CHAPTER 7

SPORT SCIENCE

CHAPTER OUTCOMES

Successful completion of this chapter will allow you to:

- Identify chemical compounds in food and state their function.
- Describe how athletes' diets may vary according to the type of event they compete in.
- Explain the role of enzymes in controlling chemical reactions in cells.
- Explain the difference between aerobic and anaerobic respiration.
- Explain the relationship between respiration and sports performance.
- Identify features that are used to predict an athlete's sporting skills.
- Discuss variations in training methods that coaches may use for athletes.
- Identify and explain some of the issues associated with the use of drugs to improve sports performance.
- Identify some of the personnel involved in sport science and explain their roles.

When the Russian swimmer, Aleksandr Popov, won the gold medal for the 100 m freestyle swimming event at the 1992 Barcelona Olympics, spectators marvelled at his smooth and apparently effortless swimming style. Popov was to become the most successful freestyle sprint swimmer of the 1990s, holding world records for most of the decade.

Popov followed his swimming coach, Gennadi Touretski, to Australia in 1993. Since then he has trained at the Australian Institute of Sport, Canberra while continuing to represent Russia at international swimming events. Touretski is also Michael Klim's swimming coach. The outstanding success of both swimmers has been attributed to Touretski's coaching methods.

He used his background in engineering and biomechanics (the study of how living things move). His swimmers train with 'superslow' laps, with head and chest pushed down to reduce drag. Touretski knows that waves forming at the water surface slow them down. If a swimmer's speed in the water doubles, the effect of this surface drag increases by a factor of 8. In 1998, the head scientist of the Russian team calculated that Aleksandr Popov, with his smooth style, used 30 per cent less energy than other swimmers at the same speed.

Touretski gets his swimmers to practise smooth arm movements by rotating their arms with a kayak paddle at the side of the pool. He uses a towing machine to drag swimmers through the water faster than they can swim. This helps them learn the best position for their body at the water surface.

The results of scientific studies are now used by all coaches in preparing athletes for important events. They must consider the effect of diet on performance and the way different training schedules affect fitness. Like Touretski, they also use biomechanics to make body movements of an athlete more efficient.

In this chapter, you will learn more about such training methods and the impact that science has on sport.

7.1 An athlete's diet

FIGURE 7.1
An athlete's body needs the right fuel if it's to produce the best possible performance.

Talk about
What substances are found in food? Why do living cells need these substances?

The main chemicals obtained from food and drink and found in the human body are water, proteins, carbohydrates and lipids. The proportions of these substances are shown in Figure 7.3.

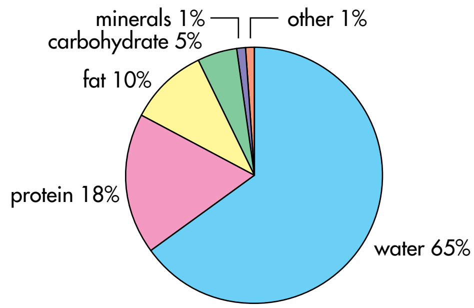


FIGURE 7.3
Composition of the human body.

Proteins

Proteins are the main building molecules in organisms and also form enzymes (see Section 7.2). There are thousands of different proteins, many of them very large and complex molecules. They are made up of smaller units called **amino acids**, of which there are twenty types. (Figure 7.2a).

Carbohydrates

There are two basic types of carbohydrate: **simple sugars** and **complex carbohydrates** (Figure 7.2b). The sugars include glucose, sucrose (table sugar) and lactose (milk sugar). The simplest of these is **glucose**. It is the body's main fuel, used in cellular respiration to release energy required for most body functions (e.g. movement). Complex carbohydrates include starch and **glycogen**. These are made up of long chains of glucose molecules. Glycogen is stored in the liver and in muscles. Starch is stored in plants.

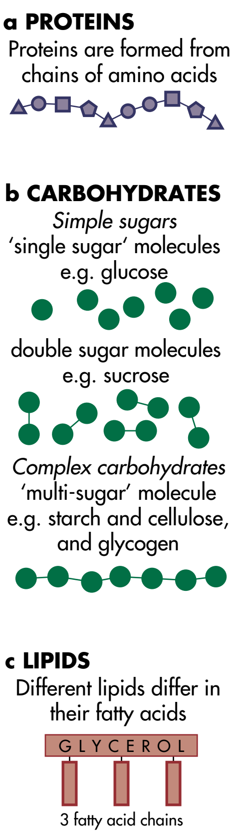


FIGURE 7.2
The chemicals of life.

Lipids

Lipids are the fats and oils (Figure 7.2c). They are energy-rich and can be converted to carbohydrates or used directly to release energy. In animals, stored lipids can also serve as insulation. Lipids, together with proteins, also make up a part of all cell membranes. In the body lipids are often in the form of large molecules made out of smaller units—glycerol and three fatty acids—known as **triglycerides**.

Vitamins

Vitamins are made mainly by plants and are required by humans in only very small amounts. The role of many vitamins is to help enzymes to function. They also act as antioxidants to destroy free radicals. Free radicals are released as oxygen reacts with carbohydrates and lipids. They damage cell structures.

Minerals

Minerals are not an energy source but are important for normal body functioning. Examples are iron to help make the haemoglobin in red blood cells, calcium for bones, and iodine to make the hormone thyroxin. Some enzymes need certain minerals to function.

Eating to compete

Protein is very important in the diet of an athlete as it provides the raw materials needed to build up the mass of muscles, as well as for the growth and repair of all body cells. Carbohydrates and lipids are important because they are the fuels that provide the energy for activity, such as muscle contraction.

The advice that a sport scientist gives about diet depends on the event. A sprinter needs a quick boost of energy. A sports drink containing glucose will provide a quick supply of glucose, but the release of insulin by the body may then quickly drop the level of glucose too low. Some studies suggest that a diet of potato or bread before an event can supply the same amount of glucose to the blood, but at a more steady level.

A marathon runner needs a steady energy supply for over 2 hours. Carbohydrate loading may be used to increase the levels of glycogen in muscle for such endurance events. For 3 days before the event, the athlete eats a diet rich in complex carbohydrates (e.g. pasta) and does only light training.

Latest evidence suggests that the type of diet just before an event is not as important as previously thought. Instead, regular consumption of energy drinks throughout endurance events is effective, though not always possible (e.g. in a long distance swimming event). Recent studies have also shown that foods such as dairy foods, lentils, oats and apples can result in steady levels of glucose in the blood for long periods.

FACT FILE

1 g of lipid gives twice as much energy as 1 g of any carbohydrate or protein.

EXPERIMENT 1 TESTING FOODS FOR VITAMIN C

AIM
To compare the amounts of vitamin C in different fruit juices.

MATERIALS
- small measuring cylinder
- large test-tube or small beaker
- teat pipettes
- fresh DCPIP solution (an indicator that turns from blue to clear in vitamin C)
- at least two fruit juices

METHOD
1 Using the measuring cylinder, put 2 mL of DCPIP into a large test-tube.
2 Using a teat pipette, add one of the fruit juices 1 drop at a time into the DCPIP until the blue colour completely disappears.
3 Record the number of drops you added.
4 Repeat the procedure for the other juice.
5 You may wish to repeat steps 1 to 4 to gain an average for each of the juices.

RESULTS
Record your results in a table and a column graph.

DISCUSSION
1 List the juices in order of most to least vitamin C.
2 How did you make sure that your comparison test was fair?

EXTENSION
It is claimed that boiling fruit and vegetables eventually destroys the vitamin C. Design and carry out an experiment to see if this is correct.

Questions

1 In what form does the liver store glucose?
2 What two chemicals are needed to make cell membranes?
3 What are two advantages of storing energy as lipids?
4 What are the building blocks of:
a proteins?
b lipids?
5 What differences might there be between the diet of a sprinter and the diet of a long distance runner?

Think about

Why do people take vitamin tablets? Do you?

7.2

Enzymes—catalysts of life

FACT FILE

By international agreement, enzyme names end in -ase. The first part(s) of the name generally refers to what it is acting on, and sometimes its method of action. For example, sucrase breaks down the carbohydrate sucrose.

At any one time in the body, thousands of chemical reactions are happening. In some cells there may be hundreds of different reactions occurring simultaneously. How then does each cell control which reactions occur—when, where and how fast? How does the cell stop them from interfering with each other? More basically, how does the cell make them happen at all? Glucose in a beaker will not release its energy, nor turn into starch on its own. What is required to make these reactions happen?

The answer to all of the above questions is: with enzymes.

Enzymes are complex protein molecules which act as biological catalysts. A **catalyst** is a substance that speeds up a reaction but is not used in the reaction itself.

Enzymes can work fast and efficiently. The enzyme you will be using in the experiment, **catalase**, can be involved in up to 5 600 000 reactions per minute.

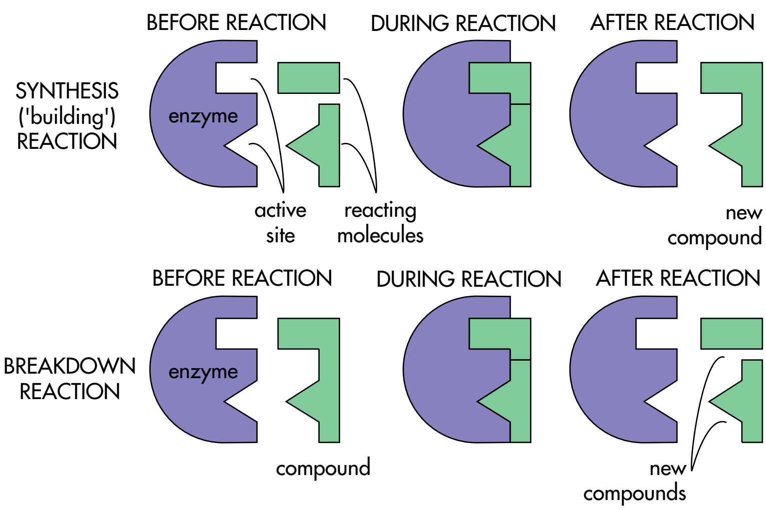


FIGURE 7.4
Enzymes speed up the rate at which both synthesis and breakdown reactions occur by helping to bring the reacting molecules together or breaking them apart. The suggested mode of action is described as 'lock and key'.

For each separate type of chemical reaction in the body there is a separate enzyme. This is because each enzyme has a particular shape, which matches up exactly with the reacting substance or substances (the **substrate**). The substrate locks in to a particular place in the enzyme called the **active site** in a process often described as '**lock and key**' (Figure 7.4). In this way, one kind of enzyme has only one job, and so the cell can control which reactions occur by controlling which enzymes are available at the time.

Some enzymes operate inside a cell: for example, those that speed up the breakdown of glucose to release energy. These enzymes are called **intracellular enzymes**. Others, such as digestive enzymes, work outside cells. These are called **extracellular enzymes**. In the experiment you will be working with an intracellular enzyme.

By having chemical reactions catalysed by enzymes, and by having a separate enzyme for each reaction type, the cell can control the complex array of reactions in an orderly fashion.

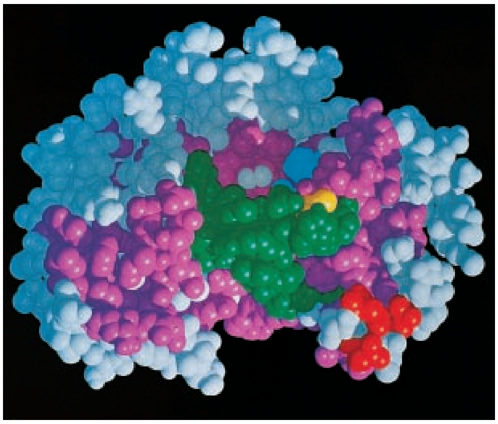


FIGURE 7.5
A computer model of the cell regulation enzyme CDK-2.

EXPERIMENT 2 INVESTIGATING A COMMON ENZYME

INTRODUCTION

Hydrogen peroxide (H_2O_2) is a mildly poisonous substance formed by many living cells: for example, when they are damaged. Cells therefore have to destroy it as soon as possible. The enzyme catalase breaks it down to harmless water and oxygen.

$$2H_2O_2 \xrightarrow{\text{catalase}} H_2O + O_2$$

AIM

To see the reaction of catalase, and to examine what factors affect the rate of the reaction.

MATERIALS

- 7 large test-tubes or vials
- spatula
- measuring cylinder
- 3% hydrogen peroxide
- detergent or liquid soap
- sand
- liver
- wood
- ruler
- cheese
- leaf
- stopwatch

METHOD

1 In each test-tube put 5 mL of hydrogen peroxide and 3 drops of detergent.

2 Add about 5 mm^3 of the following samples, one per test-tube:
whole liver; ground liver; boiled liver; finely chopped leaf; cheese; sand; wood.

3 Measure the height of the foam formed in each test-tube after 1 minute (Figure 7.6).

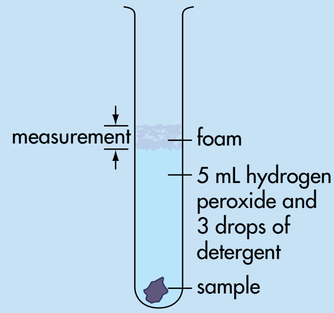


FIGURE 7.6

RESULTS

1 Enter the results in a table.

2 Draw a bar graph of your results.

DISCUSSION

1 Which substances appeared to contain catalase?

2 Which substance contained the most enzyme? How did you know?

3 What effect did boiling have on the enzyme?

4 Catalase is an intracellular enzyme. How is this statement supported by your observations with the ground liver?

5 Write a conclusion for the experiment.

EXTENSION

1 How could you show that gas given off during the breakdown of hydrogen peroxide was oxygen?

2 Design and carry out an experiment to show either:

a the effects of different temperatures on the activity of the enzyme, or

b the effects of pH on the activity of the enzyme.

Questions

1 Why are enzymes called biological catalysts?

2 What is the active site of an enzyme?

3 Why can an enzyme and its substrate be compared to a lock and key?

Think about

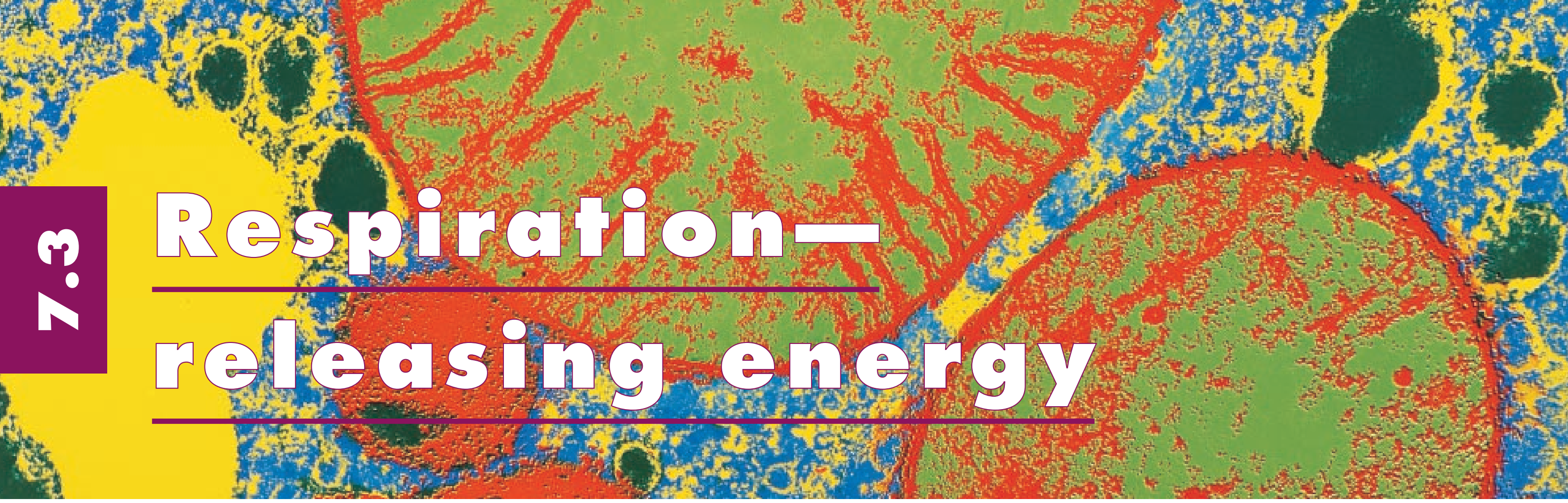
1 Why would the enzyme that breaks down the sugar sucrose not break down another sugar (e.g. maltose) as well?

2 Boiling an enzyme makes it unravel and change shape. Why would it not then do its job?

3 Why is it important for a cell that enzymes are not used up in reactions?

FACT FILE

Co-enzyme 10 is used to reduce inflammation of sports injuries. It is thought to increase the supply of oxygen at the injury site.



7.3 Respiration—releasing energy

FIGURE 7.7
The mitochondrion — power house of a cell.

> **FACT FILE**
>
> **There are two types of muscle fibres: fast twitch and slow twitch. Slow twitch fibres have more mitochondria for aerobic respiration and are important in endurance events. Fast twitch fibres produce their energy from anaerobic respiration and are important in power events.**

Our bodies need energy for:

- movement—even the smallest muscle movement requires energy;
- sending nerve messages—chemical energy is converted to electrical energy in nerve cells;
- building large molecules—energy is used to stick smaller molecules together;
- heat—released as a byproduct in energy-releasing reactions;

The energy used is obtained from the food eaten by respiration. There are two types of respiration that may occur: aerobic and anaerobic.

Aerobic respiration

Aerobic respiration uses oxygen. It involves many reactions but is summed up in the formula

glucose + oxygen → carbon dioxide + water + energy

In cells these reactions occur in organelles called **mitochondria** (Figure 7.7). Cells that need to release a lot of energy (e.g. muscle) have many mitochondria.

It is the function of the respiratory and circulatory systems to supply the oxygen to the cells and to remove the carbon dioxide.

FIGURE 7.8
These athletes are using energy to power their muscles. Chemical energy is being converted to movement. Heat also is being produced.

Aerobic respiration extracts the maximum amount of energy from the glucose, because the molecule is completely broken down.

Anaerobic respiration

Sometimes oxygen demand in cells cannot keep up with supply. This can occur with vigorous activity. In this situation there is a back-up system which releases energy without oxygen: **anaerobic respiration**:

glucose → lactic acid + energy

Unlike aerobic respiration, this reaction occurs in the cytoplasm of the cell.

This reaction releases a fraction of the energy made available by aerobic respiration (about one-eighteenth). It does not make carbon dioxide, so does not put extra pressure on the respiratory and circulatory systems. Unfortunately, the lactic acid makes muscles stiff and sore after exercise.

Yeast cells also carry out anaerobic respiration, but with different products:

glucose → alcohol + carbon dioxide + energy

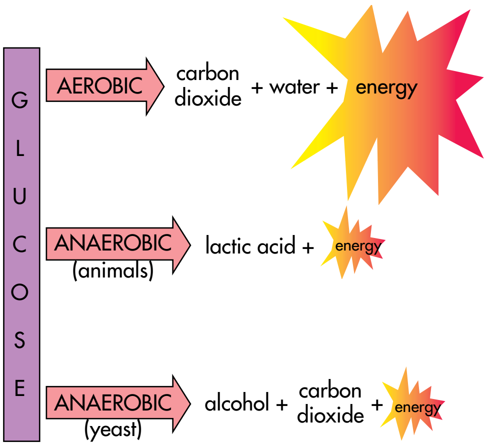


FIGURE 7.9
Glucose can be used in three ways by organisms to produce energy.

EXPERIMENT 3 CARBON DIOXIDE PRODUCTION

AIM

To show that the air we exhale contains more carbon dioxide than inhaled air.

MATERIALS

- carbon dioxide generator
- bromothymol blue indicator
- 2 large test-tubes
- glass tubing and fittings

METHOD

1 Your teacher will bubble some carbon dioxide through a test-tube of bromothymol blue to show you the colour change.

2 Set up the apparatus as shown in Figure 7.10. Use the same amount of bromothymol blue and water in each tube.

SAFETY CHECK: Do not begin until your teacher has made sure that the fittings are exactly as shown in Figure 7.10, to prevent you from inhaling any solution.

3 Breathe in and out gently through the mouth tube. Note which tubes bubble during inhalation and exhalation.

4 Continue until there is a change of colour in one of the tubes.

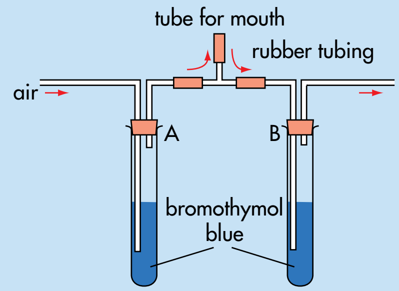


FIGURE 7.10

RESULTS

Copy the diagram of the apparatus into your work book and indicate what you saw in each tube as you inhaled and exhaled, and any colour changes.

DISCUSSION

1 How does this experiment show that carbon dioxide is produced in our bodies?

2 Describe the process that produces this gas.

EXTENSION

1 Count the number of breaths it takes to change the colour of the indicator. Now do 2 minutes of exercise and see the change in the number of breaths.

2 Use this technique to design and carry out an experiment to show how the amount of exercise increases the rate of cellular respiration.

This series of reactions is also called **fermentation**. Humans use this ability of yeast to make alcoholic drinks and in food manufacture.

Food and energy

Although glucose is the starting point for the reactions, the body can use other substances. Our bodies convert excess glucose into glycogen and store it in the muscles and liver. Glycogen can be easily converted back to glucose for respiration. Likewise, fat stores can be used for energy, but they are harder to access than glycogen. Protein is not used in respiration unless our bodies are in a state of starvation or doing extraordinary activity such as marathon running.

Questions

1 What is the difference in meaning between the terms 'aerobic' and 'anaerobic'?

2 What is an undesirable side effect of producing lactic acid in muscles?

Think about

1 Why does a person use more oxygen when exercising?

2 Why does the body need to store glycogen and fat?

3 Animals still consume energy while sleeping. Explain why.

FACT FILE

The organ that uses most energy is the brain. Nerve cells cannot respire anaerobically for more than a couple of minutes. After that, they die if they do not receive oxygen.

7.4

Respiration and human performance

FACT FILE

On average, a person breathes 6 L of air per minute while resting. This can increase to more than 100 L of air per minute during exercise.

FIGURE 7.11
Different types of exercise use different energy systems.

Talk about
What makes one person perform better than another? What happens to your body as you become fitter through training?

As we have seen previously, energy can be made available for cells in two ways: by aerobic and anaerobic respiration. This energy is stored, ready for immediate use, in a special molecule called **ATP**. Aerobic respiration causes thirty-six ATP molecules to be made, but only two are made by anaerobic respiration.

How are muscles supplied with energy as they are working? Imagine that you are going to run at a moderate rate for 5 minutes. The first source of energy used is stored ATP made by earlier respiration. After a few seconds, anaerobic respiration starts to occur, and after 1 minute it is supplying half of the energy needs. At about this time, aerobic respiration begins to increase slowly. It becomes the main supplier of energy after about 3 minutes.

Why is there the time delay until aerobic takes over? First, it involves a longer series of reactions than the anaerobic system. Second, as the body responds to the demands of your muscles, it delivers more blood, and so more oxygen, to the muscles. This takes time. Of course if at any stage you become puffed, it means that your body is not supplying the amount of oxygen that your muscles are demanding. The result is that you will change back to the anaerobic reaction. You will have less energy available, and are more liable to have stiff, sore muscles at the end. If you were racing against someone who did not become puffed, the other person would be releasing more energy from aerobic reactions and would be more likely to win.

Fuel

Glycogen and fats are both converted into glucose for the respiration reactions. Running low on glycogen causes muscle fatigue and a loss of performance. Training and correct dietary habits allow a person to build up their glycogen stores.

Changes during exercise

The body needs to deliver as much oxygen to the muscles as possible during exercise, so the circulatory and respiratory systems have to respond. The following changes occur:

- The heart rate increases—the maximum should be 220 minus your age.
- More blood is pumped per heart beat.
- Blood pressure increases.
- Blood is diverted away from organs such as the kidneys and digestive system, with more going to the muscles and to the heart muscle itself.
- Rate and depth of breathing increase.

The overall result can be a twenty times increase in the amount of oxygen a person can take into the blood and use. This level will be higher for a fitter person. How fit are you?

EXPERIMENT 4 MUSCLE FATIGUE

INTRODUCTION
Muscle fatigue is caused largely by a build-up of lactic acid in the muscles. This accumulates when there is a shortage of oxygen in the muscles.

AIM
To observe the factors affecting muscle fatigue during exercise.

METHOD
PART A: ARM RELAXED
1 Squeeze a soft foam or rubber ball as many times as you can in 30 seconds. Get someone to time for you while you keep count.
2 Have 10 seconds rest.
3 Repeat steps 1 and 2 ten times.
4 Enter your results in a table showing the number of grasps per trial. Label the row 'Normal'.

PART B: ARM RAISED
1 Now raise your hand fully above your head.
2 Repeat the experiment as in part A but without ever lowering your arm.
3 Enter your results in the table in a new row labelled 'Arm raised'.

RESULTS
Graph your results. You will have two lines in your line graph: 'Normal' and 'Arm raised'.

DISCUSSION
1 Was there any evidence of fatigue in part A ? Explain.
2 What would raising your arm do to:
a the blood supply in your arm?
b the supply of oxygen to your arm muscles?
3 What happened to your performance with your arm raised?
4 In which part would there be the most lactic acid build-up? Explain.
5 Describe the sensations in your forearm muscles during the practical.

CONCLUSION
What can you conclude about the relationship between exercise, muscle fatigue and blood supply?

Questions
1 What are the three energy systems?
2 What are the main fuels for these systems?
3 Why is it important to have an efficient circulatory system?

Think about
1 Which energy system would be used most during each of these activities?
a jogging **b throwing**
c jumping **d 800 m swim**
e basketball
2 Look at Figure 7.12.
a Which energy system provides the most energy for each of the events?
b Explain why each system is appropriate for the event.

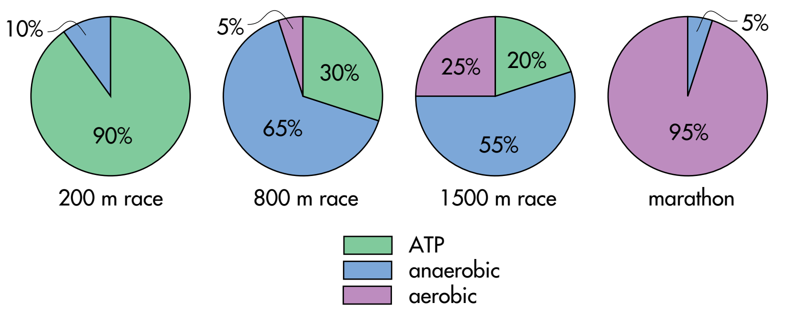


FIGURE 7.12
A comparison of the contribution of each of the energy systems in different activities.

c What changes occur as the events become longer?

Find out
Some athletes drink soda water to help reduce muscle soreness. This is called soda loading. What substance is the soda supposed to be reacting with? What studies have been done to test the effectiveness of soda loading?

7.5 Science trains the athlete

FIGURE 7.13
Body type will determine the type of event that an athlete will perform most successfully.

FIGURE 7.14
Biomechanics is used to help the efficiency of cyclists. Studies of airflow have led to cyclists being given advice to lean their bodies forward and hold them down close to the bicycle to reduce drag forces. Helmet design and tail-like extensions on the bicycle also help air to flow smoothly past the cyclist. A smaller front wheel and narrow bike contribute to less drag.

Talk about

What body shape would you expect for a champion weight-lifter? What about a high jumper?

Identifying potential athletes

In the 1990s, the Australian Institute of Sport developed a talent identification program to be used with school students. They began by searching for rowers. They were looking for young students who had long forearms and long legs, narrow hips and good flexibility in their knees. One of the young students identified, Megan Still, had never considered being a rower, but because of the encouragement she took up the sport. With Kate Slatter, she won a gold medal in the 1995 World Championships and also in the 1996 Olympic Games at Atlanta.

Matching sport and athlete

The **centre of gravity** of an object is the point about which the body can be balanced. How easily you can perform the tasks in Using Science 1 will depend on your centre of gravity. The higher your centre of gravity, the more difficult the task.

Centre of gravity is just one of many features that a sport scientist will consider before giving advice about what sport is most suitable. They will also look at the relative proportion of bones, muscle and fat. They will take into account whether your muscles have more fast twitch or slow twitch fibres. More fast twitch fibres would make an athlete more suitable for sprint or power events. More slow twitch would help in endurance events.

Training

Once a suitable sport has been chosen by an athlete, sport science can also give advice on training regimes that will help athletes produce their best performances. For example, fast twitch muscles develop more if given high intensity training with weights, whereas slow twitch fibres develop best by not working to capacity but doing many repetitions.

USING SCIENCE 1 BALANCING CHALLENGES

Try these two activities

1 Stand facing a wall with your toes just touching it. Move 3 foot lengths backwards. Then see if you can bend forwards and touch the wall in front of you with your head, while your arms are behind you.

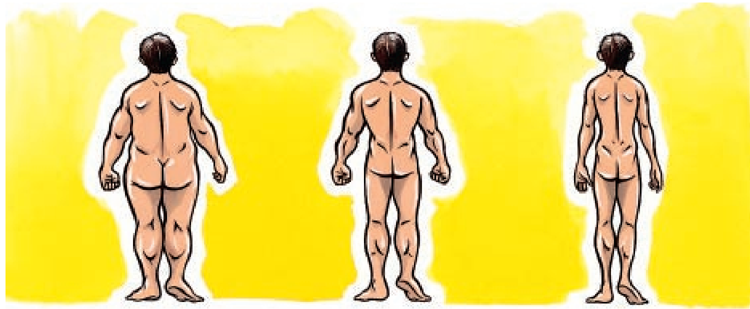
2 Place a matchbox on the floor in front of you as shown in the diagram. Then place your arms behind you as shown, and see if you can touch the matchbox with your nose.

FIGURE 7.15

DISCUSSION

For some of you the tasks will be very easy. Others may not be able to perform either task. Do girls or boys generally find it easier?

Sport scientists can also give advice about positioning the body during an event. The Fosbury flop is a high jump technique that keeps the athlete's centre of gravity as low as possible. This reduces the amount of work needed in order to clear the bar.



Endomorph
low centre of gravity, greater proportion of fat tissue

Mesomorph
well developed muscles, fast twitch

Ectomorph
high centre of gravity, long limbs, slow twitch muscles

FIGURE 7.16
The three main **somatotypes** (body types): different somatic types suit different sports.

EXPERIMENT 5 FINDING YOUR CENTRE OF GRAVITY

AIM
To determine the position of centre of gravity for a classmate.

MATERIALS
- 2 sets of bathroom scales
- long plank of wood (at least one body length)
- 2 triangular supports
- metre rule

FIGURE 7.17

METHOD
1 Weigh your classmate, and then weigh the wooden plank. Record both weights.
2 Place the triangular support on each bathroom scale and position the scales a distance apart equal to your classmate's body length.
3 Place the wooden plank on the triangular supports, so that the plank overhangs both scales by an equal distance. The readings on both scales should be the same (half the weight of the plank).
4 Let your classmate lie on the plank as shown in the diagram.
5 Record the reading shown on both scales.
6 Adjust your classmate's position along the plank until the readings on both scales are the same.
7 The centre of gravity should now be in the middle of the plank. Measure how far this point is from the bottom of your classmate's feet. Also measure how far it is from your classmate's navel.
8 Repeat the experiment for other class members.

RESULT AND DISCUSSION
Weight of classmate =
Weight of plank =
Distance of centre of gravity from classmate's feet =
Distance of centre of gravity from classmate's navel =
1 Which athletic events would be favoured by a low centre of gravity?
2 When would a high centre of gravity be an advantage?

Questions

1 For a sprinter and a long distance runner, what difference would you expect
a in body type?
b in fast and slow twitch muscle fibres?
2 Prepare an advertising poster to recruit athletes for a particular sport. Include an explanation about the physical characteristics that would lead to success in the sport chosen.
3 How can cyclists reduce the effect of air resistance on their performance?

Find out

Warming up and cooling down are recommended by sport scientists in order to reduce sports injuries. What types of activities can be used to warm up or cool down?

7.6

Energy to build bodies

FIGURE 7.18

In living organisms there can be thousands of chemical reactions occurring at any one time. Together, all these chemical reactions are called **metabolism**. In some reactions, larger molecules are broken down to smaller ones. These reactions are called **catabolic**. Reactions in which smaller molecules are joined together to make a larger molecule are called **anabolic** reactions. Most people have heard of this type of reaction through the publicity about **anabolic steroid** drugs used by some athletes.

Breakdown reactions

Catabolism

Examples of catabolic reactions are the breakdown of carbohydrates and fats for respiration (see section 7.3). This type of reaction releases energy, some of which is used to drive anabolic reactions.

Synthesis or anabolism

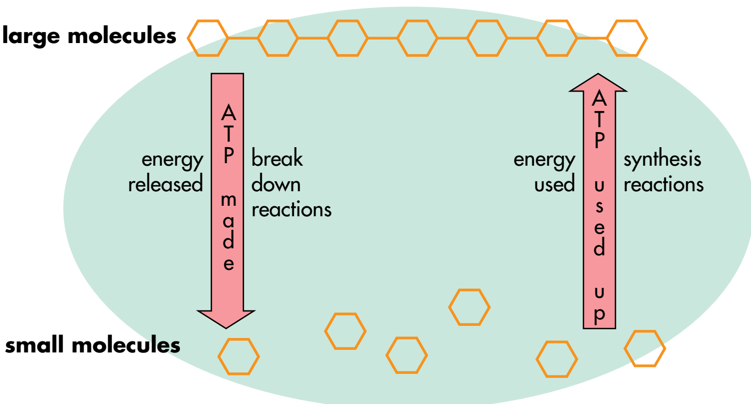
Examples of synthesis or anabolic reaction are:

- photosynthesis
- synthesising starch, glycogen and cellulose from glucose
- making lipids (fats and oils)
- protein synthesis—making protein from amino acids.

These processes all use up energy which is stored in the molecules formed, and can be released if the molecules are broken down later (Figure 7.19).

This is why we need energy to grow. The energy is used to synthesise the substances that new cells are made from. It is also needed to make the complex molecules in non-cellular substances like bone and hair.

FIGURE 7.19
Energy is released from catabolic reactions, but used in anabolic reactions. Both types of reaction happen continually in cells.



Protein synthesis

The human body contains hundreds of different types of proteins, some of which are listed in Table 7.1.

TABLE 7.1
Some of the different types of proteins in the human body

Function	Type of protein	Use
Structure	Fibres	Hair, nails, cartilage
Metabolism	Enzymes	Catalyse reactions
Body control	Hormones (e.g. insulin)	Regulation
Contraction	Muscle	Movement
Defence	Antibodies	Fight foreign substances

Since there are so many different proteins and many are large, insoluble molecules, the body cannot store them like it does carbohydrates and fat. This means proteins have to be manufactured as they are needed. There are **genes** in the **DNA** to code for each protein.

EXPERIMENT 6 HEAT ENERGY AND ENZYME ACTIVITY

INTRODUCTION
Rennin is an enzyme found in the stomachs of many animals, including humans. Here it breaks down proteins in milk, a part of the process of digestion. Being a breakdown reaction it would produce a certain amount of energy. However, energy is required to start the reaction. What effect does the amount of this energy have on the rate of the reaction?

AIM
To show that energy is a vital factor in biochemical reactions.

MATERIALS
- junket tablets (source of rennin)
- whole milk
- 5 mL and 50 mL measuring cylinders
- 50 mL and 200 mL beakers
- thermometer
- hot water
- ice

METHOD
1 Make a junket solution by dissolving one tablet in 20 mL of warm water in the 50 mL beaker.
2 Place 20 mL of milk in another beaker and warm it to 30°C by using a larger beaker as a water bath.
3 Add 2 mL of the junket solution to the milk and stir it once. Every 10 seconds, tip the beaker slightly to see when the mixture begins to thicken.
4 Record how long it takes for the mixture to turn solid.

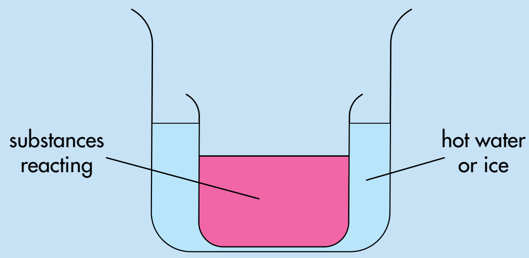


FIGURE 7.20
Using the water bath method to change and control the temperature of a reaction.

5 Repeat steps 2 to 4, but have the milk at different temperatures by putting either hot or ice water in the water bath. Repeat with a range of temperatures from 10° to 50°C.

RESULTS
Present your results in a table and a graph.

DISCUSSION
1 What happened when you reduced the amount of energy available for the reaction?
2 What was the ideal (optimal) temperature for the reaction?
3 What happened to the reaction at high temperatures?
4 Based on the results, explain why the human body temperature is kept at 37°C.

EXTENSION
The effect on the enzyme of high temperatures is called **denaturing**. Find out more about this process.

Questions
1 What is the difference between anabolism and catabolism?
2 Why do anabolic reactions require energy?

Think about
1 What do you think the term 'respiratory metabolism' means?
2 Some drugs, such as those used in chemotherapy for cancer, stop certain proteins from being made. One side effect is a loss of hair. How can this be explained?

Find out
Phenylketonuria (PKU) is a genetic disease that results in a certain enzyme not being made by the body. Find out more about this disease and how it relates to enzymes.

IMPLICATIONS OF SCIENCE FOR SOCIETY AND THE ENVIRONMENT

Performance enhancing drugs

FIGURE 7.21
These prescription drugs all contain banned substances.

FIGURE 7.22
Ben Johnson crosses the line first in the 100 m sprint at Seoul in 1988. He was later disqualified for drug use.

The problem of drug use in sport was highlighted in the 1988 Olympic Games when Canada's Ben Johnson ran the fastest 100 m ever, in a time of 9.79 seconds.

He defeated his main rival, Carl Lewis, who had also just run his personal best time of 9.92 seconds. In fact the first four sprinters completed the race in under 10 seconds. Ben Johnson was awarded the gold medal. Unfortunately for Johnson and his sport, he failed the post-race drug test, and was disqualified. Carl Lewis was then declared the true winner. At the same Olympics, another nine athletes also were disqualified for drug taking.

It had long been known that some athletes took a range of drugs to enhance their performance. Now random drug testing occurs in most sports played at the highest level.

How do these drugs work? What should our attitude be towards those who take them?

FACT FILE

Human growth hormone (hCG) may be taken by athletes to increase muscle development. Scientists are still trying to establish reliable ways of detecting artificially produced hCG. The ratio of different isotopes of carbon (C-12 and C-13) may be a possibility for identifying it.

Stimulants

Stimulants include caffeine, amphetamines and pseudo-ephedrine (found in Sudafed). They stimulate the nervous system, making a person feel more alert, and speed up reaction times. They may also increase aggression and delay tiredness. Amphetamines are potent stimulants, but can have devastating side effects. Athletes have died as a result of taking them.

Diuretics

Diuretics cause an increase in urine production and hence water loss. This loss of fluid can rapidly reduce an athlete's body weight, which can be important for weight-lifters, boxers and jockeys. They can also be taken to try to flush out other drugs. Excessive use of diuretics can lead to dehydration and serious kidney damage.

Beta-blockers

Beta-blockers are used to calm a person down in sports where a rapid pulse rate can affect performance: for example, snooker and target shooting.

Anabolic steroids

Anabolic steroids increase anabolism (protein synthesis) in the muscles. This leads to more muscle growth and so an increase in strength. Their medical use can help an athlete overcome an injury such as muscle damage. Anabolic steroids can have side effects such as liver damage and sterility.

Others

Pain killers, such as aspirin, do not increase performance, but may allow an athlete to compete even when injured. Another group of drugs reduces inflammation caused by some injuries and so allows an athlete to compete, but with the risk of further injury.

Think about ?

Since society places such high importance on winning, can we blame athletes for attempting to improve their performance with drugs—or are they just cheats?

Drug	Sport	Intended effect
Anabolic steroids	Strength sports, e.g. sprinting, weightlifting, discus	Increased strength
Caffeine	Most sports	Alertness, stimulant
Analgesics (e.g. codeine)	Endurance events, contact sports	Pain relief
Diuretics	Boxing, wrestling, weightlifting	Weight loss, flushing out other drugs
Amphetamines	Most sports	Stimulant
Beta-blockers	Target shooting, archery	Slower pulse
Pseudo-ephedrine	Most sports	Stimulant
Growth hormone	Power sports	Increased muscle development
EPO	Endurance events	Increased oxugen uptake

TABLE 7.2
Use of drugs in certain sports

FACT FILE

An electronic scanning instrument has been developed that can detect minute quantities of drugs like amphetamines and opiates in saliva.

USING SCIENCE 2 EXAMINING THE ISSUES

A good supply of oxygen to muscle tissues is important for optimum performance in an endurance event. There are a number of ways that athletes can enhance their performance by increasing their proportion of red blood cells and therefore getting more oxygen to muscle cells:

- Blood doping—an athlete may be given a transfusion of 'packed cells' (i.e. blood cells in a reduced volume of plasma) from their own blood just before an event to increase the number of red blood cells.
- High altitude training—erythropoietin (EPO) is a naturally occurring substance that stimulates the production of red blood cells. More EPO may be produced by athletes who undergo training at high altitudes in response to the lower concentration of oxygen in the air. Some studies suggest that 'live high, train low' is a better alternative. The athletes sleep in an air chamber with reduced air pressure (to simulate high altitude) but train at sea level.
- Direct injection of EPO—artificial EPO may be injected directly by an athlete to produce more red blood cells.

A future problem for sport medicine will be the use of gene therapy to deliver high levels of EPO. There is normally a feedback mechanism that stops production of EPO by the body when oxygen levels rise. A mutated gene has been identified which stops this feedback response and results in much higher levels of EPO in the blood. Research is currently being done in animals on the use of viruses to introduce new genes into the animals' cells. Viruses work by invading cells of the host, so if they can be altered to carry the mutated EPO gene into human cells, an athlete will be able to make more EPO.

DISCUSSION

In small groups, discuss each of the following questions and report your findings to the class.

1 Each of the three established methods results in a higher concentration of red blood cells. Should athletes use any of these techniques? Is one method fairer than the others?

2 What possible side effects can occur if EPO levels are increased in an athlete's blood?

3 Should gene therapy be used to enhance an athlete's performance?

EXTENSION

Use of EPO can change blood viscosity ('thickness') and also the proportion of old to new red blood cells. Australian sport scientists conducted a series of tests before the 2000 Olympics to find if these measurements were reliable enough to tell whether an athlete was taking EPO. How successful were they?

SCIENCE IN FOCUS 7.8

CURRENT ISSUES, RESEARCH AND DEVELOPMENT

Careers in sport science

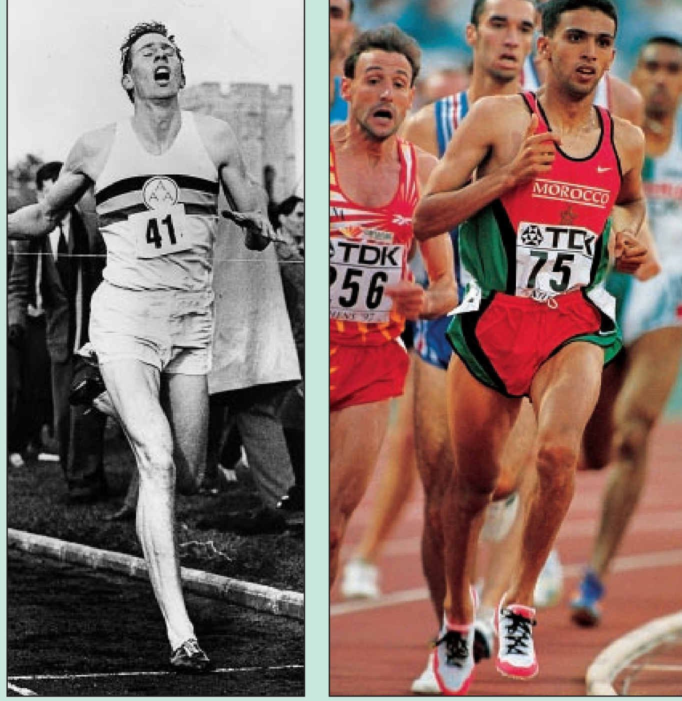


FIGURE 7.23
Roger Bannister and El-Guerrouj. Human performance continues to improve. What are the limits?

FACT FILE

A record number of athletes competed at the 2000 Olympics. The Australian Team Medical Centre had an area set aside for medical, psychological and nutritional advice; an area set aside for physiotherapy; and an area for massage therapy.

In 1954, Roger Bannister became the first person to break the 4-minute mile, running it in a time of 3 minutes 59.4 seconds. The current mile world record is 3 minutes 43.13 seconds, set by a Moroccan runner, Hicham El-Guerrouj, who also holds the 1500 m record of 3 minutes 26.00 seconds (both set in 1998).

Athletes today have the benefit of better training facilities and techniques, dietary advice, and also sports psychology. Facilities such as the Australian Institute of Sport (AIS) research ways of improving performance. Careful scientific research in analysing and training athletes has caused the dramatic improvement in performance seen over the last two decades.

What people are involved behind the scenes in the career of an athlete?

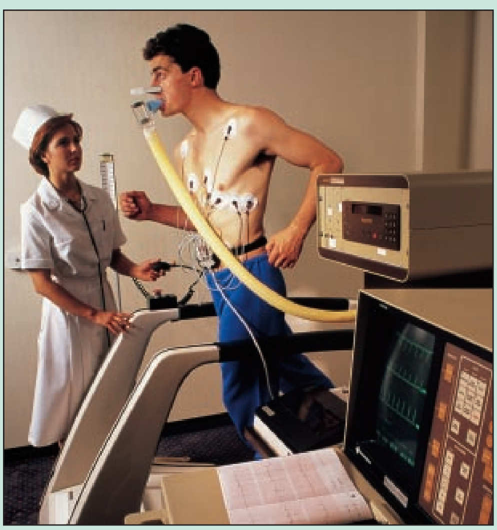


FIGURE 7.24
Sport science involves collecting and analysing data from athletes, and working out ways to improve performance.

Biomechanists

A **biomechanist** records and analyses techniques and skills. They use methods such as slow-motion video and computer simulations. They give valuable feedback to athletes and coaches.

Physiotherapists

Physiotherapists help to treat and, more importantly, prevent sports injuries.

They work closely with medical doctors in treating injuries. They use a variety of machines, such as ultrasound, provide specialised massage and advise on specific exercises.

Psychologists

The role of **sports psychologists** is to prepare the athlete mentally for the event. They give advice in such areas as goal setting, relaxation and self-encouragement.

Physiologists

Physiologists regularly test athletes for such factors as fitness and oxygen use. These scientists also carry out research into various aspects of human performance. They also help in the day-to-day monitoring of athletes to help design the best training techniques.

EXPERIMENT 7 RECOVERY TIMES

INTRODUCTION
The pulse rate is a measure of how fast the heart is beating. The time it takes for a person's heart rate to return to normal after a set period of exercise is one measure of fitness.

AIM: PART A
To measure your resting pulse rate and compare it with the class average.

METHOD
1 Count your pulse rate over 15 seconds, and multiply it by 4 to give a pulse rate per minute.
2 Repeat this three times and calculate an average.
3 Collate the data for your group or the whole class.
4 Display the results in a data table.

RESULTS AND DISCUSSION
1 How does your resting pulse rate compare with the average?
2 Suggest reasons for differences in the resting pulse rates between different people.

AIM: PART B
To measure your recovery time after exercise, and to compare two groups of people within the class.

METHOD
1 Make a list of factors that may affect an individual's recovery time. Make a class list.
2 Choose one of the factors (e.g. does regular exercise or does not do regular exercise) and suggest a hypothesis about the recovery times for the two groups.
3 Do 1 minute of step-ups or a similar activity at the same rate as the other class members.
4 Immediately after exercise, take your pulse rate for 15 seconds, and then every minute until your pulse rate returns to its resting rate.
5 Record your recovery time.
6 Repeat the experiment for a longer exercise time (e.g. 3 minutes).
7 Display your data and the group average for each group in a table.

RESULTS AND DISCUSSION
1 How did your recovery time compare with the two group averages?
2 Which group were you in? Does the data support this?
3 How could your fitness be improved?

Sport doctors
Sport doctors play an important role in the prevention and treatment of the various injuries. They also travel with athletes to provide complete health care for them. They work closely with physiotherapists and dietitians.

Dietitians
Dietitians plan appropriate meals for particular athletes and events. Some top grade athletes, such as tennis players, often have their own dietitian and often a personal cook! The dietitian has to take into account the demands of the sport and the type of training.

How do you rate your fitness? Can it, and should it, be improved?

Questions
1 How could slow motion video help an athlete improve her or his performance?
2 What sort of diet would the following be likely to have?
a weightlifter
b endurance runner
3 What type of sports injuries would you expect most often in:
a a sprinter? b a gymnast?
c a javelin thrower?

Think about
What kind of advice would a sports psychologist be likely to give an athlete before a major event?

FIGURE 7.25
An athlete being treated by a physiotherapist.

Using scientific language

1. Match the phrases in List B with the words in List A.

   List A

glucose	glycerol
amino acids	DNA
ATP	catabolism

   List B

   make up protein molecules
   genetic code molecule
   broken down to release energy
   energy carrier molecule
   part of a lipid molecule
   breaking down molecules to simpler ones

Check your knowledge

1. Which is the most efficient way to store energy? Explain your answer.
   ATP, glucose, glycogen, lipid, protein
2. Explain how the action of a lock and key can be used to describe how an enzyme works. Use a series of diagrams that show one molecule being broken down to two simpler ones.
3. List changes that occur in the body:
   a as a result of exercise
   b as a person becomes fitter.
4. What are the main differences between aerobic and anaerobic respiration?
5. Why do some athletes take anabolic steroid drugs?
6. Describe the difference between slow twitch and fast twitch muscle fibres.
7. Urine tests are used to identify whether athletes are taking illegal drugs.
   a Give examples of drugs that can be identified by urine tests.
   b Explain why some athletes might take diuretics if they are also taking other illegal drugs.
   c Which drugs, not identified by urine tests, can be identified by blood tests?

Apply your skills

1. Look at the information in Figure 7.3 (section 7.1). Calculate your actual body weights of the various components.
2. 'An enzyme is not used up in the reaction that it speeds up.' In general terms, how could you test this idea?
3. List in order the major chemical reactions that occur as someone competes in an endurance event.
4. Figure 7.16 shows the three main body types (called somatotypes). In real life, most people have a body type which fits somewhere in between these extremes. For example, a female weight thrower would ideally have a body type halfway between mesomorph and endomorph (well-developed, fast twitch muscles but low centre of gravity). Her position is shown on the Figure 7.26. Copy the diagram and plot the position you would expect the following athletes to occupy if they had an ideal body type for their chosen sport.
   a sprinter (male/female)
   b long distance runner (male/female)
   c gymnast (male/female)
   d basketball player
   e sumo wrestler
   f high jumper
   e cyclist

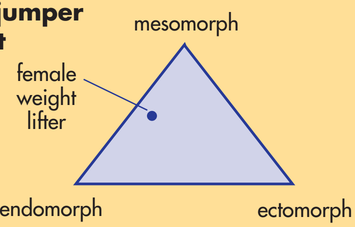


FIGURE 7.26

Challenge yourself

1. Aerobics classes are a popular keep-fit activity at gymnasiums. When many people do this for the first time, they get stiff and sore muscles.
   a Why? Is this really due to aerobic reactions?
   b Why do they not experience the same problems after they have been doing this exercise program a number of times?
2. Design a complete fitness and diet program for a particular sport (e.g. sprinting, basketball, long distance walking). You will need to research what is required of the body, and therefore what exercises and foods are best to meet the demands of that particular sport.
3. Imagine that you are recruiting a school sports team from students who have not tried the following sports. Describe the body type and other features you would look for in:
   a soccer players
   b volleyballers
   c gymnasts
   d rugby league players
   e AFL players