Write your name here

Surname	Other names

Pearson Edexcel
International
Advanced Level

Centre Number | | | | | |

Candidate Number | | | | |

Biology

Advanced

Unit 5: Energy, Exercise and Coordination

Tuesday 17 January 2017 – Afternoon
Time: 1 hour 45 minutes

Paper Reference
WBI05/01

You must have:
A copy of the scientific article (enclosed), calculator, ruler

Total Marks

Instructions

- Use **black** ink or ball-point pen.
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions.
- Answer the questions in the spaces provided
  – *there may be more space than you need.*

Information

- The total mark for this paper is 90.
- The marks for **each** question are shown in brackets
  – *use this as a guide as to how much time to spend on each question.*
- Questions labelled with an **asterisk** (*) are ones where the quality of your written communication will be assessed
  – *you should take particular care with your spelling, punctuation and grammar, as well as the clarity of expression, on these questions.*
- Candidates may use a calculator.

Advice

- Read each question carefully before you start to answer it.
- Keep an eye on the time.
- Try to answer every question.
- Check your answers if you have time at the end.

Turn over ▶

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P 4 8 3 5 8 A 0 1 2 8

Pearson

Answer ALL questions.

Some questions must be answered with a cross in a box ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

1 Mitochondria are organelles involved in the production of ATP.

The electronmicrograph below shows a section through part of a cell.

Magnification × 10 000

(a) (i) Place a cross ☒ in the box next to the part of a mitochondrion where most ATP synthesis takes place.

(1)

☒ **A** inner mitochondrial membrane

☒ **B** intermembrane space

☒ **C** matrix

☒ **D** outer mitochondrial membrane

(ii) Nucleic acid is involved in the synthesis of proteins in mitochondria. These proteins are needed to make ATP.

Place a cross ☒ in the box that shows the nucleic acid found in mitochondria.

(1)

☒ **A** DNA only

☒ **B** RNA only

☒ **C** DNA and RNA

☒ **D** neither DNA or RNA

(iii) Place a cross ☒ in the box next to the part of the mitochondrion in which protein synthesis takes place.

(1)

☒ **A** cristae

☒ **B** intermembrane space

☒ **C** ribosomes

☒ **D** stalked particles

(iv) Place a cross ☒ in the box next to the actual length of the mitochondrion.

(1)

☒ **A** 0.0005 mm

☒ **B** 0.005 mm

☒ **C** 5.0 mm

☒ **D** 50.0 mm

(v) Place a cross ☒ in the box next to the name of the structure labelled **Q** in the electronmicrograph.

(1)

☒ **A** Golgi apparatus

☒ **B** lysosomes

☒ **C** rough endoplasmic reticulum

☒ **D** smooth endoplasmic reticulum

(b) The Krebs cycle and chemiosmosis take place in mitochondria.

Explain how chemiosmosis and the production of ATP will be affected if the Krebs cycle is inhibited.

(5)

(Total for Question 1 = 10 marks)

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2 The sound made by the siren of a police car needs to be heard.

If the same sound is used repeatedly there is a risk that people will become habituated to this sound.

The auditory cortex is the part of the brain that responds to the sound made by the police siren.

(a) Explain how fMRI scanning could be used to investigate if habituation occurs when the same sound is used.

(5)

(b) Place a cross ☒ in the box to complete the following sentence.

Habituation will take place if calcium ion channels in the

(1)

☒ **A** postsynaptic membrane become less responsive

☒ **B** postsynaptic membrane become more responsive

☒ **C** presynaptic membrane become less responsive

☒ **D** presynaptic membrane become more responsive

(Total for Question 2 = 6 marks)

3 The refractory period is the time it takes for a neurone to reach its resting potential after an action potential.

(a) Describe how the resting potential is maintained in a neurone.

(3)

(b) The effect of temperature on the duration of the refractory period was investigated.

The table below shows the results of this investigation.

Temperature / °C	Mean duration of refractory period / ms
29	3.7 ± 0.7
32	2.5 ± 0.6
35	2.1 ± 0.2

Use the data in the table to describe the effect of temperature on the duration of the refractory period.

(2)

(c) A severe head injury can damage the brain and lead to epilepsy.

Epilepsy involves a sudden increase in the electrical activity of neurones in the brain. This can cause uncontrolled shaking due to the repeated contraction of muscles.

Carbamazepine is a drug used to treat epilepsy.

In an investigation, scientists stimulated neurones in a control solution and immediately measured the potential difference across the axon membrane.

They repeated this using neurones in a solution containing carbamazepine.

The table below shows the results of this investigation.

Solution	Potential difference before stimulation / mV	Potential difference after stimulation / mV
control	–70	+40
carbamazepine	–70	–70

Use the information in the table to suggest how carbamazepine is able to treat epilepsy.

(4)

(Total for Question 3 = 9 marks)

4 Krabbe disease is an inherited condition caused by a mutation of the *GALC* gene. The neurones in people with Krabbe disease gradually lose their myelin sheaths.

Galactosylceramidase is an enzyme involved in maintaining the myelin sheath in neurones.

The dominant allele of the *GALC* gene is involved in the synthesis of galactosylceramidase.

(a) Describe how the *GALC* gene is transcribed in the synthesis of galactosylceramidase.

(4)

(b) Suggest how the transmission of a nerve impulse is affected by Krabbe disease.

(2)

(c) Krabbe disease can affect the function of different parts of the brain.

Complete the table by naming the part of the brain most likely to be affected by Krabbe disease.

(2)

Symptom	Part of brain affected
loss of vision	
difficulty in walking	

(d) Explain why two healthy parents can produce a child with Krabbe disease.

(2)

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(Total for Question 4 = 10 marks)

5 Ventilation of the lungs is controlled by homeostatic mechanisms.

Six students carried out an investigation to compare the longest time they could hold their breath at rest, after exercise and after breathing in and out deeply three times.

The table below shows the mean results with standard deviations from the investigation.

Student	Longest time student was able to hold breath / s		
	At rest	After exercise	After deep breathing
1	45	16	60
2	52	7	69
3	40	12	65
4	45	4	64
5	50	20	72
6	43	17	63
Mean and standard deviation	45.8 ± 3.7	12.7 ± 5.6	65.5 ± 3.9

(a) Comment on the reliability of this investigation and data.

(2)

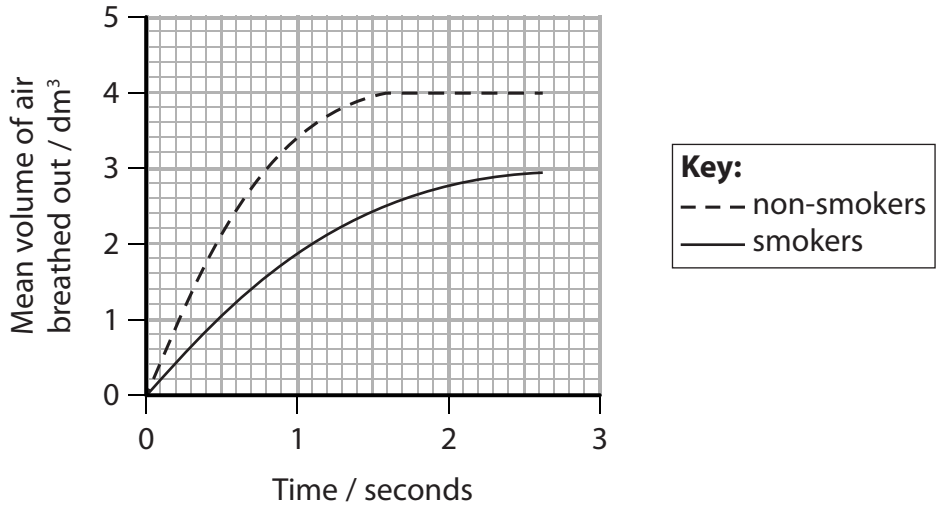
*(b) Use your knowledge of the control of ventilation to explain these results.

(6)

(c) An investigation was carried out into the effect of smoking on ventilation.

A group of smokers and a group of non-smokers were asked to breathe in as fully as possible and then breathe out as fully as possible into a spirometer.

The graph below shows the results of this investigation.



(i) The FEV_1 is the volume of air that can be forced out of the lungs in one second, after taking a deep breath in.

Place a cross ☒ in the box next to the FEV_1 for non-smokers.

(1)

☒ **A** 1.9 dm^3

☒ **B** 2.9 dm^3

☒ **C** 3.4 dm^3

☒ **D** 4.0 dm^3

(ii) Use the information in the graph to compare the results of the non-smokers with those of the smokers.

(3)

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(Total for Question 5 = 12 marks)

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6 Insecticides are widely used to reduce populations of insect pests such as locusts.

Pyrethrin is an insecticide produced naturally by chrysanthemum flowers found in East Africa.

(a) Scientists have genetically modified yeast cells to produce pyrethrin.

Suggest how yeast cells could be genetically modified to produce pyrethrin.

(4)

(b) Pyrethrin is a neurotoxin that works by binding to protein channels in the membranes of insect neurones and delaying their closure.

Suggest why pyrethrin does not affect mammalian neurones.

(2)

(c) High concentrations of some insecticides can affect the contraction of muscles that control pupil diameter in the human eye.

Explain why people who absorb high concentrations of these insecticides have pupils with a small diameter.

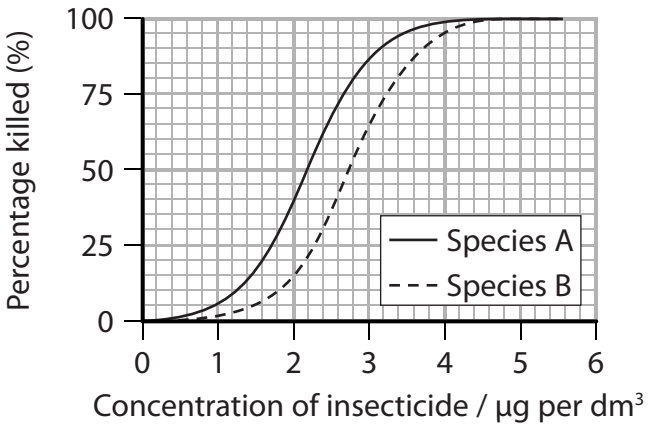
(2)

(d) Sand flies are insects that spread a disease called leishmaniasis.

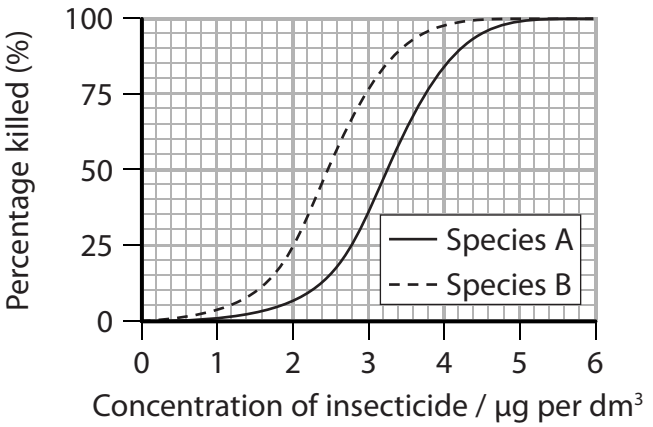
This disease causes ulcers to develop in the skin, mouth and nose.

Scientists investigated the effect of the concentration of pyrethrin and of an organochlorine insecticide on the survival of two species of sand fly, species A and species B.

The graphs below show the results.



Pyrethrin



Organochlorine

Compare the effect of the insecticides on the survival of each species of sand fly.

(3)

(e) Some insecticides also inhibit the synthesis of IAA (auxin) in plants.

Suggest how this inhibition affects these plants.

(2)

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(Total for Question 6 = 13 marks)

7 The scientific article you have studied is adapted from several sources.

Use the information from the article and your own knowledge to answer the following questions.

(a) Lance Armstrong admitted to using blood transfusions to boost his oxygen levels (paragraph 1).

He may have used autologous or homologous transfusions (paragraph 32).

Suggest why autologous transfusion would cause less risk to his health than homologous transfusion.

(2)

(b) Training can increase the cross-sectional area of individual leg muscle fibres (paragraph 4).

The table below shows the cross-sectional area of a group of leg muscle fibres sampled in a person before and after training.

Time of sampling	Cross-sectional area of group of leg muscle fibres / cm^2
Before training	82.0
After training	104.5

It was concluded that training would increase the performance of an athlete.

Explain the limitations of this conclusion.

(3)

(c) The article states that 'If the speed of movement of oxygen from the heart to where it is needed can be increased, then athletes will be able to work harder over a longer time' (paragraph 4).

Explain why increased oxygen delivery to muscle tissue enables athletes to work harder for a longer time.

(5)

(d) High blood pressure (hypertension) is an 'unwanted side effect' of steroid use (paragraph 10).

Explain why hypertension is a health risk.

(2)

(e) The review carried out by Kindermann and Meyer involved studying a number of investigations (paragraph 14).

Kindermann and Meyer looked at the methods used in these investigations.

Using your own knowledge, suggest what features of these methods gave them confidence that the conclusions were valid.

(5)

(f) ACTH is a protein hormone secreted by the pituitary gland.

Suggest how ACTH increases the secretion of hormones from the adrenal cortex (paragraph 37).

(3)

(g) State what is meant by the term 'synergistic action' (paragraph 23).

(1)

(h) Explain why HIV in a blood transfusion can have 'serious medical consequences' (paragraph 34).

(3)

*(i) The article claims that stimulants such as cocaine can affect the mental alertness of athletes (paragraph 39).

Cocaine blocks the reuptake of the neurotransmitter dopamine.

Suggest how cocaine might affect the mental alertness of an athlete.

(6)

(Total for Question 7 = 30 marks)

TOTAL FOR PAPER = 90 MARKS

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Pearson Edexcel International Advanced Level

Biology

Advanced

Unit 5: Energy, Exercise and Coordination

January 2017

Scientific Article for use with Question 7

Paper Reference

WBI05/01

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Pearson

Cheaters – drug abuse in sport

1 Lance Armstrong was a driven athlete, an American road racing cyclist who won a record number of races. The *Tour de France* is considered to be one of the toughest races, which Armstrong won a record seven consecutive times. However his career was dogged with speculation about doping – taking banned performance-enhancing substances. Although Armstrong strongly denied allegations of doping for many years, he finally admitted – in a televised interview with Oprah Winfrey in 2013 – that a deep flaw in his character, which he described as his "ruthless desire to win", led him to take banned substances throughout his career. He admitted to taking the hormones cortisone, testosterone and erythropoietin (EPO), and also to conducting blood transfusions to boost his oxygen levels. The United States Anti-Doping Agency (USADA) had formally presented evidence against Armstrong in 2012, including laboratory test results and evidence of financial payments. The Chief Executive of the USADA said at the time that this was, "the most sophisticated, professionalised and successful doping programme that the sport had ever seen." The Union Cycliste Internationale (UCI) subsequently disqualified Armstrong from all of his *Tour de France* races, stripping him of the titles and banning him from cycle road racing for life.

2 The media loved this Armstrong story; and sport is filled with similar stories about athletes prepared to use banned substances in their drive to win. George Mitchell named 89 Major League Baseball players in a report released in 2007 and based on 20 months of investigation into performance-enhancing drug use amongst players. "The illegal use of performance-enhancing substances poses a serious threat to the integrity of the game," the Mitchell Report said, and added, "Widespread use by players of such substances unfairly disadvantages the honest athletes who refuse to use them and raises questions about the validity of baseball records". So why do some athletes take banned substances? The risks are high: discovery often results in suspension from the sport we are led to believe they love, which can be career-damaging in itself. But it can be worse – Armstrong has had talks with US Justice Department officials about returning a proportion of the estimated US$40 million in sponsorship funding that his cycling team received. Some athletes have been jailed and others have died prematurely from conditions and complications associated with taking banned substances.

3 It's a cat and mouse game that the media are always keen to play. A game that's complex with high stakes and while the tests become ever more sensitive, the cheaters are always one-step ahead. Athletes understand the rewards of training hard and the elation of standing on the top of the podium. Depending on their discipline, athletes' main aim is to build muscle mass, strength and endurance and to increase the delivery (speed and amount) of oxygen to the working muscles. Training can achieve this for them, but the use of drugs can boost performance further. Additionally, they may also use drugs to mask pain, stimulate the body, relax, lose weight and of course, hide the use of other drugs. This article will look at the substances and techniques used by athletes, how drugs can affect the body, including side-effects, and how those responsible for testing are trying to keep up with the game, whilst always being at least one step behind.

Muscle mass and strength

4 Hypertrophy is the increase in size of an organ due to an increase in size of its component cells, rather than an increase in the total number of cells in the organ. Muscular hypertrophy is an increase in the cross-sectional area of individual muscle fibres, due to an increase in contractile proteins. Muscles adapt in this way when subject to increasing workloads during training sessions. Heart muscle can be developed through training, so that the heart can pump more efficiently, pushing out a greater volume of blood from its chambers with every pump and pumping more quickly. Skeletal muscle can also be developed through training by working faster and for longer periods. This is the aim of the athlete – to increase their strength and speed. Working faster – and for longer – is limited by the time it takes to move oxygenated blood from the heart to the exercising tissues, and so it is this process that is often targeted through drug use. If the speed of movement of oxygen from the heart to where it is needed can be increased, then athletes will be able to work harder over a longer time.

5 Athletes often use performance-enhancing drugs that are naturally-occurring molecules in the body, such as hormones. Taking more of these naturally-occurring substances will increase their effect. Although it is difficult to detect a substance that is found in humans naturally, increasing the levels of substances in the body can cause a range of side-effects, which can range from hardly noticeable effects to adverse or serious ones, and even death.

6 **Hormone-related substances** used by athletes to build mass and strength include:

- Anabolic steroids
- Beta-2 agonists
- Human growth hormones:
  - Human chorionic gonadotropin (HCG)
  - Luteinizing hormone (LH)
  - Human growth hormone (HGH)
  - Insulin-like growth factor (IGF-1)
  - Insulin

Anabolic steroids

7 **Anabolic steroids** build muscle and bone mass, as opposed to catabolic steroids, which break down tissues. Anabolic steroids work primarily by stimulating the muscle and bone cells to make new protein, thereby increasing muscle mass and also decreasing fat. This allows the athlete to train harder and for longer. They are manufactured drugs that mimic the effects of the male hormone testosterone, enhancing male reproductive and secondary sexual characteristics.

8 Anabolic steroids are usually injected into the muscle and often a 'cycling' method is used in order to avoid the undesirable side effects. 'Cycling' means that athletes inject the steroids for a period of time and then stop for a rest period, before starting, often synchronising the rest periods with when they are expecting to be tested, so that the tests do not detect the increased levels of the drugs.

9 Some athletes use additional steroids simultaneously, in the belief that this increases the effectiveness. This method is known as 'stacking'. Some athletes combine cycling and stacking methods, this is known as 'pyramiding'. The drug dosage is gradually increased over a period of weeks and then slowly reduced again to nothing, to allow the body a rest period, before repeating. The idea is to train harder whilst taking the drugs to maximise their effects.

10 The unwanted physiological side effects of steroid use include heart attack or stroke; tumours on liver and kidney; high blood pressure (hypertension); blood clots; fluid retention and high cholesterol. In addition, in men the following effects have been seen: reduced sperm count; infertility; shrunken testicles; baldness and breast development. In women it causes a range of male features, including hair growth on face and body; reduction of breasts; deepening of voice and menstrual problems. In addition, both men and women have experienced the psychological effects of aggressive behaviour, mood swings, manic behaviour, hallucinations and delusions.

11 Anabolic steroids are addictive – athletes may experience cravings. Habitual users will require more and more of the drug to achieve the same effect and if use is suddenly stopped, they will experience withdrawal symptoms, which may include depression and apathy; feelings of anxiety; difficulty concentrating; insomnia; anorexia; decreased sex drive; fatigue (extreme tiredness); headaches; muscle and joint pain. An addict will keep using a drug, despite its side effects.

12 Many people take anabolic steroids in the misguided belief that it will help them become fit and healthy. Adolescent boys and young men often take steroids when they consider their body not to be sufficiently big or strong. Steroid misuse is widespread in many sporting areas. Bodybuilders take them to increase bulk and strength and athletes are under even more pressure to perform, especially those requiring strength and endurance, such as weightlifters.

Beta-2 agonists

13 **Beta-2 agonists** mimic the action of adrenaline and noradrenaline that are secreted by the sympathetic nerves. They are inhaled by asthma patients to relax the smooth muscle in the airways. Asthma is chronic inflammation of the airway. It is an over-reaction to external stimuli, such as dust and pollution and can lead to bronchoconstriction. There is a genetic element to asthma and it is one of the most common chronic disorders, found in about 5% of the adult population. However, it is more common amongst athletes, found in around 10–20% of the population. This may be due, for winter sports athletes, to inhaling cold, dry air; and in the case of swimmers, where it is particularly prevalent, of training in chlorinated atmospheres. Additionally, asthmatic symptoms may be triggered by acute physical exercise, which is described as 'exercise induced asthma' (EIA).

14 If something is described as being 'ergogenic', it is intended to enhance physical performance, stamina, or recovery. In 2006, Kindermann and Meyer published the results of a review that they had carried out and concluded that "there is no ergogenic potential of inhaled beta-2 agonists in non-asthmatic athletes" and went on to recommend that "the inclusion of inhaled beta-2 agonists on the list of prohibited substances should be reconsidered".

15 The USADA Prohibited List for 2014 specifically bans all oral beta-2 agonists. It allows the use of three inhaled beta-2 agonists, but states the exact dosing that must not be exceeded. If these doses are to be exceeded then written medical consent is required, as it is for other beta-2 agonists for therapeutic use.

16 Athletes believe that when beta-2 agonists are injected into the bloodstream they have an anabolic effect (build muscle mass) and a catabolic effect (reduce body fat). They actually act to constrict blood vessels and cause a range of side-effects: constriction of blood vessel in the brain causes feelings of nausea, headaches and dizziness; constriction of blood vessels in muscles causes muscles cramps. They also stimulate heart rate, causing rapid heartbeats or flutters.

Human Growth Hormones

17 **Human chorionic gonadotrophin (HCG)** is a glycoprotein hormone which is produced in large amounts during pregnancy by the developing foetus. It is the substance that most home pregnancy test kits detect. It is not banned for female athletes, who, if pregnant, may have naturally high levels in their body.

18 Some male athletes use manufactured HCG before competition to stimulate testosterone production. It is also used to prevent infertility and testicular shrinkage to counter the effects of prolonged steroid use, ironically, as the side effects are similar to those of steroid use.

19 **Luteinising hormone (LH)** is a peptide hormone which plays an important role in maintaining normal levels of testosterone (in the male) and oestrogen (in the female). Work published by Warren in 1999 evidenced 'exercise induced amenorrhea' (absence of a menstrual period in a woman of reproductive age) in female athletes due to environmental and metabolic stresses, mainly low calorie, low fat diets, which led to the suppression of levels of LH and follicle stimulating hormone (FSH). In male athletes, excess LH or its artificial derivatives increase testosterone levels and possibly cause similar side effects to those of anabolic steroids. They are banned for male athletes.

20 **Human growth hormone (HGH)** is a naturally-occurring protein hormone which is made and secreted by cells in the anterior pituitary gland located at the base of the brain. It is involved with cellular metabolism and is important for normal growth and development.

21 The major role of HGH in body growth is to stimulate the liver and other tissues to secrete insulin-like growth factor (IGF-1), which in turn stimulates production of cartilage cells, resulting in bone growth. It also plays a key role in muscle and organ growth.

22 HGH has ergogenic, (performance-enhancing) anabolic (increasing muscle mass and bone growth) and catabolic (breakdown of fat cells) effects. Additionally, it enhances the anabolic power of steroids. HGH was difficult to detect and thus was becoming more and more popular, despite its side effects, which include acromegaly. This is the name given to enlarged face, hands and feet and enlarged internal organs, particularly the heart, kidneys, liver and tongue. In 2010, there was a blood-testing innovation that led to the suspension of a British rugby player who tested positive for HGH.

23 **Insulin-like growth factor (IGF-1)** also known as somatomedin-C, is an important protein growth hormone. It has an independent growth-stimulating effect on cartilage cells and Laron (2001) reported a possibility that this effect may be optimised by a synergistic action with HGH. Again, it also has anabolic and catabolic effects. Side effects are similar to those seen with HGH and also include hypoglycaemia (low blood sugar).

24 **Insulin** is a naturally-occurring peptide hormone produced by beta cells in the pancreas. It is vital in the regulation and metabolism of sugars, starches, fats and proteins, as it controls absorption of glucose from the blood. This absorbed glucose is stored in the liver and muscle as glycogen and stops the body from using fat as a source of energy.

25 When there is very little insulin in the blood, or none at all, glucose is not taken up and so our body uses fat as a source of energy. Athletes take insulin in combination with anabolic steroids or HGH to increase muscle mass by stimulating protein synthesis. Side effects are mainly associated with low blood sugar levels – shaking, nausea and weakness, however, excessive hypoglycaemia can lead to coma and even death.

Oxygen Delivery

26 The three main methods to increase the amount of oxygen in the tissues are the use of protein hormones, artificial oxygen carriers or blood doping.

Protein hormones

27 **Erythropoietin (EPO)** is a glycoprotein hormone, made in the kidney, that controls red blood production (erythropoiesis) in the bone marrow. EPO is released when blood oxygen levels are low to stimulate the production of red blood cells, which increase the delivery of oxygen to the tissues and organs, including the kidney. The use of EPO by endurance athletes (e.g. cross-country skiers, marathon runners and cyclists) can significantly increase their oxygen supply and its use is difficult to detect.

28 The use of EPO by athletes causes increases to their blood density, so that their blood has a constituency more like honey than water. This 'thick' blood does not flow easily and the heart must work much harder to pump the blood around the body, thereby increasing the risks of heart attack and stroke.

29 The first test for EPO was introduced at the Sydney Olympics in 2000. Synthetic EPO produces smaller than normal red blood cells, which bind more iron than natural EPO. By looking at the size of the red blood cells and their iron content, it can be established whether an athlete has taken EPO.

Artificial Oxygen Carriers

30 These are manufactured substances that mimic the role of haemoglobin. They are used legitimately by medical professionals to treat people experiencing breathing difficulties, such as premature babies, deep-sea divers and casualties with severe lung injuries. They are based around substances such as perfluorocarbons (PFCs), synthetic or modified haemoglobins and liposome-encased haemoglobins, and have the ability to carry oxygen in the body.

31 Schumacher *et al* (2001) investigated the effects of "solutions based on recombinant, bovine or human haemoglobin and perfluorocarbon-emulsions" and their tests on animals and humans demonstrated improved oxygen delivery to the muscle and thus improved aerobic exercise capacity. However, side effects are serious and can be lethal, including nephrotoxicity (kidney damage that result in the kidney no longer being able to eliminate urine and wastes); high blood pressure and problems associated with the immune system.

Blood doping

32 **Homologous blood transfusion (HBT)** is storing someone else's blood (with the same blood type), which is then injected into you when required. By contrast, autologous blood doping is the transfusion of your own blood, which has been stored (refrigerated or frozen) until needed.

33 Athletes have been using blood doping techniques to cheat for several decades and a test for homologous blood was implemented at the 2004 Summer Olympic Games in Athens. The World Anti-Doping Agency (WADA) is currently funding research projects to develop a test for autologous transfusions.

34 Unofficial blood transfusions can have serious medical consequences. Without proper screening, another person's blood may contain a virus, such as HIV. Blood also needs to be handled and stored correctly and the transfusion procedures carried out in a proper manner, in order not to put the recipient at significant health risks. Increased blood volume causes high blood pressure and increases the risk of heart attack, stroke, and pulmonary or cerebral embolism.

Pain

35 Injuries are an inevitable part of training, especially at high intensities for prolonged periods, such as undertaken by top athletes. Careers can be plagued with and hampered by injuries, which can also end careers prematurely. The sensation of pain is usually a signal for us to stop what we are doing, because something is wrong with our body: continuing may cause further damage. Athletes sometimes try to mask their injury pain with drugs, including narcotics, adrenal cortex hormones and local anaesthetics, in order to continue competing and performing beyond their normal pain threshold.

36 **Narcotics** use in sport is banned because this class of drugs impair athletes' judgment in potentially dangerous situations. Athletes have been known to use morphine, methadone and heroin. Narcotics are highly addictive and cause mental impairment, including judgement, balance and concentration as well as potentially long-term mental health issues.

37 **Adrenal cortex hormones**, such as adrenocorticotropic hormone (ACTH) are protein hormones that work to reduce injury-related inflammation and allergic reactions. ACTH is secreted by the pituitary gland and stimulates the production of hormones from the adrenal cortex. They are used by athletes to increase the production of androgens by the adrenal glands to mask injury pain. However, this also raises cortisol levels, which increases the production of glucose and which in turn raises blood glucose levels. Common side effects include stomach pains, nausea and vomiting; indigestion and weight gain; skin problems and facial swellings; irregular heartbeat, menstrual problems, muscle cramps and irregular bruising and poor healing as well as mental health problems including tiredness, hallucinations, confusion, excitement, restlessness and mood swings.

38 **Local anaesthetics** mask pain in just one area of the body, such as a dentist would use to numb an area of the mouth, without mental impairment (the dentist's patient is conscious). The main issue with their use is that, in masking pain, the athlete may further aggravate an injury. Although WADA currently does not ban the use of local anaesthetics in sport, there is the question of whether reducing or eliminating pain constitutes a performance-enhancing intervention.

Coping with stress

39 **Stimulants** are used by athletes living within strict social rules and training regimes to cope with general fatigue, to help keep them alert, to reduce tiredness and maintain aggressiveness. Commonly used stimulants include caffeine, amphetamines and cocaine, which cause the heart to beat faster, breathing rate to increase and give an increase in mental alertness. There are, of course, the inevitable side effects, including shaking, nervousness, irregular heartbeats, high blood pressure, convulsions and even death.

40 **Relaxants** are taken by some athletes to cope with a stressful timetable, strict social and dietary guidelines and the pressures of competition. **Alcohol** reduces activity in the brain and nervous system and is regularly used by many people to help them relax. It can significantly impair mental functions (judgement, balance, coordination), especially in excess and is restricted by the International Olympic Committee (IOC) and banned altogether in certain events. Meanwhile **beta-blockers** are permitted, by prescription, for athletes competing in archery and shooting competitions and other sports that require a steady hand. They are used to treat high blood pressure and work by slowing down the heart and relaxing the blood vessels. Not surprisingly, side effects include a slow heart rate, leading to fatigue and hypotension (low blood pressure).

41 The clinical value of **cannabinoids**, such as marijuana, still has to be proven, but they are said by some people to relieve pain and are used as a relaxant. Side effects include hallucinations, drowsiness, increased heart rate, impaired judgement, balance, coordination and memory.

Drug testing

42 Urine tests can detect many of the drugs used by athletes. Collecting urine samples from athletes is the responsibility of a drug control officer, who sends the sample for laboratory analysis. The test results are sent directly to the governing sports agency. Blood samples are also sometimes required for detection of certain drugs. Athletes often take additional substances to mask the use of banned drugs, although these are often banned themselves because of their masking effects.

One of the difficulties of drug testing is that the governing bodies and testing technicians have to know what to look for to be able to devise detection tests. This means that when new or different drugs start being used, a new test has to be developed to detect it and this takes time.

Masking drugs in the urine

43 **Diuretics** increase the rate of urine flow and sodium excretion to regulate the volume and composition of body fluids and are a prescribed drug for high blood pressure. They can mask the presence of other banned substances in the urine because they act on the kidneys, increasing the amount of urine produced and thereby diluting the concentration of other drugs. Diuretics are particularly favoured by athletes who are subject to weight restrictions, including jockeys, weightlifters and rowers, because urine excretion results in rapid weight loss: a convenient trick just before your weigh-in.

44 **Secretion inhibitors** prevent certain proteins from being secreted in urine and thus not be detected in urine tests. Side effects include nausea, vomiting, kidney problems and allergic reactions.

Masking drugs in the blood

45 **Epitestosterone** is a natural steroid, which is used to mask the use of testosterone and has been banned for this reason by many sporting authorities, even though it has not been shown to enhance performance itself. Testosterone is tested for by determining the ratio of testosterone to epitestosterone in the blood (T/E ratio). By injecting epitestosterone, the T/E ratio is lowered from the 1:1 ratio expected in healthy male adults.

46 **Plasma expanders** are injected by athletes to increase the volume of the fluid component of their blood and thus reduce the concentration of drugs in their system. They are used by medical professionals in the treatment of victims of shock, trauma and surgery. Side effects are mainly limited to allergic reactions.

Gas chromatography and mass spectrometry tests

47 Gas chromatography (GC) and mass spectrometry (MS) together provide powerful chemical analysis. Urine and blood samples given by athletes are subjected to these methods to detect numerous drugs.

48 **The gas chromatography test** separates all of the components in a sample. This is done by first injecting the sample into the GC machine, where the sample is vaporised in a gaseous solvent. Each substance dissolves differently in the gas and stays in the gas phase for a different length of time. This period is called the 'retention time' and is unique and specific to each substance, helping to differentiate and identify each component. The different retention times are due to different chemical and physical characteristics of the molecules, causing them to travel through the GC column at different speeds. Small, low mass molecules may travel more quickly that larger, heavier molecules. The shape of the molecules will also affect the speed at which they travel through the column, as will interaction between substances, which can increase or decrease their speed. Each component of the sample is absorbed onto a solid or liquid when it comes out of the gas phase and is analysed by a detector in the GC machine, which then provides a print out or digital image of the retention times, called a chromatogram. The location of the peaks in the sample's chromatogram are compared with standard chromatograms of known substances in order to identify and quantify the specific drugs in the athlete's sample. The size of the peaks is proportional to the quantity of the substance in the sample being analysed.

49 **Mass spectrometry** identifies substances by electrically charging the sample molecules with an electron beam and accelerating them through a magnetic field. This blows apart the molecules into charged fragments and these different charges are detected. A spectral plot displays the mass of each fragment, which is unique to that substance and can be identified against plots for known substances. These fragment masses are used to determine the mass of the original molecule, and hence its quantity.

Immuno-assays

50 These are quick and accurate tests that can be carried out on-site to detect specific molecules. The sample is mixed with a solution containing antibodies specific to the target substance and relies on the capacity of the antibodies to bind to the specific structure of a molecule. The antibodies in the test are usually labelled – either with a fluorescent dye or a radioactive substance. In this way the amount of the target substance in the sample can be determined by measuring the level of fluorescence or radioactivity.

51 **WADA is pioneering a new approach to drug detection** in the development of the Athlete Passport. This strategy moves away from individual substance detection, by instead monitoring athletes over time to gain a profile of their system, by recording selected variables. The effects of doping can then be revealed through the detection of abnormal variations. New WADA guidelines came into effect on 1st January 2014 to detect steroid doping by monitoring selected urinary steroid concentrations over time. Others are planned to be introduced as soon as they are ready.

All sporting governing bodies and anti-doping agencies have a hard task ahead of them in trying to keep sports clean; despite athletes, coaches and managers insisting that most competitors do not take drugs. Nevertheless drug testing is now an integral part of competition with routine testing of winners and random testing of others. The pressure on athletes to perform and achieve is huge and the rewards can be equally sizeable – not least through financial rewards or celebrity status – although careers can be very short.

52 The pressure has always been there and even athletes in ancient Greece were willing to take medicinal preparations that gave promises of improved performance. In 1967, Dr Gabe Mirkin asked 100 runners a question that has now also become known as 'Goldman's dilemma'. Goldman repeated the question to athletes in combat and power sports, and observed similar results i.e. over half of athletes replied in the affirmative. What was that question? "If I could give you a pill that would make you an Olympic champion – and also kill you in a year – would you take it?"

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