Muscles, joints and movement

Bones can move in relation to one another at joints. Different types of joint allow different degrees of movement. Ligaments are made of elastic connective tissue. They hold bones together and restrict the amount of movement possible at a joint. Tendons are cords of non-elastic fibrous tissue that anchor muscles to bones.

Skeletal muscles are those attached to bones and are normally arranged in antagonistic pairs. This means that there are pairs of muscles which pull in opposite directions. Flexors contract to flex, or bend a joint, e.g. biceps in the arm; extensors contract to extend, or straighten a joint, e.g. triceps in the arm.

Each skeletal muscle is a bundle of millions of muscle cells called fibres. Each muscle cell may be several centimetres long and contains several nuclei. It contains many myofibrils which are made up of the fibrous proteins actin (thin filaments) and myosin (thick filaments). The cell surface membrane of a muscle cell is known as the sarcolemma. The sarcoplasmic reticulum is a specialised endoplasmic reticulum which can store and release calcium ions. The cytoplasm inside a muscle cell is called the sarcoplasm. The specialised synapse (see page 63, Topic 8) between neurones and muscle cells is called the neuromuscular junction.

The sliding filament theory of muscle contraction

The functional unit of a muscle fibre is called a sarcomere. When the muscle contracts the thin actin filaments move between the thick myosin filaments, shortening the length of the sarcomere and therefore shortening the length of the muscle.

The prefix myo- refers to ‘muscle’ and sarco- to ‘flesh’ (i.e. muscle) so specialist terms starting with myo- or sarco- will refer to structures within muscles.

Remember that muscles can’t stretch themselves. It is the pull created by the contraction of the antagonistic muscle that stretches a muscle when it is in a relaxed state.

A typical synovial joint.

The arrangement of actin and myosin filaments in a sarcomere when relaxed (A) and contracted (B).
Myosin filaments have flexible ‘heads’ that can change their orientation, bind to actin and hydrolyse ATP (using ATPase). Actin filaments are associated with two other proteins, troponin and tropomyosin, that control the binding of the myosin heads to the actin filaments.

When a nerve impulse arrives at a neuromuscular junction, calcium ions are released from the sarcoplasmic reticulum and the following events take place that lead to the contraction of the muscle.

The sliding filament theory of muscle contraction.

### Characteristics of fast-twitch and slow-twitch muscle fibres

<table>
<thead>
<tr>
<th>Slow-twitch</th>
<th>Fast-twitch</th>
</tr>
</thead>
<tbody>
<tr>
<td>specialised for slower, sustained contraction and can cope with long periods of exercise</td>
<td>specialised to produce rapid, intense contractions in short bursts</td>
</tr>
<tr>
<td>many mitochondria – ATP comes from aerobic respiration (electron transport chain)</td>
<td>few mitochondria – ATP comes from anaerobic respiration (glycolysis)</td>
</tr>
<tr>
<td>lots of myoglobin (dark red pigment) to store O₂ and lots of capillaries to supply O₂. This gives the muscle a dark colour</td>
<td>little myoglobin and few capillaries. The muscle has a light colour</td>
</tr>
<tr>
<td>fatigue resistant</td>
<td>fatigue quickly</td>
</tr>
<tr>
<td>low glycogen content</td>
<td>high glycogen content</td>
</tr>
<tr>
<td>low levels of creatine phosphate</td>
<td>high levels of creatine phosphate</td>
</tr>
</tbody>
</table>

**Quick Questions**

- **Q1** Give one reason why fast-twitch muscles are more likely to get tired faster than slow-twitch muscles.
- **Q2** Describe the role of ATP in muscle contraction.
- **Q3** Explain why muscles are arranged in antagonistic pairs.
Energy and the role of ATP in respiration

All living organisms have to respire. There are two different ways in which they do this – **aerobic respiration** (using oxygen) and **anaerobic respiration** (without oxygen). Both of these processes make the energy stored in glucose available in the form of ATP, to power metabolic reactions.

**Aerobic respiration**

\[
\text{glucose} + \text{oxygen} \rightarrow \text{carbon dioxide} + \text{water} + \text{energy} \\
C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \sim 30 \text{ ATP}
\]

**Anaerobic respiration**

\[
\text{glucose} \rightarrow \text{lactic acid} + \text{energy} \\
C_6H_{12}O_6 \rightarrow 2C_3H_6O_3 + 2 \text{ ATP}
\]

**The structure and function of ATP**

ATP (adenosine triphosphate) is the cell’s energy currency. Energy is required to add a third phosphate bond to ADP to create ATP. When this bond is broken by hydrolysis, the energy released can be used in energy-requiring processes taking place within the cell.

**Glycolysis**

Starting with one glucose molecule, glycolysis produces two molecules of pyruvate, two molecules of reduced NAD and a net gain of two molecules of ATP. Glycolysis takes place within the cytoplasm of cells.

**Anaerobic respiration**

Glycolysis does not need molecular oxygen (O\(_2\)). However, for glycolysis to continue, a constant supply of NAD is required. In aerobic respiration the NAD is produced by the electron transport chain. The reduced NAD must be oxidised to NAD. During anaerobic respiration, NAD must come from elsewhere. In animals, pyruvate from glycolysis is reduced to give lactate, NAD is formed and can keep glycolysis going.

---

**ResultsPlus**

**Watch out!**

Remember that energy cannot be created or destroyed, but can change from one form into another – so never refer to energy being produced or used.

**Examiner tip**

Remember that the formation of ATP is an example of a condensation reaction, the reverse of which is hydrolysis:

\[
\text{ATP} + H_2O \rightarrow \text{ADP} + \text{Pi} + \text{energy}
\]
Anaerobic respiration allows animals to make a small amount of ATP. It is an inefficient process but it is rapid and can supply muscles with ATP when oxygen is not being delivered quickly enough to cells.

Lactate forms lactic acid in solution which lowers the pH. This can inhibit enzymes and, if allowed to build up, it can cause muscle cramp. Once aerobic respiration resumes most lactate is converted back to pyruvate. It is oxidised via the Krebs cycle into carbon dioxide and water. The extra oxygen required for this process is called the oxygen debt.

Investigating the rate of respiration using a respirometer

The rate of aerobic respiration can be determined using a respirometer by measuring the rate of oxygen absorbed by small organisms. Any CO₂ produced is absorbed by the potassium hydroxide (KOH) solution, so that any oxygen absorbed by the organism results in the fluid in the manometer tube moving towards the organism (see arrow on diagram). The tube on the right-hand side compensates for any changes in pressure or temperature within the apparatus.

Q1 Suggest four examples of biological processes that require the use of ATP.

Q2 Compare the role of ATP with glycogen.

Q3 Describe the role of NAD in anaerobic respiration.

Remember that in the A2 Biology exams you may be asked to:
• bring together scientific knowledge and understanding from different areas
• apply knowledge and understanding of more than one area to a particular situation or context
• use knowledge and understanding of principles and concepts in planning experimental and investigative work and in the analysis and evaluation of data.

The respiration topic is a common choice for such synoptic questions because the process links to many other areas such as photosynthesis, food chains and muscle contraction.
In aerobic respiration, the pyruvate (from glycolysis) is completely oxidised into carbon dioxide and water using oxygen.

Aerobic respiration takes place in two stages:

- First pyruvate is oxidised into carbon dioxide and hydrogen (accepted by the coenzymes NAD and FAD). This takes place in the matrix of the mitochondria and involves the Krebs cycle.

- In the second stage, most of the ATP generated in aerobic respiration is synthesised by oxidative phosphorylation associated with the electron transport chain. This involves chemiosmosis and the enzyme ATPase. It takes place on the cristae (inner membranes) of the mitochondria.

**Preparation for the Krebs cycle (the link reaction)**

In aerobic respiration each pyruvate molecule coming from glycolysis in the cell’s cytoplasm enters the matrix of the mitochondrion. It is converted from pyruvate (3C) to an acetyl (2C) group. This involves the loss of CO₂ (decarboxylation) and hydrogen (dehydrogenation) generating reduced NAD. The acetyl group is carried by coenzyme A as acetyl coenzyme A.

**The Krebs cycle**

The Krebs cycle occurs in the matrix of the mitochondria. The main purpose of the cycle is to supply a continuous flow of hydrogen (and therefore electrons) to the electron transport chain for use in the synthesis of ATP by oxidative phosphorylation.

---

**ResultsPlus Examiner tip**

Many of the reactions involved in respiration are redox reactions where one substrate is oxidised and another is reduced. When a molecule is oxidised, it either loses hydrogen or one or more electrons are lost. A molecule that gains electrons or hydrogen is reduced. One way of remembering this is to think of OILRIG (oxidation is loss, reduction is gain). When a molecule gains hydrogen it is reduced, and the molecule that loses the hydrogen is oxidised. For example: pyruvate → acetyl + 2H (is oxidation); NAD + 2H → reduced NAD (is reduction).

**ResultsPlus Examiner tip**

You do not need to know the names of the intermediate compounds of the Krebs cycle for the exam, but you are expected to appreciate that aerobic respiration is a many-stepped process with each step controlled and catalysed by a specific intracellular enzyme.
Each molecule of the 2-carbon acetyl coenzyme A from the link reaction is used to generate:
- three molecules of reduced NAD
- one molecule of reduced FAD
- two molecules of CO₂
- one molecule of ATP by **substrate-level phosphorylation** (synthesised directly from the energy released by reorganising chemical bonds)
- one molecule of a 4-carbon compound, which is regenerated to accept an acetyl group and start the cycle again.

Note that for each glucose molecule entering glycolysis two acetyl groups are formed, so the Krebs cycle will turn twice (i.e. producing two ATP and six reduced NAD, etc.)

**Oxidative phosphorylation, chemiosmosis and the electron transport chain**

Most of the ATP generated in aerobic respiration is synthesised by the electron transport chain.

The electron transport chain and chemiosmosis result in ATP synthesis by oxidative phosphorylation.

The majority of ATP generated by aerobic respiration comes from the activity of the electron transport chain in the inner membrane of the mitochondria (cristae).

The overall reaction of aerobic respiration can be summarised as the splitting and oxidation of a respiratory substrate (e.g. glucose) to release carbon dioxide as a waste product, followed by the reuniting of hydrogen with oxygen to release a large amount of energy in the form of ATP.

**Quick Questions**

Q1 Describe what happens to the carbon and hydrogen atoms from a glucose molecule in aerobic respiration.

Q2 Explain what oxidative phosphorylation means.

Q3 Explain why the electron transport chain and the Krebs cycle would stop if there was no oxygen.

**Thinking Task**

Q1 Sketch a simple diagram of a cell and mitochondria and outline where the main steps in aerobic respiration take place.
The heart, energy and exercise

The control of the cardiac cycle

The impulse to contract originates within the heart itself from the sinoatrial node – the heart is said to be myogenic.

1. Electrical impulses from the SAN spread across the atria walls, causing contraction. This is called atrial systole.
2. Impulses pass to the ventricles via the AVN after a short delay to allow time for the atria to finish contracting.
3. Impulses pass down the Purkyne fibres to the heart apex.
4. The impulses spread up through the ventricle walls causing contraction from the apex upwards. Blood is squeezed into the arteries. This is ventricular systole.

After contracting (systole), the cardiac muscle then relaxes for a period called diastole when the blood returning from the veins fills the atria.

Measuring electrical changes in the heart

Electrical currents caused by the spread of the electrical impulse (wave of depolarisation) during the cardiac cycle can be detected with an electrocardiogram (ECG).

If disease disrupts the heart’s normal conduction pathways changes will occur in the ECG pattern which can be used for diagnosis of cardiovascular disease.

- The P wave is the time of atrial systole.
- The QRS complex is the time of ventricular systole.
- The T wave is caused by repolarisation of the ventricles during diastole.

A normal ECG pattern in a healthy heart.

Regulation of cardiac output

Blood is pumped around the body to supply O₂ and remove CO₂ from respiring tissues. How much is pumped in a minute (cardiac output) depends on two factors: how quickly the heart is beating (heart rate) and the volume of blood leaving the left ventricle with each beat (stroke volume).

\[
\text{cardiac output (dm}^3\text{min}^{-1}) = \text{stroke volume (dm}^3\text{)} \times \text{heart rate (min}^{-1}\text{)}
\]
The heart rate can be affected by hormones (e.g. adrenaline) and nervous control. The cardiovascular control centre in the medulla of the brain controls the sinoatrial node via nerves. The sympathetic nerve speeds up the heart rate in response to falls in pH in the blood due to CO₂ and lactate levels rising, increases in temperature and mechanical activity in joints.

Impulses carried by the vagus nerve (parasympathetic) slow down the heart rate when the demand for O₂ and removal of CO₂ reduces.

**Regulation of ventilation rate**

The rate at which someone breathes is called the ventilation rate. This is often expressed as the volume of air breathed per minute (the minute ventilation). The volume of air breathed in or out of the lungs per breath is called the tidal volume. The maximum volume of air that can be forcibly exhaled after a maximal intake of air is called the vital capacity.

\[
\text{ventilation rate} = \text{tidal volume} \times \text{number of breaths per minute}
\]

The ventilation centre in the medulla controls the rate and depth of breathing in response to impulses from chemoreceptors in the medulla and arteries which detect the pH and concentration of CO₂ in the blood. Impulses are sent from the ventilation centre to stimulate the muscles involved in breathing. A small increase in CO₂ concentration causes a large increase in ventilation. It also increases in response to impulses from the motor cortex and from stretch receptors in tendons and muscles involved in movement. We also have voluntary control over breathing.

**Measuring lung volumes using a spirometer**

A person using a spirometer breathes in and out of an airtight chamber causing it to move up and down and leaving a trace on a revolving drum (kymograph).

\[
\text{ventilation rate} = \text{tidal volume} \times \text{number of breaths per minute}
\]

You can calculate the volume of O₂ absorbed in a given time by measuring the differences in volume between the troughs labelled A and B in the diagram and dividing by the time between A and B.
Homeostasis is the maintenance of a stable internal environment, within a narrow limit, of the optimum conditions needed by cells so they can function properly. A homeostatic system therefore requires:

- receptors to detect the change away from the norm value (stimulus)
- a control mechanism that can respond to the information. The control mechanism uses the nervous system or hormones to switch effectors on or off
- effectors to bring about the response (usually to counteract the effect of the initial change). Muscles and glands are effectors.

Negative feedback helps to keep the internal environment constant. A change in the internal environment will trigger a response that counteracts the change, e.g. a rise in temperature causes a response that will lower body temperature. For negative feedback to occur, there must be a norm value or set point, e.g. 37.5 °C for core body temperature.

Homeostasis and exercise

We have already seen that the body responds to the demands of exercise by increasing cardiac output and ventilation rate under the control of centres in the medulla (see page 51 – The heart, energy and exercise). Not only does the increased respiration rate during exercise produce a lot of CO₂ and/or lactate, but the energy transfers also release a lot of heat energy. This can be enough for a 1 °C rise in body temperature every 5–10 minutes if we can’t disperse the heat away from the body.

The control of core body temperature through negative feedback is called thermoregulation. Thermoreceptors in the skin detect changes in temperature. In addition thermoreceptors in the hypothalamus (in the brain) can detect changes in the core blood temperature. If a rise in temperature is detected above the norm value the heat loss centre in the hypothalamus will stimulate effectors to increase heat loss from the body – usually through the skin.
Q1 Using your revision in this section and pages 45, 50 and 51 explain why some animals are adapted to short bursts of fast or powerful exercise, while others are adapted to long periods of continuous exercise.

**Medical technology to enable those with injuries and disabilities to participate in sport**

The development of **keyhole surgery** using fibre optics has made it possible for surgeons to repair damaged joints (including torn cruciate ligaments in the knee) with precision and minimal damage. This is because only a small incision (cut) is needed so there is less bleeding and damage to the joint, and recovery is much quicker.

A **prosthesis** is an artificial body part designed to regain some degree of normal function or appearance. The design of prostheses has improved significantly and many disabled athletes are now able to compete at a very high level, e.g. with dynamic response feet that can literally provide them with a spring in their step. Damaged joints (such as knee joints) can also now be repaired with small prosthetic implants to replace the damaged ends of bones, freeing the patient from a life of pain and restoring full mobility.

### Quick Questions

**Q1** Explain what is meant by the term ‘negative feedback’.

**Q2** Suggest what the consequences might be if you were unable to lose heat from the body during exercise.

**Q3** Describe the body’s likely responses to the core temperature dropping below 37 °C.

---

**Diagram:**

- **Heat loss centre**
  - Stimulates: sweat glands to secrete sweat.
  - Inhibits: contraction of arterioles in skin (dilates capillaries in skin)
  - hair erector muscles (relax – hairs lie flat)
  - liver (reduces metabolic rate)
  - skeletal muscles (relax – no shivering).

- **Heat gain centre**
  - Stimulates: arterioles in the skin to constrict
  - hair erector muscles to contract
  - liver to raise metabolic rate
  - skeletal muscles to contract in shivering.
  - Inhibits: sweat glands.

**Negative feedback in thermoregulation.**

Above or below certain temperatures homeostasis fails (e.g. because the hypothalamus may be damaged). Instead, positive feedback may occur resulting in a high temperature continuing to rise or a low temperature falling still further. This can result in hyperthermia or hypothermia and may lead to death.
### The possible effects of too little exercise

There are many benefits to regular moderate exercise. Here are a few possible effects of a lack of exercise over a prolonged period of time:

- Reduced physical endurance, lung capacity, stroke volume and maximum heart rate
- Increased resting heart rate, blood pressure and storage of fat in the body
- Increased risk of coronary heart disease, type II diabetes, some cancers, weight gain and obesity
- Impaired immune response due to lack of natural killer cells
- Increased levels of LDL ('bad' cholesterol) and reduced levels of HDL ('good' cholesterol)
- Reduced bone density, therefore increased risk of osteoporosis.

### The possible effects of too much exercise

Overtraining can lead to symptoms such as immune suppression and increased wear and tear on joints. It can also result in chronic fatigue and poor athletic performance.

Too much exercise generally may also increase the amount of wear and tear on joints. Damage to cartilage in synovial joints can lead to inflammation and a form of arthritis. Ligaments can also be damaged. Bursae (fluid-filled sacs) that cushion parts of the joint can become inflamed and tender.

There is also some evidence of a correlation between intense exercise and the risk of infection such as colds and sore throats. This could be caused by an increased exposure to pathogens, or a suppression of the immune system. There is some evidence that the number and activity of some cells of the immune system may be decreased while the body recovers after vigorous exercise. It may also be the case that damage to muscles during exercise and the release of hormones such as adrenaline may cause an inflammatory response which could also suppress the immune system.

### Some ethical positions relating to the use of performance-enhancing substances by athletes

Some athletes will do anything they can, in the pursuit of excellence. This might include the use of illegal performance-enhancing substances. Others may feel they need to follow suit because they don’t want to be at a disadvantage. This has been a subject for debate in the sporting world for many years.

These ethical frameworks can be used when considering both sides of the argument:

- Rights and duties
- Maximising the amount of good in the world
- Making decisions for yourself
- Leading a virtuous life.

For example, doping in sport could be considered not acceptable because athletes have a right to fair competition, but could equally be considered acceptable because athletes have the right to exercise autonomy, for example to choose to achieve their best performance, and also have a duty to any sponsor they may have.

Remember that in order to maintain that something is ethically acceptable or not, you must provide a reasonable explanation as to why that is the case.

Ethical absolutists see things as very clear cut. They would take one of two positions:

1. It is never acceptable for athletes to use performance-enhancing substances (even if they are legal), or
2. It is always acceptable for athletes to use any substance available to them to compete more effectively, even if there are associated risks to their health.

Ethical relativists would realise that people and circumstances may be different, e.g:

- It is wrong for athletes to use performance-enhancing substances, but there may be some cases and circumstances where it is acceptable.
How can drugs affect your genes?

Some drugs such as anabolic steroids are closely related to natural steroid hormones. They can pass directly through cell membranes and be carried into the nucleus bound to a receptor molecule. These hormone/receptor complexes act as transcription factors. They bind to the promoter region of a gene allowing RNA polymerase to start transcription. As a result more protein synthesis takes place in the cells. For example testosterone increases protein synthesis in muscle cells, increasing the size and strength of the muscle tissue. Peptide hormones do not enter cells directly, but they bind with receptors on the cell surface membrane. This starts a process that results in the activation of a transcription factor within the nucleus. For example erythropoietin (EPO) stimulates the production of red blood cells. This means that the blood can carry more oxygen which is an advantage for an athlete.

Genes are switched on by successful formation and attachment of the transcription initiation complex to the promoter region.

Genes remain switched off by failure of the transcription initiation complex to form and attach to the promoter region. This is due to the absence of protein transcription factor(s) or the action of repressor molecules.

DNA transcription is controlled by transcription factors.

Quick Questions

Q1 Describe why a lack of exercise may lead to an increased risk of coronary heart disease.

Q2 Explain why a lack of T helper cells may increase the risk of an athlete suffering from a sore throat.

Q3 Outline the role of transcription factors in the control of gene expression.

Thinking Task

Q1 Even if all performance-enhancing substances were formally banned, would we ever have a level playing field for athletes?
## Topic 7 – Run for your life checklist

By the end of this topic you should be able to:

<table>
<thead>
<tr>
<th>Revision spread</th>
<th>Checkpoints</th>
<th>Spec. point</th>
<th>Revised</th>
<th>Practice exam questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Muscles and movement</td>
<td>Describe the structure of a muscle fibre and explain the differences between fast and slow twitch muscle fibres.</td>
<td>LO2</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td></td>
<td>Explain how skeletal muscle contracts using the sliding filament theory.</td>
<td>LO3</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td></td>
<td>Recall the way in which muscles, tendons, the skeleton and ligaments interact to allow movement.</td>
<td>LO4</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Energy and the role of ATP</td>
<td>Describe aerobic respiration as splitting of glucose to release carbon dioxide, water and energy.</td>
<td>LO5</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td></td>
<td>Describe a practical to investigate rate of respiration.</td>
<td>LO6</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td></td>
<td>Recall what ATP is and how it supplies energy for cells.</td>
<td>LO7</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td></td>
<td>Describe the roles of glycolysis in both aerobic and anaerobic respiration. You do not need to know all the stages but you do need to know that glucose is phosphorylated and ATP, reduced NAD and pyruvate are produced.</td>
<td>LO8</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td></td>
<td>Explain what happens to lactate after you stop exercising.</td>
<td>LO11</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>The Krebs cycle and the electron transport chain</td>
<td>Describe how the Krebs cycle produces carbon dioxide, ATP, reduced NAD and reduced FAD. You should also understand that respiration has lots of enzyme-controlled steps.</td>
<td>LO9</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td></td>
<td>Describe how ATP is made by oxidative phosphorylation in the electron transport chain including the roles of chemiosmosis and ATPase.</td>
<td>LO10</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>The heart, energy and exercise</td>
<td>Understand that cardiac muscle is myogenic and describe how electrical activity in the heart allows it to beat. You should also know how ECGs can be used.</td>
<td>LO12</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td></td>
<td>Explain that tissues need rapid delivery of oxygen and removal of carbon dioxide during exercise and that changes in ventilation and cardiac output allow this to happen. You should understand how heart rate and ventilation rate are controlled.</td>
<td>LO13</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td></td>
<td>Describe how to use data from spirometer traces to investigate the effects of exercise.</td>
<td>LO14</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Homeostasis</td>
<td>Explain the principle of negative feedback.</td>
<td>LO15</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td></td>
<td>Discuss the concept of homeostasis and how it maintains the body during exercise, including controlling body temperature.</td>
<td>LO16</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Health, exercise and sport</td>
<td>Explain how genes can be switched on and off by DNA transcription factors including hormones.</td>
<td>LO17</td>
<td>☐</td>
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</tr>
<tr>
<td></td>
<td>Analyse and interpret data on the possible dangers of exercising too little and too much. You should also be able to talk about correlation and cause.</td>
<td>LO18</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td></td>
<td>Explain how medical technology helps people with injuries or disabilities to take part in sport.</td>
<td>LO19</td>
<td>☐</td>
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</tr>
<tr>
<td></td>
<td>Outline the ethics of using performance-enhancing substances.</td>
<td>LO20</td>
<td>☐</td>
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</tbody>
</table>
Animals that are predators often show bursts of very fast movement. Their prey tend to be able to carry out sustained movement over longer periods of time. Close examination shows that the muscles of predator and prey show a different composition of fast- and slow-twitch fibres.

(a) (i) Outline the differences between fast- and slow-twitch muscle fibres. (2)
(ii) State whether predator or prey would show a higher proportion of slow-twitch fibres. (1)
(iii) Discuss why predators show different proportions of fast- and slow-twitch muscle fibres from their prey. (2)

Examiner tip
If you are asked for the differences, make sure you refer to both or use a comparative word, e.g. ‘more’.

Student answer | Examiner comments
--- | ---
(a) (i) Slow-twitch muscle fibres have more mitochondria and more capillaries supplying oxygen than fast twitch fibres. 
(ii) Prey. 
(iii) Predators are likely to have more fast-twitch than slow-twitch fibres, in comparison to their prey. This is because predators tend to be fast and powerful over short distances to catch and kill their prey and therefore use anaerobic respiration to release ATP quickly.

This is a good response because not only does it provide a likely comparison, it also provides a clear and plausible explanation.

(b) During fast movement, lactate builds up in the muscles of a predator, such as a cheetah. Explain what happens to this lactate after the chase has ended. (3)

Student answer | Examiner comments
--- | ---
Lactate diffuses from the muscle into the blood where it is carried away from the muscle to prevent cramp.

This response is a correct but only partial explanation. It explains how the lactate is moved away from the muscle, but not how it is removed from the body.

Lactate is oxidised back into pyruvate using NAD that has been oxidised in the electron transport chain using oxygen. The extra oxygen needed is the oxygen debt.

This response will gain maximum marks because it provides a chemical explanation of the fate of the lactate, clearly demonstrating an understanding of both aerobic and anaerobic respiration, as well as recognition of the need for extra oxygen.

(c) During the chase, the core body temperature of both predator and prey rises. Describe how changes in blood circulation help to return their core body temperatures to normal. (3)

Examiner tip
In longer questions like this try to be clear on writing cause and effect. Where possible use key terms and concepts from your course as part of your description as you will often receive credit for these. However, the terms need to be in the correct context – you will not gain marks for lists of random terms that do not demonstrate your understanding of what they mean.

Student answer | Examiner comments
--- | ---
An increase in core temperature causes vasodilation so that more heat is lost from the skin.

This response would only score 1 mark for the recognition that more heat would be lost from the skin. The reference to vasodilation is not enough as it does not describe what change occurs to the blood circulation.

This is an example of homeostasis using a negative feedback mechanism. Changes to the core temperature are detected by thermoreceptors in the hypothalamus which send nerve impulses to arterioles in the skin. This causes vasodilation resulting in increased blood flow to the skin.

This response is better because it includes key terms and structures in the correct context of how the change is caused (homeostasis, negative feedback, hypothalamus). It also clearly describes the effect of vasodilation on the blood circulation.

(Edexcel GCE Biology (Salters-Nuffield) Advanced Unit 5 June 2008.)
1 (a) Name the region of the human brain involved in control of heart rate.  
(b) Heart rate increases during exercise. Explain the mechanisms involved in controlling this increase in heart rate.  
**Total 5 marks**  
(Edexcel GCE Biology (Salters-Nuffield) Advanced Unit 5 June 2007)

2 Doing too little exercise can lead to health problems, but too much exercise can also be harmful. Discuss the benefits and potential dangers of exercise in humans.  
**Total 6 marks**  
(Edexcel GCE Biology (Salters-Nuffield) Advanced Unit 5 June 2007)

3 The table below refers to three major stages of aerobic respiration and the products of each stage. Copy and complete the table by inserting the part of the cell in which the stage occurs and two products in the blank spaces.

<table>
<thead>
<tr>
<th>Stage</th>
<th>Part of cell in which it occurs</th>
<th>Two products</th>
</tr>
</thead>
<tbody>
<tr>
<td>glycolysis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Krebs cycle</td>
<td>matrix of mitochondrion</td>
<td>ATP and water</td>
</tr>
<tr>
<td>electron transport chain</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Total 4 marks**  
(Edexcel GCE Biology Advanced Unit 4 – paper 3 June 2007)

4 The diagrams show one sarcomere in its fully relaxed state and when it is partially contracted.

(a) Calculate the percentage change in width of the H zone when the sarcomere is partially contracted. Show your working.  
(b) During the contraction of this sarcomere, the myosin filaments pull the actin filaments towards the centre of the sarcomere. Explain how this is brought about.  
**Total 7 marks**  
(Edexcel GCE Biology Advanced Unit 4 – paper 3 June 2007)

5 The diagram shows the ways in which the respiratory system and different parts of the brain interact with each other to regulate breathing.