HL Paper 2

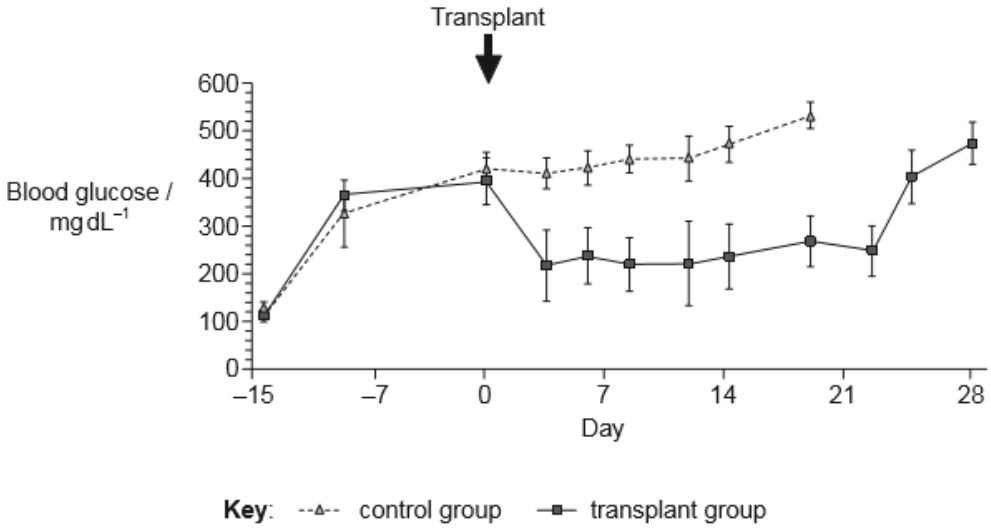
a. Describe **four** different types of transport of substances across a membrane. [4]

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]

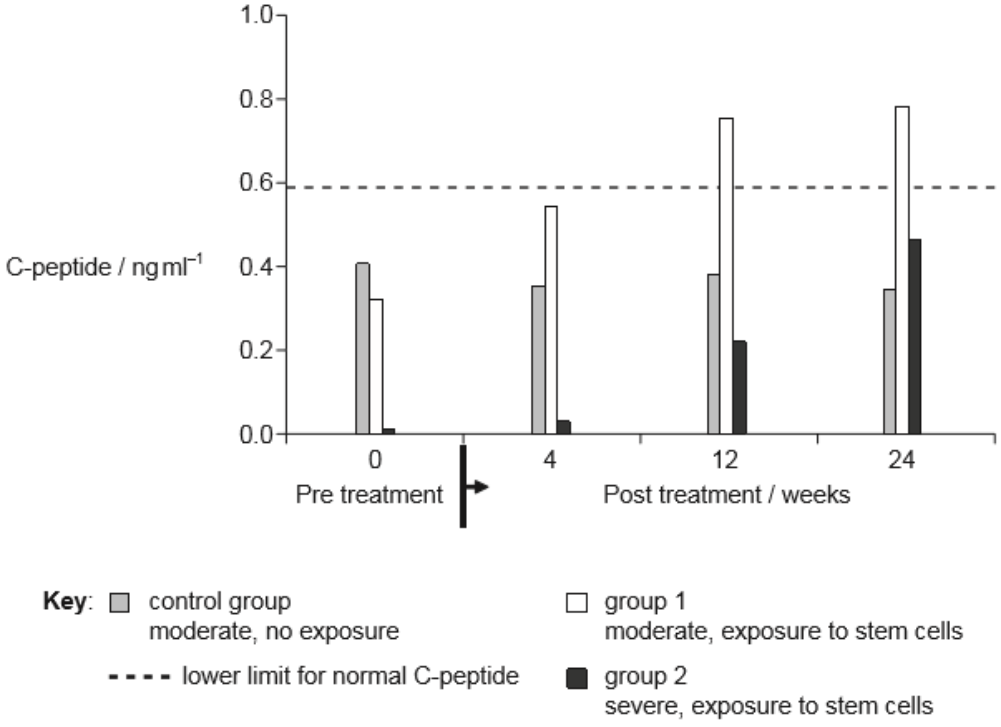
c. In the placenta, many substances are transported across membranes. Explain the structure and role of the placenta. [8]

Type I diabetes is a leading cause of death in advanced countries and is associated with various severe or fatal complications, including blindness, kidney failure, heart disease, stroke, neuropathy, and amputations. Embryonic stem cells are considered to be a powerful tool in the treatment of diabetes.

In a study, embryonic stem cells were grown in culture and tested for insulin mRNA. A drug was injected into two groups of healthy mice in order to simulate type I diabetes 15 days prior to the transplant of embryonic stem cells. The mice in the transplant group received embryonic stem cells that produce insulin mRNA. The control group did not receive the transplant. The graph shows the blood glucose concentration in both groups.



A few years later, a third study used a treatment with umbilical cord stem cells on patients who had suffered from moderate or severe type I diabetes for an average of 8 years. They were divided into two groups: group 1 had moderate diabetes and group 2 had severe diabetes. The patients' blood was circulated outside the body and exposed to umbilical cord stem cells before returning to the patients' circulation. The control group had moderate diabetes and received the same treatment but without umbilical cord stem cells.



[Source: doi:10.1186/1741-7015-10-3
Zhao *et al.*: Reversal of type 1 diabetes via islet ß cell regeneration following immune modulation by cord blood-derived multipotent stem cells. *BMC Medicine* 2012 10:3.]

a. State the highest mean concentration of blood glucose in the mice with transplants. [1]

.....mg dL^{-1}

b. Outline the cause of type I diabetes in humans. [1]

c. Describe the reason for testing for insulin mRNA in the embryonic stem cell cultures. [1]

d. Compare and contrast the concentration of blood glucose resulting from the embryonic stem cell transplant with the control. [2]

e. Evaluate the effectiveness of the embryonic stem cell treatment in controlling blood glucose. [2]

h. Compare and contrast the results of the treatment on group 1 with the results of the treatment on group 2. [3]

i. Suggest an ethical advantage of using this type of therapy over embryonic stem cell therapy. [1]

j. Using the data from all three studies, evaluate the use of embryonic stem cells as a treatment for type I diabetes. [4]

---

a. Define the term *passive immunity*. [1]

b. State **one** use of monoclonal antibodies in diagnosis. [1]

c. Define the term *pathogen*. [1]

d. Outline why antibiotics are effective against bacteria but not against viruses. [2]

a. Draw a labelled diagram of the heart showing the chambers, associated blood vessels and valves. [4]

b. Describe the processes involved in blood clotting. [6]

c. Discuss the benefits and risks associated with vaccination programmes. [8]

---

a. Outline how antibiotic resistance in bacteria can arise in response to environmental change. [5]

b. Outline the principle of immunity. [6]

c. Discuss the benefits and dangers of vaccination. [7]

---

a. Outline the mechanisms involved in the control of heartbeat. [3]

b. Explain how the direction of blood flow in the heart is controlled. [2]

---

a. Draw a labelled diagram of a mature sperm cell. [4]

b. Outline the role of hormones in the menstrual cycle. [6]

c. Discuss the cause, transmission and social implications of AIDS. [8]

---

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

b. Outline how skeletal muscle contracts. [5]

c. Explain how nerve impulses are transmitted along and between neurons. [9]

---

a. Draw a labelled diagram of the human heart showing the attached blood vessels. [6]

b. Describe the action of the heart in pumping blood. [5]

c. All parts of the body change the composition of the blood. Explain how the nephron changes the composition of blood. [7]

a. Draw a labelled diagram of the adult female reproductive system. [4]

b. Outline the roles of progesterone and estrogen in the human menstrual cycle [6]

c. Explain the function and structure of the placenta. [8]

---

a. Outline the process of glycolysis. [5]

b. Describe how pancreatic cells directly affect blood glucose levels. [5]

c. Explain why diabetes could be detected through the analysis of urine. [8]

---

a. Outline the role of the skin in temperature regulation. [5]

b. Outline the role of hormones in the process of birth in humans [4]

c. Explain the principles of vaccination. [9]

---

a. Outline a possible cause of Down syndrome. [4]

b. Outline the processes involved in oogenesis within the human ovary. [8]

c. Discuss the ethical issues surrounding IVF. [6]

---

a. Describe the process of blood clotting. [4]

b. Factor IX is a blood clotting protein which some hemophiliacs lack. In the future hemophilia could be treated using clotting factors synthesized by genetically modifiedbacteria.Outlinethebasictechniqueusedforthisgenetransfer. [6]

c. Explain how males inherit hemophilia and how females can become carriers for the condition. [8]

---

c. State the role of plasma cells in the immune system. [1]

d.i. Describe the production of hybridoma cells. [2]

d.ii. State **one** possible use of hybridoma cells. [1]

---

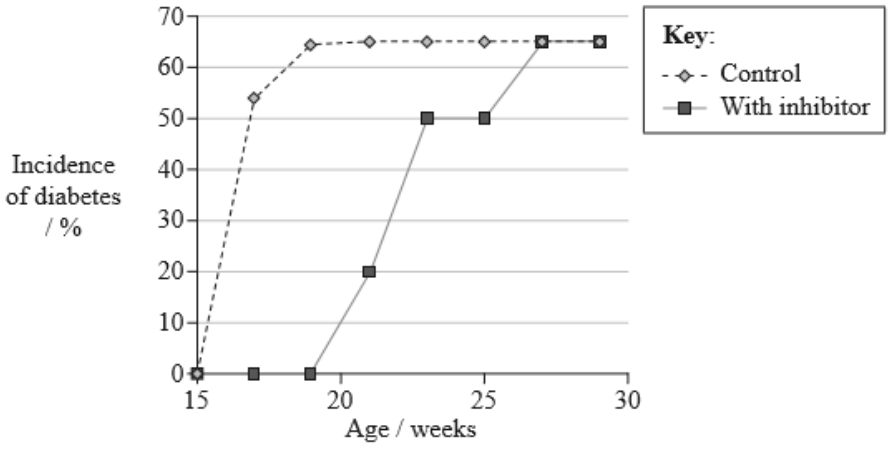
a. Blood is a liquid tissue containing glucose, urea, plasma proteins and other components. List the other components of blood. [5]

b. Outline how the human body prevents blood glucose concentration from rising excessively. [5]

c. Blood plasma, glomerular filtrate and urine have different concentrations of solutes, such as glucose, protein and urea. Explain the processes occurring in the kidney that cause differences in the concentrations of these solutes between blood plasma, glomerular filtrate and urine. [8]

Type I diabetes is an autoimmune disease resulting from destruction of the insulin-producing β cells in the islets of Langerhans. Islet regeneration can occur when stem cells reach the pancreas after leaving the bone marrow.

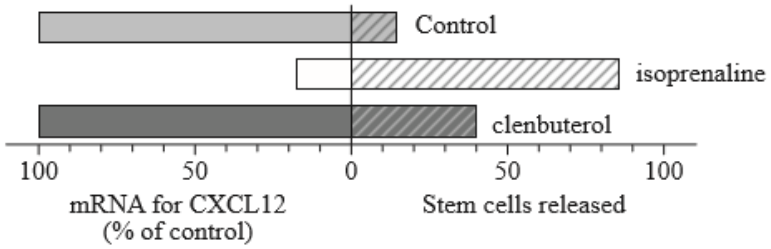
Studies have shown a link between CXCL12 and type I diabetes. Mice predisposed to develop the disease were given an inhibitor of CXCL12 for 3 weeks. The incidence of diabetes was measured after 28 weeks and compared to control mice that were not given the inhibitor.



[Source: adapted from Q Leng, *et al.*, (2008), *BMC Immunology*, **9**, page 51]

One important chemical in the mobilization of stem cells is a protein, CXCL12, which maintains the stem cells inside the bone marrow. The breakdown of CXCL12 causes the mobilization of stem cells to the blood vessels.

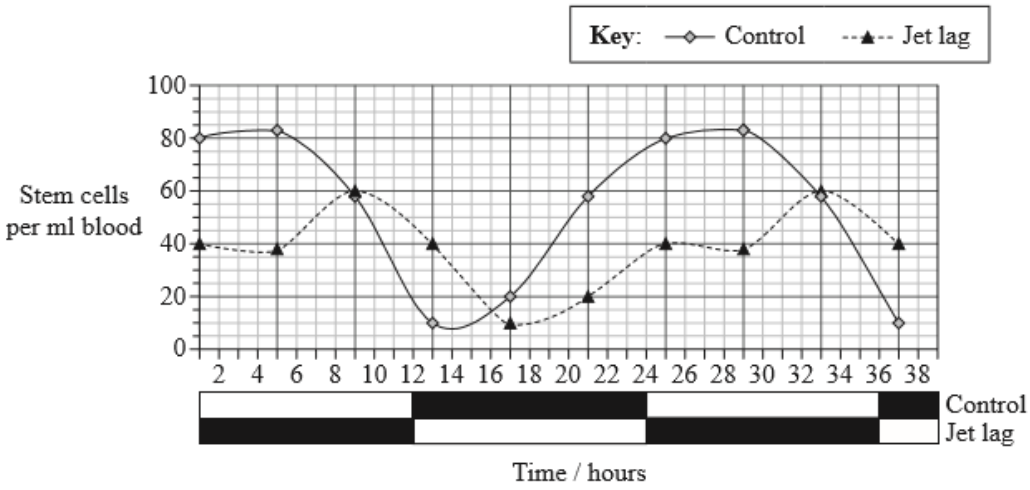
The graph below shows the mobilization of stem cells and the production of mRNA for CXCL12 when the bone marrow is treated with two different chemicals (isoprenaline and clenbuterol).



Méndez-Ferrer, S., Lucas, D., Battista, M. and Frenette, P.S. (2008) 'Haematopoietic stem cell release is regulated by circadian oscillations'. Nature 452: 442–447.

Stem cells in the bone marrow can be forced into blood vessels in a process called mobilization. Mobilization of stem cells from the bone marrow into the blood vessels represents the basis for modern bone marrow transplantation procedures.

To test the effect of light on the mobilization of stem cells, mice were subjected to a simulated "jet lag" by advancing the light-dark cycle by 12 hours. This was done by subjecting mice to a 24-hour light period before the results shown in the graph were recorded. The results were compared to the stem cells in control mice under normal conditions of 12 hours of light (□) and 12 hours of darkness (■).



f (i). Outline the effect of CXCL12 inhibition on the incidence of diabetes. [2]

f (ii). Suggest how the breakdown of CXCL12 in the bone marrow may be related to diabetes. [1]

g. Evaluate the possible use of isoprenaline in the treatment of diabetes. [2]

h. Research is being conducted into treatment for diabetes based on stem cells. Discuss the ethical issues involved in stem cell research. [3]

a (i). State the maximum number of stem cells per ml blood in the control mice. [1]

a (ii). Determine the number of hours of light needed to release the maximum number of stem cells in blood in control mice. [1]

b. Distinguish between the trends shown in the number of stem cells per ml blood by the mice subjected to jet lag and the control mice. [2]

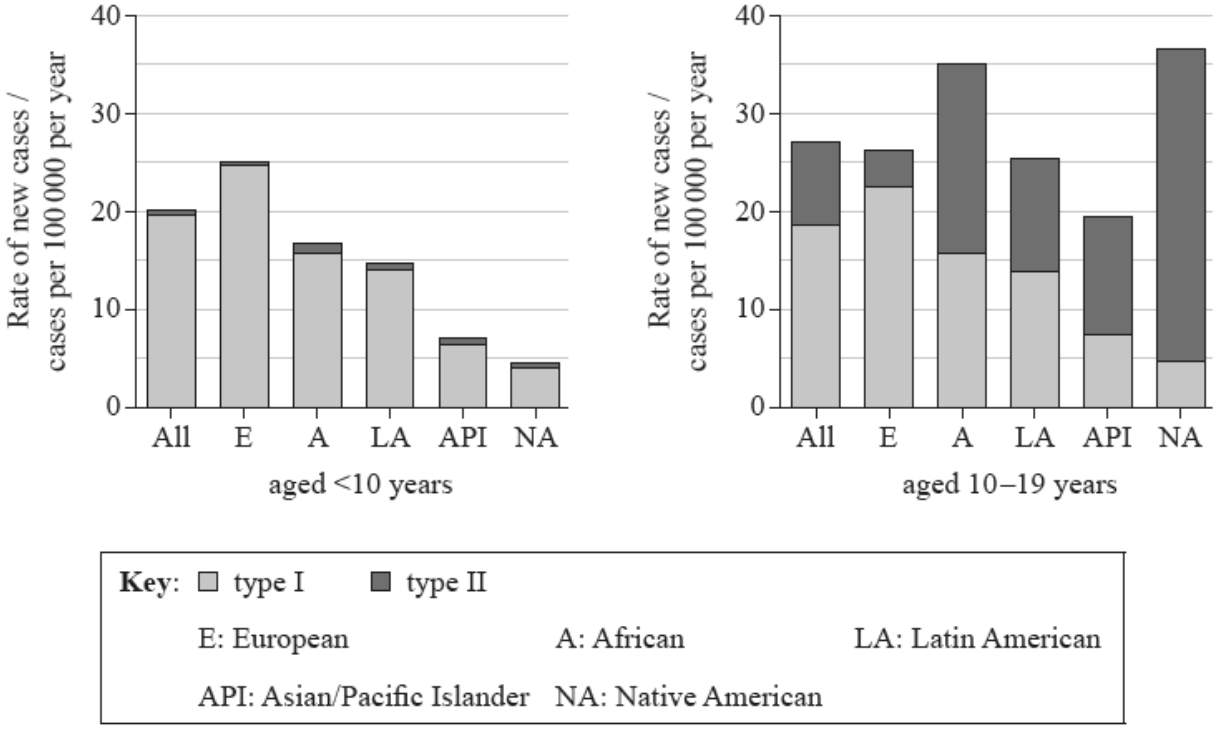
c. Other studies suggest that a greater number of blood stem cells for transplantation may be obtained if they are harvested during darkness. [2]

Evaluate this hypothesis.

d. Explain how the amount of mRNA for CXCL12 gives an indication of the amount of protein CXCL12 produced. [1]

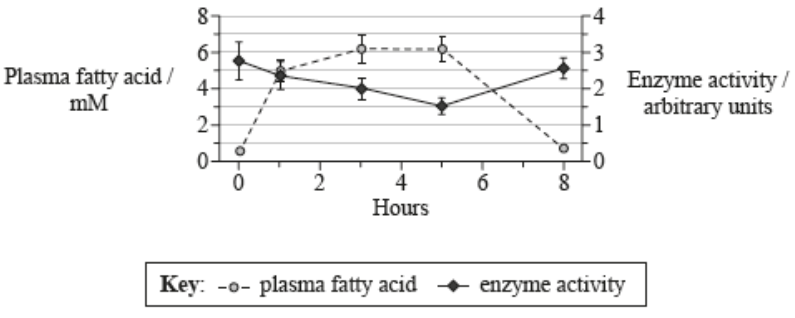
e. Compare the effect of isoprenaline and clenbuterol with the normal release of stem cells and the production of mRNA for CXCL12. [3]

Diabetes in Youth is a study that examined diabetes (type I and type II) among children and adolescents in the United States. The graphs show the rate per year of new cases of type I and type II diabetes among young people (aged less than 20 years) by ethnicity between 2002–2005.



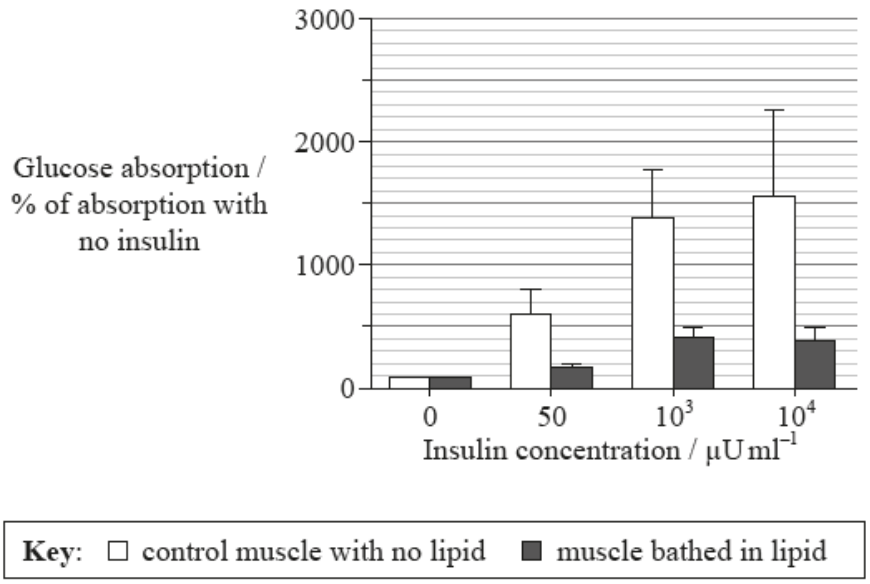
[Source: Adapted from www.cdc.gov/diabetes/pubs/estimates11.htm#fig2]

Skeletal muscle fibres normally respond to insulin by absorbing glucose. Failure of skeletal muscle to respond to insulin is a major factor in the development of type II diabetes. A study was undertaken to investigate the effect of plasma lipids on the process of glucose absorption in response to insulin by muscle fibers. Muscle was bathed in a lipid solution for 5 hours. The lipid was then washed out over the next 3 hours. The graph shows the level of plasma fatty acids and the activity of an enzyme involved in glucose absorption in response to insulin over the period of the study. (Values are means ± standard error)



[Source: Chunli Yu, *et al.* (2002), *The Journal of Biological Chemistry*, **277**, pp. 50 230–50 236]

A further study was undertaken to look at the effect of increasing the concentration of insulin on glucose absorption in muscle bathed in lipids. A wide range of insulin concentrations were used in the same type of muscle. Glucose absorption was then measured after 5 hours.



[Source: Chunli Yu, *et al.* (2002), *The Journal of Biological Chemistry*, **277**, pages 50 230–50 236]

a. Identify, among young people aged 10–19 years, which ethnic group showed the highest rate of new cases of type I diabetes and type II diabetes. [1]

Type I diabetes:

Type II diabetes:

b. Determine the rate of new cases of type II diabetes among children of African ethnicity aged 10–19 years. [1]

c. Compare rates of diabetes between the two age groups studied. [2]

d. (i) Compare the relative proportions of type I and type II diabetes between the different ethnic groups. [3]

(ii) Suggest a reason for the different rates of type II diabetes among the ethnic groups.

e. State the relationship between plasma fatty acid level and enzyme activity. [1]

f. Calculate the percentage change of enzyme activity after 5 hours exposure to lipids. [1]

g. Discuss, using the data, whether the effect of lipids on this enzyme is reversible. [2]

h. Comment on the effect of increased insulin concentration on glucose absorption in the muscle bathed in lipid. [2]

i. Some investigators suggest that there is a strong relationship between high lipid diet and the body's response to insulin. Using the data provided, evaluate this hypothesis. [2]

---

a. Outline how and where energy is stored in plants. [4]

b. Ecologists sometimes display data from an ecosystem using a diagram called a pyramid of energy. Describe what is shown in pyramids of energy. [6]

c. Explain the control of body temperature in humans. [8]

---

a. Describe the production of semen. [6]

b. Explain the structure and function of the placenta. [8]

c. Outline the hormonal control of birth. [4]

---

a. Draw a labelled diagram of a mitochondrion as seen in an electron micrograph. [4]

b. A supply of oxygen is needed for aerobic respiration in mitochondria. Describe the features of alveoli in human lungs that adapt them for efficient absorption of oxygen. [6]

c. Explain the mechanism of ventilation of human lungs. [8]

---

a. Draw a labelled diagram of the digestive system. [4]

b. Many people cannot digest lactose and benefit from a diet containing no lactose. Outline the production of lactose-free milk. [6]

c. Explain how the kidney helps to retain useful substances in the blood and eliminate substances which the body does not need. [8]

---

a (i) Blood transports molecules throughout the body. State where the blood absorbs hormones. [1]

a (ii) Blood transports molecules throughout the body. State where the blood absorbs carbon dioxide. [1]

b. Describe **three** features of alveoli that adapt them to gas exchange. [3]

c. Explain how the structure of capillaries relates to their functions. [3]

---

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]

Defence occurs on the micro and macro levels.

a. Describe the functioning of immunoglobulins. [3]

b. Outline how antibiotics offer protection from certain forms of infectious disease. [4]

c. Coughing to clear the airways is accomplished by muscle contractions. Explain muscle contraction. [8]

---

a. List the general functions of non-membrane proteins. [4]

b. Outline the digestion, absorption and assimilation of proteins in humans. [6]

c. Actin and myosin are two proteins found in muscles. Explain how skeletal muscle contracts, including the interaction of these proteins. [8]

The human circulatory system is structured to serve the organs and tissues of the body efficiently.

a. Explain how circulation of the blood to the lungs and to other systems is separated in humans and what the advantages of this separation are. [8]

c. Distinguish between the composition of the blood of the renal artery and the blood of the renal vein. [3]

---

a. Predict the genotypic and phenotypic ratios of the possible offspring of a male hemophiliac and a female carrier using suitable symbols for the alleles in a Punnett grid. [3]

Genotypic ratio:

Phenotypic ratio:

b. Hemophilia is a disorder where the ability to control blood clotting or coagulation is impaired. Describe the process of blood clotting. [2]

---

a. Outline what is meant by homeostasis. [4]

b. Describe how body temperature is maintained in humans. [6]

c. Explain the processes occurring in the kidney that contribute to osmoregulation. [8]

---

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

b. Outline how the human body responds to high blood glucose levels. [5]

c. Explain the role of the nephron in maintaining the water balance of the blood in the human body. [8]

---

a. Outline how reproductive isolation can occur in an animal population. [3]

b. Describe the different cell types in the seminiferous tubules that are involved in the process of spermatogenesis. [4]

c. Explain the roles of specific hormones in the menstrual cycle, including positive and negative feedback mechanisms. [8]

---

b. Explain how skeletal muscle contracts. [8]

c. Active skeletal muscle requires a good supply of oxygen. Outline the mechanism of ventilation in the lungs. [6]

---

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]

HIV was discovered in 1981 and is now one of the most serious causes of disease in the world. It causes the immune system to fail, leaving the patient vulnerable to other infections.

b. Outline how monoclonal antibodies are produced. [2]

c. Discuss how the HIV virus is transmitted. [2]

d. Explain why antibiotics are ineffective against viruses. [2]

---

a. Outline, with examples, the types of carbohydrate found in living organisms. [4]

b. Describe the importance of hydrolysis in digestion. [6]

c. Explain the effect of inhibitors on the activity of enzymes. [8]

Cells in the alveolus wall produce a surfactant. Its function is to prevent alveoli collapse at the end of expiration. Surfactants are used in the treatment of respiratory system disease in premature babies.

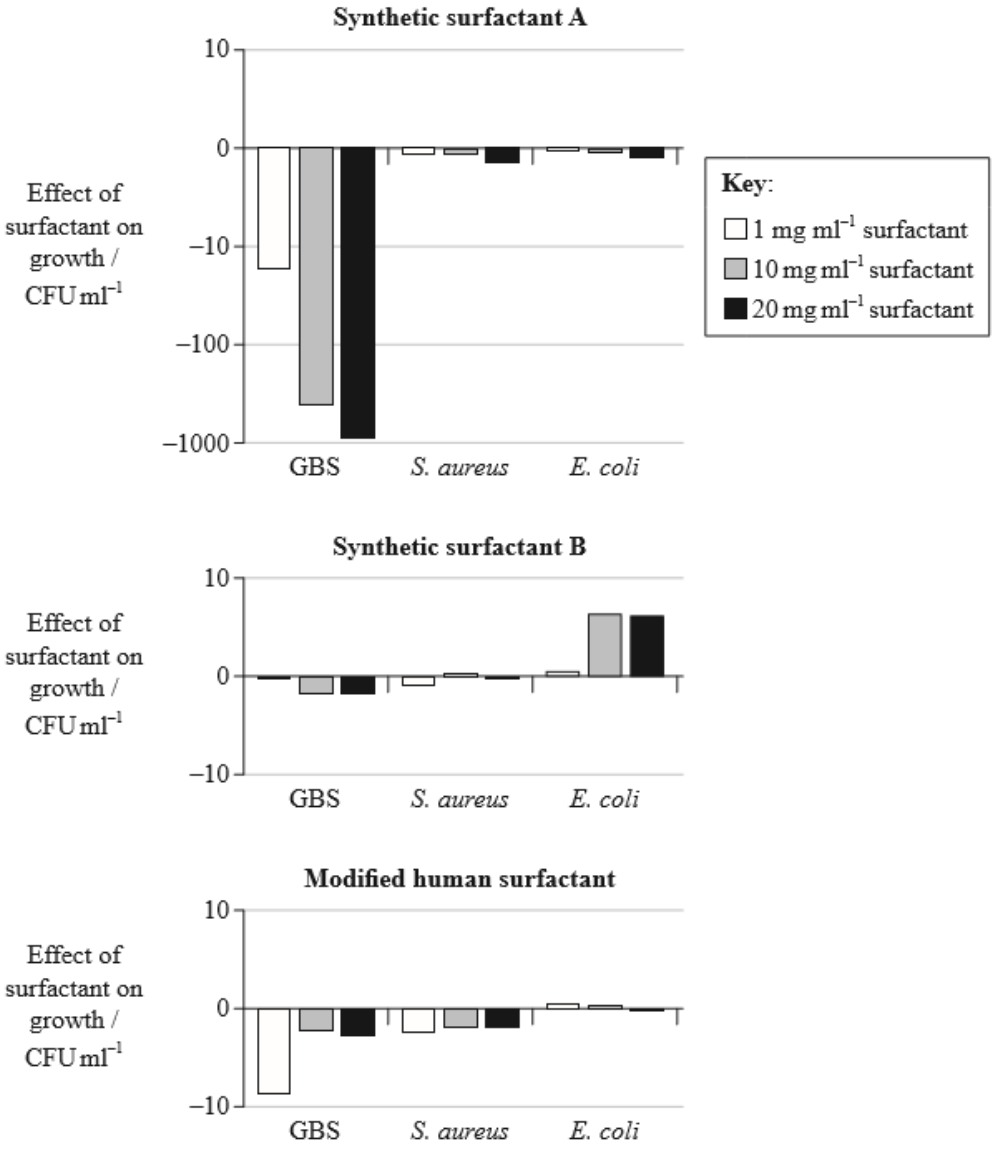
The table shows some of the components of different surfactant preparations.

Component	Percentage composition by mass			
	Synthetic surfactant A	Synthetic surfactant B	Natural human surfactant	Modified human surfactant
Phospholipids	99	84	81	100
Cholesterol	0	not stated	5 to 10	0
Fatty acids	<0.5	6	1.5	0
Proteins	1	0.5 to 1	5 to 10	0

[Source: *Clinical and Diagnostic Laboratory Immunology*, 2000, 7(5), pp. 817–822, 2012, January 9, 2013]

The effect of three different surfactants on the growth of three types of bacteria was assessed. Group B streptococci (GBS), *Staphylococcus aureus*, and *Escherichia coli* were incubated with three different concentrations of surfactant (1, 10 and 20 mg ml^{-1}).

The bar charts show whether each concentration of surfactant increased or decreased bacterial growth, compared with the growth without surfactant. The difference in growth is shown as colony forming units (CFU) per millilitre.



[Source: *Clinical and Diagnostic Laboratory Immunology*, 2000, 7(5), pp. 817–822, 2012, January 9, 2013]

a. State the surfactant that contains the least amount of phospholipids. [1]

b. Compare the composition of natural human surfactant with synthetic surfactants. [2]

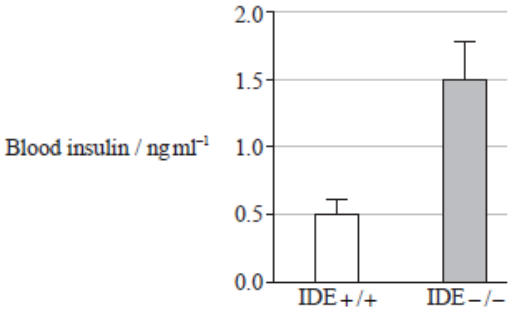
c. Phospholipids found in the surfactants form a surface film on the moist lining of the alveoli. Outline how the hydrophilic and hydrophobic parts of the phospholipids in the surfactants are aligned on the alveolar surface. [1]

d. Identify the effect of increasing the concentration of synthetic surfactant A on the growth of GBS. [1]

e. Compare the effect of the three surfactants, synthetic surfactants A and B and the modified human surfactant, on the growth of the different bacteria at a concentration of 20 mg ml^{-1}. [3]

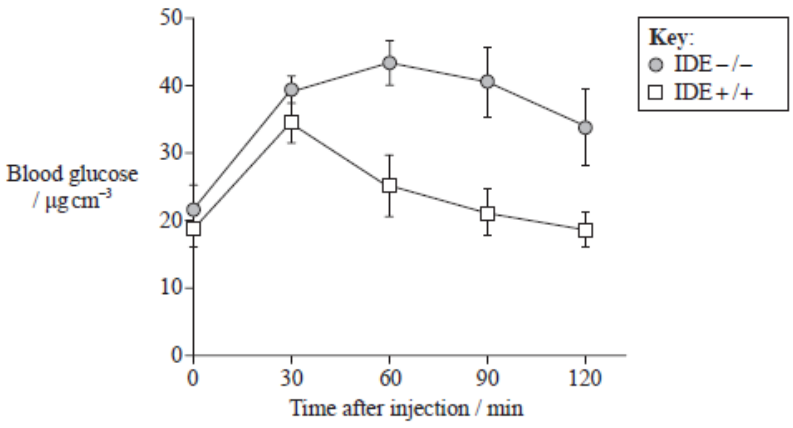
f. Using all the data provided, evaluate the hypothesis that the presence of proteins in surfactants can decrease bacterial growth. [3]

Type II diabetes is having an impact on the health of many individuals worldwide. The condition is characterized by elevated levels of both insulin and glucose in the bloodstream. Some animals produce an insulin-degrading enzyme (IDE) which breaks down the insulin molecule. In an attempt to develop a model of type II diabetes, genetically modified mice have been developed. In these mice, both copies of the IDE gene have been removed (IDE – /–) and the enzyme is not produced. The bar chart below shows the mean concentration of insulin in the bloodstream of IDE – /– mice and that of control mice (IDE + /+).



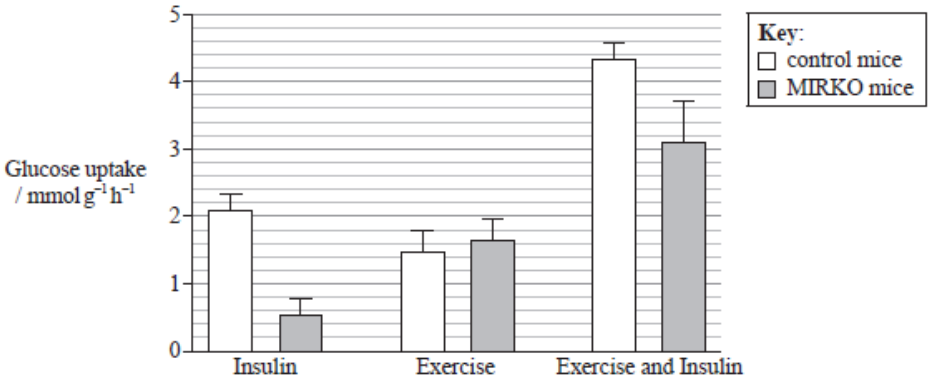
[Source: adapted from R.W Farris, *et al.*, (2003), *PNAS*, **100**, pages 4162– 4167]

In another experiment, groups of IDE – /– and IDE + /+ mice were injected with a fixed amount of glucose. The levels of blood glucose were measured at various time intervals following glucose injection. The data are shown in the graph below.



[Source: adapted from R.W Farris, *et al.*, (2003), *PNAS*, **100**, pages 4162–4167]

In animals that do not have type II diabetes, insulin stimulates glucose uptake into skeletal muscle. Glucose uptake into skeletal muscle is also stimulated when skeletal muscle is exercised. Genetically modified mice have been developed in which the insulin receptor is not produced in skeletal muscle and these are known as MIRKO mice. In another experiment, the effect of insulin and exercise on glucose uptake in skeletal muscle from control and MIRKO mice was examined. The results are shown in the bar chart below.



[Source: adapted from JF Wojtaszewski, *et al.*, (1999), *Journal of Clinical Investigation*, **104**, pages 1257–1264]

a. Calculate the percentage increase between mean blood insulin levels in IDE + /+ mice and those in IDE – /– mice. [1]

b. Explain the difference in blood insulin concentrations between the two groups of mice. [2]

c. Distinguish between the response of the two groups of mice to the injection of glucose. [2]

d. Deduce, with a reason, whether transgenic IDE –/– mice are an appropriate model of type II diabetes. [2]

e. Explain the reason for the differences in insulin-stimulated glucose uptake between control mice and MIRKO mice. [2]

f. Distinguish between the effects of insulin alone and exercise alone on glucose uptake in skeletal muscle of MIRKO mice. [1]

g. Evaluate, using the data, whether exercise would be an appropriate therapy for human patients with type II diabetes. [3]

h. State which cells secrete insulin and the organ in which they are located. [2]

Cells:

Organ:

i. State the name of **one** hormone other than insulin involved in the regulation of blood glucose. [1]

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.

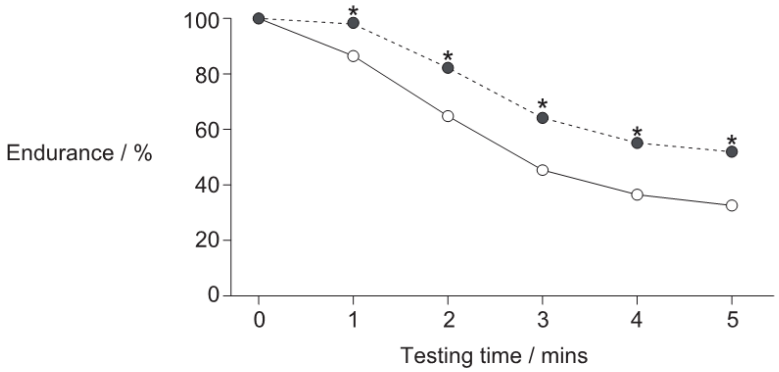
A group of 36 adult male rats were kept for 6 weeks in low oxygen while 36 adult male rats were kept in normal oxygen levels.

		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]

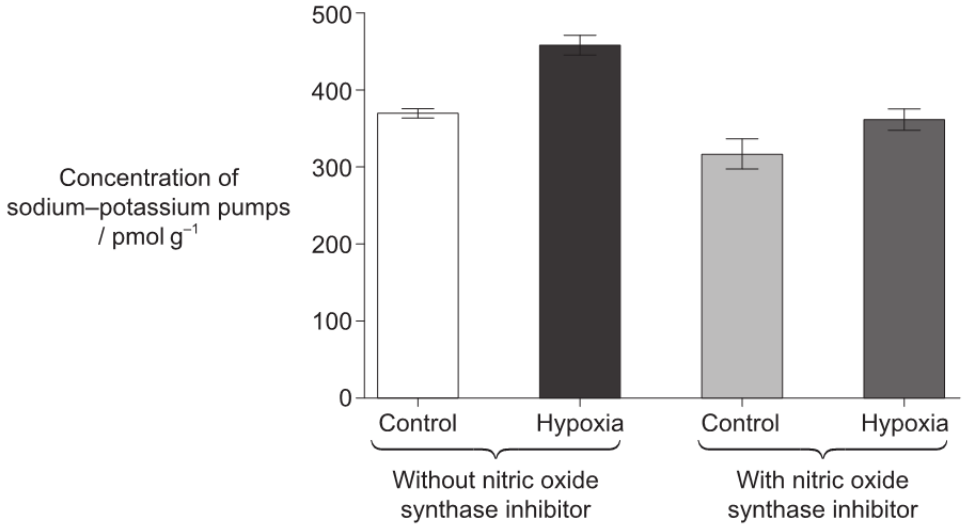
The graph shows the effect of hypoxia on the endurance of rats' diaphragm muscle after 6 weeks. Endurance is the change in force measured as a percentage of the initial force.



Key: * indicates significant difference from control ($p < 0.0001$)
hypoxia
control

[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]

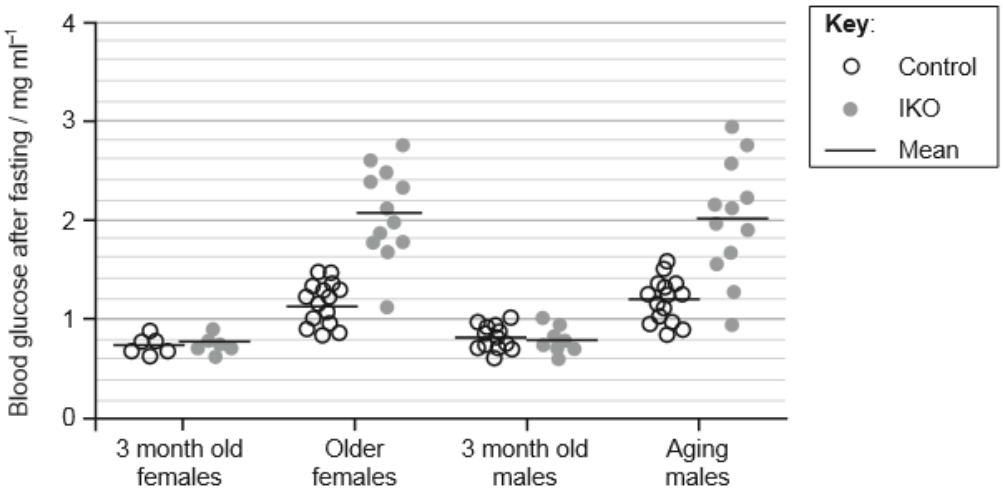
e.ii. Hypoxia caused a 13 % increase in the surface area to volume ratio of the diaphragm. Suggest a reason for this change. [1]

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]

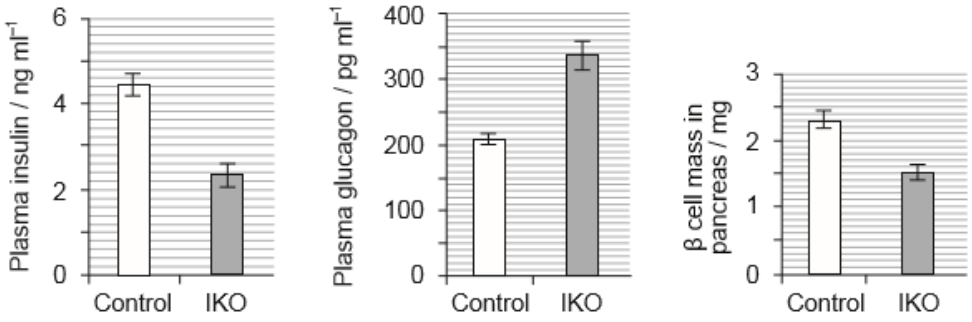
Diabetes is often associated with the failure of the β (beta) cells in the pancreas, but it is unclear what actually causes this failure. FoxO1 is a protein which acts as a transcription factor to regulate the expression of genes involved in cell growth. FoxO1 also regulates increase in number and differentiation in cells such as pancreatic β cells.

A study was conducted using mice lacking the gene for FoxO1 in β cells (IKO) as well as normal (control) mice. Blood glucose levels after fasting were compared for four groups of mice: young (3 months old) male mice, young (3 months old) female mice, older females (who have had several pregnancies) and aging males (16–20 months).



[Source: Chutima Talchai, Shouhong Xuan, Hua V. Lin, Lori Sussel, Domenico Accili, "Pancreatic β Cell Dedifferentiation as a Mechanism of Diabetic β Cell Failure", *Cell*, Volume 150, Issue 6, 14 September 2012, Pages 1223–1234]

The levels of pancreatic hormones and β cell mass in older female control mice and older female IKO mice lacking FoxO1 were then investigated.



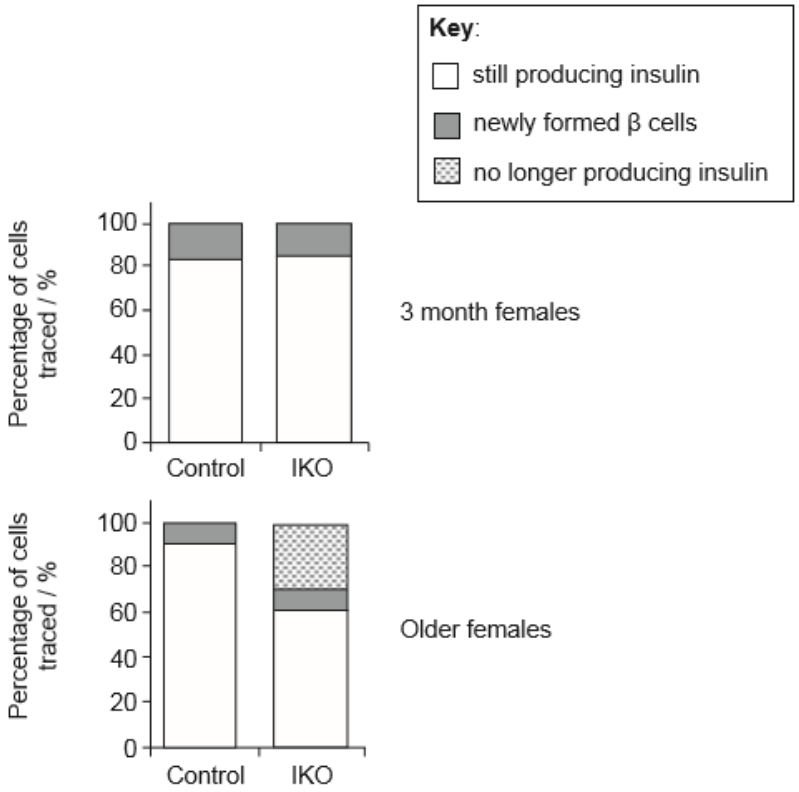
[Source: Chutima Talchai, Shouhong Xuan, Hua V. Lin, Lori Sussel, Domenico Accili, "Pancreatic β Cell Dedifferentiation as a Mechanism of Diabetic β Cell Failure", *Cell*, Volume 150, Issue 6, 14 September 2012, Pages 1223–1234]

To examine whether the changes observed were due to lack of β cell function or change in β cell number, investigators traced marked cells. They were able to determine if cells were:

• still producing insulin

• newly formed β cells

• no longer producing insulin.



[Source: Chutima Talchai, Shouhong Xuan, Hua V. Lin, Lori Sussel, Domenico Accili, "Pancreatic β Cell Dedifferentiation as a Mechanism of Diabetic β Cell Failure", *Cell*, Volume 150, Issue 6, 14 September 2012, Pages 1223–1234]

a. Compare blood glucose levels after fasting in young control mice and young IKO mice without FoxO1. [2]

b. Aging and having pregnancies are considered to be physiological stresses. Deduce the effect of stress on blood glucose levels. [2]

c. Outline the relationship between blood glucose levels after fasting and lack of FoxO1 in the mice studied. [2]

d. Calculate the percentage difference in β cell mass of the IKO mice compared to the control mice. [2]

e. State the correlation between lack of FoxO1 and pancreatic hormones in mice. [1]

f. State which group of cells showed the least change in the mice studied. [1]

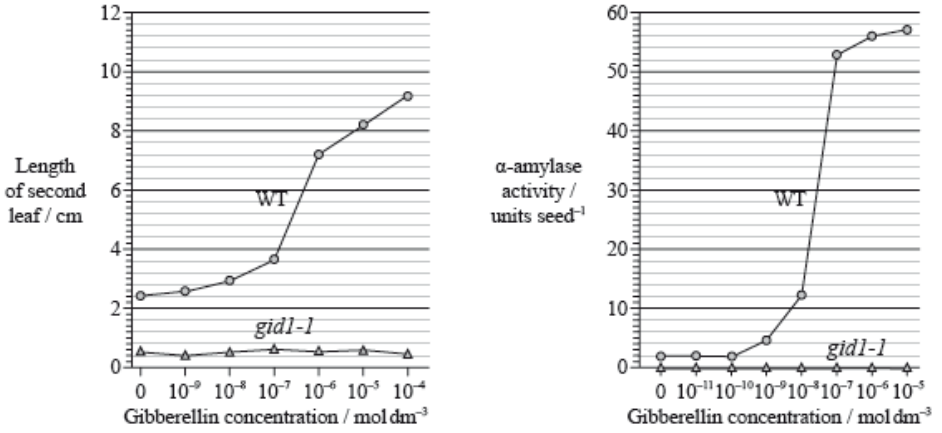
g. Deduce the effects of aging on the distribution of cell types in mice. [2]

h. A hypothesis has been suggested that diabetes is caused by β cells losing their ability to act as β cells, not by the death of β cells. In other words they dedifferentiate. [2]

Using all the information provided, discuss whether the data support this hypothesis.

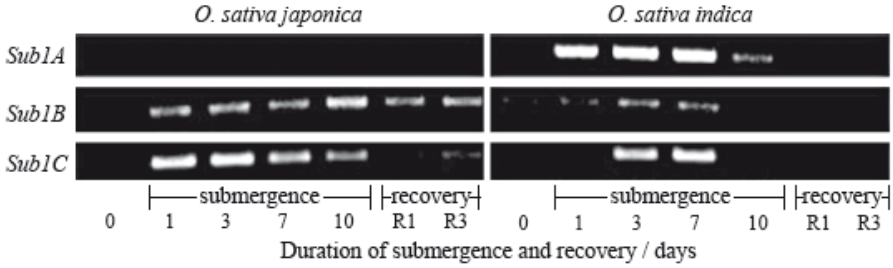
i. When there are high blood glucose levels, more FoxO1 is found in the nucleus of the cell than in the cytoplasm. Suggest a role of FoxO1 considering this and the data. [2]

Gibberellin promotes both seed germination and plant growth. Researchers hypothesize that the gene *GID1* in rice (*Oryza sativa*) codes for the production of a cell receptor for gibberellin. The mutant variety *gid1-1* for that gene leads to rice plants with a severe dwarf phenotype and infertile flowers when homozygous recessive. It is suspected that homozygous recessive *gid1-1* plants fail to degrade the protein SLR1 which, when present, inhibits the action of gibberellin. The graphs show the action of gibberellin on the leaves and α-amylase activity of wild-type rice plants (WT) and their *gid1-1* mutants.



[Source: adapted from M. Ueguchi-Tanaka et al. (2005) 'Gibberellin-insensitive dwarf1 encodes a soluble receptor for gibberellin'. Nature, 437, pp. 693—698. Adapted by permission from Macmillan Publishers Ltd (c) 2005.]

Most rice varieties are intolerant to sustained submergence under water and will usually die within a week. Researchers have hypothesized that the capacity to survive when submerged is related to the presence of three genes very close to each other on rice chromosome number 9; these genes were named *Sub1A*, *Sub1B* and *Sub1C*. The photograph below of part of a gel shows relative amounts of messenger RNA produced from these three genes by the submergence-intolerant variety, *O. sativa japonica*, and by the submergence-tolerant variety, *O. sativa indica*, at different times of a submergence period, followed by a recovery period out of water.

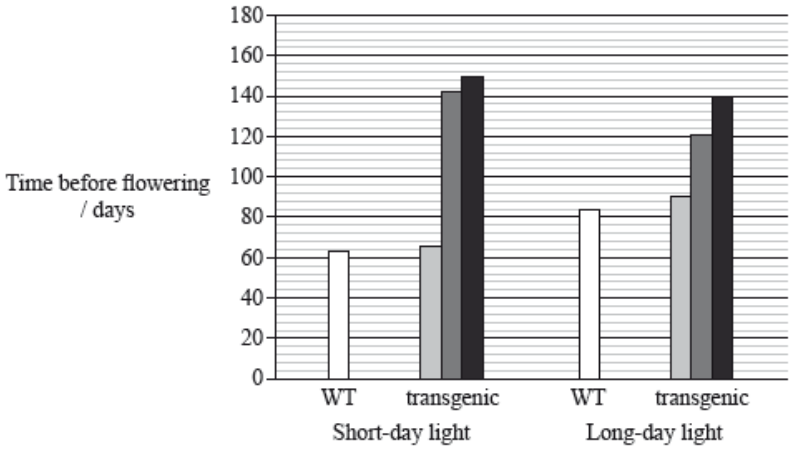


[Source: Adapted from "Sub1A is an ethylene-response-factor-like gene that confers submergence tolerance to rice" (2006) Kenong Xu, Xia Xu, Takeshi Fukao, Patrick Canlas, Reycel Maghirang-Rodriguez et al. Nature, 442, pp. 705—708. Adapted by permission from Macmillan Publishers Ltd (c) 2006.]

The *OsGI* gene causes long-day flowering and the effect of its overexpression has been observed in a transgenic variety of rice. Some wild-type rice (WT) and transgenic plants were exposed to long days (14 hours of light per day) and others to short days (9 hours of light per day).

The shades of grey represent the genotypes of the transgenic plants, where:

- –/– do not have the overexpressed *OsGI* gene
- +/– are heterozygous for the overexpressed *OsGI* gene
- +/+ are homozygous for the overexpressed *OsGI* gene.



[Source: adapted from R. Hayama, S. Yokoi, S. Tamaki, M. Yano and K. Shimamoto (2003) 'Adaptation of photoperiodic control pathways produces short-day flowering in rice.' Nature, 422, pp. 719—722. Adapted by permission from Macmillan Publishers Ltd (c) 2003.]

a(i). State which variety of rice fails to respond to gibberellin treatment. [1]

a(ii). The activity of α-amylase was tested at successive concentrations of gibberellin. Determine the increment in gibberellin concentration that produces the greatest change in α-amylase activity in wild-type rice plants (WT). [1]

b. Discuss the consequence of crossing *gid1-1* heterozygous rice plants amongst themselves for food production. [3]

c(i). Determine which gene produced the most mRNA on the first day of the submergence period for variety *O. sativa japonica*. [1]

c(ii). Outline the difference in mRNA production for the three genes during the submergence period for variety *O. sativa indica*. [2]

d. Using only this data, deduce which gene confers submersion resistance to rice plants. [2]

e(i). State the overall effect of overexpression of the *OsGI* gene in plants treated with short-day light. [1]

e(ii). Compare the results between the plants treated with short-day light and the plants treated with long-day light. [2]

e(iii). State, giving **one** reason taken from the data opposite, if unmodified rice is a short-day plant **or** a long-day plant. [1]

g. Evaluate, using all the data, how modified varieties of rice could be used to overcome food shortages in some countries. [2]

---

a. The image shows a transverse section of an intestinal wall at 100 x magnification. [2]

[Source: Ed Reschke/Getty Images]

Identify the tissues labelled I and II on the image.

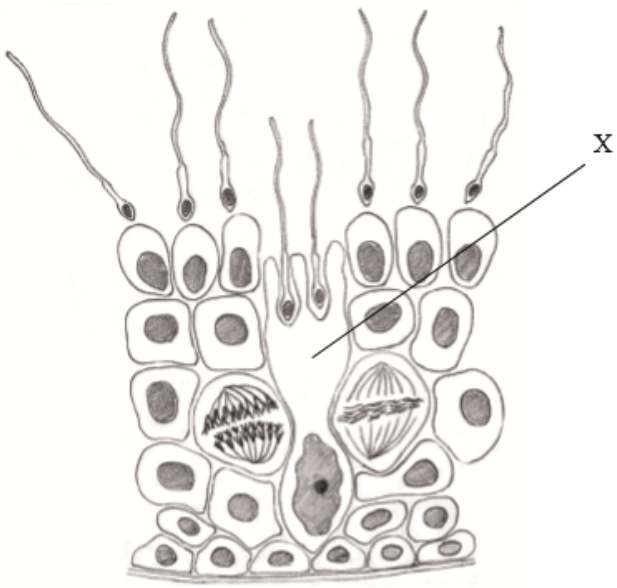
I: .....
II: .....

b. All motor neurons use acetylcholine to activate skeletal muscle. Explain the effect of neonicotinoid pesticides in insect synapses in the central nervous system. [3]

c. Resistance to neonicotinoid pesticides has been observed in some insects. [2]

Describe briefly how this resistance could have arisen in populations of insects.

The diagram below shows a small portion of the tissue in a transverse section of a testis.



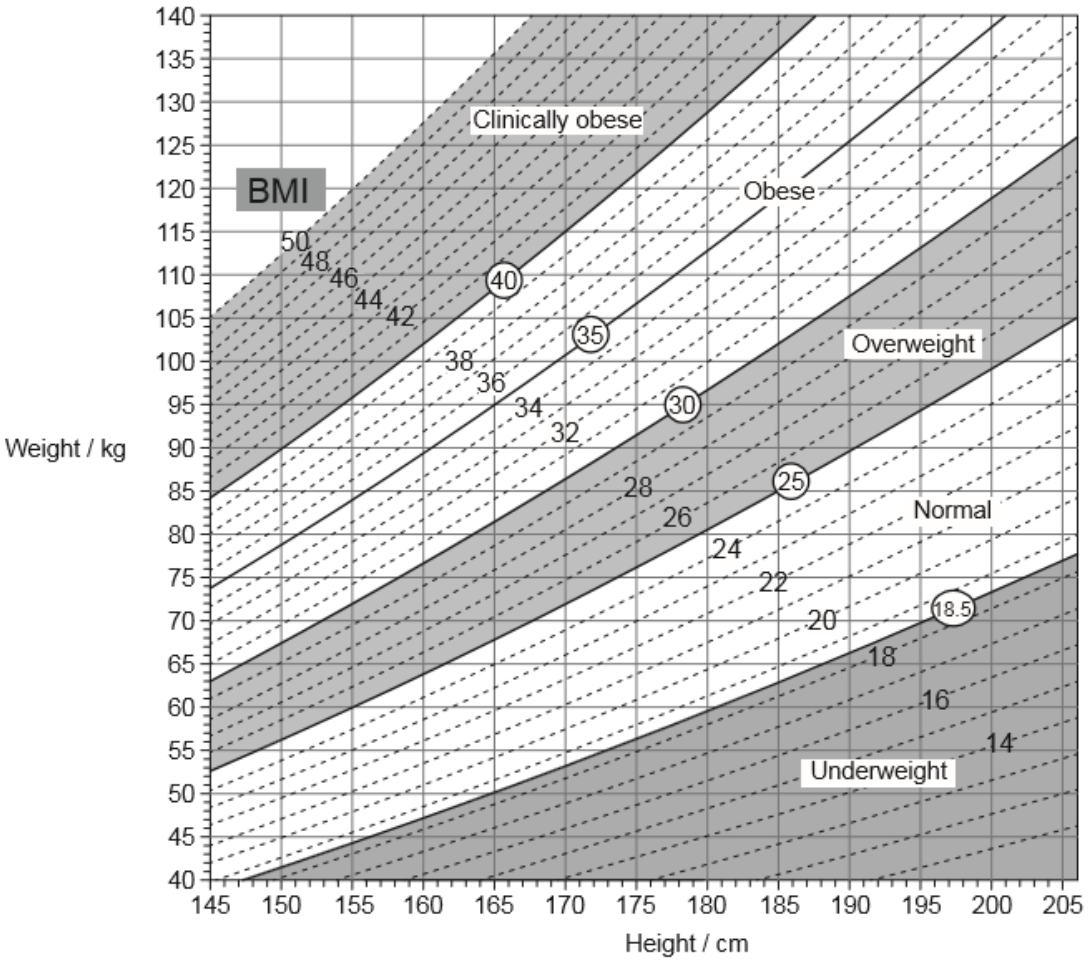
a. Outline the process of *in vitro* fertilization (IVF). [3]

b (i) Identify the cell labelled X. [1]

b (ii) Outline the function of this cell. [1]

c. Explain how meiosis results in genetic variation in gametes. [2]

The image shows a nomogram.



[Source: © All rights reserved. *Canadian Guidelines for Body Weight Classification in Adults*. Health Canada, 2003. Adapted and reproduced with permission from the Minister of Health, 2016.]

a. (i) Using the nomogram, state the lower weight limit for a woman with the height of 155 cm who is classified as overweight, giving the units. [2]

Lower weight limit: .....

(ii) State a major health problem of the circulatory system that is correlated with obesity.

b. Draw the structure of a saturated fatty acid. [2]

c. Describe how the hormone leptin helps to prevent obesity. [3]

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

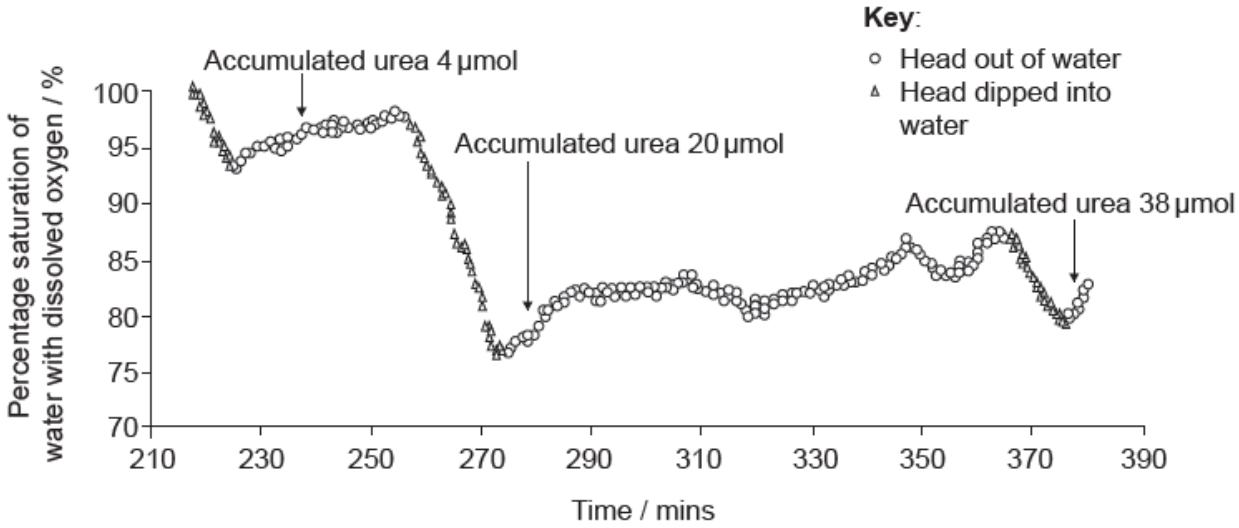
These turtles have fully developed lungs and kidneys, however, many microvilli have been discovered in the mouth of *P. sinensis*. A study was undertaken to test the hypothesis that oxygen uptake and urea excretion can simultaneously occur in the mouth.

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

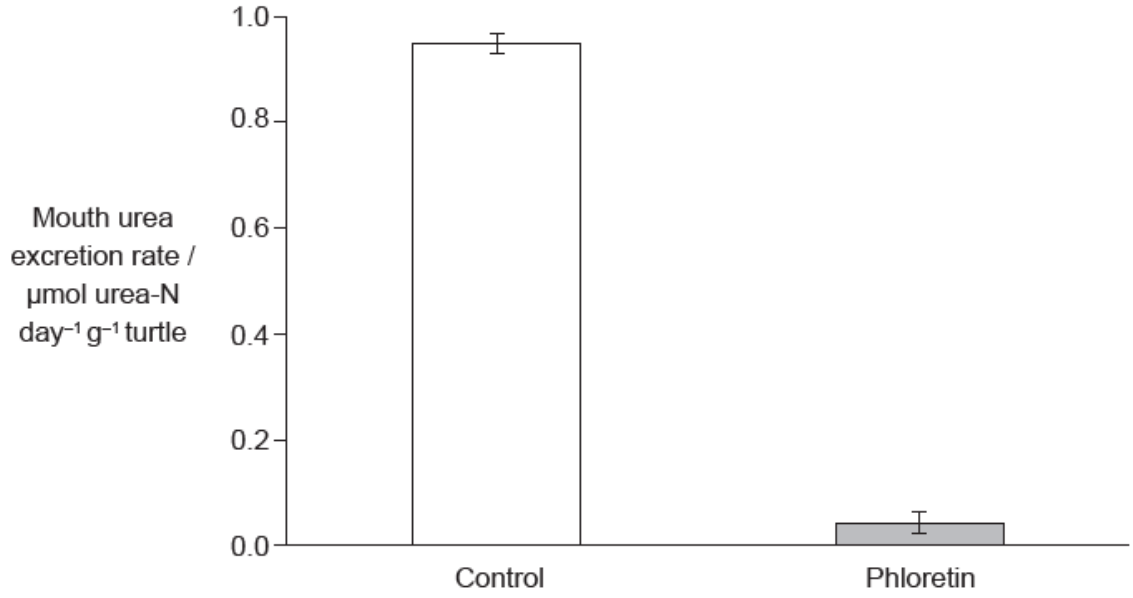
[Source: Reproduced with permission, Y. Ip *et al*. (2012) *The Journal of Experimental Biology*, 215, pages 3723—3733. jeb.biologists.org. doi: 10.1242/jeb.068916]

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.



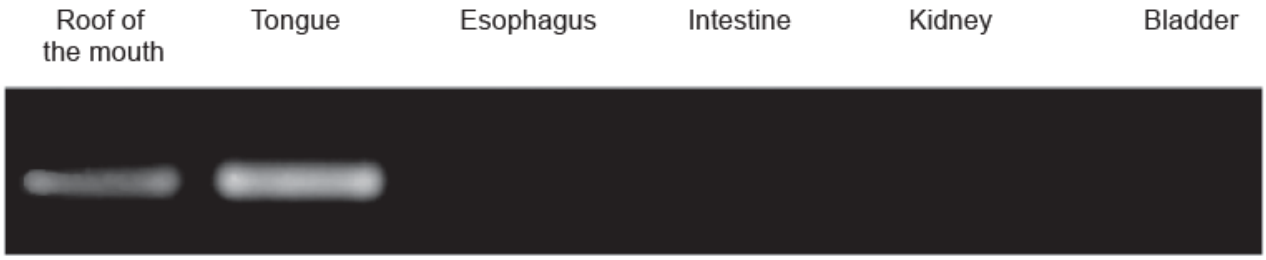
[Source: adapted with permission from Y. Ip *et al*. (2012) *The Journal of Experimental Biology*, 215, pages 3723–3733.]

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.



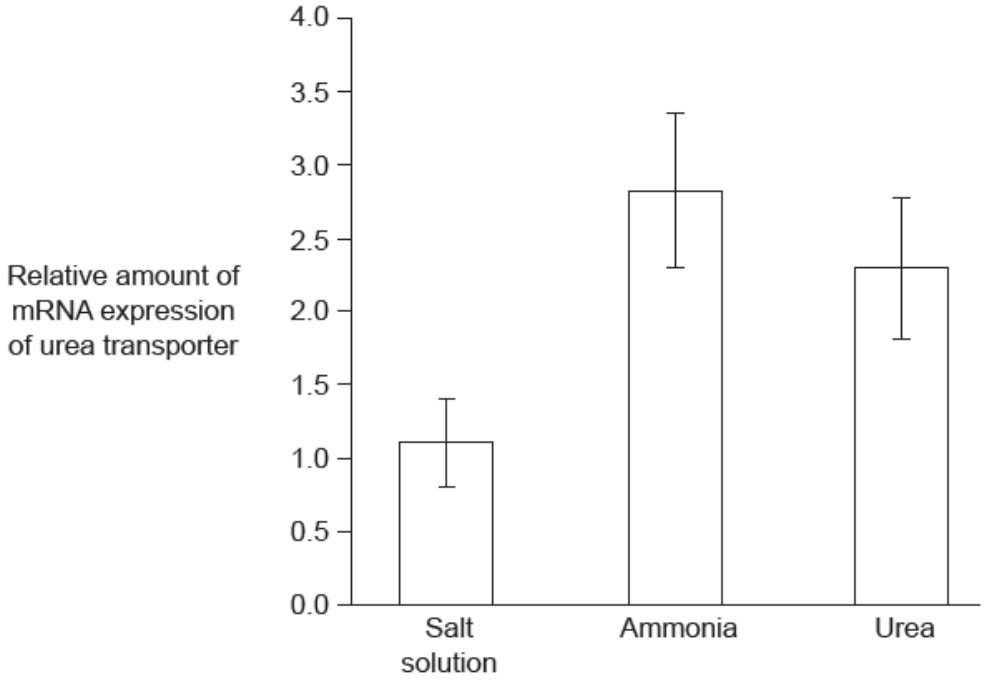
[Source: Reproduced with permission from Y. Ip *et al*. (2012) *The Journal of Experimental Biology*, 215, pages 3723–3733. jeb.biologists.org.]

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]

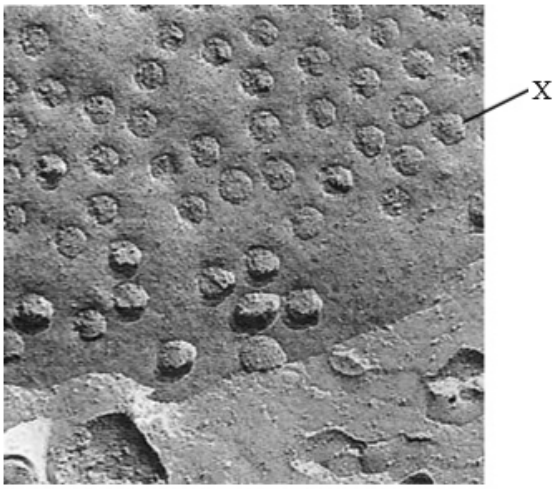
e. Outline the additional evidence provided by the gel electrophoresis results shown above. [2]

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]

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]

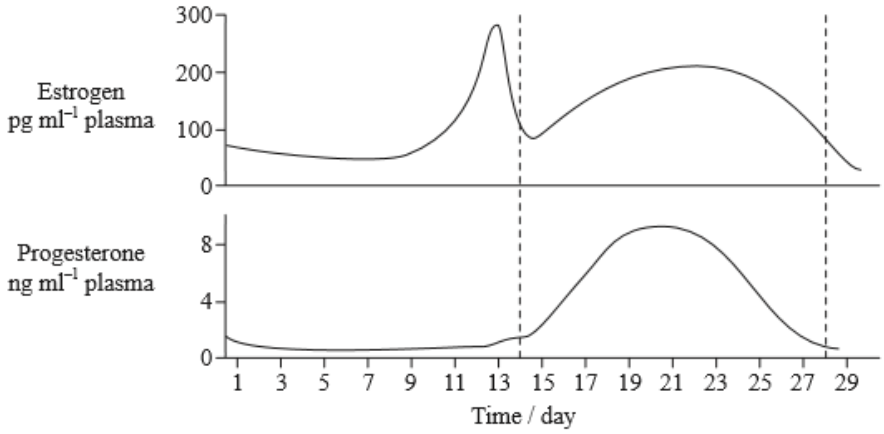
a (i) Calculate the power of magnification of the image. [1]

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]



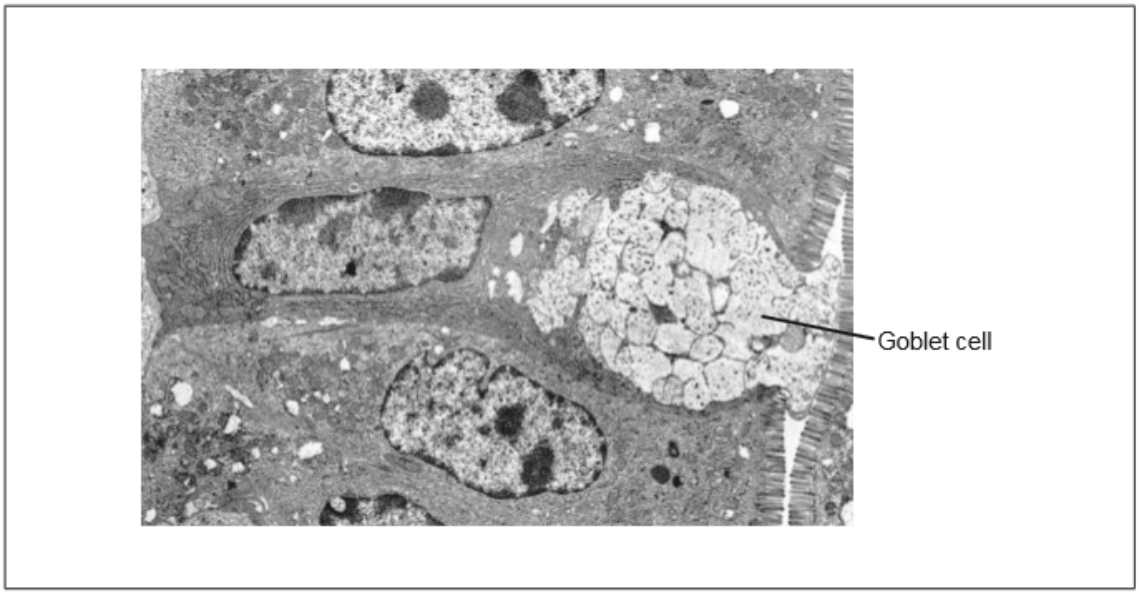
[Source: adapted from www.mivf.com.au/ivf/infertility/images/cyclediagram.GIF]

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

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

---

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]