# HL Paper 2

a. Outline the various stages of the cell cycle. [4]

c. Define the term *transpiration* and explain the factors that can affect transpiration in a typical terrestrial plant. [9]

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a. Describe the characteristics of stem cells that make them potentially useful in medicine. [5]

b. Outline a technique of gene transfer resulting in genetically modified organisms. [5]

c. Explain the use of karyotyping in human genetics. [8]

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a. Explain how minerals move into plants. [8]

b. Outline the conditions needed for the germination of a typical seed. [3]

c. Following germination of seeds, plants undergo a rapid increase in the number of cells. Describe stages in the cell cycle that result in this increase of cells. [7]

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a. Draw a labelled diagram to show the structure of the plasma membrane. [5]

b. The light-dependent reactions in photosynthesis take place on the thylakoid membranes. Explain the light-dependent reactions. [8]

c. Outline two factors that affect the rate of photosynthesis. [5]

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a. Draw a labelled diagram of the ultrastructure of *Escherichia coli* as an example of a prokaryote. [4]

b. Describe the events that occur in the four phases of mitosis in animals. [6]

c. Explain the process of aerobic cell respiration after glycolysis has occurred. [8]

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a. Draw a labelled diagram to show the molecular structure of a membrane. [4]

b. Some proteins in membranes act as enzymes. Describe a model that accounts for the ability of enzymes to catalyse reactions. [6]

c. Membranes of pre-synaptic and post-synaptic neurons play an important role in transmission of nerve impulses. Explain the principles of synaptic transmission. [8]

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a. Draw a labelled diagram that shows the positions of proteins within the cell membrane. [3]

b. Outline the effects of putting plant tissue in a hypertonic solution. [4]

c. Explain how the structure of the nephron and its associated blood vessels enable the kidney to carry out its functions. [8]

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Oxygen is needed to complete aerobic cell respiration.

a. Explain how chemical energy for use in the cell is generated by electron transport and chemiosmosis. [8]

b. Outline **four** different functions of membrane proteins. [4]

c. Distinguish between anabolism, catabolism and metabolism. [3]

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a. Describe **four** different types of transport of substances across a membrane. [4]

b. Hormones such as FSH (follicle stimulating hormone) and LH (luteinizing hormone) affect the development of certain cells by binding to receptors in the plasma membranes. Outline the role of FSH and LH in the menstrual cycle. [6]

c. In the placenta, many substances are transported across membranes. Explain the structure and role of the placenta. [8]

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a. Draw a labelled diagram of a eukaryotic plant cell as seen in an electron micrograph. [4]

b. Outline how the energy flow through food chains limits their length. [3]

c. In hot, dry conditions plants lose water rapidly due to transpiration. Explain how the structures and processes of the plant allow this water to be replaced. [8]

a. Draw a labelled diagram of the ultrastructure of a prokaryote. [4]

b. Explain the process of DNA replication. [8]

c. Outline how the structure of the ribosome is related to its function in translation. [6]

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a. Draw a labelled diagram to show the structure of a sarcomere. [5]

b. Explain how an impulse passes along the axon of a neuron. [8]

c. Describe the process of endocytosis. [5]

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a. Draw a labelled diagram of a prokaryotic cell. [4]

b. Outline transcription in prokaryotes. [6]

c. Some prokaryotes cause infectious disease in humans. Explain the principles of vaccination. [8]

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b. Outline, with an example, the process of exocytosis. [5]

c. Translation occurs in living cells. Explain how translation is carried out, from the initiation stage onwards. [9]

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a. Draw a labelled diagram of *Escherichia coli* as an example of a prokaryote. [4]

b. Explain the process of transcription in prokaryotes. [8]

c. Some prokaryotes cause infectious diseases which stimulate the body’s immune system. Outline the principles that form the basis of immunity. [6]

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a. Draw a labelled diagram showing the ultra-structure of a liver cell. [4]

b. Distinguish between prokaryotic cells and eukaryotic cells. [6]

c. Explain prokaryotic DNA replication. [8]

a. Draw a labelled diagram to show the ultrastructure of *Escherichia coli*. [5]

b. Distinguish between active and passive movements of materials across plasma membranes, using **named** examples. [4]

c. Explain how chemiosmosis assists in ATP production during oxidative phosphorylation. [9]

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a. Cells go through a repeating cycle of events in growth regions such as plant root tips and animal embryos. Outline this cell cycle. [4]

b. Draw a labelled diagram of the formation of a chiasma by crossing over. [3]

c. Explain the control of gene expression in eukaryotes. [8]

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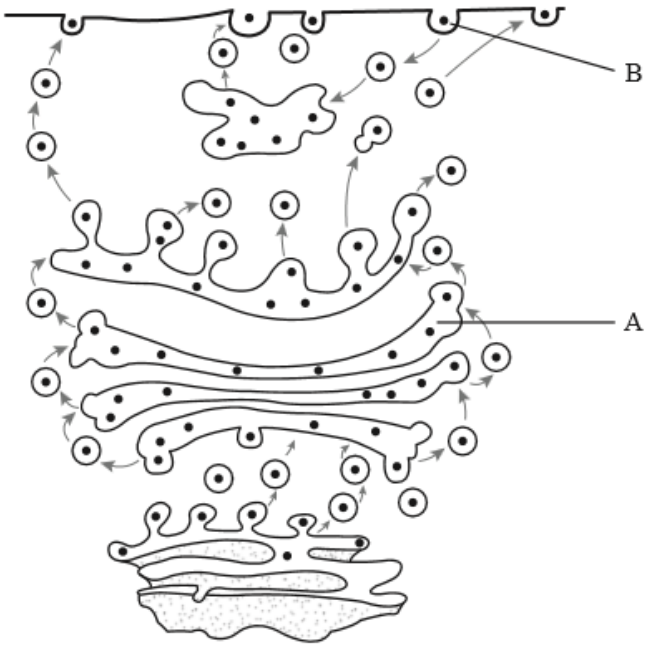
The diagram shows how vesicles are used to transport materials in a cell.




a (i) State the name of organelle A. [1]

a (ii) State the process occurring at B. [1]

b. Describe how the structure of the membrane allows the formation of vesicles. [2]

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The diagram shows a human karyotype.

[Source: http://en.wikipedia.org/wiki/File:NHGRI_human_male_karyotype.png, courtesy of the National Human Genome Research Institute.]

a. Analyse this karyotype. [2]

b. Outline the inheritance of hemophilia in humans. [2]

c. Using an example, describe polygenic inheritance. [3]

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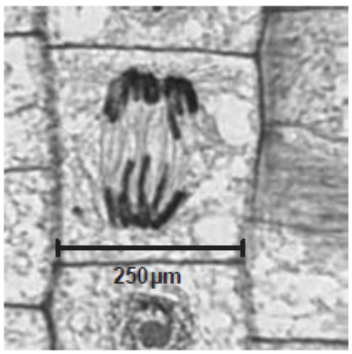
The micrograph shows a cell from the root of an onion (*Allium cepa*) during mitosis.




[Source: adapted from http://img.ehowcdn.com]

a(i).Calculate the magnification of the image. [1]

a(ii)Deduce the stage of mitosis shown in the micrograph. [1]

a(iii) The onion (*Allium cepa)* is an angiospermophyte. The honey bee (*Apis mellifera*) is an arthropod. State **three** structural differences between the cells of an onion and a honey bee. [2]

b. State what is indicated by the presence of polysomes in a cell. [1]

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Hypoxia is a condition in which tissues of the body are deprived of an adequate oxygen supply. A study was carried out in rats to examine the effects of continuing hypoxia on the structure of the diaphragm, and to determine whether nitric oxide is implicated in adaptation of the diaphragm to hypoxia. The diaphragm helps to supply oxygen to tissues and organs in the body by ventilating the lungs.

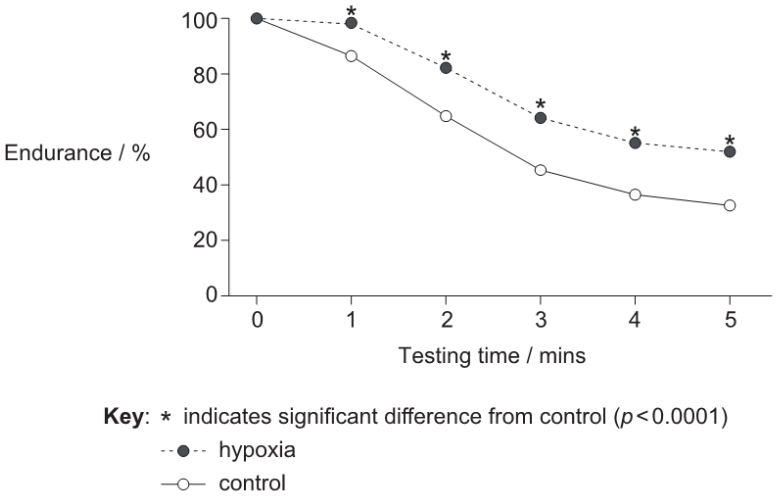
A group of 36 adult male rats were kept for 6 weeks in low oxygen while 36 adult male rats were kept in normal oxygen levels.

| | | Body mass / g | Erythrocytes / % of total blood volume | Mass of right ventricle muscle / mg |
|---|---|---|---|---|
| **1 week** | Control | 305.7 ± 7.4 | 39.3 ± 1.7 | 154.3 ± 7.4 |
| | Hypoxia | *238.3 ± 5.0 | *62.6 ± 1.9 | *194.8 ± 8.9 |
| **2 weeks** | Control | 302.3 ± 5.0 | 39.6 ± 1.1 | 157.8 ± 3.4 |
| | Hypoxia | *229.7 ± 4.6 | *70.1 ± 1.0 | *204.7 ± 11.2 |
| **3 weeks** | Control | 325.0 ± 10.3 | 45.0 ± 0.7 | 166.8 ± 3.6 |
| | Hypoxia | *255.0 ± 8.3 | *71.3 ± 1.0 | *238.7 ± 18.9 |
| **6 weeks** | Control | 369.8 ± 5.9 | 43.0 ± 2.6 | 164.7 ± 3.9 |
| | Hypoxia | *277.5 ± 7.9 | *75.1 ± 1.4 | *251.3 ± 8.0 |

**Key**: * indicates significant difference from corresponding control value (student's *t*-test, $p < 0.05$)

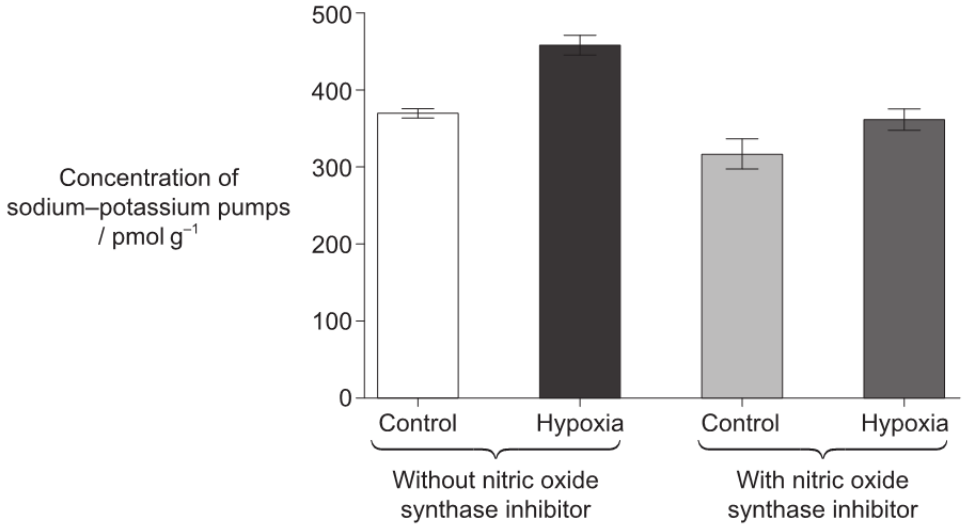
[Source: Reproduced with permission of the © ERS 2011. European Respiratory Journal June 2011, 37 (6) 1474–1481; DOI: 10.1183/09031936.00079810]

The graph shows the effect of hypoxia on the endurance of rats' diaphragm muscle after 6 weeks. Endurance is the change in force measured as a percentage of the initial force.




[Source: Reproduced with permission of the © ERS 2011. European Respiratory Journal June 2011, 37 (6) 1474–1481; DOI: 10.1183/09031936.00079810]

The sodium–potassium pump plays a role in muscle activity. Nitric oxide may have a role in the recovery of hypoxic muscles. The production of nitric oxide can be blocked with an inhibitor of the enzyme nitric oxide synthase. The graph shows the concentration of sodium–potassium pumps in the diaphragm of control and hypoxic rats without and with nitric oxide synthase inhibitor.




[Source: Reproduced with permission of the © ERS 2011. European Respiratory Journal June 2011, 37 (6) 1474–1481; DOI: 10.1183/09031936.00079810]

Skeletal muscle contractions can take two different forms: if they are stimulated by a single action potential they take the form of a twitch and if they are stimulated by a series of action potentials the contraction is longer lasting (tetanic). The table shows the effects of hypoxia on the force of twitch and peak tetanic contraction in the diaphragm.

| | | **Twitch contraction / N cm$^{-2}$** | **Peak tetanic contraction / N cm$^{-2}$** |
|---|---|---|---|
| **Diaphragm** | Control | 4.0 ± 0.7 | 20.0 ± 2.3 |
| | Hypoxia | 2.8 ± 0.4 | 14.2 ± 1.8 |

[Source: Reproduced with permission of the © ERS 2011. European Respiratory Journal June 2011, 37 (6) 1474–1481; DOI: 10.1183/09031936.00079810]

a. Outline the effect of hypoxia on body mass and erythrocyte percentage. [1]

b. Using the data in the graph, deduce whether hypoxia increases **or** decreases the endurance of the rats' diaphragm muscle. [2]

c. Using the data presented in this question, explain the effect of hypoxia on the body. [2]

d.i. Analyse the graph to obtain **two** conclusions about the concentration of sodium–potassium pumps. [2]

d.ii. Muscle fibres are stimulated to contract by the binding of acetylcholine to receptors in their membranes and the subsequent depolarization. [1]

Suggest a reason for increasing the concentration of sodium–potassium pumps in the membranes of diaphragm muscle fibres.

e.i. Outline the effect of hypoxia on the force of contraction of the diaphragm. [1]

e.ii. Hypoxia caused a 13 % increase in the surface area to volume ratio of the diaphragm. Suggest a reason for this change. [1]

f. Using all relevant data in the question, evaluate the effectiveness of the rats' adaptation to hypoxia. [3]

g. Discuss the advantages and disadvantages of using rats as models in this investigation. [2]

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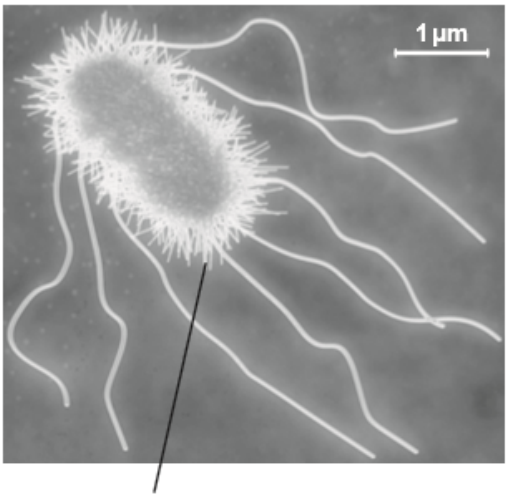


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a. Outline the cell theory. [2]

b (i) Annotate the electron micrograph of the *Escherichia coli* cell with the function of the indicated structure. [1]

b (ii) Calculate the magnification of the electron micrograph. [1]

c (i) Explain the role of the following enzymes in DNA replication. [1]

Helicase

c (iv) Explain the role of the following enzymes in DNA replication. [1]

DNA ligase

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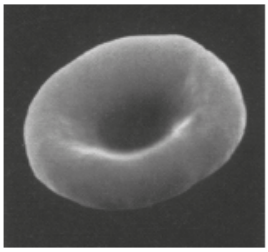
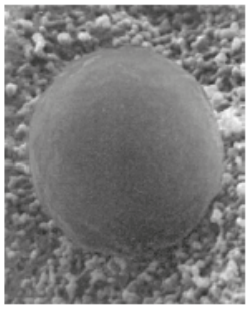
This image shows a normal red blood cell.

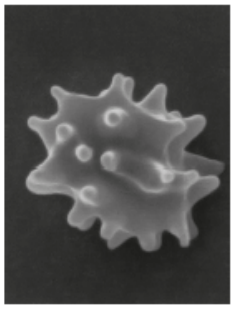


These images show two red blood cells that have been placed in solutions with different concentrations of solutes.

Red blood cell 1



Red blood cell 2



[Source: adapted from www.acbrown.com]

a. Outline the properties of water molecules that permit them to move upwards in plants. [2]

b. Define osmolarity. [1]

c. Deduce, with a reason, which red blood cell has been placed in a hypertonic solution. [1]

d. State what change there has been in the cell surface area to volume ratio in red blood cell 1. [1]

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The Chinese soft-shelled turtle, *Pelodiscus sinensis*, lives in salt water marshes. The turtle can live under water and out of water.

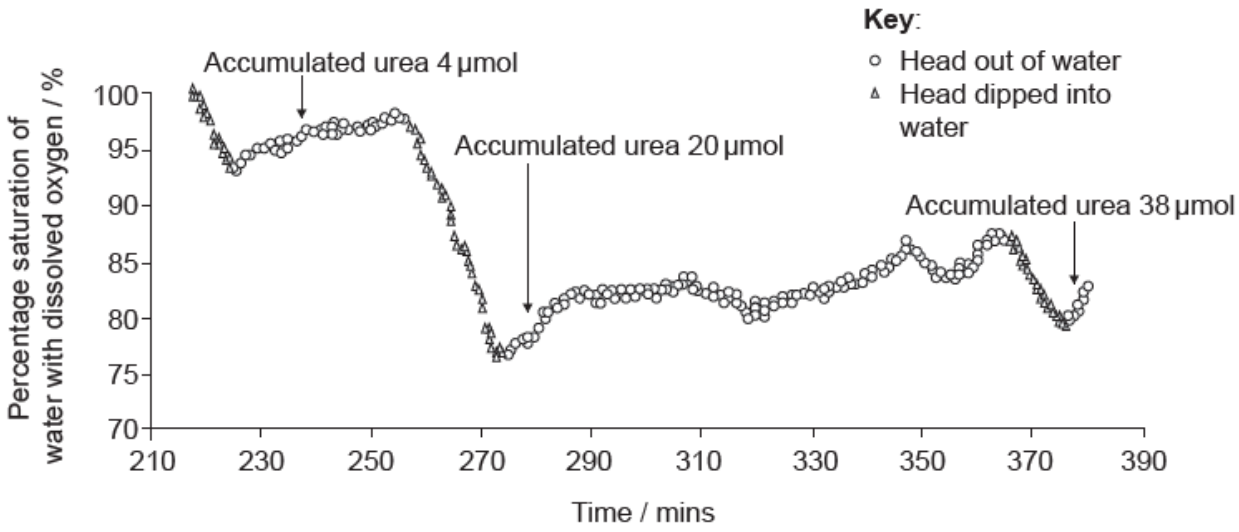
These turtles have fully developed lungs and kidneys, however, many microvilli have been discovered in the mouth of *P. sinensis*. A study was undertaken to test the hypothesis that oxygen uptake and urea excretion can simultaneously occur in the mouth.

Initial experiments involved collecting nitrogen excretion data from *P. sinensis*. The turtle urinates both in water and out of water. When in water it allows waste products to be washed out of its mouth. When out of water it regularly dips its head into shallow water to wash its mouth. The table shows the mean rates of ammonia and urea excretion from the mouth and kidney over six days.

| | Excretion of nitrogen by the mouth / μmol $day^{-1}$ $g^{-1}$ turtle | | Excretion of nitrogen by the kidney / μmol $day^{-1}$ $g^{-1}$ turtle | |
|---|---|---|---|---|
| | Turtle submerged in water | Turtle out of water | Turtle submerged in water | Turtle out of water |
| **Ammonia** | 0.29 | 0.30 | 0.63 | 0.54 |
| **Urea** | 0.90 | 1.56 | 0.07 | 0.73 |

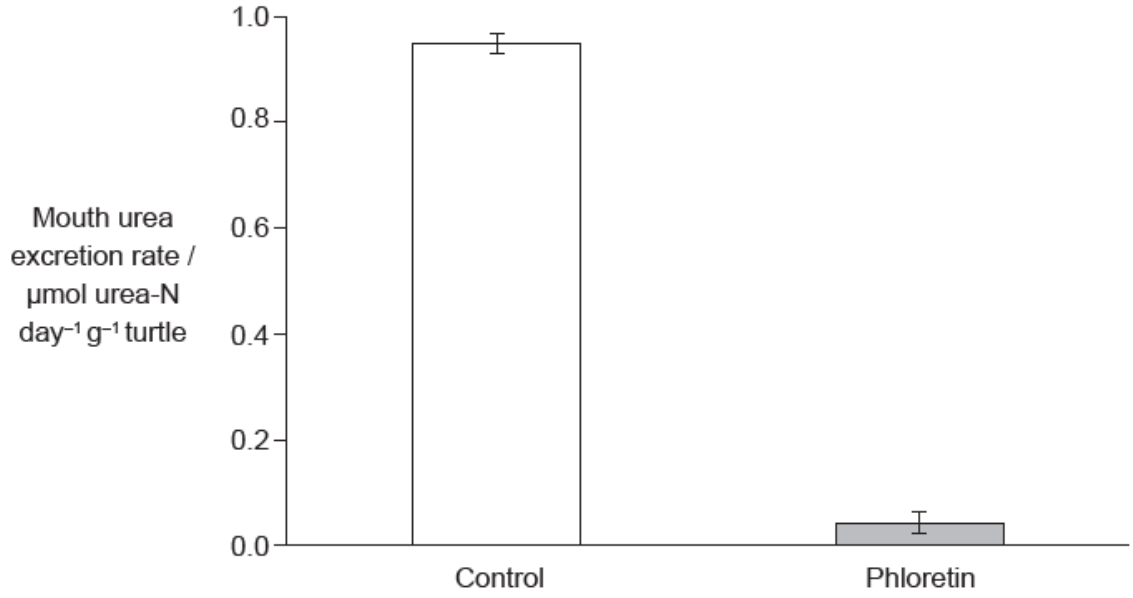
[Source: Reproduced with permission, Y. Ip *et al*. (2012) *The Journal of Experimental Biology*, 215, pages 3723—3733. jeb.biologists.org. doi: 10.1242/jeb.068916]

It was noted that during long periods out of water, turtles rhythmically moved their mouths to take in water from a shallow source and then discharge it. Changes in the dissolved oxygen and the quantity of accumulated urea in the rinse water discharged by the turtles were monitored over time as shown in this graph.



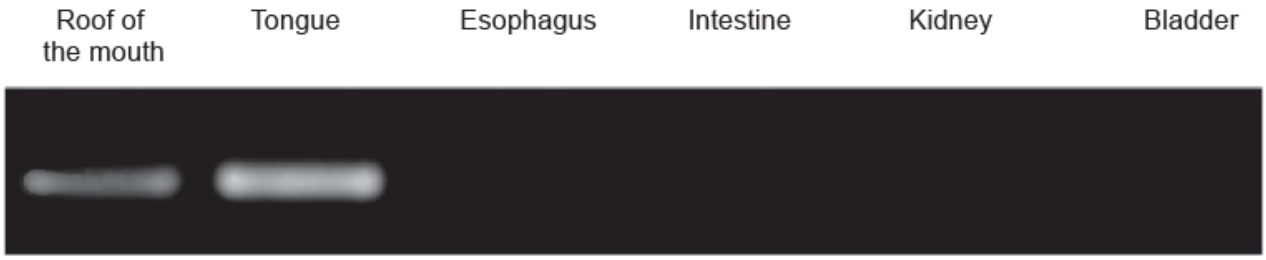

[Source: adapted with permission from Y. Ip *et al*. (2012) *The Journal of Experimental Biology*, 215, pages 3723–3733.]

In order to test whether a urea transporter was present in the mouth tissues of the turtles, phloretin (a known inhibitor of membrane proteins that transport urea) was added to the water in which a further set of turtles submerged their heads. The results of that treatment are shown.



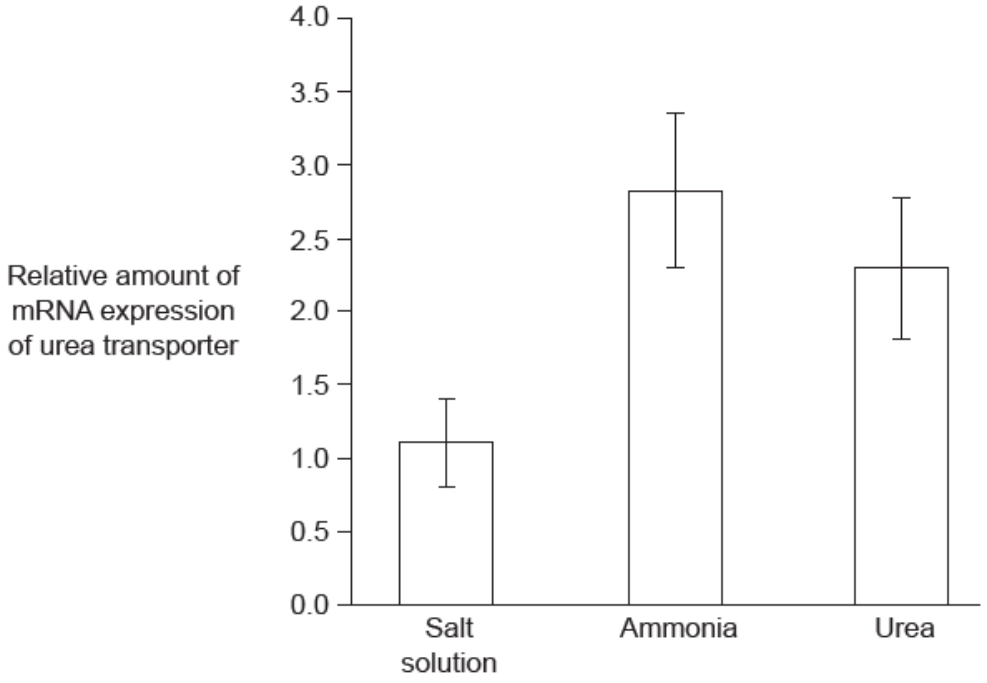

[Source: Reproduced with permission from Y. Ip *et al*. (2012) *The Journal of Experimental Biology*, 215, pages 3723–3733. jeb.biologists.org.]

Further research was conducted to determine where mRNA expression of a urea transporter gene might be occurring in *P. sinensis*. Gel electrophoresis was used to analyse different tissue samples for mRNA activity.




[Source: Reproduced with permission from Y. Ip *et al*. (2012) *The Journal of Experimental Biology*, 215, pages 3723–3733. jeb.biologists.org.]

Expression of the urea transporter gene by cells in the turtle's mouth was assessed by measuring mRNA activity. Turtles were kept out of water for 24 hours and then injected with either a salt solution that matched the salt concentration of the turtle, dissolved ammonia or urea, followed by another 24 hours out of water.




[Source: © International Baccalaureate Organization 2017]

a. Deduce whether the excretion of ammonia or urea changes more when a turtle emerges from water. [2]

b. Compare and contrast the changes in urea excretion in the mouth with the changes in urea excretion in the kidney when a turtle emerges from the water. [3]

c.i. Describe the trends shown by the graph for dissolved oxygen in water discharged from the mouth. [1]

c.ii. Suggest reasons for these trends in dissolved oxygen. [2]

d. Deduce with a reason whether a urea transporter is present in the mouth of *P. sinensis*. [2]

e. Outline the additional evidence provided by the gel electrophoresis results shown above. [2]

f.i. Identify which of these turtle groups represent the control, giving a reason for your answer. [1]

f.ii. Suggest a reason for the greater expression of the gene for the urea transporter after an injection with dissolved ammonia than an injection of urea. [2]

g. The salt marshes where these turtles live periodically dry up to small pools. Discuss the problems that this will cause for nitrogen excretion in the turtles and how their behaviour might overcome the problems. [3]

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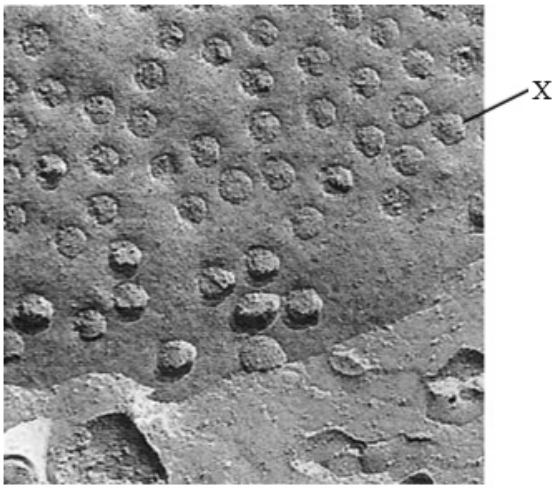
The scanning electron micrograph below shows the surface of the nuclear envelope with numerous nuclear pores.




[Source: adapted from D Nelson and M Cox, (2000), *Lehninger Principles of Biochemistry*, third edition, page 35]

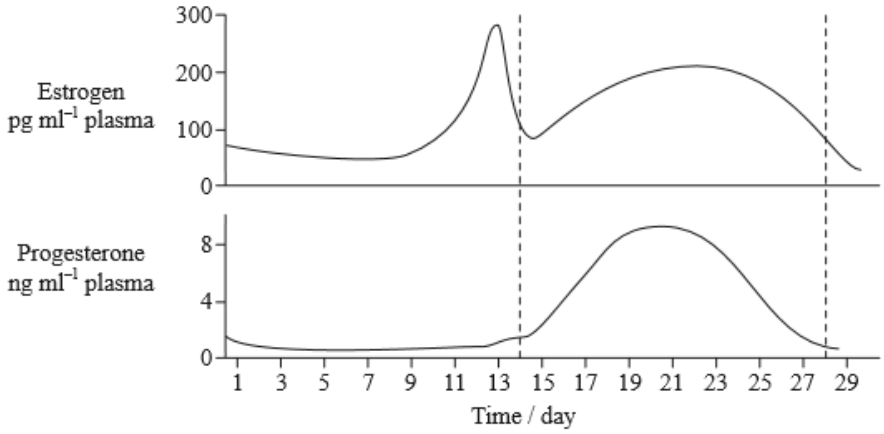
a (i) Calculate the power of magnification of the image. [1]

a (ii) State the diameter of the pore labelled X. [1]

b. List **two** examples of how human life depends on mitosis. [1]

c. Describe the importance of stem cells in differentiation. [3]

d (i) The graphs below show the normal menstrual cycle. [2]




[Source: adapted from www.mivf.com.au/ivf/infertility/images/cyclediagram.GIF]

Predict, with a reason, how the graphs will change if the woman becomes pregnant.

d (ii) List **two** roles of testosterone in males. [1]

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a. Cell biologists play an important role in research into disease, fertility, evolution and many other areas of science. [4]

Describe the origin of eukaryotic cells according to the endosymbiotic theory.

b. Cell biologists play an important role in research into disease, fertility, evolution and many other areas of science. [8]

Compare and contrast the processes of spermatogenesis and oogenesis.

c. Cell biologists play an important role in research into disease, fertility, evolution and many other areas of science. [3]

Outline the evidence for evolution provided by selective breeding.

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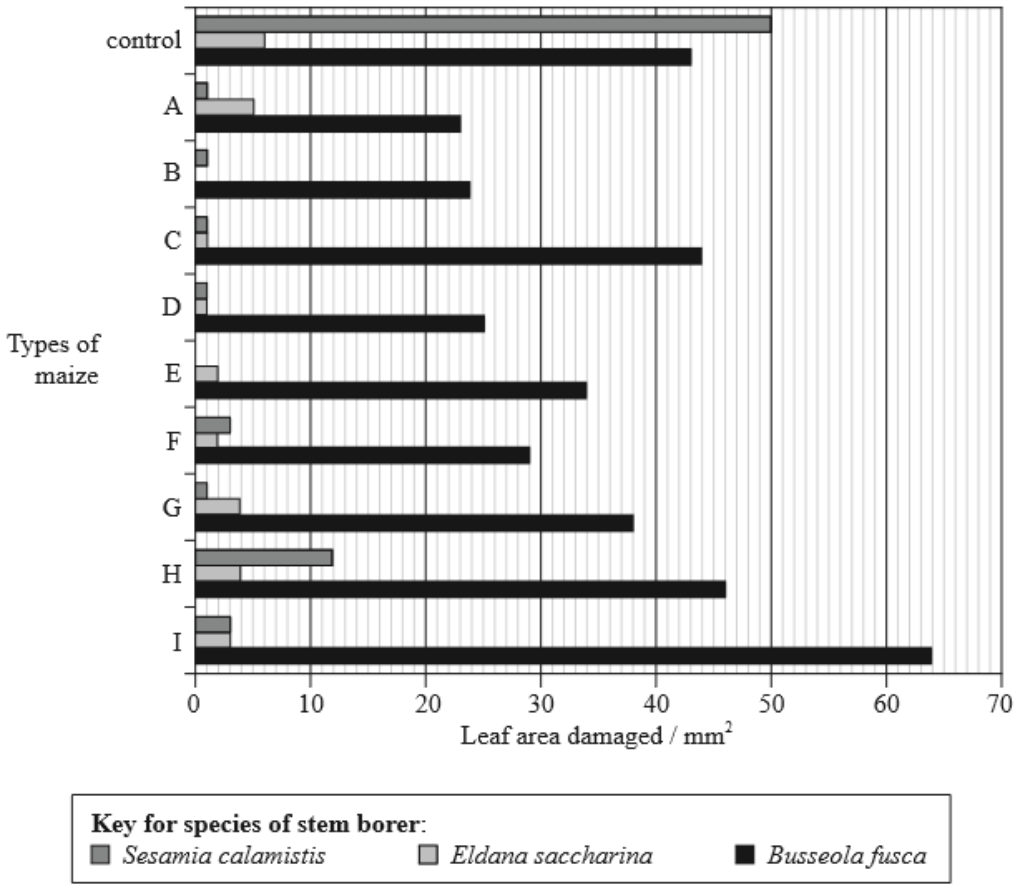
Genetic engineering allows genes for resistance to pest organisms to be inserted into various crop plants. Bacteria such as *Bacillus thuringiensis* (Bt) produce proteins that are highly toxic to specific pests.

Stem borers are insects that cause damage to maize crops. In Kenya, a study was carried out to see which types of Bt genes and their protein products would be most efficient against three species of stem borer. The stem borers were allowed to feed on nine types of maize (A–I), modified with Bt genes. The graph below shows the leaf areas damaged by the stem borers after feeding on maize leaves for five days.

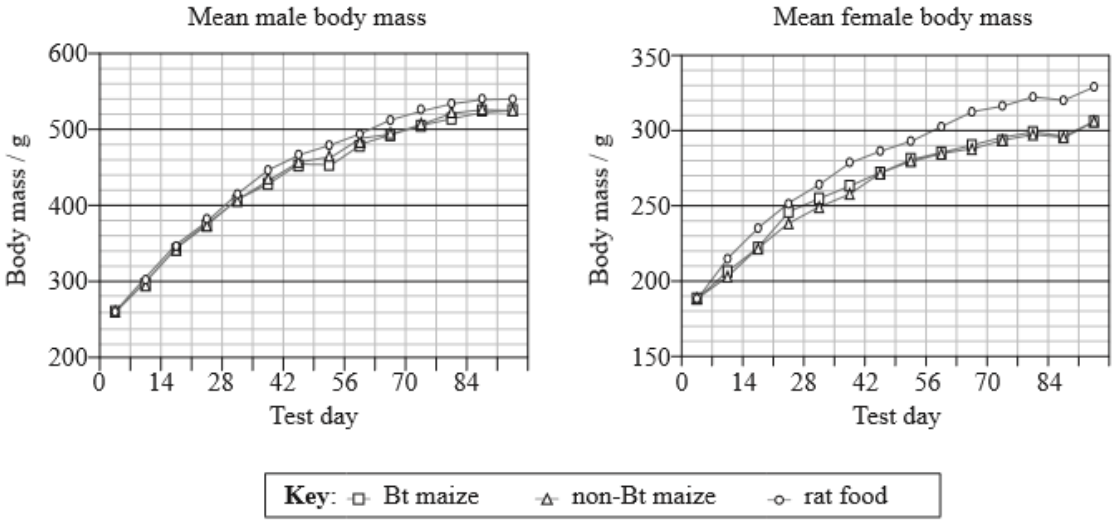



[Source: adapted from S Mugo, *et al.*, (2005), *African Journal of Biotechnology*, **4** (13), pages 1490–1504]

Before the use of genetically modified maize as a food source, risk assessment must be carried out. A 90-day study was carried out in which adult male and female rats were fed either:

- seeds from a Bt maize variety
- seeds from the original non-Bt maize variety
- commercially prepared rat food.

All the diets had similar nutritional qualities.




[Source: adapted from L A Malley, *et al.*, (2007), *Food and Chemical Toxicology*, **45**, pages 1277–1292]

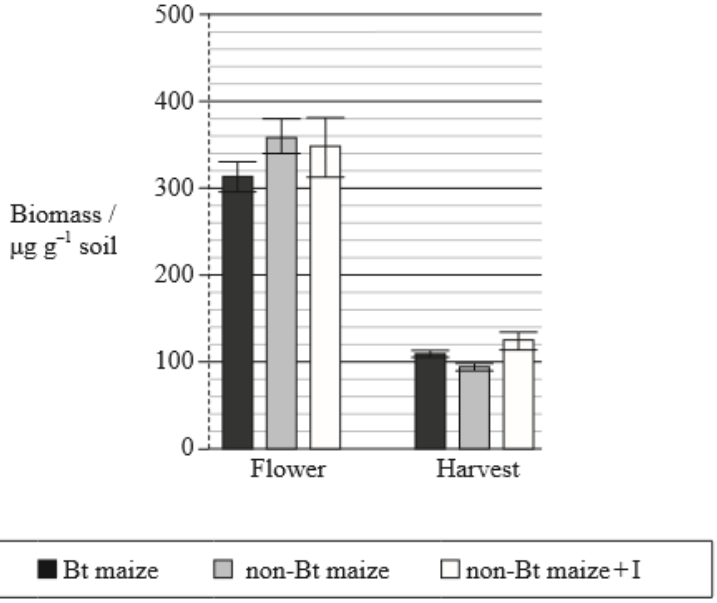
Studies have shown that Bt proteins are released by plant roots and remain in the soil. One study looked at the biomass of microorganisms in soil surrounding the roots of:

• Bt maize

• non-Bt maize

• non-Bt maize with an insecticide (I).

The graph below shows the biomass of microorganisms at two different times in the growth cycle of the plants (Flower and Harvest). Error bars represent standard error of the mean.




[Source: adapted from M Devare, *et al.*, (2007), *Soil Biology and Biochemistry*, **39**, pages 2038–2047]

Bt proteins act as toxins to insects, primarily by destroying epithelial cells in the insect's digestive system. Below is the three-dimensional structure of one such protein.


[Source: M Soberon, *et al.*, (2007), *Toxicon*, **49**, pages 597–600]

a. Calculate the percentage difference in leaf area damaged by *Sesamia calamistis* between the control and maize type H. Show your working. [2]

b. Discuss which species of stem borer was most successfully controlled by the genetic engineering of the maize plants. [3]

c. Calculate the change in mean mass of male and of female rats fed on Bt maize from day 14 to 42. [2]

d. Evaluate the use of Bt maize as a food source on the growth of the rats. [2]

e. Comment on the use of Bt maize as a food source compared to the other diets tested. [1]

g. Compare the biomass of microbes in the soils surrounding the roots of Bt maize and non-Bt maize. [2]

h. The researchers' original hypothesis stated that microorganisms would be negatively affected by the Bt protein released by the plant roots. [2]

Discuss whether the data supports the hypothesis.

i (i). State the type of structure shown in the region marked A in the diagram above. [1]

i (ii). Outline how this structure is held together. [2]

i (iii). Region A inserts into the membrane. Deduce, with a reason, the nature of the amino acids that would be expected to be found in this region. [2]

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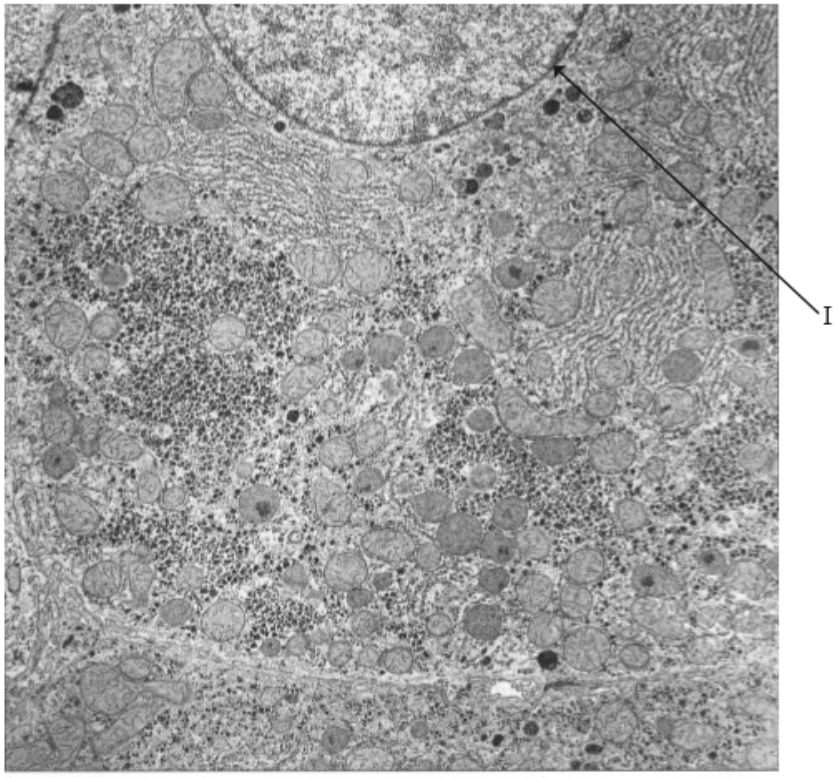
The electron micrograph below shows a section of a liver cell.




[Source: D Friend, (2002), *Molecular Biology of the Cell*, 4th Edition, Garland Science Publishing, Fig. 12.2]

a (i) Identify the structure labelled I and state **one** function of this structure. [1]

a (ii) Calculate the magnification of this photograph. Show your working. [1]

a (iii) Explain the evidence from the electron micrograph that indicates that liver cells are very active. [2]

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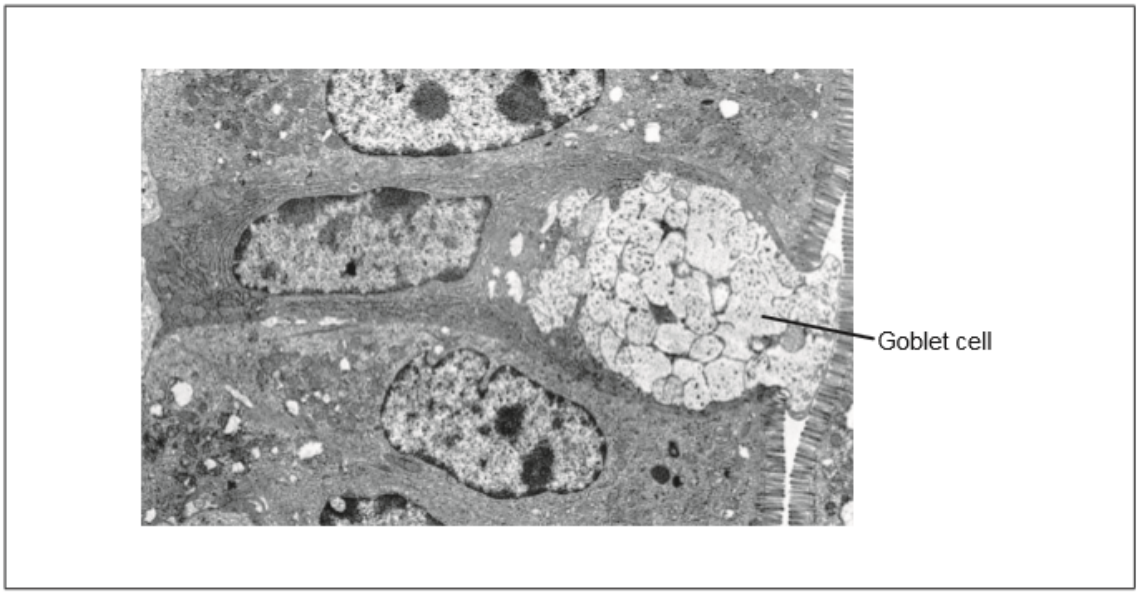
a. The image is an electron micrograph of the lining of the small intestine. [3]




[Source: adapted from A. L. Mescher (2009), *Junqueira's Basic Histology: Text and Atlas*, 12th Edition, © 2009 McGraw-Hill Education]

(i) Label the microvilli using the letter M and a nucleus using the letter N.

(ii) State the function of the goblet cell.

(iii) Deduce, with a reason, whether or not the goblet cell is likely to divide.

b. Explain how the cell cycle is controlled. [4]