SL Paper 2

a. Milk contains lactose which some people can digest but some cannot. [1]

State what type of sugar lactose is.

b. Milk contains lactose which some people can digest but some cannot. [1]

State a function of lactose.

c. Milk contains lactose which some people can digest but some cannot. [3]

Explain the production of lactose-free milk.

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a. Draw a labelled diagram to show the human ventilation system. [4]

b. Outline anaerobic cell respiration in plant cells. [5]

c. Explain the concept of homeostasis, using the control of blood sugar as an example. [9]

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a. State the type of bonds that [2]

(i) connect base pairs in a DNA molecule.

(ii) link DNA nucleotides into a single strand.

b. Distinguish between DNA and RNA nucleotides by giving **two** differences in the chemical structure of the molecules. [2]

c. Explain the role of transfer RNA (tRNA) in the process of translation. [2]

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a. Distinguish between ventilation, gas exchange and cell respiration. [4]

b. Outline the process of aerobic respiration. [6]

c. Respiration and other processes in cells involve enzymes. Explain the factors that can affect enzymes. [8]

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a. Describe the genetic code and its relationship to polypeptides and proteins. [5]

b. Outline the role of proteins in active and passive transport of molecules through membranes. [5]

c. Many cell functions, like synthesis of macromolecules and transport, require energy in the form of ATP. Explain how ATP is generated in animal cells. [8]

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a. Describe the structure and function of starch in plants. [3]

b. Outline the production of carbohydrates in photosynthesis. [4]

c. Discuss the processes in the carbon cycle that affect concentrations of carbon dioxide and methane in the atmosphere and the consequences for climate change. [8]

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a. Explain why DNA must be replicated before mitosis and the role of helicase in DNA replication. [4]

b. Explain how the base sequence of DNA is conserved during replication. [5]

c. Describe the events that occur during mitosis. [9]

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a. Define metabolism. [1]

b. Identify the following processes as **either** anabolism **or** catabolism by placing a tick (√) in the correct box. [2]

Process	Anabolism	Catabolism
Photosynthesis	☐	☐
Glycolysis	☐	☐

c. Describe cell respiration in terms of metabolism. [2]

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a. State **one** disaccharide and the **two** monomers from which it can be synthesized. [2]

Disaccharide:

1:

Monomers:

1:

and 2:

b. Discuss the roles of the enzymes secreted by the pancreas during digestion. [3]

c. Compare and contrast cis-fatty acids and trans-fatty acids. [2]

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a. Draw a labelled diagram of the structure of DNA, showing the arrangement of subunits. [3]

b. Explain DNA replication. [3]

DNA research, involving biotechnology, has led to benefits for society but has given rise to some controversy.

a. Outline how translation depends on complementary base pairing. [3]

b. Describe the polymerase chain reaction (PCR), including the role of Taq DNA polymerase. [4]

c. Explain benefits and risks of using genetically modified crops for the environment and also for human health. [8]

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a. State **four** elements that are needed by living organisms, other than carbon, hydrogen and oxygen, giving **one** role of each. [4]

b. Outline how light energy is used and how organic molecules are made in photosynthesis. [6]

c. Explain the significance of complementary base pairing for replication, transcription and translation. [8]

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a. Outline the role of hydrolysis in the relationships between monosaccharides, disaccharides and polysaccharides. [4]

b. Describe the use of biotechnology in the production of lactose-free milk. [6]

c. Explain the importance of enzymes to human digestion. [8]

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b. Outline the process of gas exchange necessary for aerobic respiration in a unicellular eukaryotic organism. [3]

c. Explain how the process of evolution occurs. [8]

a. Outline the difference in absorption of red, blue and green light by chlorophyll. [4]

b. Explain how the process of photosynthesis affects carbon dioxide concentrations in the atmosphere during a typical year **and** the likely consequences on Earth of the yearly rises in carbon dioxide concentrations. [8]

In ecosystems, energy is used to convert inorganic compounds into organic matter. Energy enters ecosystems through producers.

a. Explain the processes by which energy enters and flows through ecosystems. [8]

b. Producers extract phosphates and nitrates from soil. Outline how these ions are used in the synthesis of organic molecules. [3]

c. Draw a labelled diagram of a pyramid of energy. [4]

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a. State **one** role in living organisms for each of the following: sulfur, calcium, phosphorus and iron. [4]

b. Outline the role of condensation and hydrolysis in the relationship between fatty acids, glycerol and triglycerides. [6]

c. Explain the relationship between the properties of water and its uses in living organisms as a coolant, a medium for metabolic reactions and a transport medium. [8]

James Beard, a famous chef, once said “Food is our common ground, a universal experience.”

a. Explain how the small intestine moves, digests and absorbs food. [8]

b. Distinguish between the structures of the different types of fatty acids in food. [4]

c. Outline how leptin controls appetite. [3]

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a. Draw a molecular diagram of an amino acid to show its general structure. [3]

b. Outline the role of ribosomes in translation. [4]

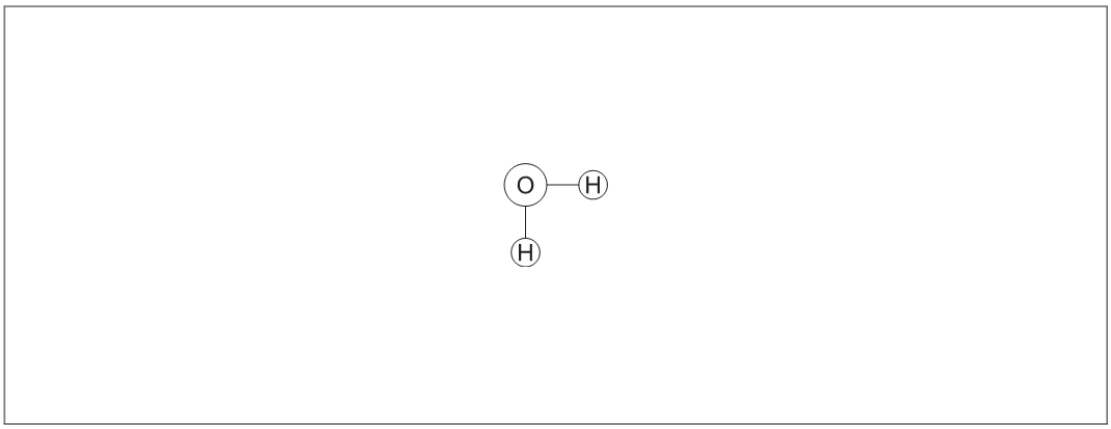
c. Some blood proteins are involved in defence against infectious disease. Explain the roles of **named** types of blood proteins in different defence mechanisms. [8]

a. Outline the role of condensation and hydrolysis in metabolic reactions involving carbohydrates. [4]

b. Metabolic reactions are catalysed by enzymes. Explain how enzymes catalyse reactions and how a change in pH could affect this. [8]

c. Describe the digestion of food in the human digestive system. [6]

a. The figure represents a water molecule. [2]



Draw a second water molecule to show how bonds can form between water molecules, including the name of the bond.

b. Water has important solvent properties. Explain these properties using an example to illustrate your answer. [3]

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a. List **two** functions of membrane proteins. [2]

b. Explain why digestion of large food molecules is essential. [1]

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

d. Outline the use of polymerase chain reaction (PCR) to copy and amplify minute quantities of DNA. [2]

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a. Explain how materials are moved across membranes of cells by active transport. [2]

b. Explain the effects of pH on enzyme catalysed reactions. [3]

c. Distinguish between the process of anaerobic respiration in yeast and humans. [2]

---

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

b. Outline how **three** different environmental conditions can affect the rate of photosynthesis in plants. [6]

c. Explain how the emission of gases, both naturally and through human activity, can alter the surface temperature of the Earth. [8]

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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 flow of energy between trophic levels in ecosystems. [8]

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a. Describe the properties of water that make it a useful component of blood. [4]

b. Explain the relationship between structure and function of arteries, capillaries and veins. [8]

c. Outline how leucocytes defend the body against pathogens. [6]

a. State the source, substrate, products and optimal pH condition for lipase in the human digestive system. [4]

b. Outline the use of **named** enzymes in gene transfer using plasmids. [6]

c. Explain the effect of changes of pH, substrate concentration and temperature on enzyme activity. [8]

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a. Draw a labelled diagram of the molecular structure of DNA including **at least four** nucleotides. [5]

b. A small DNA sample found at a crime scene can be used in an investigation. Describe the steps taken in the processing of this small sample of DNA. [6]

c. Discuss the relationship between **one** gene and **one** polypeptide. [7]

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a. All organisms take in and also release carbon compounds. Draw a labelled diagram of the carbon cycle. [5]

b. Describe how the rate of photosynthesis can be measured. [6]

c. Explain the mechanism of ventilation in humans. [7]

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a. Outline the bonding between DNA nucleotides. [2]

b. Explain how chemical bonding between water molecules makes water a valuable coolant in living organisms. [2]

c. Describe the movement of water across membranes. [2]

d. Outline the role of water in photosynthesis. [2]

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a. Draw a labelled diagram to show how **two** nucleotides are joined together in a single strand of DNA. [3]

b. Outline a basic technique for gene transfer. [6]

c. Explain the process of translation. [9]

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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. Outline enzyme-substrate specificity. [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. Define *active site*. [1]

b. Explain enzyme-substrate specificity. [3]

Plants have widespread influences, from food chains to climate change.

a. Draw a diagram of a palisade mesophyll cell labelling only the structures that would not be present in a pancreatic cell. [3]

b. Explain the process of photosynthesis. [8]

c. Describe the process of peat formation. [4]

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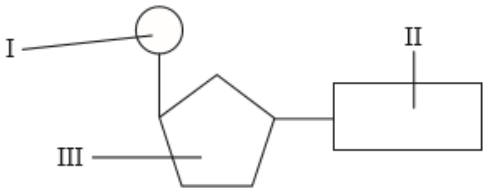
a. The diagram below represents a DNA nucleotide. [1]



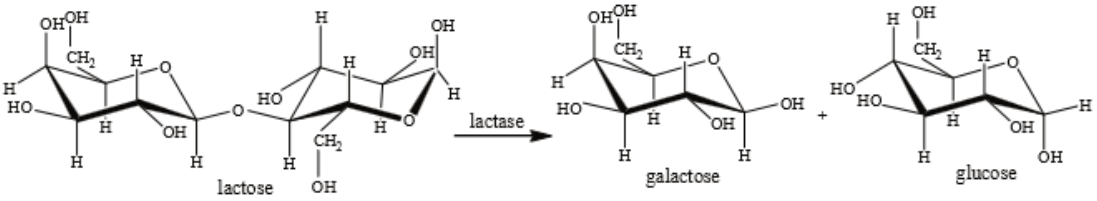
Identify the phosphate group and deoxyribose.

Phosphate group: .....
Deoxyribose: .....

b. Draw a labelled diagram to show how four nucleotides are joined together to form a double-stranded DNA molecule with two base pairs. [3]

c. State **two** differences between RNA and DNA nucleotides. [2]

The equation below shows the production of glucose and galactose from lactose.



a. Glucose and galactose are examples of monosaccharides. State **one** other example of a monosaccharide. [1]

b (i) There are several different types of carbohydrate. State which type of carbohydrate lactose is. [1]

b (ii) State the type of chemical reaction that occurs when lactose is digested into glucose and galactose. [1]

d. Simple laboratory experiments show that when the enzyme lactase is mixed with lactose, the initial rate of reaction is highest at 48°C. In food processing, lactase is used at a much lower temperature, often at 5°C. Suggest reasons for using lactase at relatively low temperatures. [2]

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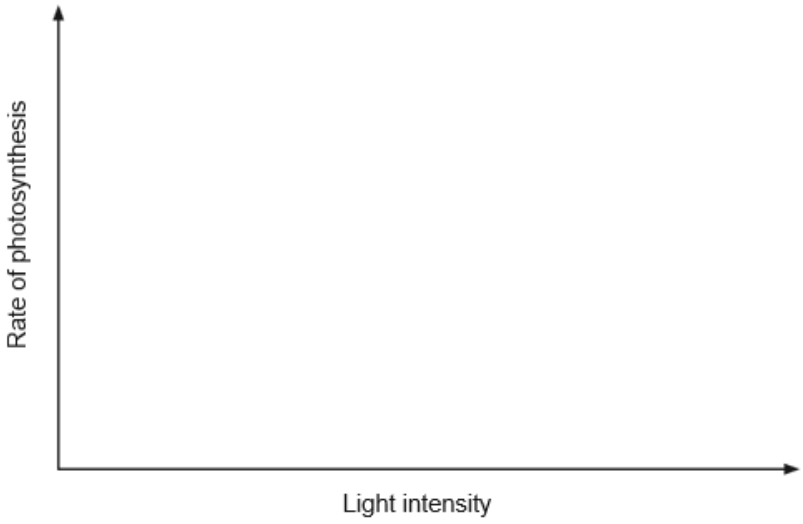
a. Distinguish between absorption of red, green and blue light by chlorophyll. [2]

b (i) Draw a graph to show the effect of increasing light intensity on the rate of photosynthesis. [1]



b (ii) Explain one way of directly measuring the rate of photosynthesis. [2]

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a. Draw a labelled diagram to show the fluid mosaic structure of a plasma membrane, indicating the hydrophilic and hydrophobic regions. [5]

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

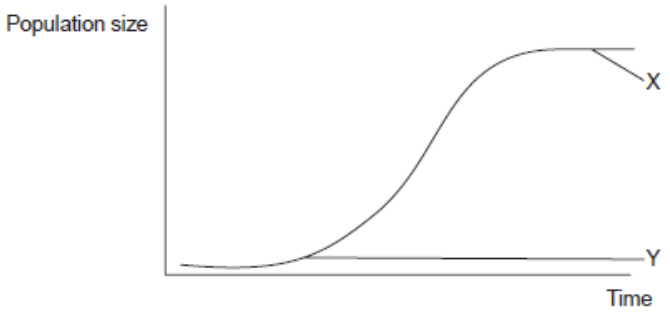
c. Explain how the properties of water are significant to living organisms. [9]

a. State the functions of the following organelles of a eukaryotic animal cell: lysosome, Golgi apparatus, free ribosomes, plasma membrane, rough endoplasmic reticulum. [5]

b. Distinguish between anaerobic and aerobic cell respiration in eukaryotes. [4]

c. Explain the mechanism of ventilation in the lungs in order to promote gas exchange for cell respiration. [9]

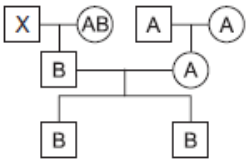
The graph shows a sigmoid population growth curve.



The table summarizes the genome size of several organisms.

Organism type	Organism	Genome size / base pairs
Bacterium	*Helicobacter pylori*	1667867
Fruit fly	*Drosophila melanogaster*	130000000
Rice	*Oryza sativa*	420000000
Human	*Homo sapiens*	3200000000

The figure shows a pedigree chart for the blood groups of three generations.



a. Identify the phases labelled X and Y. [1]

X:

Y:

b. Outline how fossil records can provide evidence for evolution. [2]

c(i). Distinguish between the terms genotype and phenotype. [1]

c(ii) Outline a structural difference between the chromosomes of *Helicobacter pylori* and *Homo sapiens*. [1]

c(iii) Deduce the percentage of adenine in *Oryza sativa* if the proportion of guanine in that organism is 30 %. [1]

d(i) Deduce the possible phenotypes of individual X. [1]

d(ii) Describe ABO blood groups as an example of codominance. [1]

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a. Draw a labelled diagram showing the **interconnections** between the liver, gall bladder, pancreas and small intestine. [2]

b. Outline the role of glucagon in homeostasis of glucose. [2]

c. List **two** examples of polysaccharides. [1]

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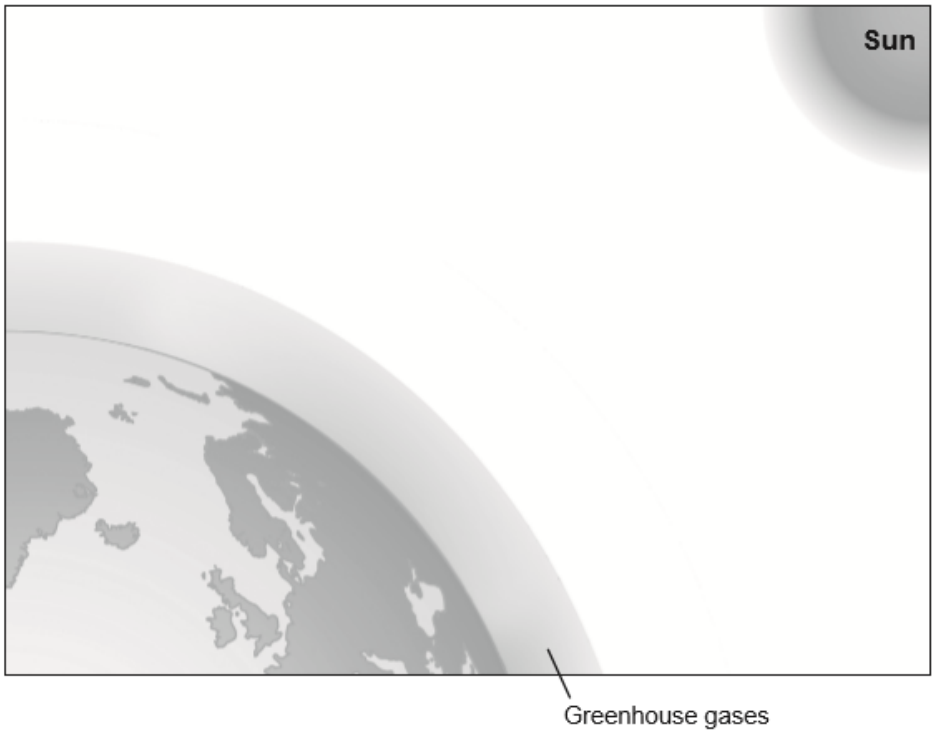
a. (i) Distinguish between the thermal properties of water and methane. [4]

(ii) Explain the reasons for the unique thermal properties of water.

b. Using the diagram, explain the interaction of short and long wave radiation with greenhouse gases in the atmosphere. [3]



[Source: © International Baccalaureate Organization 2016]

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a. Outline the stages of the cell cycle. [5]

b. Explain the process of translation in cells. [8]

c. Outline the production of a dipeptide by a condensation reaction, showing the structure of a generalized dipeptide. [5]

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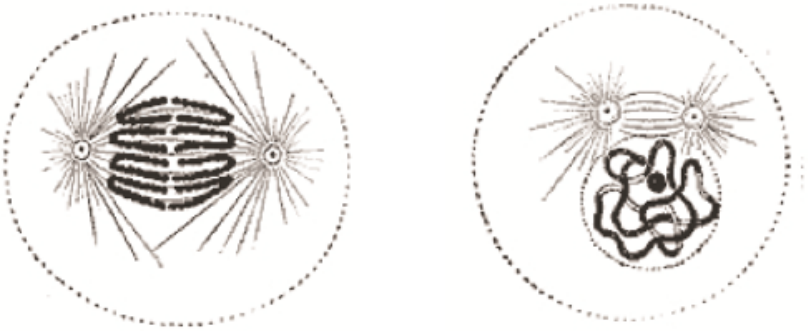
a. Draw a labelled diagram of a section of DNA showing four nucleotides. [5]

b. Outline a technique used for gene transfer. [5]

c. Explain how evolution may happen in response to an environmental change. [8]

The electron micrographs show mitosis in a cell at an early stage and an intermediate stage.

Phase A **Phase B**



[Source: Phase A from: http://upload.wikimedia.org/wikipedia/commons/f/f5/Anaphase.jpg
Phase B from: http://upload.wikimedia.org/wikipedia/commons/d/db/Prophase.jpg]

a (i) State the name of each phase shown, recording whether each phase has taken place at an early or intermediate stage of mitosis. [2]

Phase A: . . . . . .occurs at an. . . . . stage
Phase B: . . . . . .occurs at an. . . . . stage

a (ii) Outline the events occurring in phase A. [2]

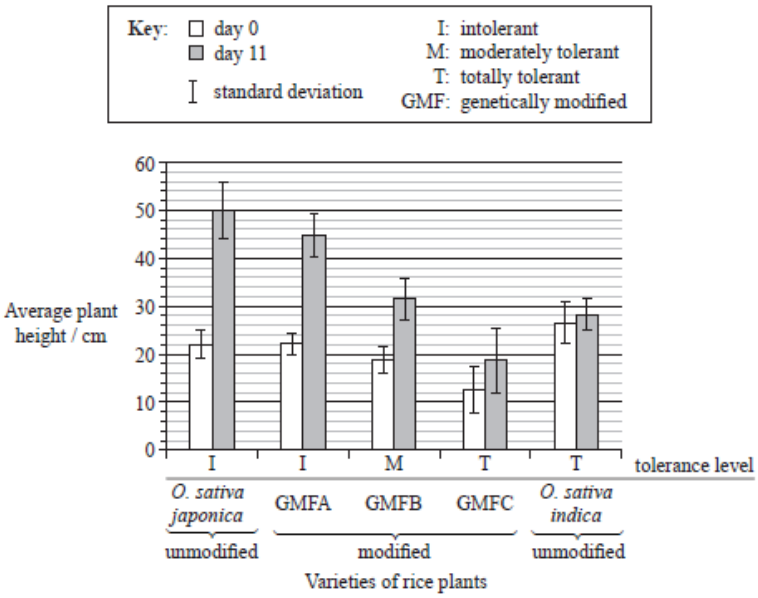
b. State what results when there is an uncontrolled division of cells in living organisms. [1]

c. DNA in chromosomes undergoes replication before mitosis. Outline how complementary base pairing is important in this process. [2]

Rice (*Oryza sativa*) is usually intolerant to sustained submergence under water, although it grows rapidly in height for a few days before dying. This is true for one variety, *Oryza sativa japonica*. The variety *Oryza sativa indica* is much more tolerant to submergence.

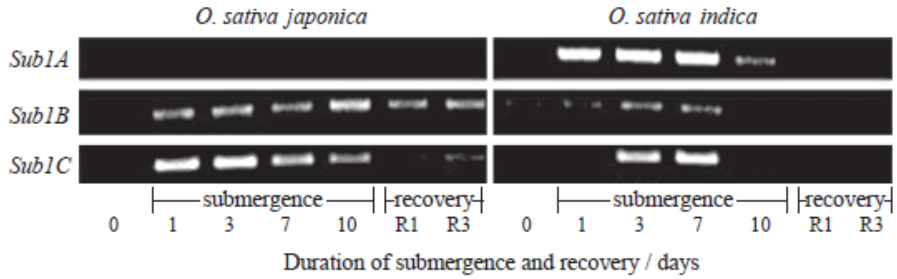
Three genetically modified forms of *O. sativa japonica*, GMFA, GMFB and GMFC, were made using different fragments of DNA taken from *O. sativa indica*.

The plants were then submerged for a period of 11 days. The heights of all the plants were measured at the beginning and at the end of the submergence period.



[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.]

In the same experiment, the researchers 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.



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a(i). State which group of rice plants were the shortest at the beginning of the experiment. [1]

a(ii) Calculate the percentage change in height for the *O. sativa japonica* unmodified variety during the submergence period. Show your working. [2]

c. Deduce the general relationship between the growth of all the *japonica* varieties and their stated tolerance level. [1]

d. Outline the use of the binomial system of nomenclature in *Oryza sativa*. [2]

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

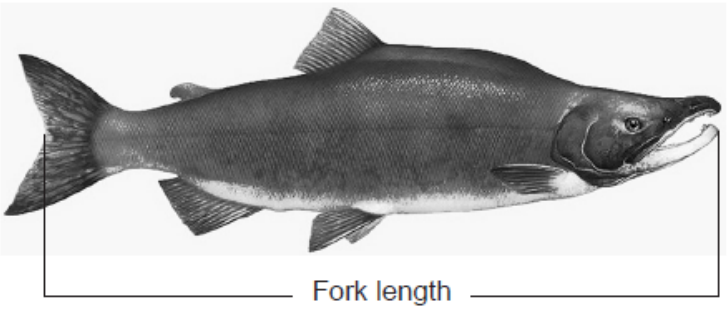
e(ii) Outline the difference in mRNA production for the three genes during the submergence period for variety *O. sativa indica*. [2]

e(iii) Compare the mRNA production for the three genes during the submergence period between the two varieties. [2]

f. Deduce, using all the data, which gene was used to modify GMFC. [2]

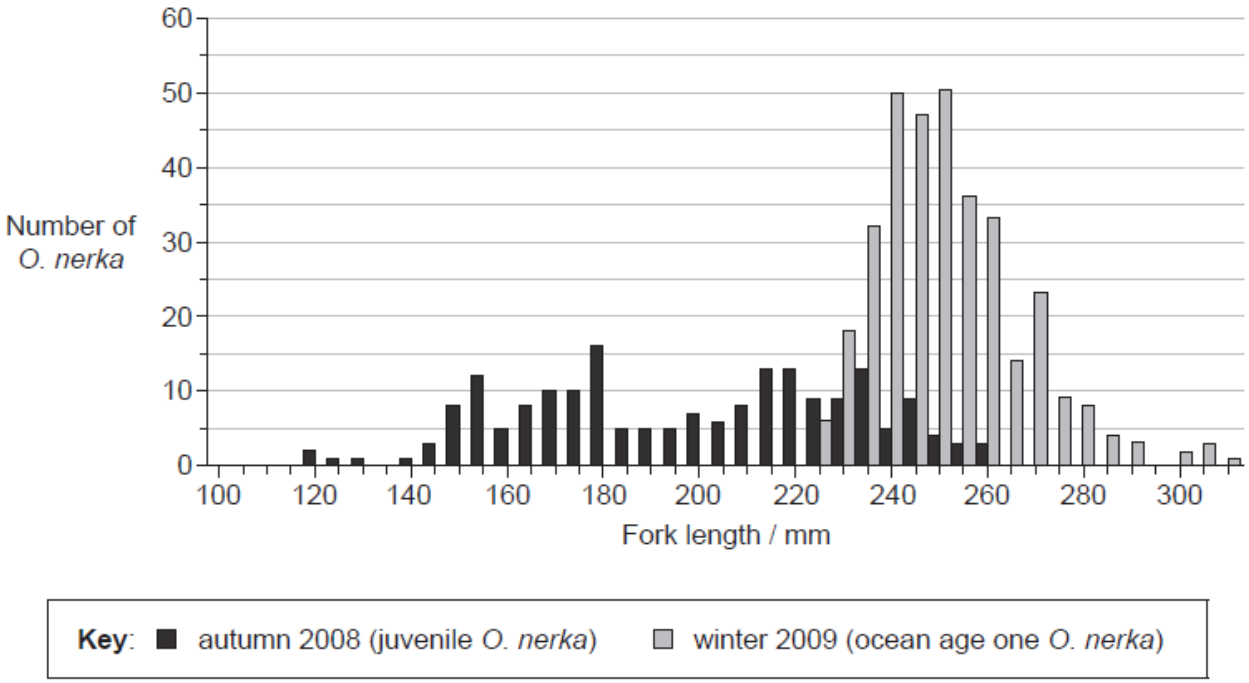
g. Evaluate, using all the data, how modified varieties of rice could be used to overcome food shortages in some countries. [2]

Sockeye salmon (*Oncorhynchus nerka*) spend the first years of their lives in the freshwater lakes of Alaska before migrating to marine waters. Their first months in marine waters are spent foraging and growing near the shore line. They then move to offshore regions of the North Pacific Ocean for 2 to 3 years.



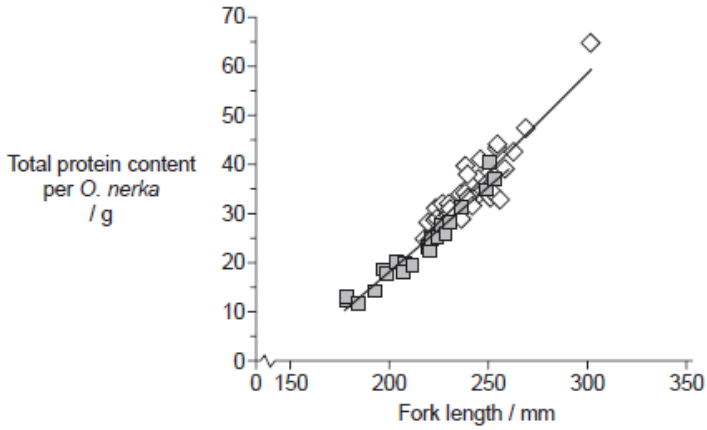
[Source: adapted from http://pnwfolklore.org]

The graph shows fork length frequency of juvenile *O. nerka* caught during their first months in marine waters in autumn 2008 and ocean age one *O. nerka* caught 15 months later during winter 2009 in the North Pacific Ocean.



[Source: adapted from E V Farley, *et al.*, (2011), *ICES Journal of Marine Science*, **68** (6), pages 1138–1146]

Protein content in *O. nerka* was measured to evaluate possible differences during their first 15 months at sea. The graph shows the relationship between fork length and total protein content per *O. nerka* caught during autumn 2008 and winter 2009.



Key: ▫ autumn 2008 (juvenile *O. nerka*) ◇ winter 2009 (ocean age one *O. nerka*)

[Source: adapted from EV Farley, *et al.*, (2011), *ICES Journal of Marine Science*, **68** (6), pages 1138–1146]

Scientists measured mercury levels in different fish. The table shows the results.

	Mercury / μg g^{-1}				
	Mean	Standard deviation	Minimum	Maximum	Number of samples
Cod	0.111	0.066	0.001	0.989	115
Monkfish	0.181	0.075	0.056	0.289	9
Shark	0.979	0.626	0.001	4.540	356
Trout	0.071	0.025	0.001	0.678	35

a. Identify the most frequent fork length for *O. nerka* caught during autumn 2008 and winter 2009. [1]

Autumn 2008:

Winter 2009:

b. Distinguish between the fork lengths of *O. nerka* in autumn 2008 and winter 2009. [2]

c. Suggest a reason for the variation in fork length of ocean age one *O. nerka*. [1]

d(i). Compare the protein content for *O. nerka* caught during autumn 2008 and winter 2009. [2]

d(ii). Outline the difficulty in predicting the age of *O. nerka* from fork length. [1]

e. Using the data, suggest **one** reason for the relationship between protein content and fork length. [1]

f(i). Compare the results shown in the table for monkfish and shark. [2]

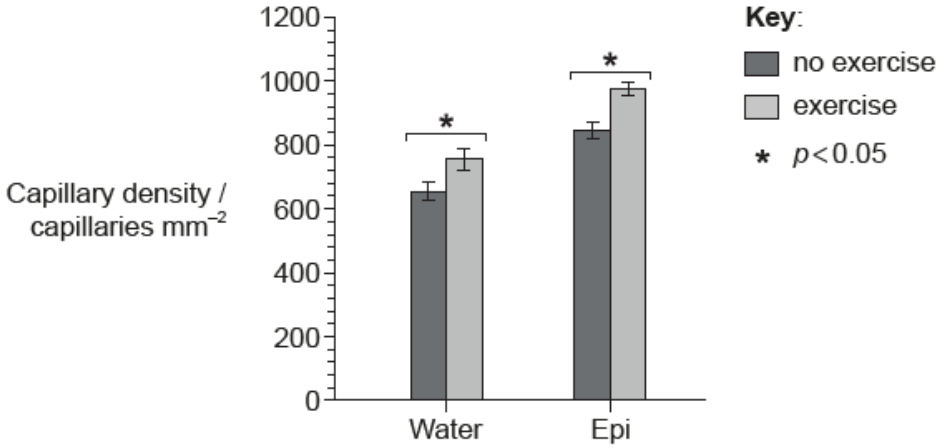
f(ii). Suggest additional information that would be helpful in evaluating these data. [1]

g. State which type of fish shows the most variation. [1]

Consumption of dark chocolate has been shown to have health benefits. A study was undertaken to see the effects of epicatechin (Epi), a substance in dark chocolate, on the aerobic capacity of leg muscles of mice.

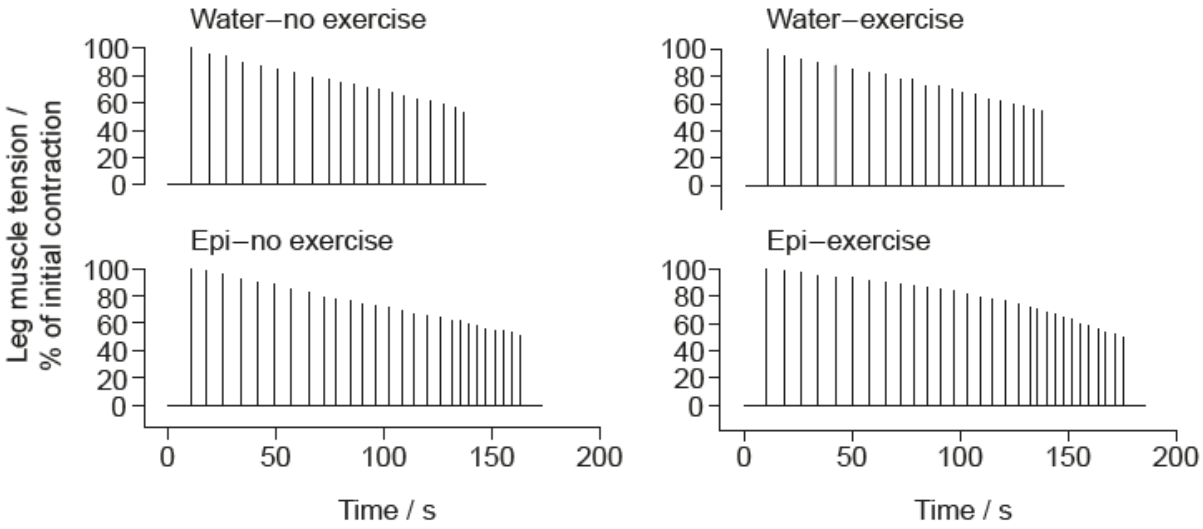
A group of adult mice was used to measure the effects of a low dose of Epi given over 15 days. The mice were divided into four groups and given either water or Epi and were either kept idle (no exercise) or made to exercise on a treadmill.

After 15 days, the results were analysed. The blood capillary density in leg muscle was measured under the light microscope.



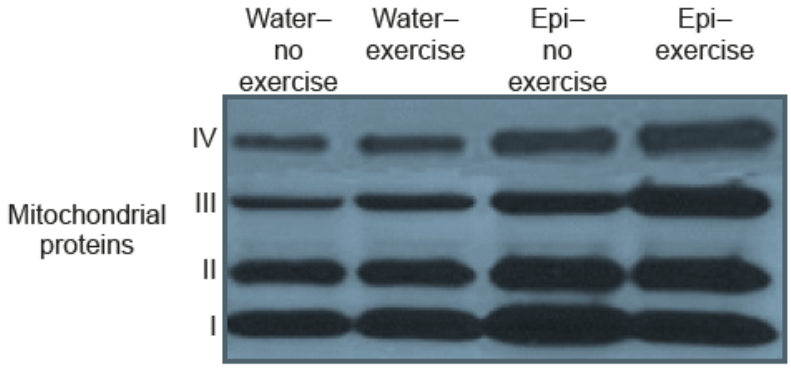
[Source: adapted from L Nogueira, *et al.*, (2011), *The Journal of Physiology*, **589** (part 18), Wiley, pages 4615–4631]

Leg muscle tension was measured over time during a treadmill exercise in all four groups. The muscle is considered to reach a point of fatigue when there is a decrease in tension to 50 % of the initial tension.



[Source: adapted from L Nogueira, *et al.*, (2011), *The Journal of Physiology*, **589** (part 18), Wiley, pages 4615–4631]

The scientists tested the expression of four different mitochondrial proteins. The protein samples were taken from leg muscles. The technique that was used to quantify the amount of protein expressed was Western blotting. In this procedure the thickness of the band is an indicator of the amount of protein.



[Source: adapted from L Nogueira, *et al*., (2011), *The Journal of Physiology*, **589** (part 18), Wiley, pages 4615–4631]

a.i. State the significance of the statement: $p<0.05$. [1]

a.ii. Outline the trends in capillary density in the results of this experiment. [2]

b. Describe how increased capillary density could affect the aerobic capacity of muscle. [2]

c.i. State the time when the point of fatigue occurred in the Epi–exercise group. [1]

c.ii. Compare and contrast the results for the water–no exercise group and the Epi–no exercise group. [3]

d. Discuss the effect of exercise on the results of the experiment. [2]

e. Analyse the effect of exercise on the presence of the mitochondrial proteins in the leg muscle. [2]

f. Mitochondria are essential for aerobic respiration. Suggest **one** possible role of the proteins that were studied. [1]

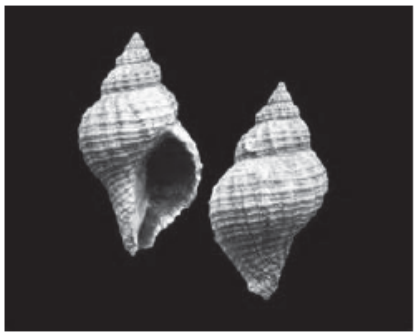
g. The scientists concluded that Epi significantly increased aerobic capacity in leg muscle. [3]

Evaluate the strength of the evidence provided by all of the data for dark chocolate improving the aerobic capacity of athletes.

Native oyster populations are decreasing where rivers meet the ocean along the northwest coast of North America. These oyster populations are being attacked by a gastropod.

Adult oyster, *Ostrea lurida*

[Source: © International Baccalaureate Organization 2017]



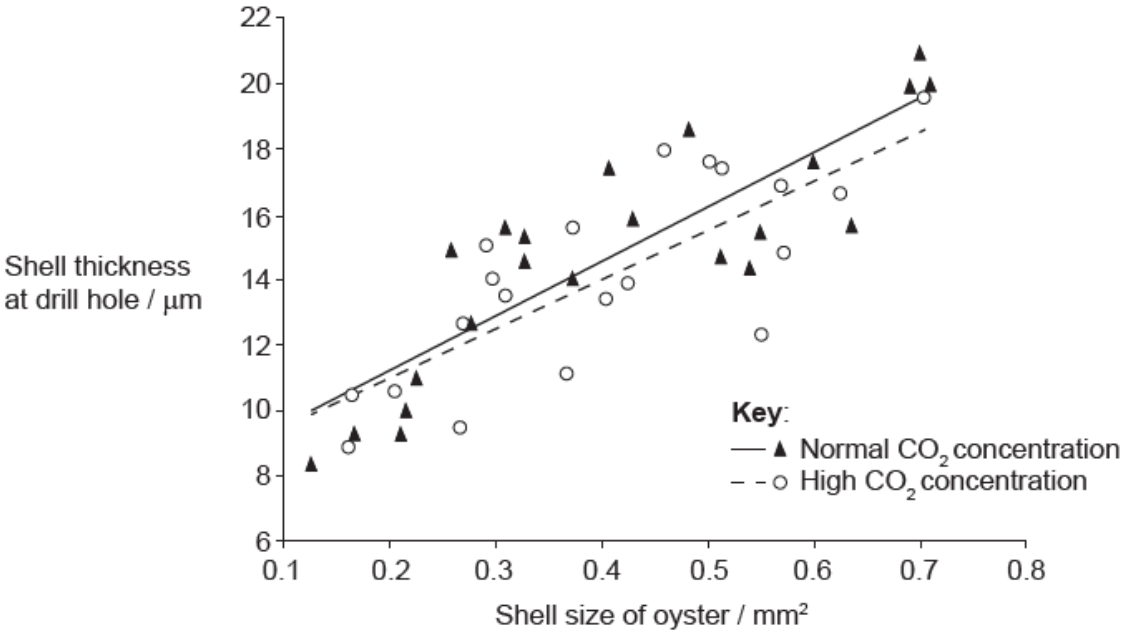
Adult gastropod shell, *Urosalpinx cinerea*

[Source: © International Baccalaureate Organization 2017]

It is known that oysters and gastropods have hard parts composed of calcium carbonate and that ocean acidification is increasing. Studies were carried out using juvenile oysters and gastropods to investigate the effects of acidification on the decrease in the population of oysters.

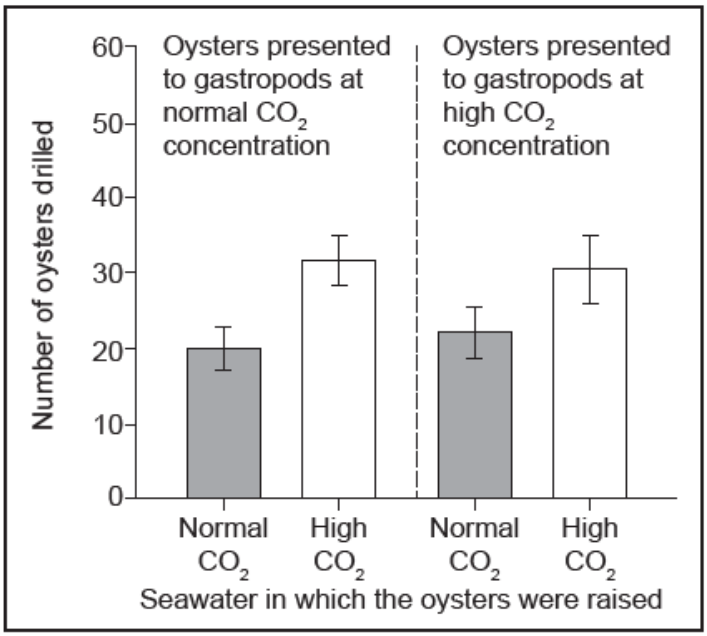
The first step was to raise oysters in two different mesocosms. One had seawater at a normal concentration of CO_2 and the other had sea water with a high concentration of CO_2. Gastropods were raised in two further mesocosms with normal and high CO_2 concentrations respectively.

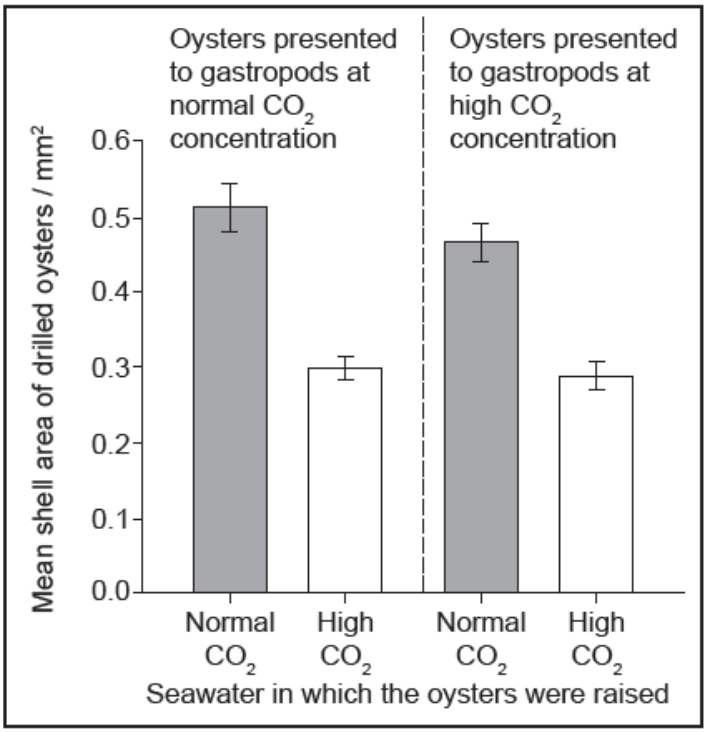
A juvenile gastropod will attack a juvenile oyster by using its tongue-like structure (radula) to drill a hole through the oyster shell. Once the hole has been drilled, the gastropod sucks out the soft flesh. Researchers investigated the shell thickness at the site of the drill hole in relation to the size of the oyster. The results are seen in this graph.



[Source: E Sanford *et al*. (2014) *Proceedings of the Royal Society B*, 281, by permission of the Royal Society.]

Equal numbers of oysters raised in seawater with a normal CO_2 concentration and in seawater with a high CO_2 concentration were then presented together to the gastropod predators in seawater with a normal CO_2 concentration. The same numbers of oysters from the two groups were also presented together to the gastropods in seawater with a high CO_2 concentration. The bar charts show how many of the oysters were drilled by the gastropods and the mean size of drilled oysters.





[Source: © International Baccalaureate Organization 2017]

a. Outline how acidified sea water could affect the shells of the oyster. [1]

b. Outline the trends shown in the data in the graph. [2]

c. Estimate how much smaller drilled oysters raised in seawater at a high CO_2 concentration were than drilled oysters raised in seawater at a normal CO_2 concentration. [1]

d.i. Deduce from the data in the bar charts which factors were and were not correlated significantly with the number of oysters drilled by the gastropods. [2]

d.ii. Suggest reasons for the differences in the numbers of oysters drilled, as shown in the bar charts. [2]

d.iii The radula in a gastropod is hard but not made of calcium carbonate. Outline how this statement is supported by the drilling success of the gastropods in seawater with normal or high CO_2 concentrations. [2]

e. Using all the data, evaluate how CO_2 concentrations affect the development of oysters and their predation by gastropods. [2]