Please check the examination details below before entering your candidate information

Candidate surname	Other names

Centre Number | Candidate Number

Pearson Edexcel International Advanced Level

Time 1 hour 45 minutes

Paper reference **WBI15/01**

Biology

International Advanced Level
UNIT 5: Respiration, Internal Environment, Coordination and Gene Technology

You must have:
Scientific article (enclosed), scientific calculator, ruler, HB pencil

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.*
- **Show all your working out** in calculations and **include units** where appropriate.

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.*
- In questions marked with an **asterisk** (*), marks will be awarded for your ability to structure your answer logically, showing how the points that you make are related or follow on from each other where appropriate.

Advice

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

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Answer ALL questions.

Write your answers in the spaces provided.

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 supply energy for the processes in cells.

(a) (i) How many of these statements about the inner membrane of a mitochondrion are correct?

(1)

- it is folded (has cristae)
- it is the location of ATP synthase
- it is the site of the electron transfer chain
- it is a site of protein synthesis

☒ **A** 1

☒ **B** 2

☒ **C** 3

☒ **D** 4

(ii) Anaerobic respiration produces lactate as a waste product.

Which is the result of lactate production?

(1)

☒ **A** blood becomes less acidic

☒ **B** muscle becomes less fatigued

☒ **C** pH of the blood increases

☒ **D** muscle becomes more acidic

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(b) Describe how chemiosmosis is involved in the synthesis of ATP.

(2)

(c) A culture containing respiring cells was supplied with radioactive oxygen molecules.

Which will be the first substance to contain radioactive oxygen atoms?

(1)

- ☒ **A** ATP
- ☒ **B** carbon dioxide
- ☒ **C** reduced NAD
- ☒ **D** water

(Total for Question 1 = 5 marks)

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2 The giraffe is the tallest mammal and has a long neck.

The photograph shows a giraffe.

(Source: © Eugen Haag/Shutterstock)

(a) (i) Which structure joins the bones of the neck together?

(1)

- ☒ **A** actin
- ☒ **B** ligament
- ☒ **C** muscle
- ☒ **D** tendon

(ii) Which structure joins a muscle to a bone?

(1)

- ☒ **A** actin
- ☒ **B** ligament
- ☒ **C** myosin
- ☒ **D** tendon

(iii) Which chemical group contains actin and myosin?

(1)

- ☒ **A** carbohydrates
- ☒ **B** fatty acids
- ☒ **C** nucleic acids
- ☒ **D** proteins

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(b) Giraffes must bend down to drink water.

(Source: © Wim Hoek/Shutterstock)

(i) Explain how the knee joint can be held steady in this position as the giraffe drinks.

(2)

(ii) Describe the role of ATP in the sliding filament theory of muscle contraction.

(3)

(Total for Question 2 = 8 marks)

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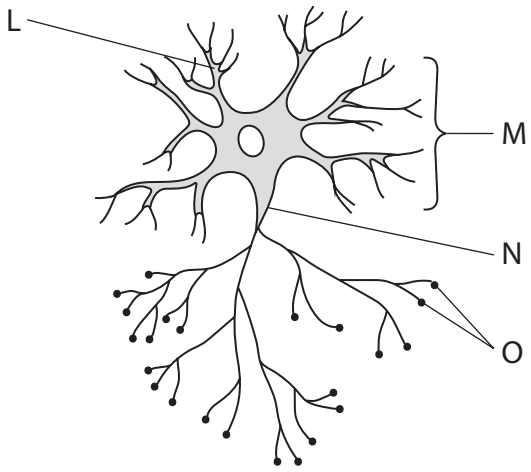
3 The diagram shows a relay neurone.



(a) (i) Complete the table by filling in the names of each labelled part.

(2)

Label	Part
L	
M	
N	
O	

(ii) Lidocaine is a drug that is used as a local anaesthetic.

Lidocaine works by

(1)

- ☒ **A** blocking the binding of acetylcholine to its receptor
- ☒ **B** blocking the release of acetylcholine
- ☒ **C** inhibiting potassium ion channels
- ☒ **D** inhibiting sodium ion channels

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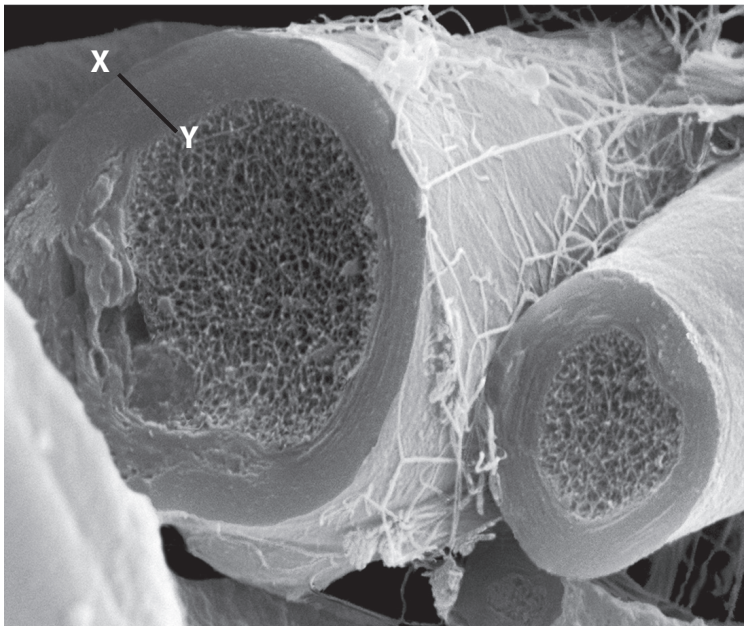
(b) The photograph shows a nerve with an outer layer of connective tissue.



(Source: © Science Photo Library/Alamy Stock Photo)

Magnification × 3300

(i) State the type of microscope used to produce this image.

(1)

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(ii) Calculate the thickness of the connective tissue layer between the points X and Y.

Give your answer in micrometres (μm).

(2)

Answer ..... μm

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(iii) The nerve shown in the photograph contains many myelinated neurones.

Explain why a myelinated neurone conducts an impulse faster than a non-myelinated neurone of the same diameter.

(3)

(Total for Question 3 = 9 marks)

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4 Animal species have different resting heart rates.

(a) The table shows the resting heart rate and mean life expectancy for some animal species.

Animal species	Resting heart rate / bpm	Mean life expectancy / years	Mean mass / kg	Mean resting metabolic rate / $dm^3\ O_2\ kg^{-1}\ hr^{-1}$
elephant	30	80	5780	1400
horse	38	30	500	910
human	72	78	110	360
rabbit	205	12	7	48
rat	420	1.8	2	10.8
humming bird	1260	7	0.02	0.012

(i) Describe the relationships between resting heart rate and the data shown in the table.

(2)

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(ii) Calculate the volume of oxygen produced each hour by a resting elephant with a mass of 4500 kg.

Give your answer in standard form.

(3)

Answer .....

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(b) The photograph shows a cheetah.

(Source: © Stu Porter/Shutterstock)

The heart rate for a cheetah increases from 120 bpm to 250 bpm during a chase. It can reach speeds of 100 km hr^{-1}

(i) Explain how the heart rate of a cheetah can be increased during a chase.

(4)

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(ii) Suggest why a cheetah can maintain this heart rate and speed for only a short period of time.

(2)

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(Total for Question 4 = 11 marks)

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5 The photograph shows a camel.

(Source: © Shengyong Li/Shutterstock)

Camels are an important livestock species. They are adapted to living in hot, dry environments.

(a) How many of the following adaptations enable a camel to reduce its water loss?

- production of very concentrated urine
- high glomerular filtration rate
- long loop of Henle
- reduced release of ADH

(1)

☒ **A** 0

☒ **B** 1

☒ **C** 2

☒ **D** 3

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(b) The table shows the water use of five species of animal.

Species	Water use / $cm^3\ kg^{-1}\ day^{-1}$	Mean mass / kg
buffalo	150	697
camel	57	850
goat	136	80
sheep	95	110
zebu	120	195

(i) Calculate the difference in the volume of water use in a day by a buffalo and a camel.

Give your answer in dm^3 to two significant figures.

(2)

Answer ..... dm^3

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(ii) Suggest two reasons why there is no correlation between water use and mean mass for the species given in the table.

(2)

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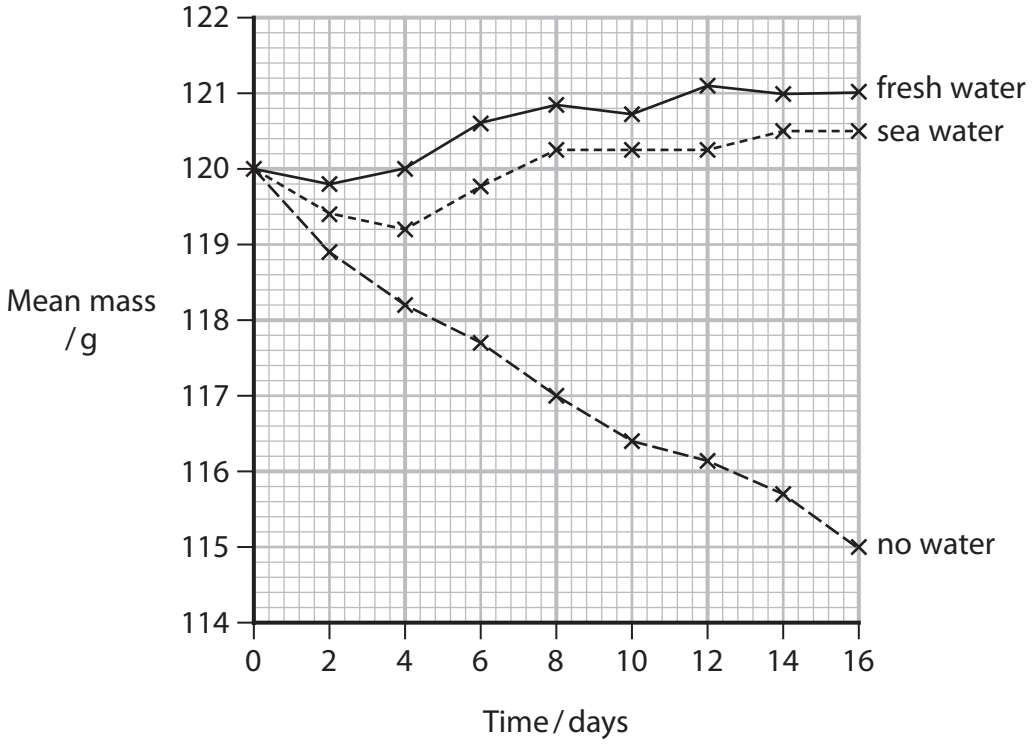
(c) The kangaroo rat is another animal that lives in a hot, dry environment.

In an investigation, kangaroo rats were given either fresh water, sea water or no water.

The graph shows the mean body mass of kangaroo rats which were fed on a diet of soya beans over a 16-day period.



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Determine the effect of the type of water given on the mean mass of the kangaroo rats in this investigation.

Use the information in the graph to support your answer.

(3)

(d) The kangaroo rat's kidneys play an important role in the process of conserving water.

Explain how the nephrons (kidney tubules) in the kidneys of the kangaroo rat are able to produce very concentrated urine.

(2)

(Total for Question 5 = 10 marks)

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6 Plants respond to external stimuli.

(a) Phytochrome molecules are found in plants.

Phytochrome exists in two forms, Pr (P_{660}) and Pfr (P_{730}).

Which row shows the action of these two forms of phytochrome?

(1)

		Absorbs far red light	Breaks down in the dark
☒	**A**	Pfr	Pfr
☒	**B**	Pfr	Pr
☒	**C**	Pr	Pfr
☒	**D**	Pr	Pr

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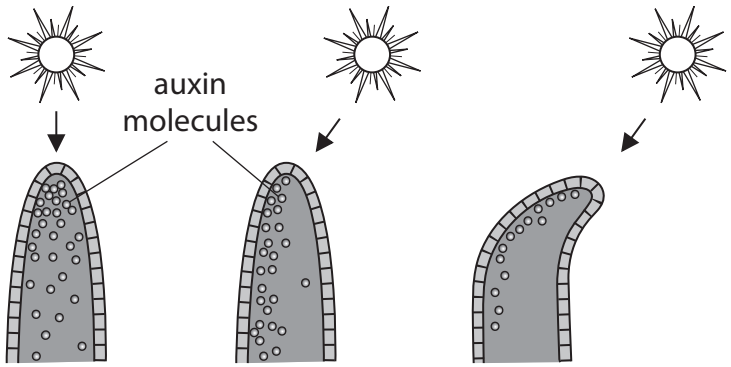
(b) Auxins (IAA) are plant growth substances.

The diagram shows auxin molecules producing a phototropic response in a shoot.



Explain the role of auxins in this phototropic response.

Use the information in the diagram to support your answer.

(3)

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(c) Seeds contain starch. This starch is used to supply energy when the seed germinates.

Gibberellins are a group of naturally occurring plant growth substances.

Gibberellins regulate starch hydrolysis in the seed.

Explain how gibberellins can produce this effect on the seed.

(4)

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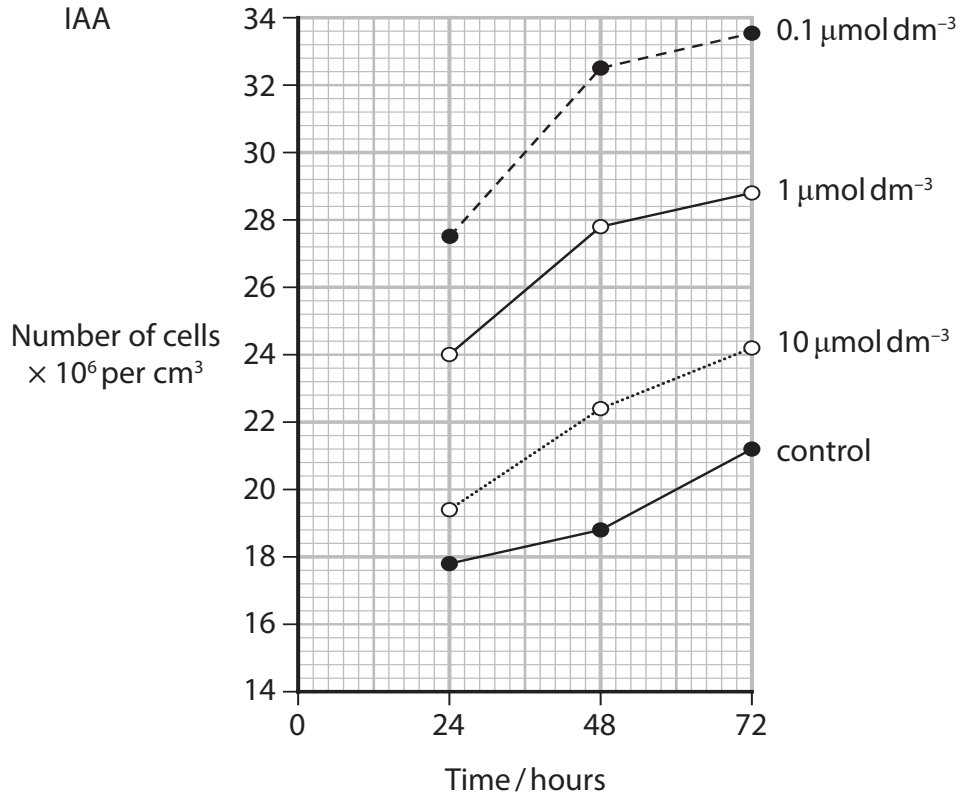
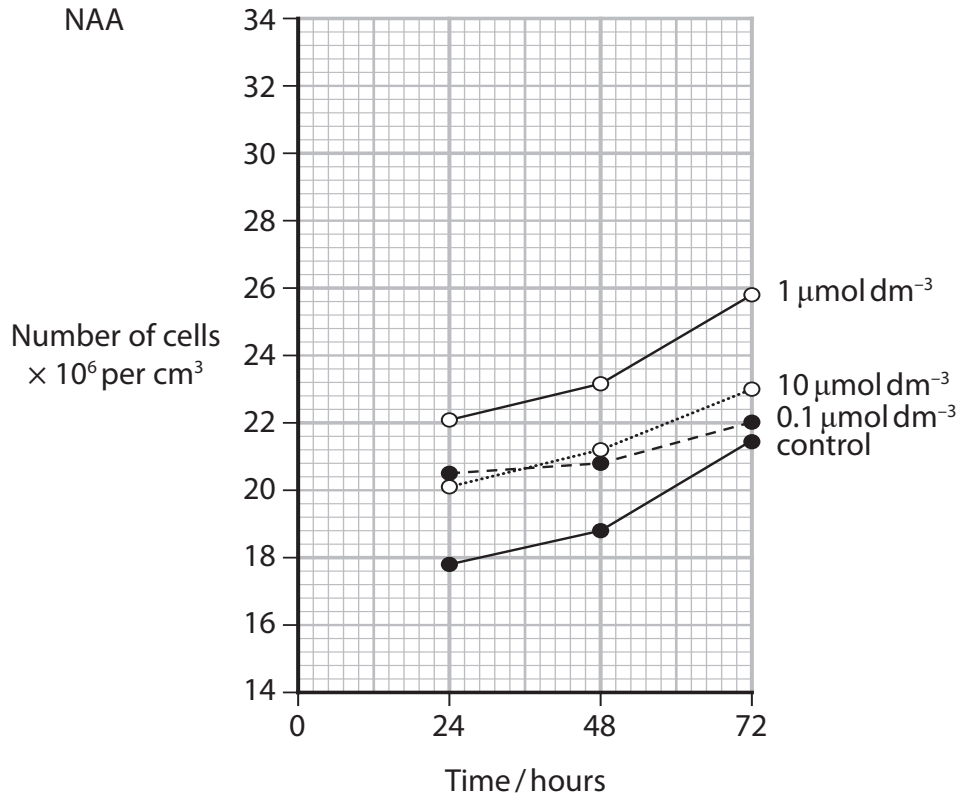
(d) Indole acetic acid (IAA) is a natural plant auxin. 1-Naphthaleneacetic acid (NAA) is a synthetic auxin.

The effects of these two auxins on the growth of *Chlorella* was investigated.

Chlorella is a single-celled photosynthetic organism.

The graphs show the effect of different concentrations of the auxins on the growth of *Chlorella*.





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Comment on the effect of these auxins on the growth of *Chlorella*.

(4)

(Total for Question 6 = 12 marks)

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7 Animals and plants can be genetically modified.

(a) Recombinant human erythropoietin (rHE) is a protein drug that can be given to patients with low haemoglobin concentrations.

(i) Sheep have been genetically modified to produce rHE in their milk.

Explain how a sheep could be genetically modified to produce rHE in its milk.

(4)

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(ii) In a clinical study, 4382 patients were treated with rHE. They showed a mean increase in blood haemoglobin from 80 g dm^{-3} to 142 g dm^{-3}.

Calculate the percentage increase in the mean blood haemoglobin concentration as a result of rHE treatment.

(1)

Answer ..... %

(iii) Some patients receiving rHE develop anti-rHE antibodies.

Describe how these antibodies may be produced.

(4)

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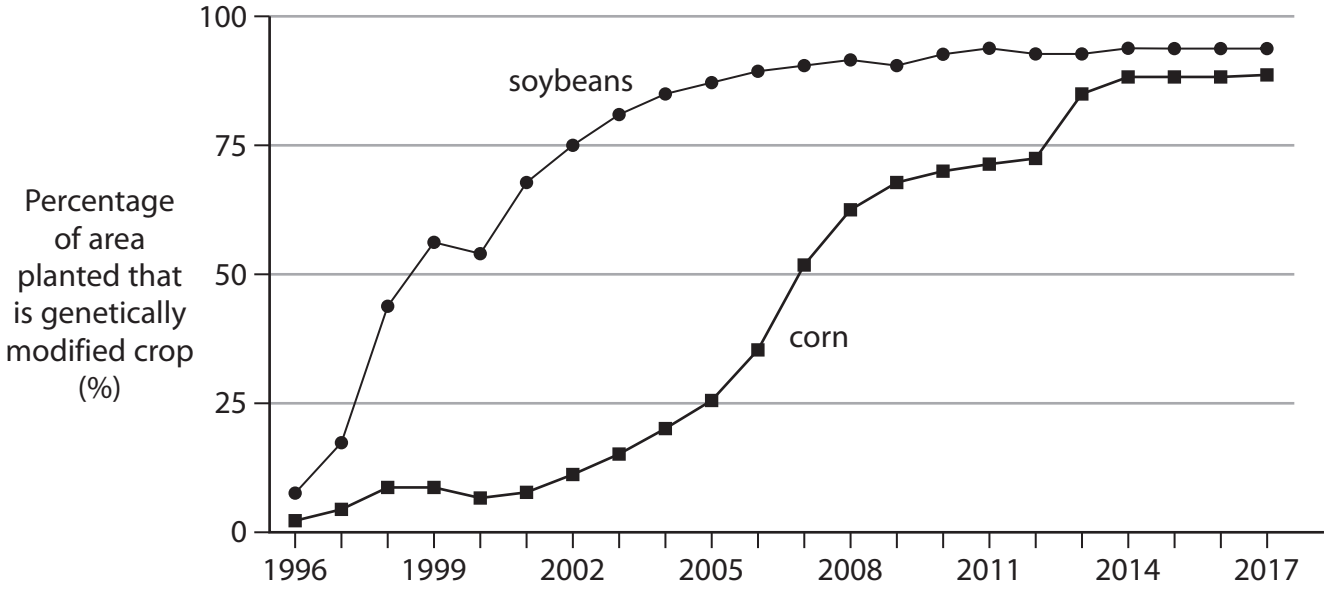
(b) Advances in genetic engineering have allowed for precise control of the genetic changes introduced into plants.

The table describes some examples of the use of genetic modification in plants.

Trait	Plant	Details
herbicide tolerance	soybean	glycophosphate herbicide tolerance using a gene from the bacterium *A. tumefaciens*
insect resistance	corn	resistance to European corn borer using a gene from *B. thuringiensis*

The graph shows the increase in the use of genetically modified crops in the United States from 1996 to 2017.



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Discuss the risks and benefits of genetic modification in valuable agricultural plants.

Use all the data and your own knowledge to support your answer.

(6)

(Total for Question 7 = 15 marks)

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8 The scientific document you have studied is adapted from an article *'How we perceive the world' by Julius D. and Patapoutian A.* in 2021.

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

(a) Describe how light is detected by the rod cells in the eye (paragraph 1).

(4)

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(b) Suggest how the genes expressed in a sensory neurone could be identified (paragraph 4).

(3)

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(c) Explain how capsaicin could activate nerve cells causing a pain sensation (paragraph 4).

(3)

(d) Explain how changes in ion channel protein can result in nerve impulses in the nervous system (paragraph 5).

(3)

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(e) Explain how mechanical stimuli, e.g. pressure, are converted into electrical signals in cells (paragraphs 5 and 7).

(3)

(f) Explain what is meant by the phrase 'Based on its similarity to Piezo 1, a second ion channel was found (Piezo 2)' (paragraph 7 and Figure 3).

(2)

(g) Suggest the role of TRPV1 in maintaining core body temperature (paragraph 9).

(2)

(Total for Question 8 = 20 marks)

TOTAL FOR PAPER = 90 MARKS

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Biology

International Advanced Level
UNIT 5: Respiration, Internal Environment, Coordination and Gene Technology

Scientific article for use with Question 8

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Scientific article for use with Question 8

How do we perceive the world?

1 One of the great mysteries facing humanity is the question of how we sense our environment. The mechanisms underlying our senses have triggered our curiosity for thousands of years, for example, how light is detected by the eyes, how sound waves affect our inner ears, and how different chemical compounds interact with receptors in our nose and mouth generating smell and taste. We also have other ways to perceive the world around us. Imagine walking barefoot across a lawn on a hot summer's day. You can feel the heat of the sun, the caress of the wind, and the individual blades of grass underneath your feet. These impressions of temperature, touch and movement are essential for our adaptation to the constantly changing surrounding.

2 In the 17th century, the philosopher René Descartes envisioned threads connecting different parts of the skin with the brain. In this way, a foot touching an open flame would send a mechanical signal to the brain (Figure 1). Discoveries later revealed the existence of specialized sensory neurons that register changes in our environment. Joseph Erlanger and Herbert Gasser received the Nobel Prize in Physiology or Medicine in 1944 for their discovery of different types of sensory nerve fibers that react to distinct stimuli, for example, in the responses to painful and non-painful touch. Since then, it has been demonstrated that nerve cells are highly specialized for detecting and transducing differing types of stimuli, allowing a nuanced perception of our surroundings; for example, our capacity to feel differences in the texture of surfaces through our fingertips, or our ability to discern both pleasing warmth, and painful heat.

3 Prior to the discoveries of David Julius and Ardem Patapoutian, our understanding of how the nervous system senses and interprets our environment still contained a fundamental unsolved question: how are temperature and mechanical stimuli converted into electrical impulses in the nervous system?

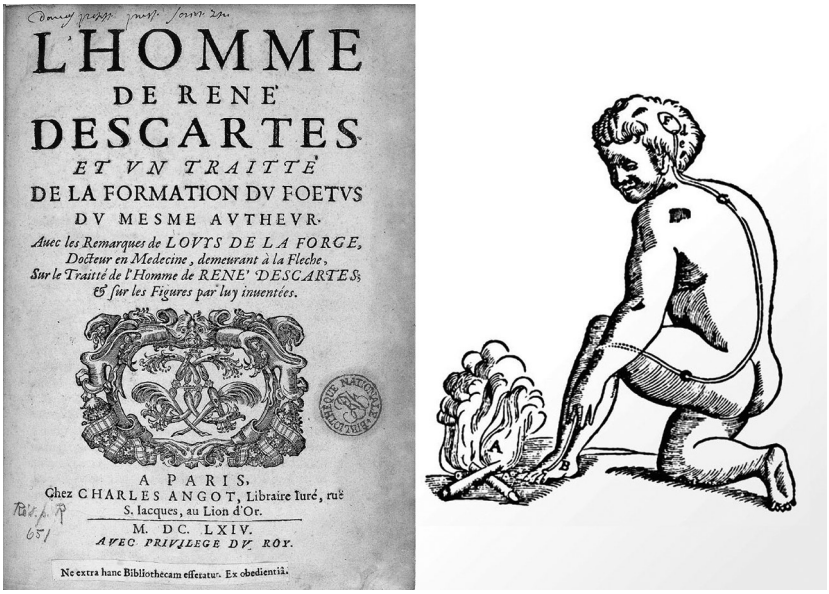

Figure 1 Illustration depicting how the philosopher René Descartes imagined how heat sends mechanical signals to the brain.

The science heats up!

4 In the latter part of the 1990's, David Julius at the University of California, San Francisco, USA, saw the possibility for major advances by analyzing how the chemical compound capsaicin causes the burning sensation we feel when we come into contact with chili peppers. Capsaicin was already known to activate nerve cells causing pain sensations, but how this chemical actually exerted this function was an unsolved riddle. Julius and his coworkers created a library of millions of DNA fragments corresponding to genes that are expressed in the sensory neurons which can react to pain, heat, and touch. Julius and colleagues hypothesized that the library would include a DNA fragment encoding the protein capable of reacting to capsaicin. They expressed individual genes from this collection in cultured cells that normally do not react to capsaicin. After a laborious search, a single gene was identified that was able to make cells capsaicin sensitive (Figure 2). The gene for capsaicin sensing had been found! Further experiments revealed that the identified gene encoded a novel ion channel protein and this newly discovered capsaicin receptor was later named TRPV1. When Julius investigated the protein's ability to respond to heat, he realized that he had discovered a heat-sensing receptor that is activated at temperatures perceived as painful (Figure 2).

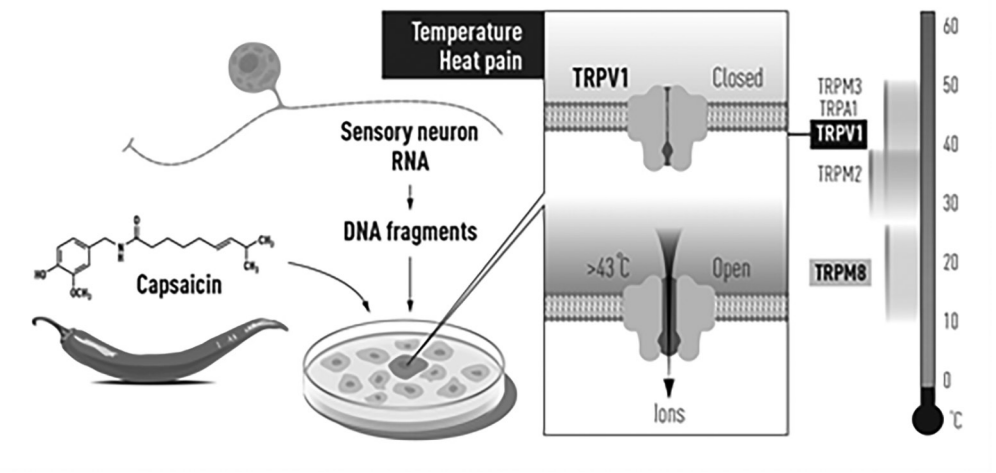

Figure 2 David Julius used capsaicin from chili peppers to identify TRPV1, an ion channel activated by painful heat. Additional related ion channels were identified and we now understand how different temperatures can induce electrical signals in the nervous system.

5 The discovery of TRPV1 was a major breakthrough leading the way to the unravelling of additional temperature-sensing receptors. Independently of one another, both David Julius and Ardem Patapoutian used the chemical substance menthol to identify TRPM8, a receptor that was shown to be activated by cold. Additional ion channels related to TRPV1 and TRPM8 were identified and found to be activated by a range of different temperatures. Many laboratories pursued research programs to investigate the roles of these channels in thermal sensation by using genetically manipulated mice that lacked these newly discovered genes. David Julius' discovery of TRPV1 was the breakthrough that allowed us to understand how differences in temperature can induce electrical signals in the nervous system.

Research under pressure!

6 While the mechanisms for temperature sensation were unfolding, it remained unclear how mechanical stimuli could be converted into our senses of touch and pressure. Researchers had previously found mechanical sensors in bacteria, but the mechanisms underlying touch in vertebrates remained unknown. Ardem Patapoutian, working at Scripps Research in La Jolla, California, USA, wished to identify the elusive receptors that are activated by mechanical stimuli.

7 Patapoutian and his collaborators first identified a cell line that gave off a measurable electric signal when individual cells were poked with a micropipette. It was assumed that the receptor activated by mechanical force is an ion channel and in a next step 72 candidate genes encoding possible receptors were identified. These genes were inactivated one by one to discover the gene responsible for mechanosensitivity in the studied cells. After an arduous search, Patapoutian and his co-workers succeeded in identifying a single gene whose silencing rendered the cells insensitive to poking with the micropipette. A new and entirely unknown mechanosensitive ion channel had been discovered and was given the name Piezo1, after the Greek word for pressure (píesh; *píesi*). Through its similarity to Piezo1, a second gene was discovered and named Piezo2. Sensory neurons were found to express high levels of Piezo2 and further studies firmly established that Piezo1 and Piezo2 are ion channels that are directly activated by the exertion of pressure on cell membranes (Figure 3).

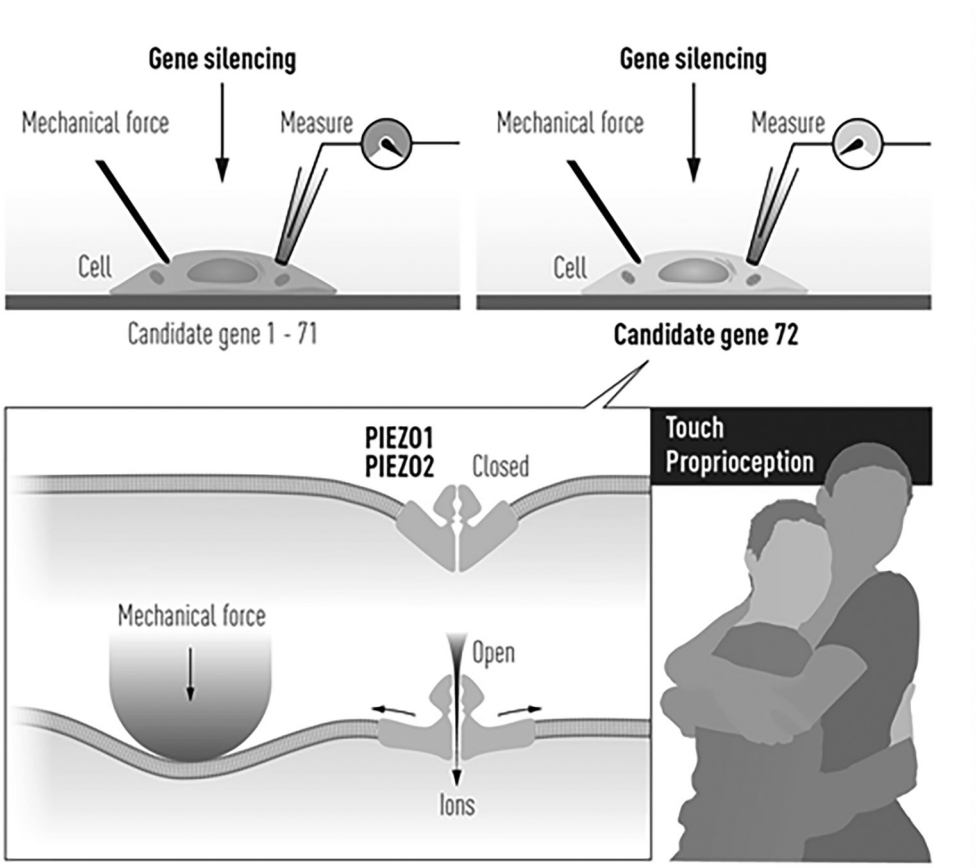

Figure 3 Patapoutian used cultured mechanosensitive cells to identify an ion channel activated by mechanical force. After painstaking work, Piezo1 was identified. Based on its similarity to Piezo1, a second ion channel was found (Piezo2).

8 The breakthrough by Patapoutian led to a series of papers from his and other groups, demonstrating that the Piezo2 ion channel is essential for the sense of touch. Moreover, Piezo2 was shown to play a key role in the critically important sensing of body position and motion, known as proprioception. In further work, Piezo1 and Piezo2 channels have been shown to regulate additional important physiological processes including blood pressure, respiration and urinary bladder control.

It all makes sense!

9 The groundbreaking discoveries of the TRPV1, TRPM8 and Piezo channels by this year's Nobel Laureates have allowed us to understand how heat, cold and mechanical force can initiate the nerve impulses that allow us to perceive and adapt to the world around us. The TRP channels are central for our ability to perceive temperature. The Piezo2 channel endows us with the sense of touch and the ability to feel the position and movement of our body parts. TRP and Piezo channels also contribute to numerous additional physiological functions that depend on sensing temperature or mechanical stimuli. Intensive ongoing research originating from this year's Nobel Prize awarded discoveries focusses on elucidating their functions in a variety of physiological processes. This knowledge is being used to develop treatments for a wide range of disease conditions, including chronic pain (Figure 4).

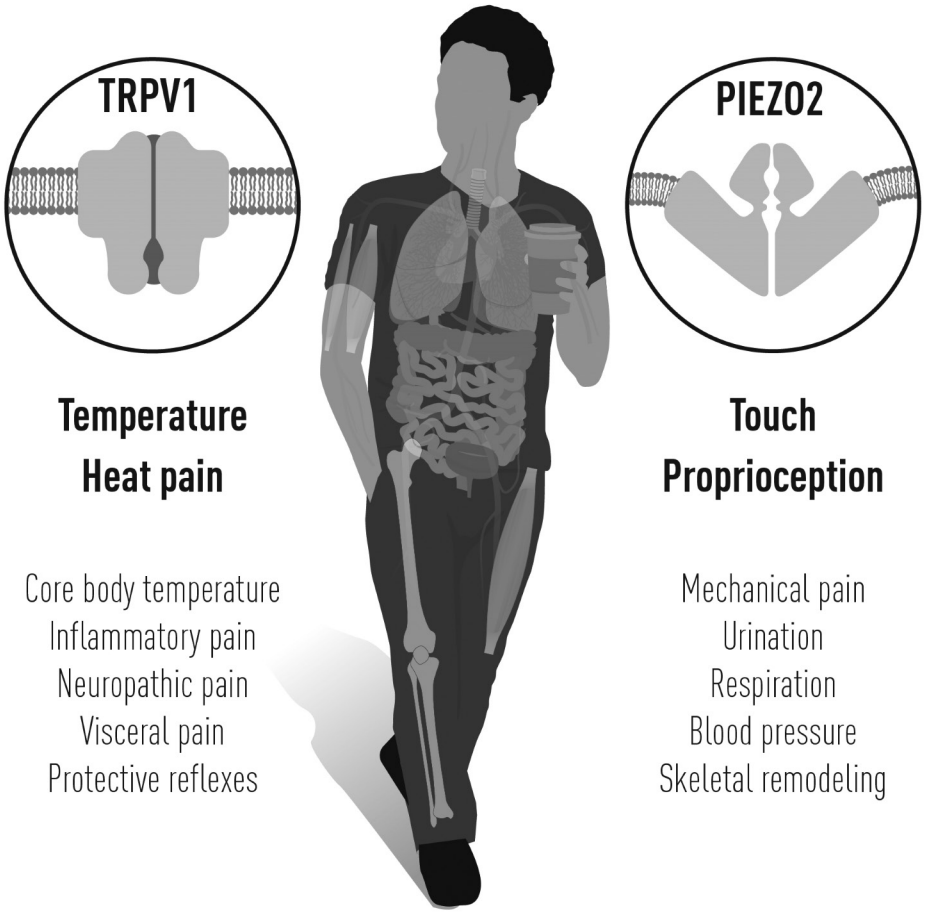

Figure 4 The seminal discoveries by this year's Nobel Laureates have explained how heat, cold and touch can initiate signals in our nervous system. The identified ion channels are important for many physiological processes and disease conditions.

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