stroke volume)*
- *↑ blood flow to muscles*
- *↑ systolic blood pressure*
- *↑ gas exchange at tissues*
- *↑ oxygen consumption*

Units 1 & 2: Chronic Adaptations to Training

Answer

c) Chronic cardiovascular adaptation (any one for 1 mark)

- *↑ cardiac output (↑ stroke volume)*
- *↑ blood volume (& haemoglobin)*
- *↑ gas exchange at muscles (↑ capillaries)*

d) Chronic muscular adaptation (any one for 1 mark)

- *↑ fuel storage*
- *hypertrophy*
- *↑ mitochondria*
- *↑ enzymes for fuel use*

Units 1 & 2: Chronic Adaptations to Training

Exam style question

Craig Mottram is an elite Australian distance runner. Many years of training for his event has altered the way his skeletal muscles use carbohydrate and fat compared to an untrained person.

(3 marks)

a) Explain two changes in fuel use during the event occurring as a result of endurance training.

b) Explain how the changes in fuel use will assist his performance towards the end of the race.

Units 1 & 2: Chronic Adaptations to Training

Answer

a) Describe two changes in fuel use during the event occurring as a result of endurance training. (2 marks)

i. ↑ *ability to oxidise fat compared to untrained*

ii. ↑ *ability to oxidise carbohydrate aerobically compared to untrained*

b) Explain how the changes in fuel use will assist his performance towards the end of the race. (1 mark)

i. ↑ *ability to oxidise fat allows carbohydrate stores to be preserved for longer throughout the race*

Units 1 & 2: Components of Fitness

The health-related components of fitness include:

- Cardiorespiratory fitness
- Muscular fitness
  - Muscular strength
  - Muscular endurance
  - Flexibility
- Body composition

Units 1 & 2: Components of Fitness



Cardiorespiratory endurance (or aerobic fitness) relates to the ability of the respiratory and circulatory systems to supply oxygen to the working muscle during exercise

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Units 1 & 2: Components of Fitness

Muscular fitness relates to optimising the ***strength***, ***endurance*** and ***flexibility*** characteristics of our muscles



Units 1 & 2: Components of Fitness



Muscular strength –
the ability to exert force in a single maximal effort

Units 1 & 2: Components of Fitness

Muscular endurance – the ability to perform repeated submaximal contractions without undue fatigue





Units 1 & 2: Components of Fitness

Flexibility – the range of motion about a joint



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Units 1 & 2: Components of Fitness

Body composition relates to the proportion of fat and lean muscle mass in the body





Units 1 & 2: Components of Fitness

The performance or skill-related components of fitness include:

- ***Agility*** – the ability to rapidly change direction
- ***Balance*** – the ability to maintain stability while in motion
- ***Coordination*** – the ability to integrate the senses and movement of body parts to perform tasks efficiently
- ***Reaction time*** – the time taken from when a stimulus is presented to when the appropriate reaction is taken
- ***Speed*** – the ability to perform a movement quickly
- ***Power*** – the ability to perform a strong movement quickly

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Units 1 & 2: Components of Fitness

Different sports (and positions within a given sport) have differing demands on each component of fitness





Units 1 & 2: Principles of Training

- The way in which the body responds to exercise training depends on the type of training undertaken
- This is the principle of ***specificity of training***

Units 1 & 2: Principles of Training

- ***Progressive overload*** must be applied to achieve training adaptations
- Progressive overload can be applied by increasing the intensity, duration or frequency of exercise



Units 1 & 2: Principles of Training

- Adaptations to training are not permanent and can be lost with detraining
- This is the principle of ***reversibility of training***



Units 1 & 2: Methods of Training



Continuous training involves exercising in a continuous fashion for a prolonged period of time

Units 1 & 2: Methods of Training

Cross-training involves an alternative mode/s of exercise to the one that an athlete is actually training for



Units 1 & 2: Methods of Training

Fartlek training is a method of continuous training involving variations in pace between periods of harder work and periods of easier work for relief



Units 1 & 2: Methods of Training

Interval training involves repeated bouts of work, alternated with periods of recovery. Intervals can be aerobic or anaerobic in nature.

Units 1 & 2: Methods of Training

Resistance training stimulates the body to adapt to coping with heavier loads

By changing the load (%1RM), number of sets, repetitions and the speed of motion, we can change the focus from enhancing muscular strength, power or endurance.



Units 1 & 2: Methods of Training

Circuit training typically involves performing as many repetitions as possible in a given period of time (~1 min)

Generally the exercises involved are set up in a circular (circuit) fashion, in which athletes move from one exercise *station* to the next



Units 1 & 2: Methods of Training

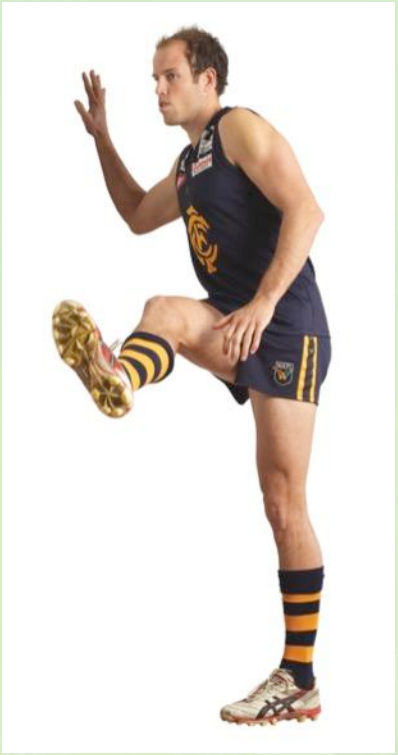
Flexibility may be improved by:



Static stretching



PNF stretching



Ballistic stretching

Units 1 & 2: Methods of Training

Plyometrics is a form of resistance training that uses the weight of the body to apply resistance in dynamic activities such as jumping



Units 1 & 2: Fitness Components & Methods of Training

Exam style question

A basketball guard is required to perform a range of different activities throughout a game including standing, walking, jogging, running, sprinting and jumping.

a) List the three most important components of fitness to playing the guard position in basketball. (3 marks)

b) State and briefly describe an appropriate physical test for each of the components identified above. (3 marks)

c) Which training method would most likely lead to improvement in the guard players court speed? (1 mark)

d) Discuss the effect of manipulating the duration of the rest intervals on the intended aim of this training method. (3 marks)

Units 1 & 2: Fitness Components & Methods of Training

Answer

a) List the three most important components of fitness to playing the guard position in basketball. (3 marks)

i. power
ii. agility
iii. cardiorespiratory endurance

b) State and briefly describe an appropriate physical test for each of the components identified above. (3 marks)

i. vertical jump test (power)
ii. 505 agility test (agility)
iii. shuttle run (cardiorespiratory endurance)

Units 1 & 2: Fitness Components & Methods of Training

Answer

c) Which training method would most likely lead to improvement in the guard players court speed? (1 mark)

- *interval training*

d) Discuss the effect of manipulating the duration of the rest intervals on the intended aim of this training method. (3 marks)

- *shorter rest intervals will allow for less repletion of CP (1 mark) and removal of lactic acid (1 mark)*
- *this will provide a greater stimulus for training adaption (although the "quality" of work will be lower) (1 mark)*

Units 1 & 2: Fitness Components & Methods of Training

Exam style question

Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
Jog 20 min	Swim 20 min	Jog 25 min	Swim 20 min	Jog 30 min	Jog 35 min
Circuit training 20 min	Running 2x400m 4x200m 6x60m	Circuit training 20 min		Running 2x400m 6x200m 8x60m	Cycle 30 min
Cycle 20 min	-	Skipping 10 min	Cycle 25 min	-	-

a) Name three training methods used in the program above. (3 marks)

b) Identify one training principle that has been applied in the program above. (1 mark)

c) Identify one training principle that is not evident in the program above. (1 mark)

d) What component of fitness is this program most likely to develop. (1 mark)

Units 1 & 2: Fitness Components & Methods of Training

Answer

a) Name three training methods used in the program above (3 marks)

- *continuous training*
- *circuit training*
- *interval training*

b) Identify one training principle that has been applied in the program above (1 mark)

- *progressive overload*

c) identify one training principle that is not evident in the program above (1 mark)

- *specificity of training*

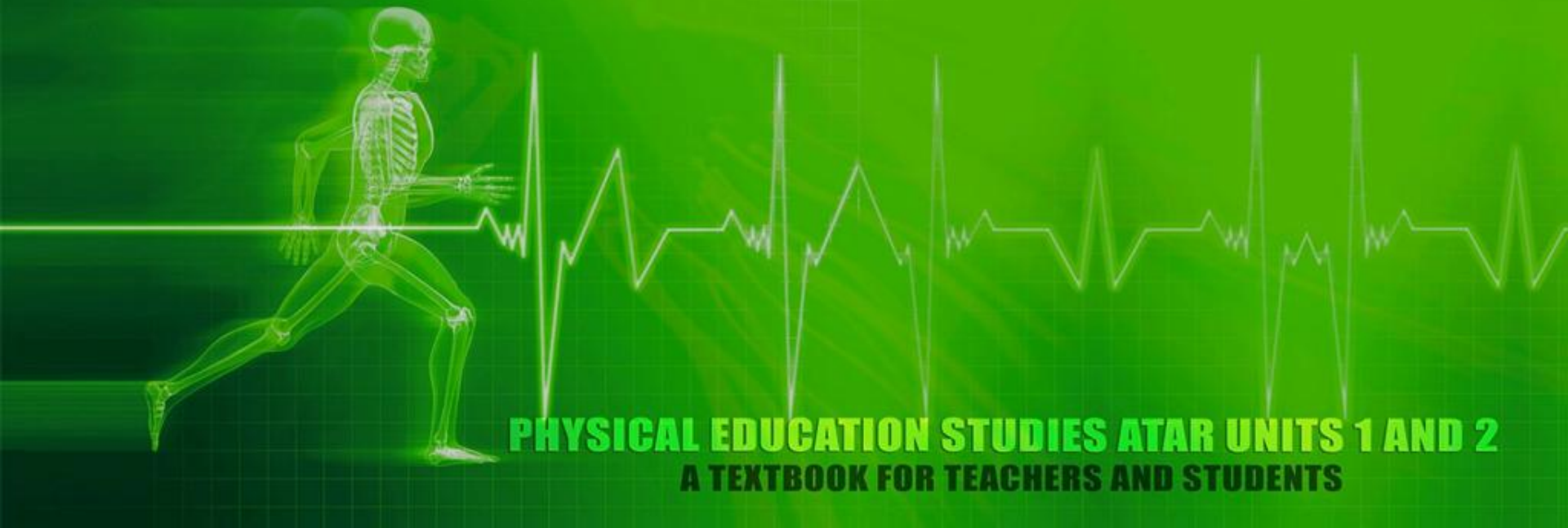
d) What component of fitness is this program most likely to develop (1 mark)

- *cardiorespiratory endurance*

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SPORT PSYCHOLOGY

Dr James Dimmock
Dr Peter Whipp
Ms Monica Leslie



Units 1 & 2: Individual Zone of Optimal Functioning

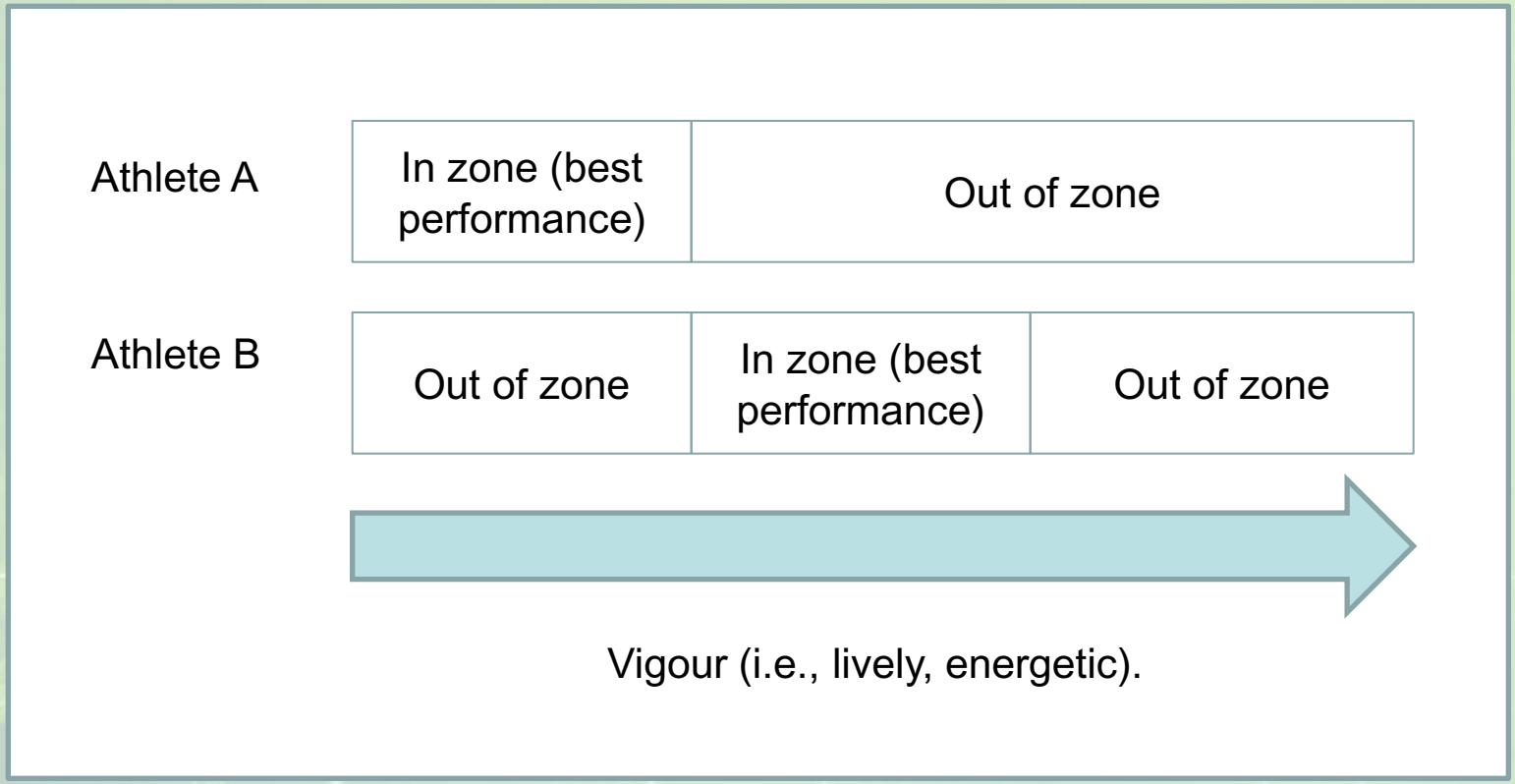


Emotions include:

Vigour, fatigue, state anxiety, and anger

Units 1 & 2: Individual Zone of Optimal Functioning

Zone of optimal functioning (IZOF) for two different athletes



Units 1 & 2: Individual Zone of Optimal Functioning

Exam style question

Explain how you would use the IZOF model to help an athlete find an optimal amount of state anxiety for their sport.

(3 marks)



Units 1 & 2: Individual Zone of Optimal Functioning

Answer

Explain how you would use the IZOF model to help an athlete find an state anxiety for optimal amount of their sport. (3 marks)

Firstly, the athlete could be monitored over a series of games or events. The athlete could be asked to report their thoughts and feelings before, during or after the performance. (1 mark) After analysing this information, the athlete could develop zones of optimal performance for different emotions. (1 mark)This information could be used to help the athlete to prepare for future performance. (1 mark)

Units 1 & 2: Motivation

Intrinsic motivation:

The pursuit of an activity for the inherent satisfaction (enjoyment) that the activity provides.

E.g., Two brothers kicking a football together for fun.

Extrinsic motivation:

The pursuit of a task for contingencies other than inherent satisfaction.

E.g., Two brothers kicking a football together to receive praise from a parent.

Units 1 & 2: Motivation



The influence of age, skill level, and the type of activity on motivation

- It is possible to possess intrinsic and/or extrinsic motivation regardless of your age

- Intrinsic motivation depends on satisfying needs such as competence

- Intrinsic motivation is only possible for tasks that are perceived to be interesting, novel, challenging, or have aesthetic value



Units 1 & 2: Arousal

Arousal refers to a state of heightened psychological and physical activation

Arousal can stem from positive or negative events



Units 1 & 2: Anxiety

Anxiety is a negative emotional state

- Nervousness, apprehension, and worry (cognitive anxiety)
- Associated with arousal of the body (somatic anxiety)



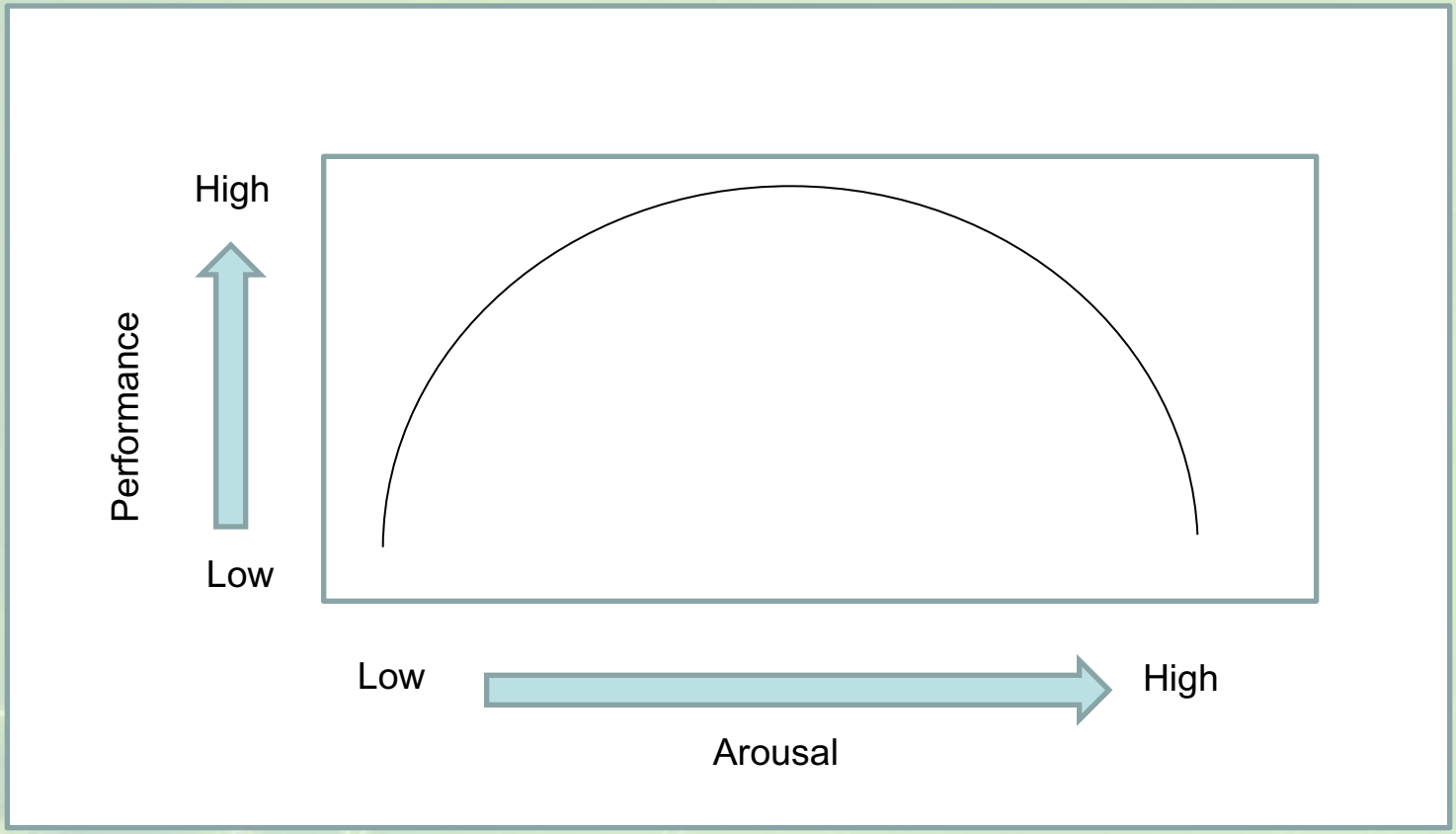
Units 1 & 2: The Inverted-U Hypothesis



The ***inverted-U hypothesis*** indicates that performance is best when athletes experience a moderate level of arousal.

Performance can suffer when arousal is above or below this level.

Units 1 & 2: The Inverted-U Hypothesis



Units 1 & 2: The Inverted-U Hypothesis

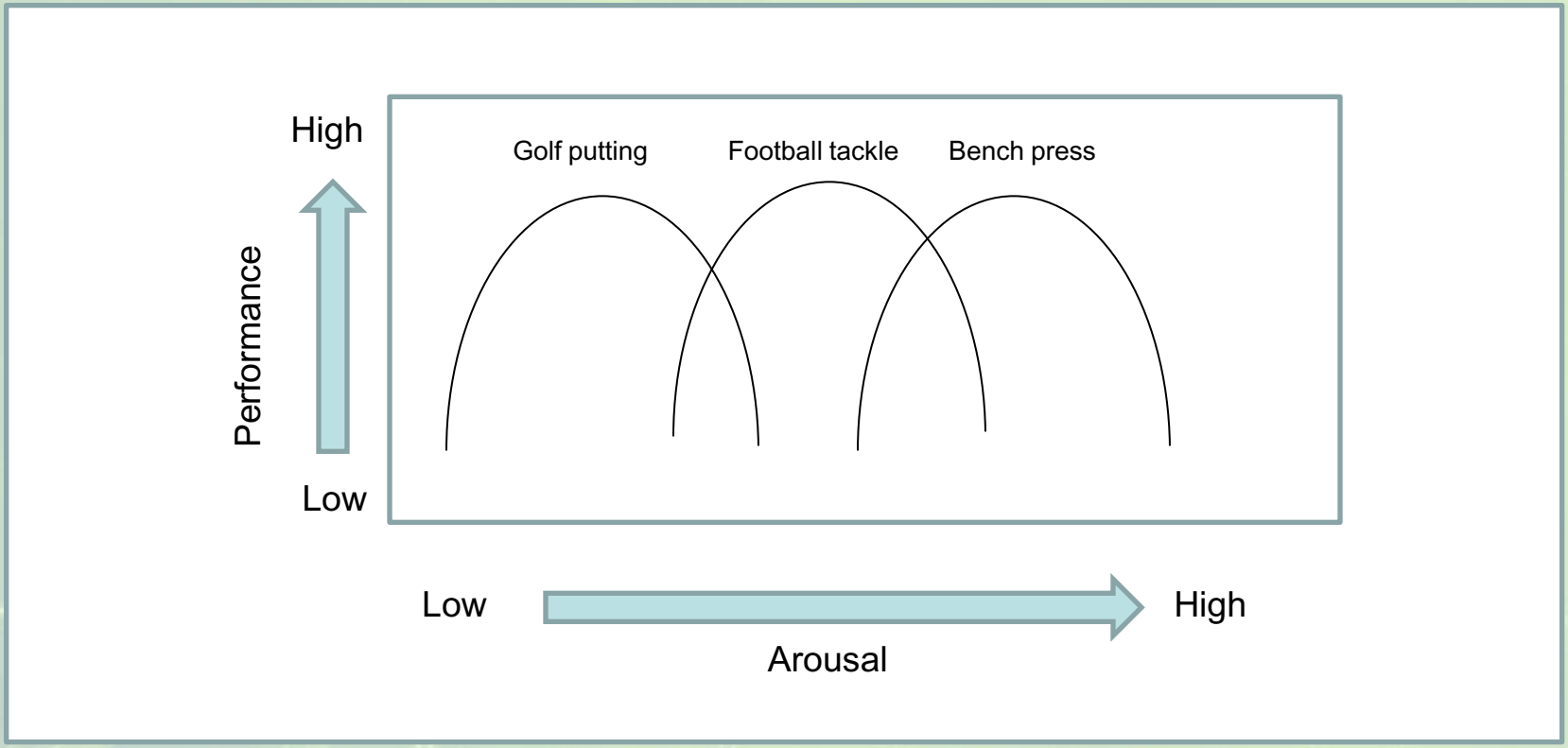
Factors that can influence the relationship between arousal and performance:

1. The nature of the task
2. Skill level of the performer
3. Individual differences



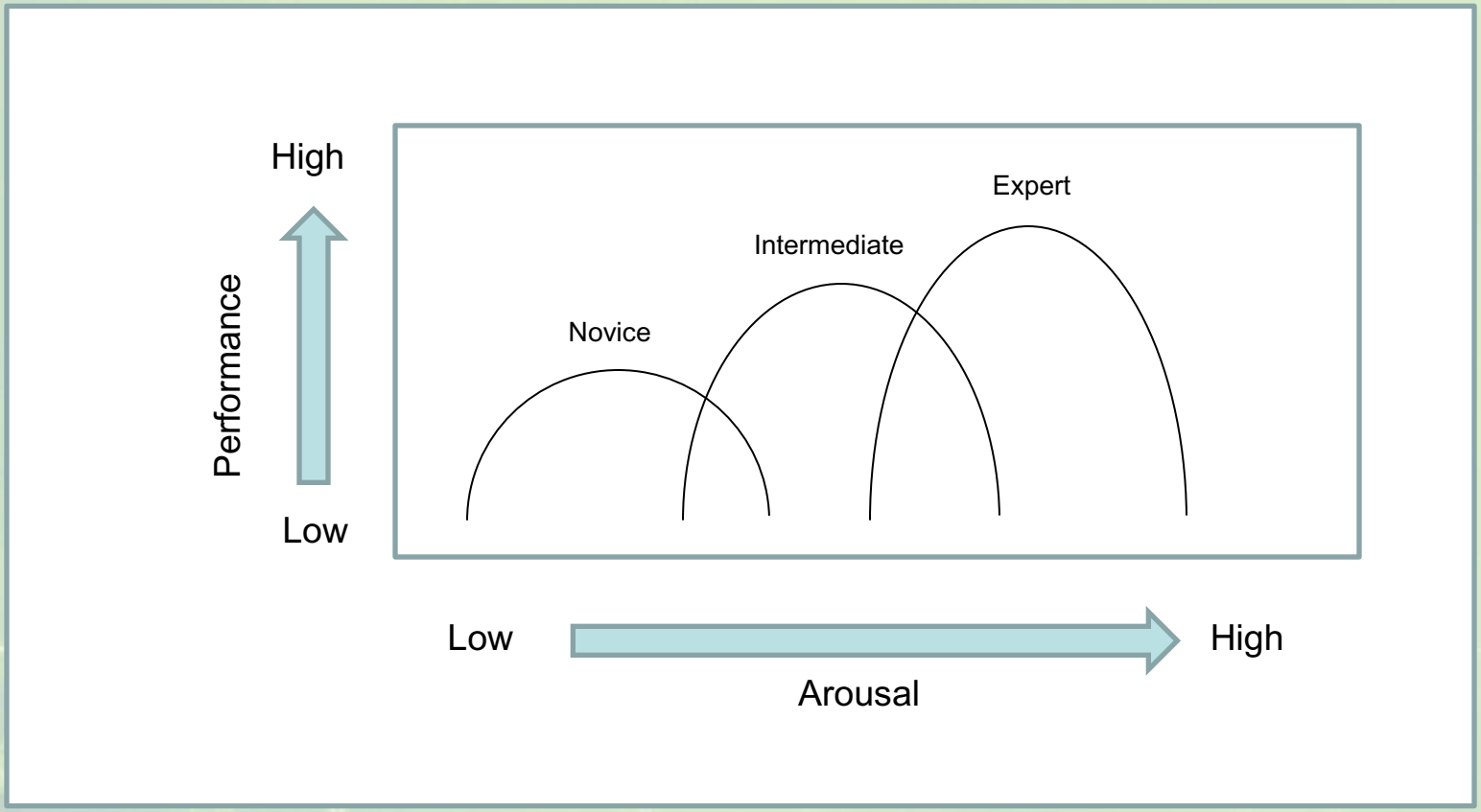
Units 1 & 2: The Inverted-U Hypothesis

Shifted inverted-U to reflect different types of activities

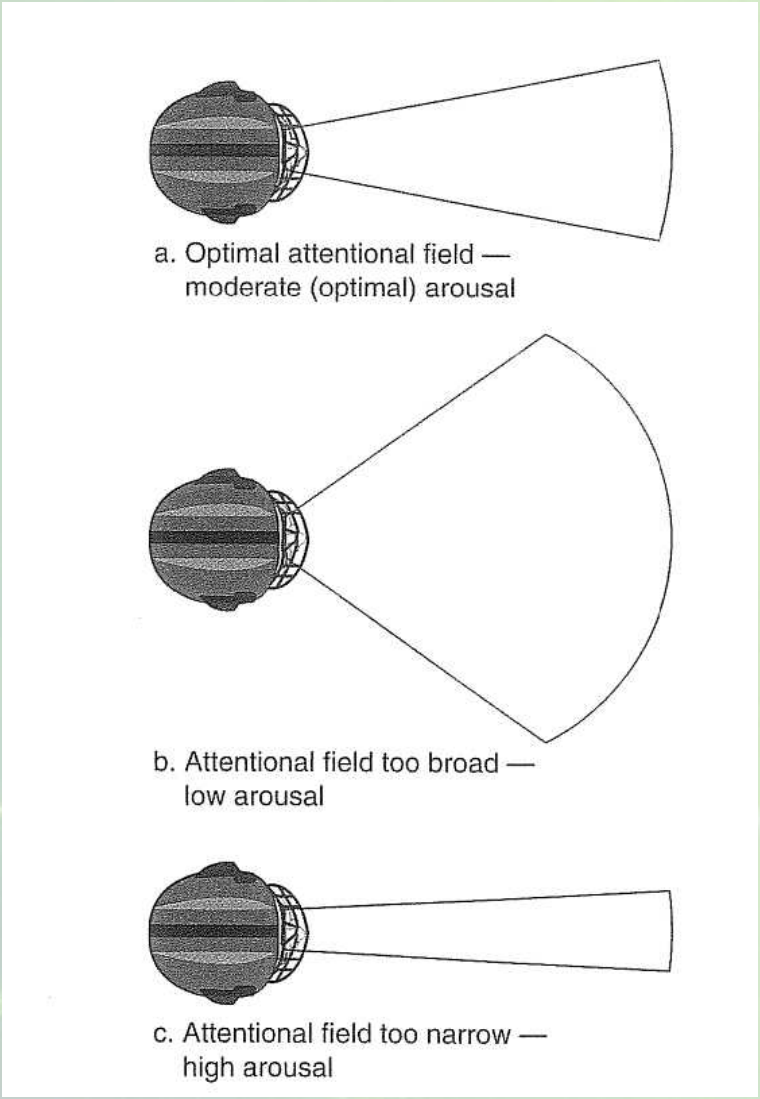


2A-2B: The Inverted-U Hypothesis

Inverted-U for players with different levels of skill



Units 1 & 2: Arousal



How arousal influences performance

Arousal influences performance by causing changes to:

- Muscle tension, fatigue, and coordination
- Attention, and vision

Units 1 &2: Arousal

Arousal/Anxiety reduction

Reducing somatic anxiety:

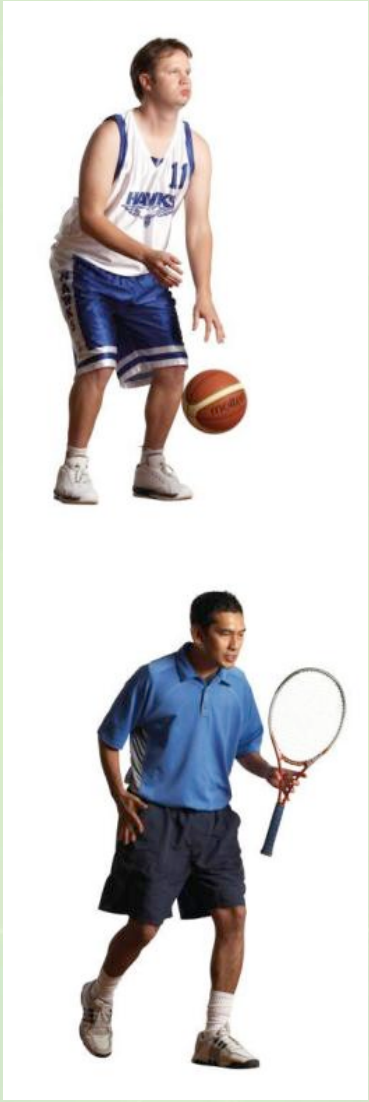
- Progressive relaxation
- Breathing control

Reducing cognitive anxiety:

- Autogenic training
- Thought stopping

Multimodal techniques:

- Stress inoculation training



Arousal/Anxiety reduction

The ***matching hypothesis***:

> The idea that cognitive anxiety should be reduced with mental relaxation, whereas somatic anxiety should be reduced with physical relaxation.

Units 1 & 2: Anxiety

Exam style question

Two players from the Fremantle Dockers come to you for advice on their pre-match states. One of the players indicates that he often feels physically tense and ill prior to games, even though he doesn't feel cognitively anxious. The other indicates that his physical symptoms aren't too bad but he worries about how he is going to perform and finds himself engaging in negative self-talk. Identify and explain the types of anxiety-reduction techniques would you recommend for these two players?

(4 marks)

Units 1 & 2: Anxiety

Answer

Two players from the Fremantle Dockers come to you for advice on their pre-match states. One of the players indicates that he often feels physically tense and ill prior to games, even though he doesn't feel cognitively anxious. The other indicates that his physical symptoms aren't too bad but he worries about how he is going to perform and finds himself engaging in negative self-talk. Identify and explain the types of anxiety-reduction techniques would you recommend for these two players? (4 marks)

The first player has described symptoms of somatic anxiety. (1 mark) He could use progressive relaxation or breath control techniques (that focus on reducing somatic anxiety). (1 mark)

The second player has described cognitive anxiety. (1 mark) For him, autogenic training or thought-stopping techniques could be employed. (1 mark)

OR

In addition, the coach could employ the stress inoculation technique (1 mark) (multimodal) at training to assist both somatic and cognitive anxiety. (1 mark)

Units 1 & 2: Arousal



Increasing arousal

- act energised
- listen to upbeat music
- use energising imagery
- use positive self-talk





Units 1 & 2: Stress

Stress:

A process in which there is a substantial imbalance between demand and response capability, under conditions where failure to meet that demand has important consequences.

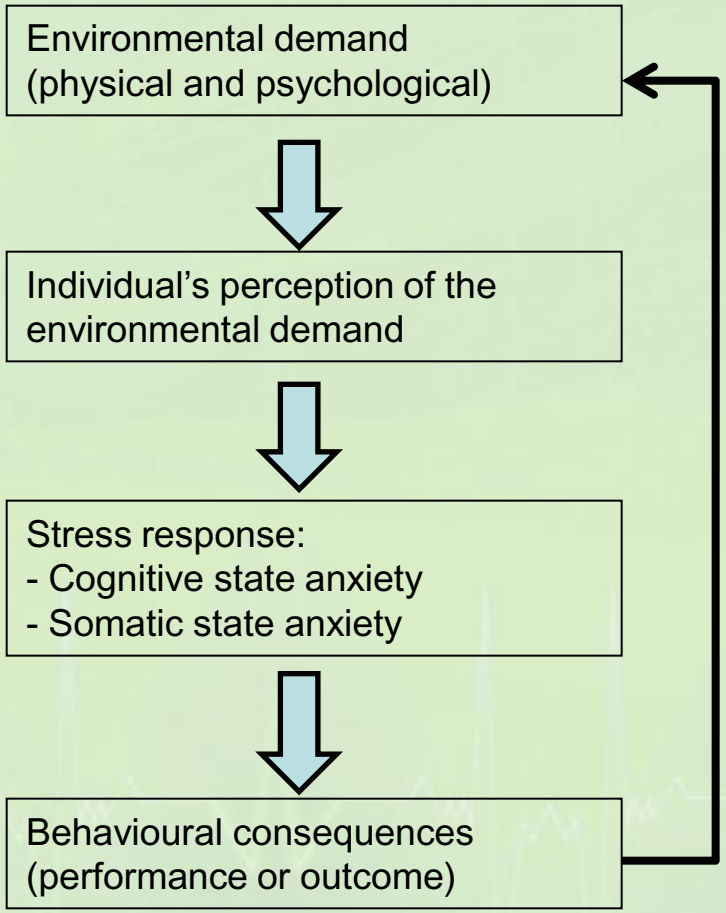


Four stages (McGrath, 1970):

1. Environmental demand
2. Perception of demand
3. Stress response
4. Behavioural consequence

Units 1 & 2: Stress

The stress process (McGrath, 1970)



Units 1 & 2: Stress

Exam style question

Two high school students have been asked to perform a difficult volleyball skill in front of the class. One of the students feels threatened by this task but the other student does not appraise the situation as threatening at all. Which stage in McGrath's stress model describes the importance of these appraisals?

(1 mark)

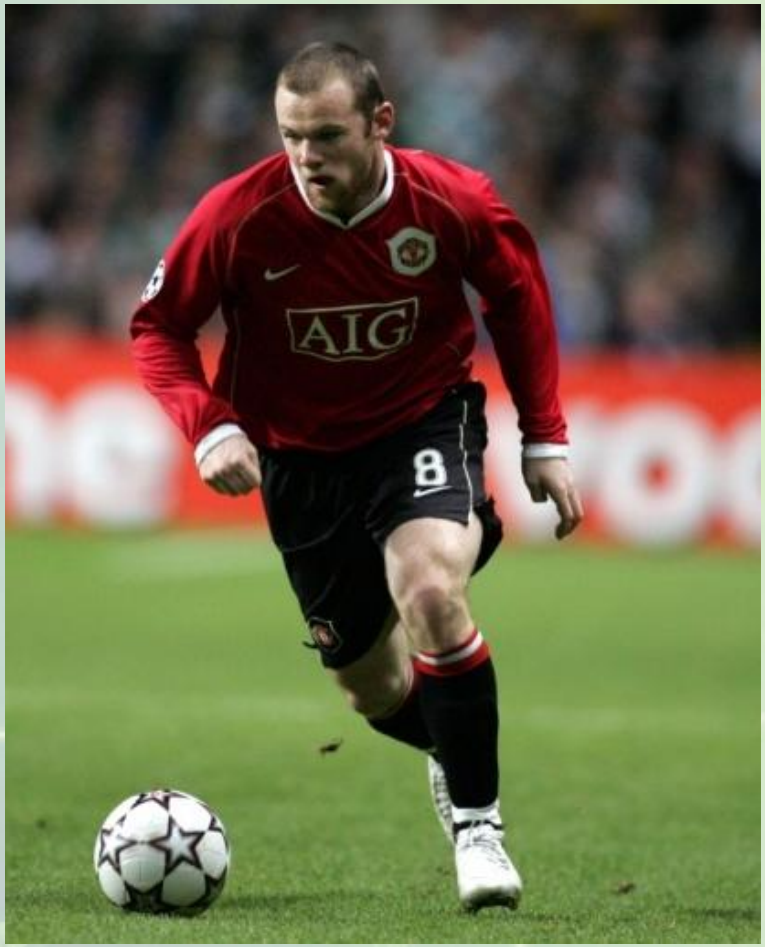
Units 1 & 2: Stress

Answer

Two high school students have been asked to perform a difficult volleyball skill in front of the class. One of the students feels threatened by this task but the other student does not appraise the situation as threatening at all. Which stage in McGrath's stress model describes the importance of these appraisals? (1 mark)

Perception of demand: Stage 2 of McGrath's model. These athletes appraised the stressors differently.

Units 1 & 2: Stress



Coping with stress

Problem-focused coping involves methods to manage the issue that is causing the problem.

Emotion focused coping involves the regulation of emotions to deal with the problem.

Units 1 & 2: Confidence

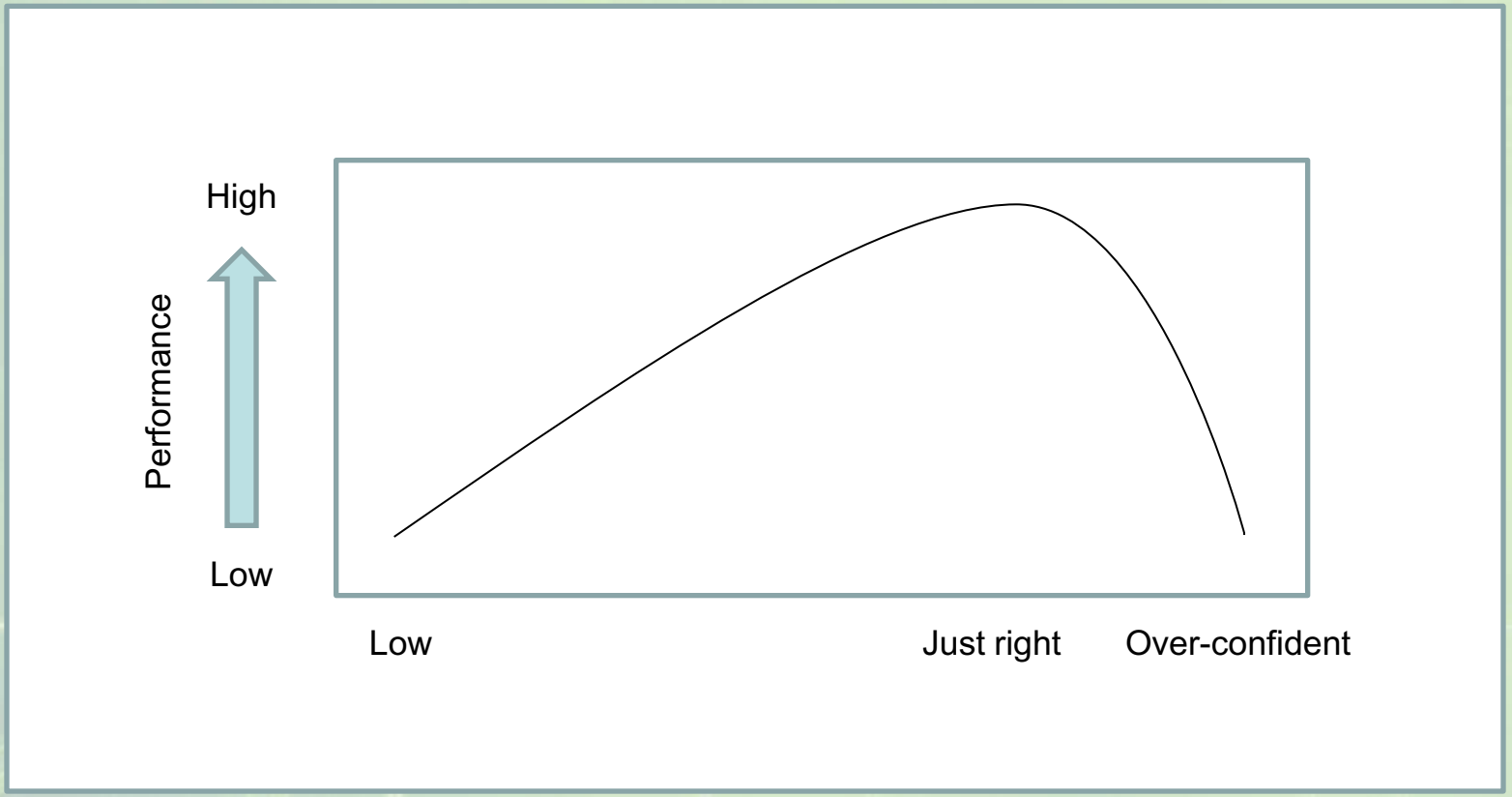
***Confidence*: Our expectations about success**

Reduces anxiety and influences concentration, emotions, goal setting, and persistence at tasks



Units 1 & 2: Confidence

Relationship between confidence and performance



Units 1 & 2: Confidence

Self-confidence is influenced by the following (Bandura, 1986):

- Performance accomplishments
- Vicarious experiences
- Verbal persuasion
- Imaginal experiences
- Physiological states
- Emotional states



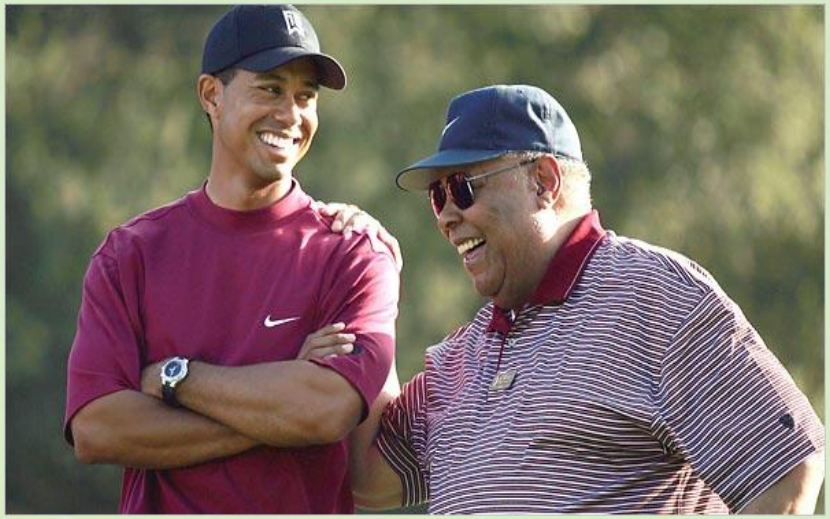




Units 1 & 2: Concentration

Concentration involves an ability to:

- Focus on relevant cues in the environment
- Maintain that focus over time
- Possess situational awareness
- Shift attentional focus



Units 1 & 2: Attentional Focus

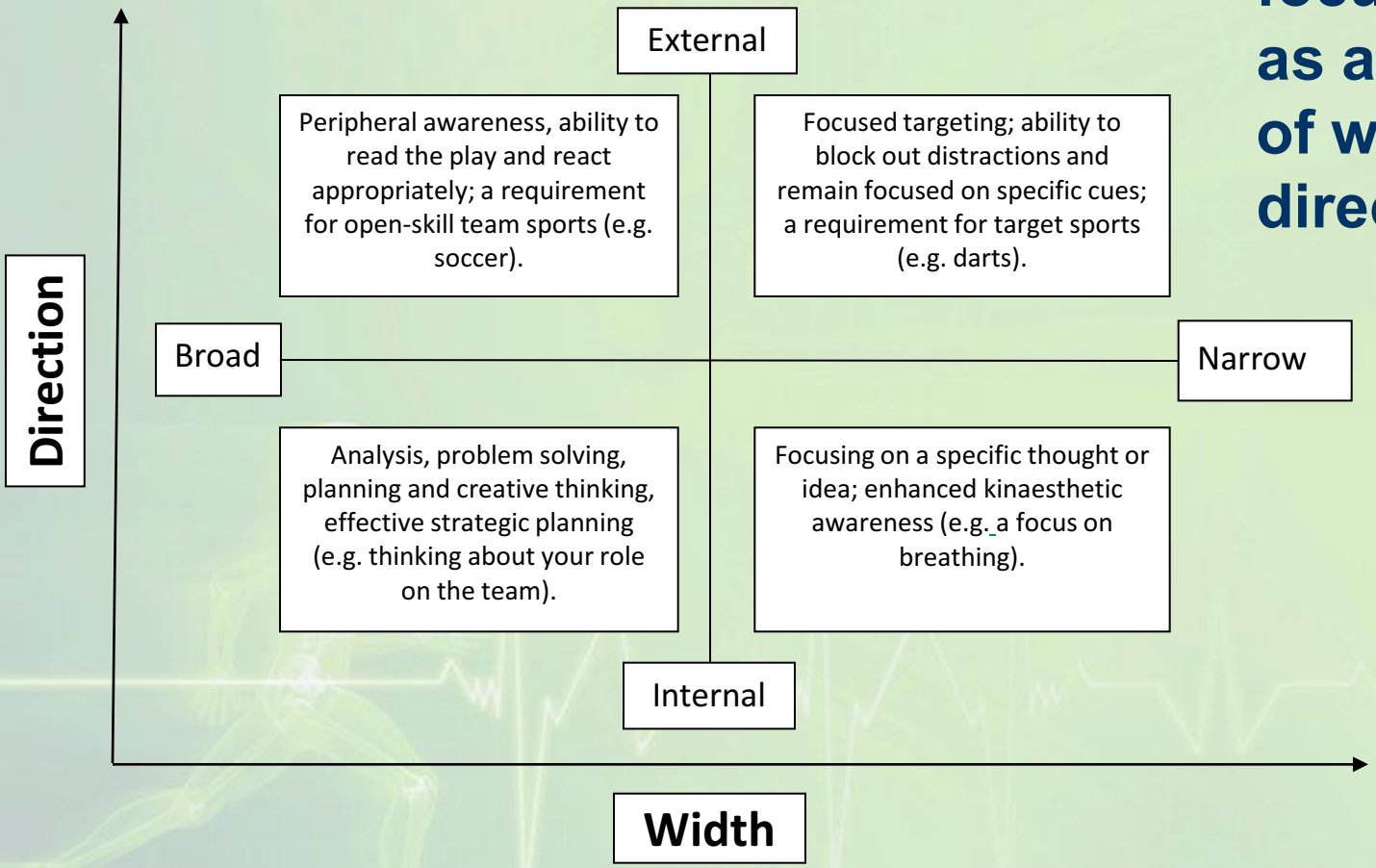




Attentional focus can vary according to whether it is ***narrow*** or ***broad*** or according to whether it is ***internal*** or ***external*** (e.g., Nideffer, 1981).

Units 1 & 2: Attentional Focus

Attentional focus varies as a function of width and direction



Units 1 & 2: Attentional Focus

Exam style question

Whilst swimming a 400 m medley race in a pool, the athlete is approaching the wall to complete the first 100 m (butterfly). They hit the wall and turn and begin the second 100 m (backstroke). Explain how the swimmer could employ broad, narrow, internal and external attentional focus.

(4 marks)

2A-2B: Attentional Focus

Answer

Whilst swimming a 400m medley race in a pool, the athlete is approaching the wall to complete the first 100m (butterfly). They hit the wall and turn and begin the second 100m (backstroke). Explain how the swimmer could employ broad, narrow, internal and external attentional focus. (4 marks)

Broad attentional focus may be used to scan the pool to determine their position relative to other swimmers. (1 mark) Worthy of note, this may not be recommended by coaches as it is seen to potentially have a negative effect on performance. A narrow attentional focus would be on the levelling of the head position to assist the body to minimise the amount of drag through the water. (1 mark) An internal attention focus would allow the swimmer to focus on how they are feeling (1 mark); slow and fatigued or fast and full of energy. The swimmer exemplifies an external attentional focus by focusing on the black 'T' on the bottom of the pool to judge their distance from the wall and when to initiate their turn. (1 mark)

Units 1 & 2: Goal Setting

Different types of goals:

- ***Objective goals*** focus on attaining a specific standard of proficiency on a task, usually within a specified time

- ***Subjective goals*** refer to general statements of intent that are not measurable

Units 1 & 2: Goal Setting

Principles of goal setting

Specific
- Goals should be specific rather than general and broad

Measureable
- An athlete should be able to measure goal accomplishment

Action oriented
- Athletes should specify how a goal is going to be achieved

Realistic
- Moderately difficult goals are best

Time-bound
- A time-frame for goal achievement should be identified

Self-determined
- Goals should have input from the participant

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Units 1 & 2: Goal Setting

Exam style question

A 10-year-old girl indicates that her dream is to play for the Hockeyroos. Identify the principles of short-term goal setting that the girl could adopt to progress her towards this long-term ambition.

(2 marks)

Units 1 & 2: Goal Setting

Answer

A 10-year-old girl indicates that her dream is to play for the Hockeyroos. Identify the principles of short-term goal setting that the girl could adopt to progress her towards this long-term ambition. (2 marks)

It is important that each short-term goal that is identified is developed in accordance with the SMARTS criteria. (1 mark)

It is also important that the athlete is prepared to alter their goals over time. (1 mark)

Units 1 & 2: Goal Setting

Exam style question

A 10-year-old girl indicates that her dream is to play for the Hockeyroos. Identify using two specific examples as to 'how and why' her goals might need to be reassessed during her progress to becoming a Hockeyroo.

(2 marks)

Units 1 & 2: Goal Setting

Answer

A 10-year-old girl indicates that her dream is to play for the Hockeyroos. Identify using two specific examples as to 'how and why' her goals might need to be reassessed during her progress to becoming a Hockeyroo. (2 marks)

Goals need to be reassessed for a variety of reasons. Below are some reasons why athletes should be prepared to reassess goals (select two of the following):

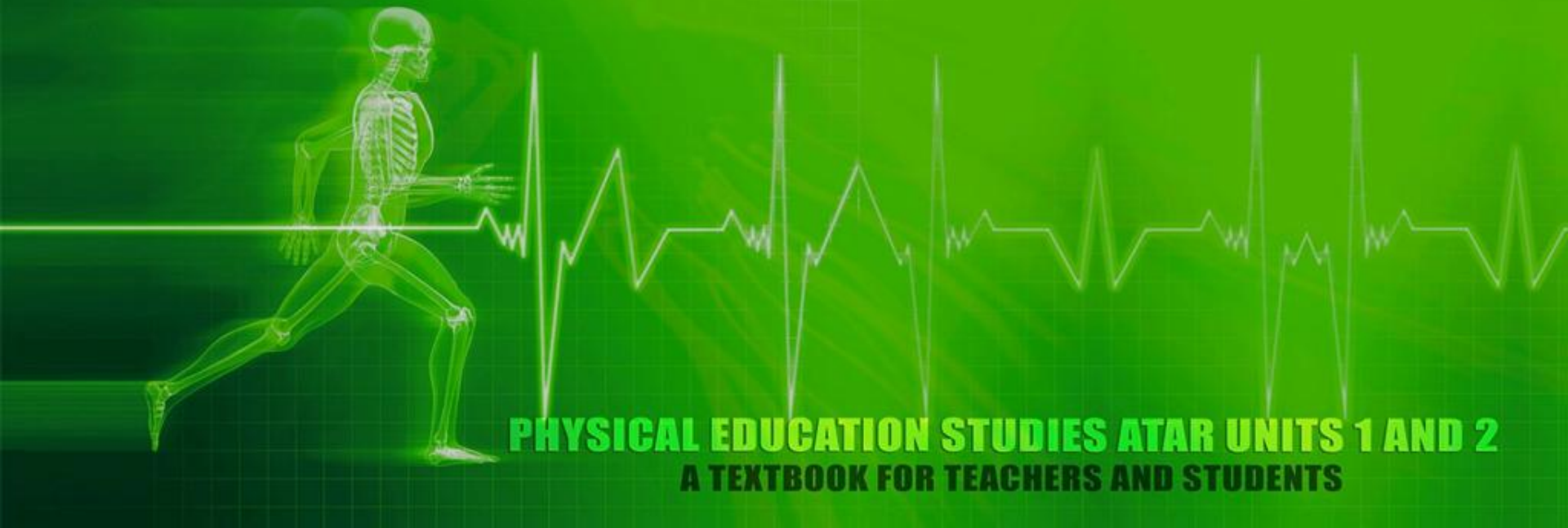
- *Injury*
- *Loss of form/confidence*
- *Issues away from hockey (such as family moving to rural area; need to commit extra time to studying for exams and so on)*
- *Slow physical maturation (meaning that they are not physically strong enough or quick enough to compete at defined levels)*
- *External decision making (for example, the junior hockey coach doesn't play you in your favourite position)*

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MOTOR LEARNING AND COACHING

Dr Brendan Lay

Dr Peter Whipp



Units 1 & 2: Skilled Performance

Highly skilled performers are:

- Faster
- More consistent
- Able to display greater control and timing
- More physiologically efficient
- Make correct decisions





Units 1 & 2: Motor, Perceptual and Cognitive Skills

Motor skill

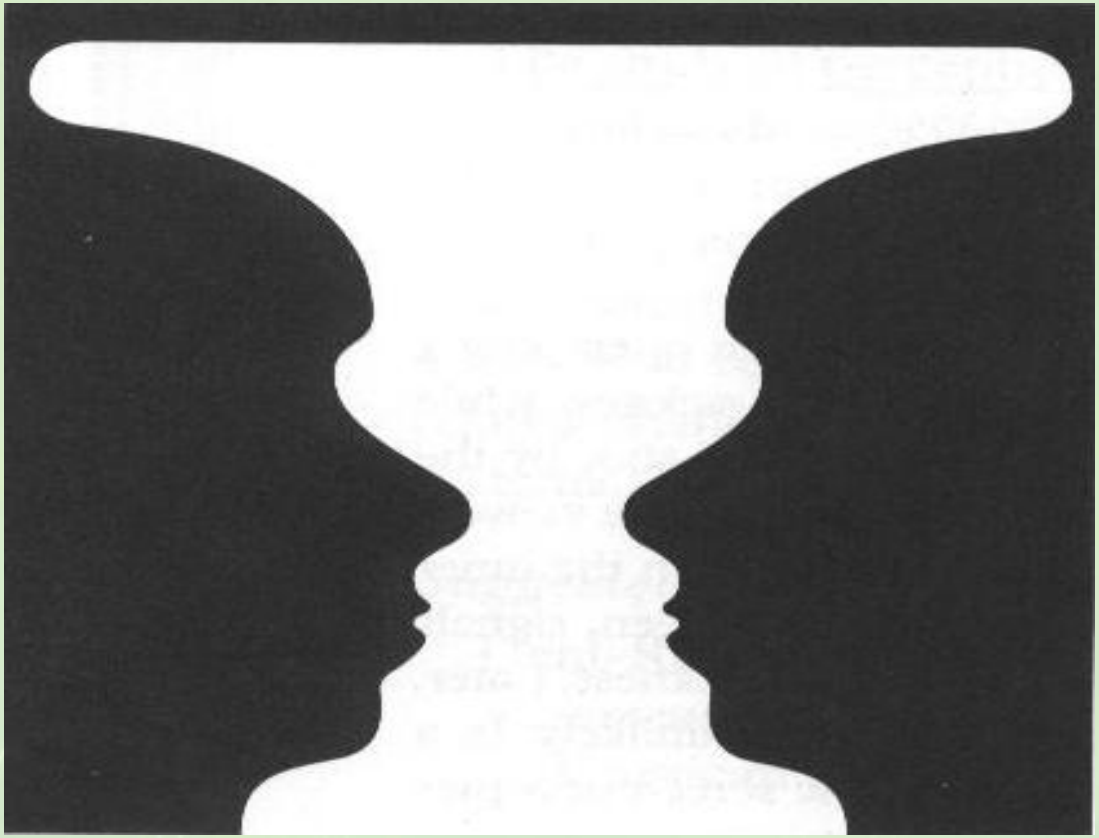
The learned ability to bring about pre-determined results with maximum certainty, often with minimum outlay of time or energy or both (Guthrie 1952)



Units 1 & 2: Motor, Perceptual and Cognitive Skills

Perceptual skill

The process of recognising and then interpreting information from the environment



Units 1 & 2: Motor, Perceptual and Cognitive Skills

Cognitive skill

The mental processing that incorporates:

- problem solving
- remembering
- decision making



Units 1 & 2: Skill and Skilled Performance

The superior perceptual and cognitive skills of expert sportspeople often provide them with more time to execute their motor skills than lesser skilled opponents







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Units 1 & 2: Motor Learning vs Performance

Motor Learning:

- a relatively permanent change in motor skill capabilities that is associated with practice or experience

Motor Performance:

- an observable behaviour at a specific time and location

Units 1 & 2: Motor Learning vs Performance

Performance

- Observable behaviour
- Temporary
- May not be due to practice

Learning

- Inferred from performance
- Relatively permanent
- Due to practice



Units 1 & 2: Classification of Motor Skills

Closed – Open motor skill

Closed skills:

- the performer dictates the timing of the skill
- the environment is predictable or stable



Open skills:

- the timing of the skill is dictated by factors external to the performer
- the environment is unpredictable or unstable



Units 1 & 2: Classification of Motor Skills

CLOSED SKILL

OPEN SKILL

- Serving in tennis
- Throwing a dart
- Delivering a lawn bowl



- Catching a wave on a surfboard
- Leading for the ball in Australian Rules football
- Returning the serve in tennis



Units 1 & 2: Classification of Motor Skills

Fine – Gross motor skill

- ***Fine motor skills:*** use controlled movement of small muscles
- ***Gross motor skills:*** use large muscles

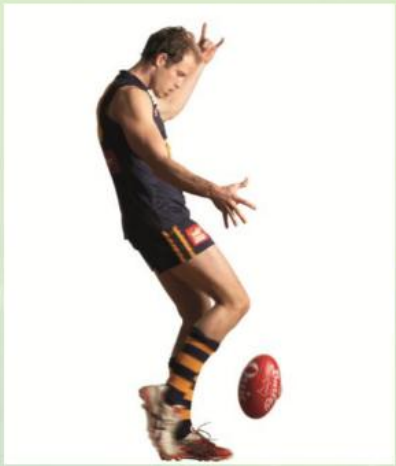
Units 1 & 2: Classification of Motor Skills

FINE SKILL ⟷ GROSS SKILL

- Writing your name
- Typing
- Pistol shooting



- Walking
- Running
- Kicking a football



Units 1 & 2: Classification of Motor Skills

Discrete – Serial – Continuous motor skill

- Discrete skills: identifiable start and finish
- Continuous skills: no distinct beginning and end points and contain repetitive movements
- Serial skills: a sequence of discrete skills together to form more complicated skills

Units 1 & 2: Classification of Motor Skills

DISCRETE SKILL

CONTINUOUS SKILL

SERIAL SKILL

- serving in tennis
- pitching a softball





- dance routine
- gymnastics floor routine

- running
- swimming
- cycling



Units 1 & 2: Classification of Motor Skills

Simple – Complex motor skill

The complexity of a motor skill is defined by:

- the amount of information to be processed
- the required level of movement precision or accuracy
- the time available to perceptually and cognitively process information

Units 1 & 2: Classification of Motor Skills

SIMPLE SKILL ⟷ COMPLEX SKILL

- throwing a dart
- throwing a bocce ball
- shooting an arrow



- catching a wave on a surfboard
- performing a gymnastics routine
- returning the serve in tennis



Units 1 & 2: Classification of Motor Skills

Exam style question

Using the example of batting in cricket, define this activity using the motor skill classification systems identified below and justify your choice.

(8 marks)

i. Is it a closed or open skill?

ii. Is it a fine or gross skill?

iii. Is it a discrete, serial or continuous skill?

iv. Is it a simple or complex skill?

Units 1 & 2: Classification of Motor Skills

Answer

Using the example of batting in cricket, define this activity using the motor skill classification systems identified below and justify your choice. (8 marks)

i. Is it a closed or open skill?

Batting in Cricket is an open skill (1 mark) as the initiation of any stroke will depend on when the bowler releases the ball and the movement of the ball through the air will also dictate changes to the batsmen's planned stroke. (1 mark)

ii. Is it a fine or gross skill?

There are elements of fine motor skill in batting such as the grip and how the wrists may move to perform different strokes, however, the major muscles involved in the task, including the legs, trunk and shoulders are large (1 mark) and the skill is best classified as a gross skill. (1 mark)

Units 1 & 2: Classification of Motor Skills

Answer

Using the example of batting in cricket, define this activity using the motor skill classification systems identified below and justify your choice. (8 marks)

iii. Is it a discrete, serial or continuous skill?

Batting in cricket is a discrete skill (1 mark) because each stroke has a definite beginning and end. (1 mark)

iv. Is it a simple or complex skill?

If we consider all of the components involved in performing a stroke (footwork, perceptual skill of watching the ball, preparatory arm movements and then the actual stroke) then it would be classified as closer to the complex end of this classification system (1 mark). Batting also requires the performer to concentrate on the ball about to be delivered, while also remembering where the fielders around them are placed which confirms that batting is a complex skill. (1 mark)

Units 1 & 2: Phases of Motor Learning

Cognitive phase of learning

- The athlete tries to gain an understanding of ‘what to do’
- Errors are large in number and magnitude
- The athlete has little capacity to correct their own errors
- Instruction and feedback from a coach can be very beneficial



Units 1 & 2: Phases of Motor Learning

Associative phase of learning

- The athlete is able to perform the basic skill
- The athlete is better able to adjust to the environment when performing the motor skill
- Errors become less in number and magnitude
- The athlete begins to detect and correct their own errors
- The athlete is encouraged to use their own feedback



Units 1 & 2: Phases of Motor Learning

Autonomous phase of learning

- The athlete does not consciously think about the specific movement characteristics of the skill
- The athlete can perform other tasks at the same time
- Low performance variability
- The athlete can detect their own errors and make adjustments to correct them



Units 1 & 2: Cues to Improve Performance

Visual cues

- Demonstration
- Visual aids
- Enhancing the visual environment

Units 1 & 2: Cues to Improve Performance

A verbal cue is a concise phrase that…

- Directs attention to the most important feature(s) in the performance environment
- Prompts performers to attend to the key components of the skill
- Should be appropriate for the learner

Units 1 & 2: Cues to Improve Performance

Kinaesthetic or Proprioceptive cues

Provides internal sensory information about joints, muscles and the orientation of a body in space



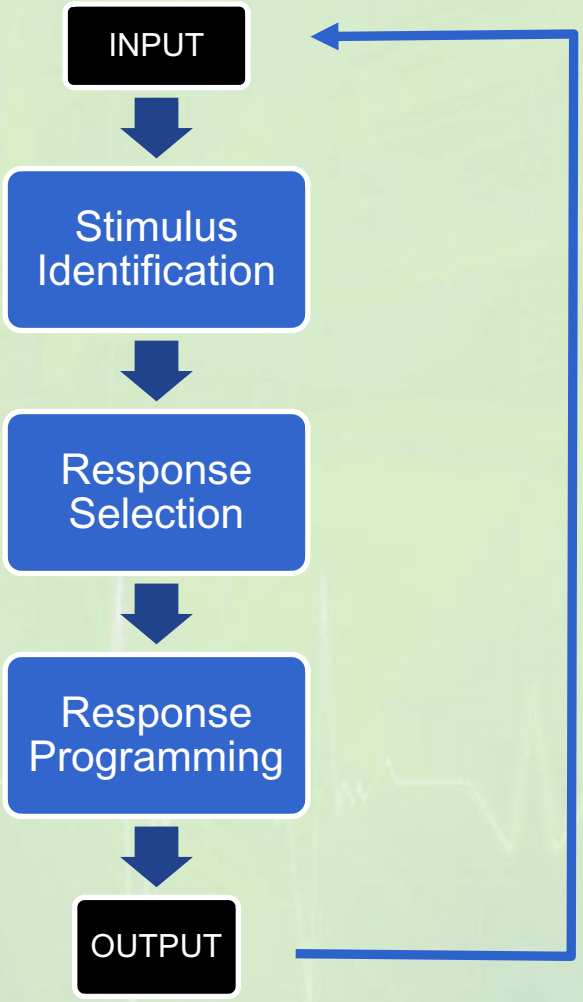




Units 1 & 2: Learning Styles

1. Visual (seeing)
2. Aural (hearing)
3. Read/write
4. Kinaesthetic (feeling or doing)

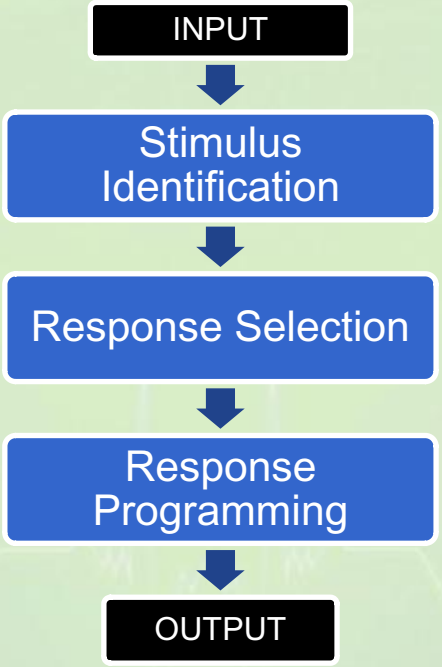
Units 1 & 2: Information Processing During Skill Performance



Units 1 & 2: 3-Phases of Information Processing

Phase 1 – Stimulus identification (PERCEPTION)

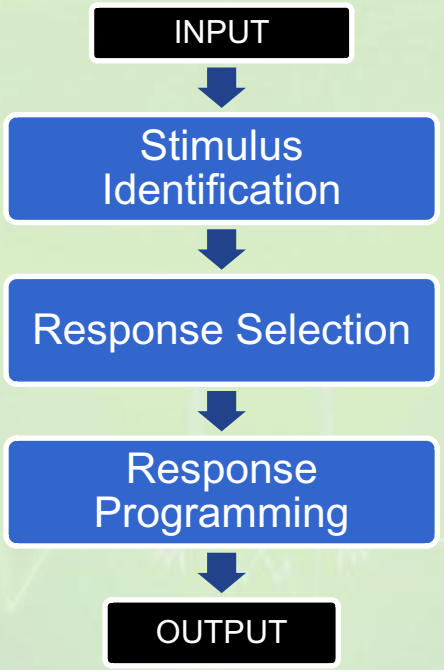
- Sensing and identifying a stimulus
- The individual analyses the environment for content
- From a variety of sources – vision, audition, touch, kinethaesis, smell etc…



Units 1 & 2: 3-Phases of Information Processing

Phase 2 – Response selection (DECISION)

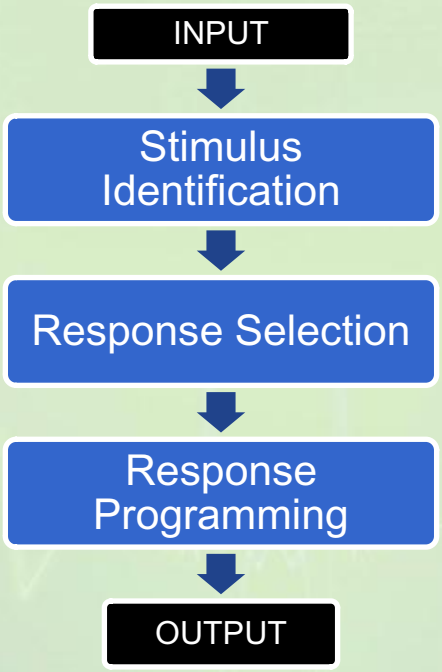
- ***Phase 2*** begins once the performer has sufficient information from ***phase 1***
- The decision of what, if any, response should be made



Units 1 & 2: 3-Phases of Information Processing

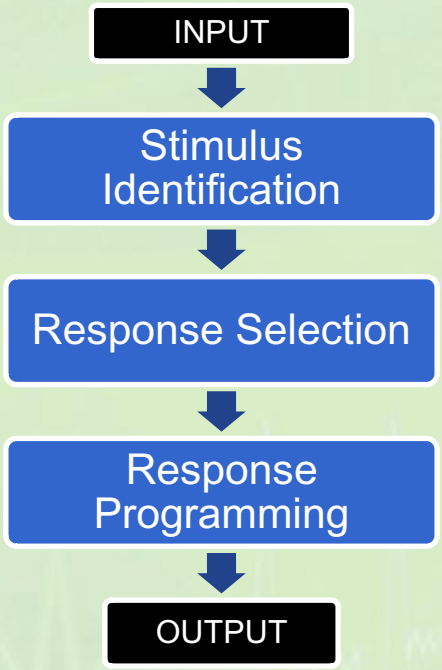
Phase 3 – Response programming (ACTION)

- ***Phase 3*** begins once the performer has decided what movement is to be made at ***phase 2***
- Preparing and organising the desired movement

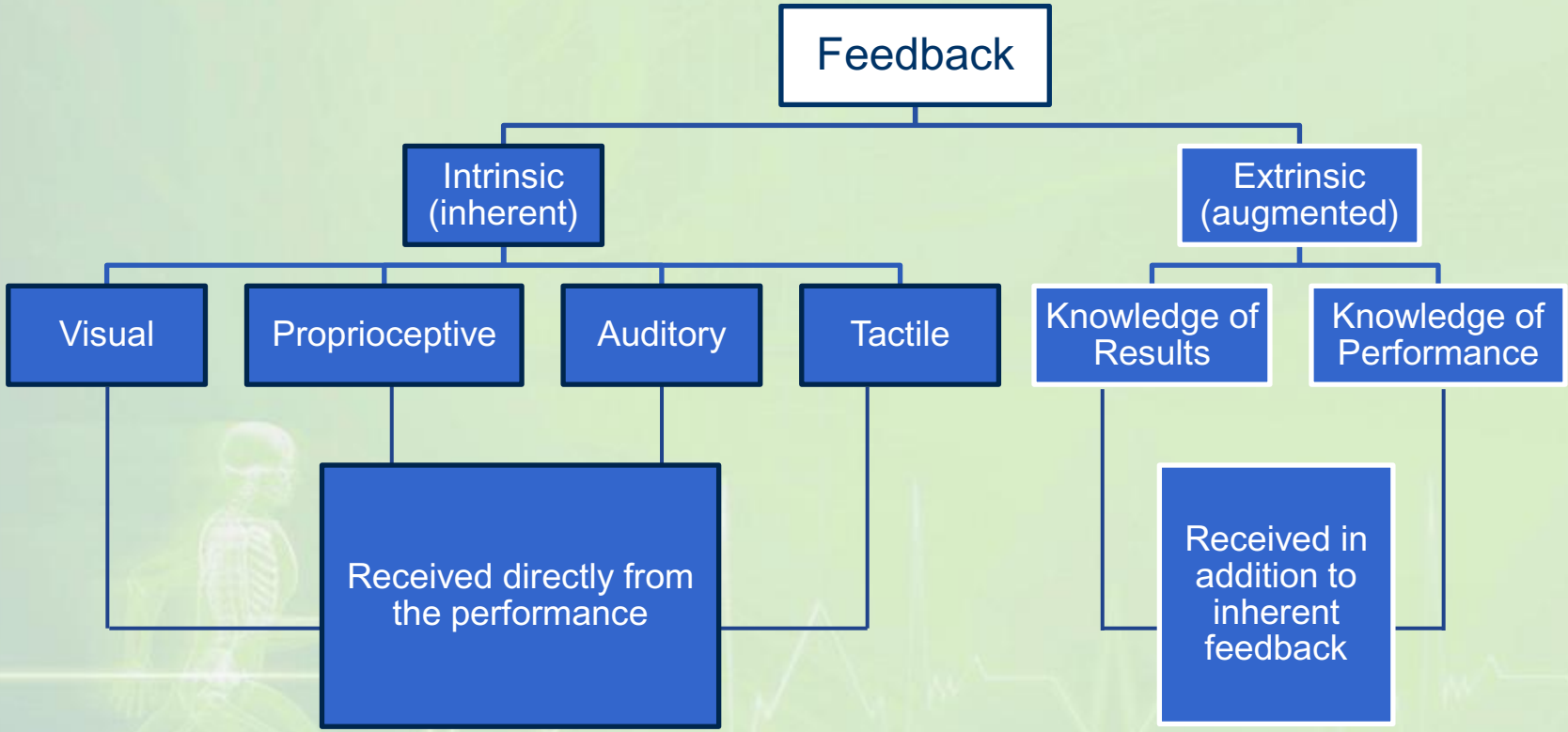


Units 1 & 2: 3-Phases of Information Processing

- After completing information processing, a movement is initiated which is the output
- Feedback, accessed during and after the performance, is used to improve subsequent performances



Units 1 & 2: Feedback Family



Units 1 & 2: Feedback for Motor Learning

Intrinsic (inherent) feedback

Sensory information that is a natural part of performing the skill

- Visual
- Proprioceptive
- Auditory information
- Tactile



Units 1 & 2: Feedback for Motor Learning

Extrinsic (augmented) feedback

Extra information that is not inherent to the task

- ***Knowledge of results (KR)*** – information about the movement outcome relative to the task goal
- ***Knowledge of performance (KP)*** – information about the nature of the movement pattern

Units 1 & 2: Timing of Augmented Feedback

Terminal feedback

Information presented after the performance that can be delayed or presented immediately after the performance is completed

Effective in all learning situations:

- A coach should not wait too long after the performance to provide feedback, and
- There should not be too much time after the feedback is provided before another practice attempt is made

Units 1 & 2: Timing of Augmented Feedback

Concurrent feedback

Information presented during the performance

- Good for continuous skills e.g. rowing, cycling



Units 1 & 2: Feedback for Motor Learning

Verbal feedback

- Serves to inform and reinforce or motivate and includes:
  - ***Qualitative*** - best used for the early phase of learning
  - ***Quantitative*** - best used for the later phase of learning
  - ***Descriptive*** - identifies the errors
  - ***Prescriptive*** - identifies the errors and a means to correct them

Units 1 & 2: Feedback for Motor Learning

Non-Verbal feedback

- Real-time cameras
- Mirrors
- Video replay
- Biofeedback

Units 1 & 2: Feedback for Motor Learning

- During the early phase of learning, extrinsic feedback should be provided consistently and immediately after the performance is completed
- Too much feedback can create a learner dependence
- Learners should be encouraged, through delaying extrinsic feedback, to self-evaluate performance using intrinsic feedback

Units 1 & 2: Feedback for Motor Learning

Exam style question

Discuss by comparing and contrasting the motor learning feedback that you would provide to a high-level performer (autonomous phase of learning) with the feedback you would provide to an individual in the early phase of learning (cognitive). Consider the following aspects;

- Immediate and delayed timing,
- Descriptive and prescriptive,
- Knowledge of results and knowledge of performance.

(6 marks)

Units 1 & 2: Feedback for Motor Learning

Answer Discuss by comparing and contrasting the motor learning feedback that you would provide to a high-level performer (autonomous phase of learning) with the feedback you would provide to an individual in the early phase of learning (cognitive). Consider the following aspects; (6 marks)

Early phase of learning (cognitive):

Immediate

- *Ensures that their performance is fresh in their mind*
- *With learners unable to interpret intrinsic feedback, the delay may not serve a purpose (1mark)*

Descriptive and Prescriptive

- *Describe what has happened, and*
- *Combined with prescriptive feedback, assists the learner to focus on what actions to do next time to correct the errors in performance (1mark)*

Knowledge of Performance

- *Facilitates more efficient performance actions, success and learning outcomes (1mark)*

Units 1 & 2: Feedback for Motor Learning

Answer Discuss by comparing and contrasting the motor learning feedback that you would provide to a high-level performer (autonomous phase of learning) with the feedback you would provide to an individual in the early phase of learning (cognitive). Consider the following aspects; (6 marks)

Final phase of learning (autonomous):

Immediate or Delayed Feedback

- *Beneficial to high-level performers if they are given the opportunity to reflect on and correct their own performance before the coach provides feedback (1 mark)*

Descriptive and Prescriptive

- *Less prescriptive and more descriptive with feedback because at the autonomous stage of learning the athlete can correct their own errors and should be encouraged to do so (1 mark)*

Knowledge of Results and Knowledge of Performance

- *Both KR and KP can be used because high-level performer can correct their own errors*
- *That said, it is always important for a coach not to let their athletes develop bad habits with their technique. (1 mark)*

Units 1 & 2: Skill Learning and Individual Differences

Considerations for skill learning programs

The characteristics of the individual:

- Age
- Skill level
- Fitness level
- Injury

Units 1 & 2: Skill Learning and Individual Differences

Considerations for skill learning programs

The characteristics of the task that is being practised:

- Type of activity, which is impacted by all of the individual difference variables
  - ***Physical:*** age, skill level, fitness level and injury
  - ***Psychological:*** motivation, confidence, arousal, anxiety, concentration, personality, group dynamics and inter-personal relationships

Units 1 & 2: Skill Learning and Individual Differences

Considerations for skill learning programs

The environment in which the task is being performed:

- Level of competition
  - Matching training to the needs and aspirations of the individual