SL Paper 2

a. Define *codominant allele*, *recessive allele*, *locus* and *sex linkage*. [4]

b. ABO blood groups are inherited from parents, but it is possible for a child to have a different blood group from either parent. Outline how this can happen using a Punnett grid. [6]

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

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a. Meiosis in humans produces cells that participate in fertilization. Outline the processes involved in meiosis. [5]

b. Following fertilization, cells in the developing embryo differentiate. Outline a technique for cloning using differentiated animal cells. [5]

c. Discuss ethical issues of therapeutic cloning in humans. [8]

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. Draw a labelled diagram of the human adult male reproductive system. [5]

b. Describe the application of DNA profiling to determine paternity. [5]

c. Explain the inheritance of colour blindness. [8]

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a. Define the term *allele* as used in genetics. [1]

b. List the possible genotypes for blood group B. [1]

a. State the property of stem cells that makes them useful in medical treatment. [1]

b. Explain how multicellular organisms develop specialized tissues. [2]

c. Outline some of the outcomes of the sequencing of the human genome. [3]

a. Define *habitat*, *population, community* and *ecosystem.* [4]

b. Outline how energy flows through an ecosystem. [6]

c. Discuss the benefits and possible harmful effects of altering species by **one** example of genetic modification. [8]

The diploid number of chromosomes in horses (*Equus ferus*) is 64 and the diploid number in donkeys (*Equus africanus*) is 62. When a male donkey and a female horse are mated, the result is a mule which has 63 chromosomes.

a. State the haploid number for horses. [1]

b. Explain reasons that mules cannot reproduce. [2]

c. Discuss whether or not horses and donkeys should be placed in the same species. [2]

d. A mule was born at the University of Idaho in the USA with 64 chromosomes. Suggest a mechanism by which this could happen. [1]

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a. Describe karyotyping and **one** application of its use. [4]

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

c. Using a **named** example, discuss the benefits and harmful effects of genetic modification. [9]

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a. Draw a labelled diagram of the adult male reproductive system. [5]

b. Describe the role of sex chromosomes in the control of gender and inheritance of hemophilia. [7]

c. Discuss the ethical issues associated with IVF. [6]

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

b. Outline the inheritance of a **named** sex-linked condition in humans. [5]

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

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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]

Reproduction in eukaryotes can be sexual or asexual.

a. Describe the origin of eukaryotic cells according to the endosymbiotic theory. [4]

b. Explain how hormones are used to control the human menstrual cycle. [8]

c. Outline natural methods of cloning in some eukaryotes. [3]

a. State **three** processes occurring in a cell during interphase of the cell cycle but not in mitosis. [3]

1. .....
2. .....
3. .....

c. Explain how sexual reproduction can allow evolution to occur. [3]

b. Describe how natural selection leads to evolution. [6]

c. Explain the consequences of altering a DNA base in the genome of an organism. [8]

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]

a (i) Using the table, state whether recessive, dominant and codominant alleles are expressed in heterozygous and homozygous genotypes by writing yes, no **or** both. [2]

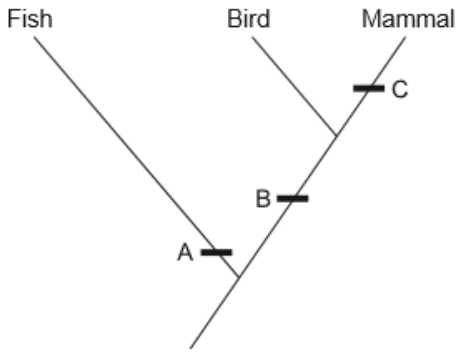
	Recessive allele	**Dominant allele**	**Codominant alleles**
Heterozygous genotype			
Homozygous genotype			

a (ii) State **two** alleles in blood groups that are codominant. [1]

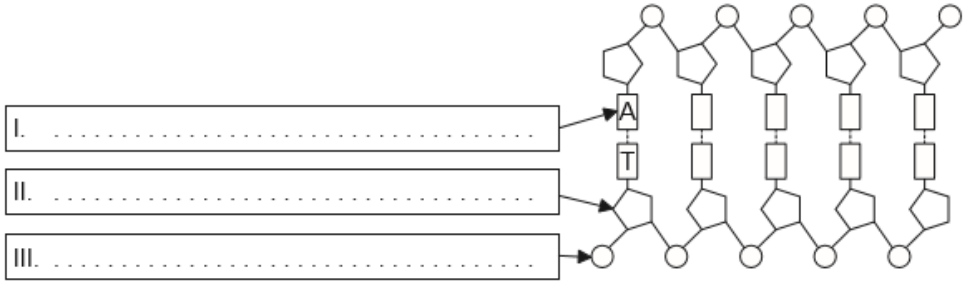
b. Clouded leopards live in tropical rainforests of South-East Asia. The normal spots (brown with a black outline) are dominant and black spots are recessive. The trait is sex-linked. A male with black spots was crossed with a female with normal spots. She had four cubs, two males and two females. For each sex, one cub had normal spots and the other cub had black spots. [3]

Deduce the genotype of the mother. Show your work in a Punnett grid.

The image shows part of a cladogram.



a. Label the parts of two paired nucleotides in the polynucleotide of DNA. [3]

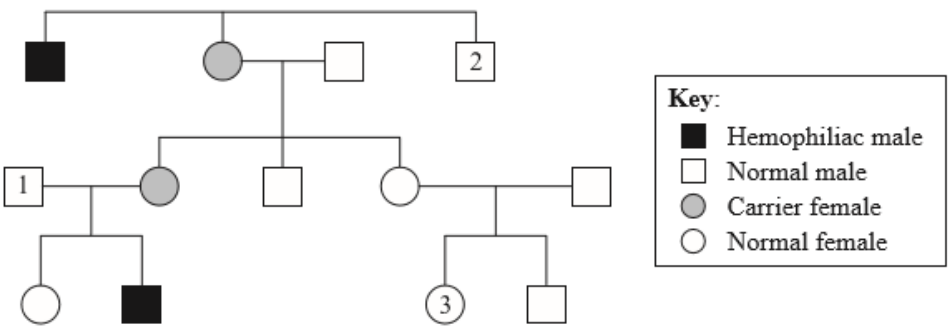


b. Using the cladogram, identify **one** diagnostic feature that characterizes the given groups of vertebrates at A, B and C. [3]

A: .....
B: .....
C: .....

c. State the name of the domain to which these organisms belong. [1]

Hemophilia is a disease where the blood does not clot properly. The pedigree chart below shows the inheritance of this condition in a family.



a (i) Determine the genotype of person 1. [1]

a (ii) Deduce the genotype of the mother of person 2. [1]

a (iii). person 3 has a son, and the father is a hemophiliac male, predict the son's phenotype. [1]

b. Suggest how sheep could be genetically modified to help the treatment of hemophilia in humans. [1]

Mutations are the ultimate source of genetic variation and are essential to evolution.

Lice are wingless insects that belong to the phylum arthropoda.

a.i. State **one** type of environmental factor that may increase the mutation rate of a gene. [1]

a.ii. Identify **one** type of gene mutation. [1]

b. State **two** characteristics that identify lice as members of the arthropoda. [2]

1.

2.

b.ii. Some lice live in human hair and feed on blood. Shampoos that kill lice have been available for many years but some lice are now resistant to those shampoos. Two possible hypotheses are: [3]

Hypothesis A	Hypothesis B
Resistant strains of lice were present in the population. Non-resistant lice died with increased use of anti-lice shampoo and resistant lice survived to reproduce.	Exposure to anti-lice shampoo caused mutations for resistance to the shampoo and this resistance is passed on to offspring.

Discuss which hypothesis is a better explanation of the theory of evolution by natural selection.

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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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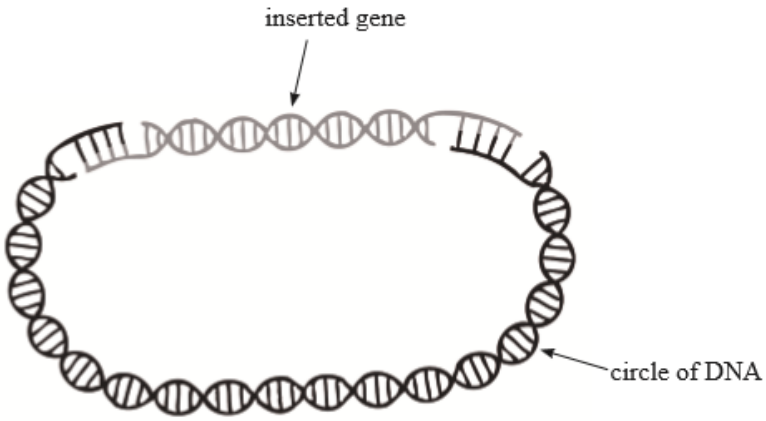
a. Gene transfer to bacteria often involves small circles of DNA into which genes can be inserted. State the name of a small circle of DNA, used for DNA transfer, in bacteria. [1]

b. The diagram below shows a cut circle of DNA into which a gene is being inserted. Before it can be transfered into a bacterium, the ring must be altered, using an enzyme. [2]

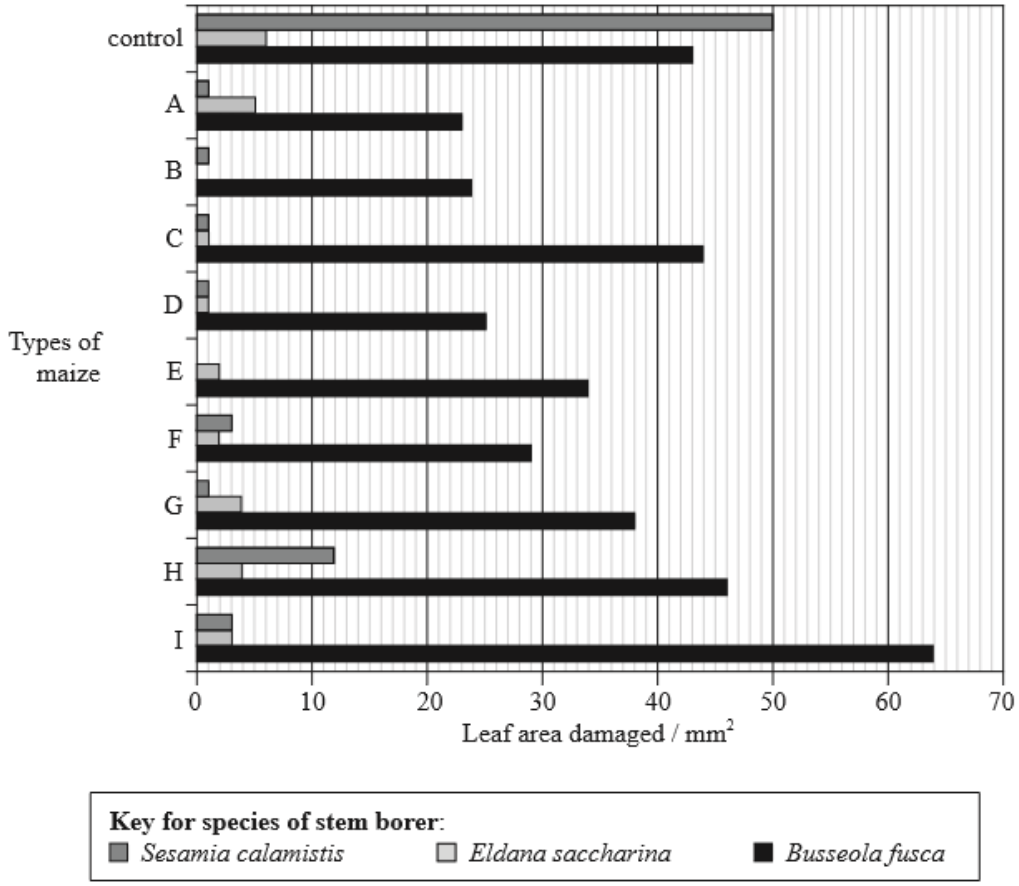


Outline what must be done next to complete the process of gene insertion into the DNA circle, including the name of the enzyme that is used.

c. Discuss the potential benefit and possible harm of **one named** example of gene transfer between species. [3]

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.

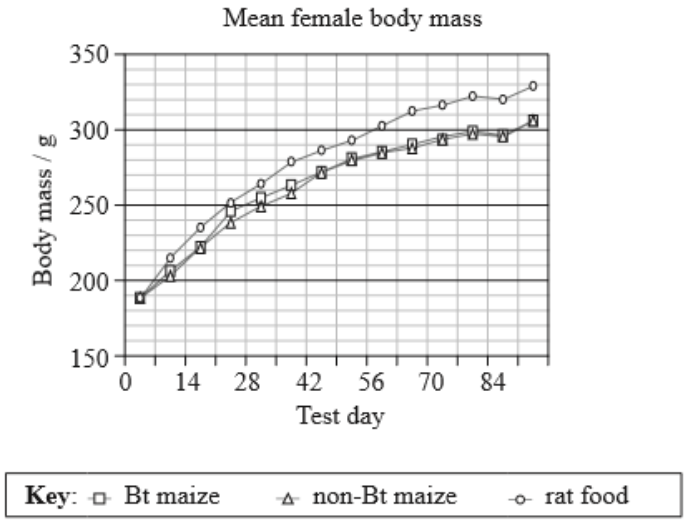


[Source: adapted from S Mugo, *et al.*, (2005), *African Journal of Biotechnology*, **4**(13), pages 1490–1504]

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 3 groups of 12 adult 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]

a (i) State what would be used as the control in this experiment. [1]

b. Outline the effects of the three species of stem borer on Bt maize type A. [2]

c. Evaluate the efficiency of the types of Bt maize studied, in controlling the three species of stem borers. [2]

e. Describe the change in mean mass for the female rats during the 90-day experiment. [2]

f. Evaluate the use of Bt maize as a food source compared to the other diets tested. [3]

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. (i) State the technique used to collect cells for pre-natal testing. [3]

(ii) State the method used to arrange the chromosomes in a karyotype.

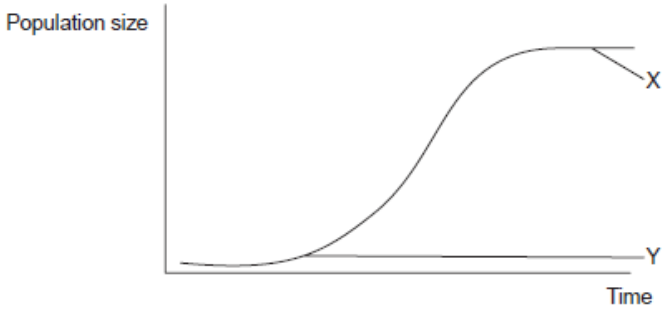
(iii) State at what stage in the cell cycle the cells would be when this photograph was taken.

c. Albinism is inherited as a recessive trait; the alleles of the gene involved are A and a. An individual with albinism produces little or no pigment in the eyes, skin and hair. In a family, one sister has albinism while the parents and other sister have normal pigmentation. [3]

(i) Determine, using a Punnett grid to show your reasoning, the possible genotypes of the sister with normal pigmentation.

(ii) Deduce the probability that the next child of this couple will have albinism.

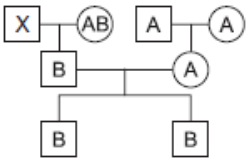
The graph shows a sigmoid population growth curve.



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 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]

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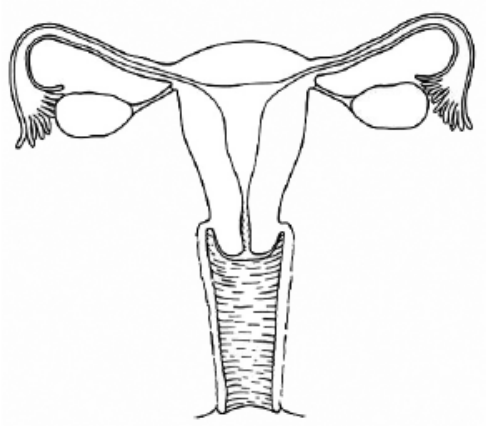
a. The diagram below shows the female reproductive system. [1]



Label the diagram above with the letter U to show the uterus.

b. Outline the role of luteinizing hormone (LH) **after** ovulation. [1]

c. Explain how sexual reproduction can lead to variation in a species. [3]

The following sequence of pictures, made using an electronic imaging technique, shows a cell undergoing division.

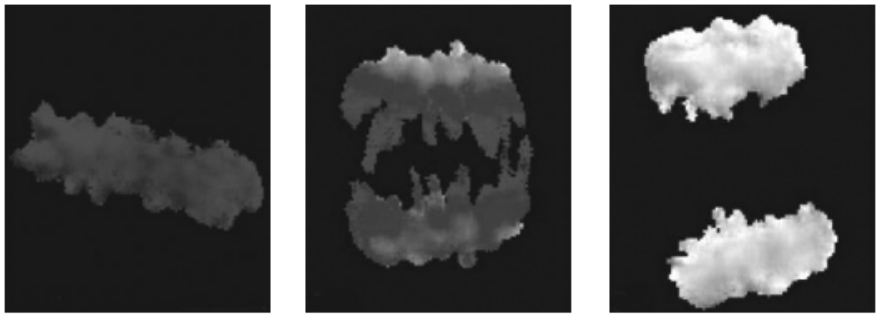


Image I Image II Image III

[Midzone activation of aurora B in anaphase produces an intracellular phosphorylation gradient, Brian G. Fuller, Michael A. Lampson, Emily A. Foley, Sara Rosasco-Nitcher, Kim V. Le et al. Nature, vol 453, issue 7198, 2008 Nature Publishing Group. Reproduced with permission.]

a. State the stage of mitosis typified by image II. [1]

b. List **two** processes that involve mitosis. [2]

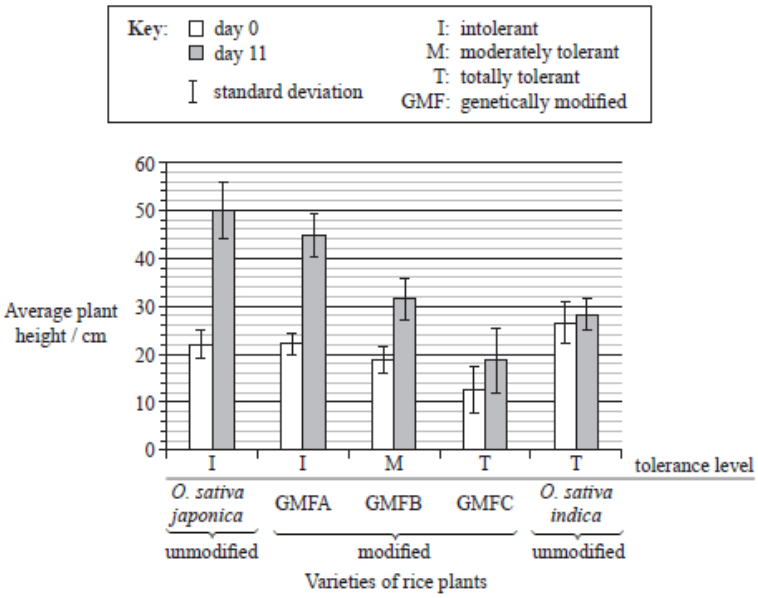
c. State the process that results in tumour (cancer) formation or development. [1]

d. Explain, using **one** example, how non-disjunction in meiosis can lead to changes in chromosome number. [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.

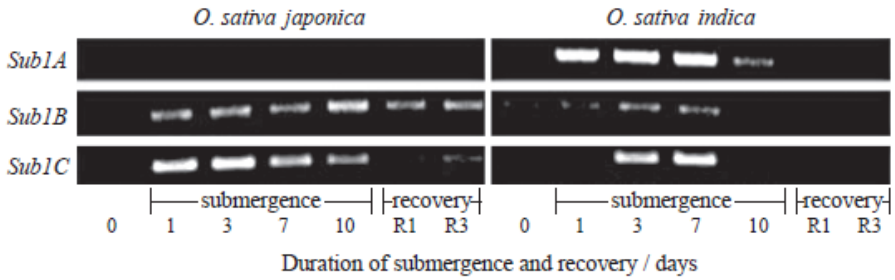
Three genetically modified forms of *O. sativa japonica*, GMFA, GMFB and GMFC, were made using different fragments of DNA taken from *O. sativa indica*.

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.



[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.]

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]

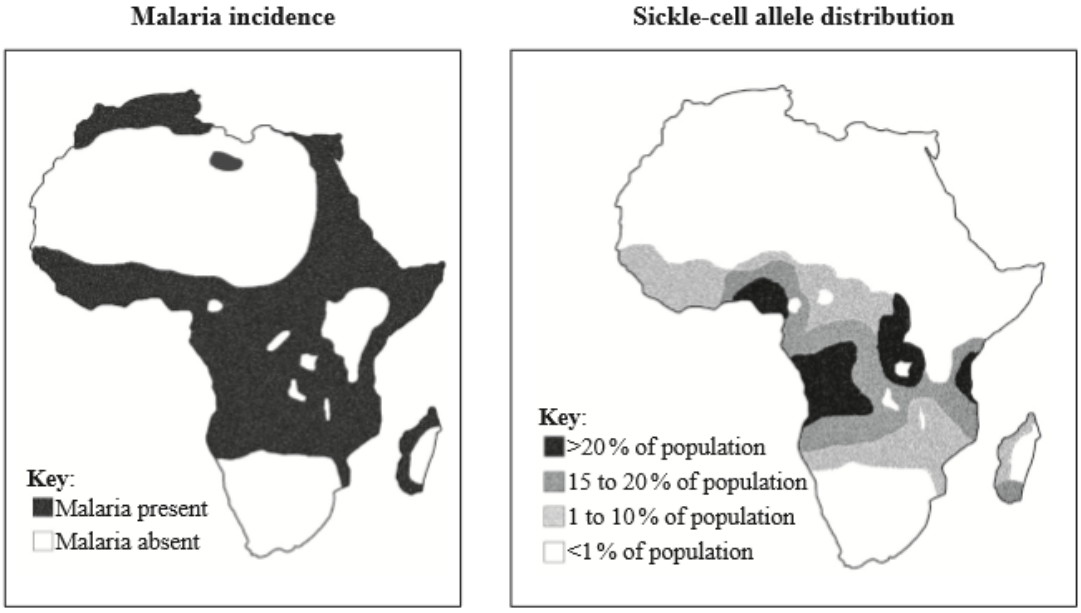
e(ii). Outline the difference in mRNA production for the three genes during the submergence period for variety *O. sativa indica*. [2]

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]

Sickle-cell anemia is a disease caused by a base substitution mutation, where GAG has changed to GTG. The distribution of the sickle-cell allele is correlated with the incidence of malaria in many places, as shown by the map of Africa.



[Source: Image courtesy of Anthony Allison; image source: Wikimedia Commons]

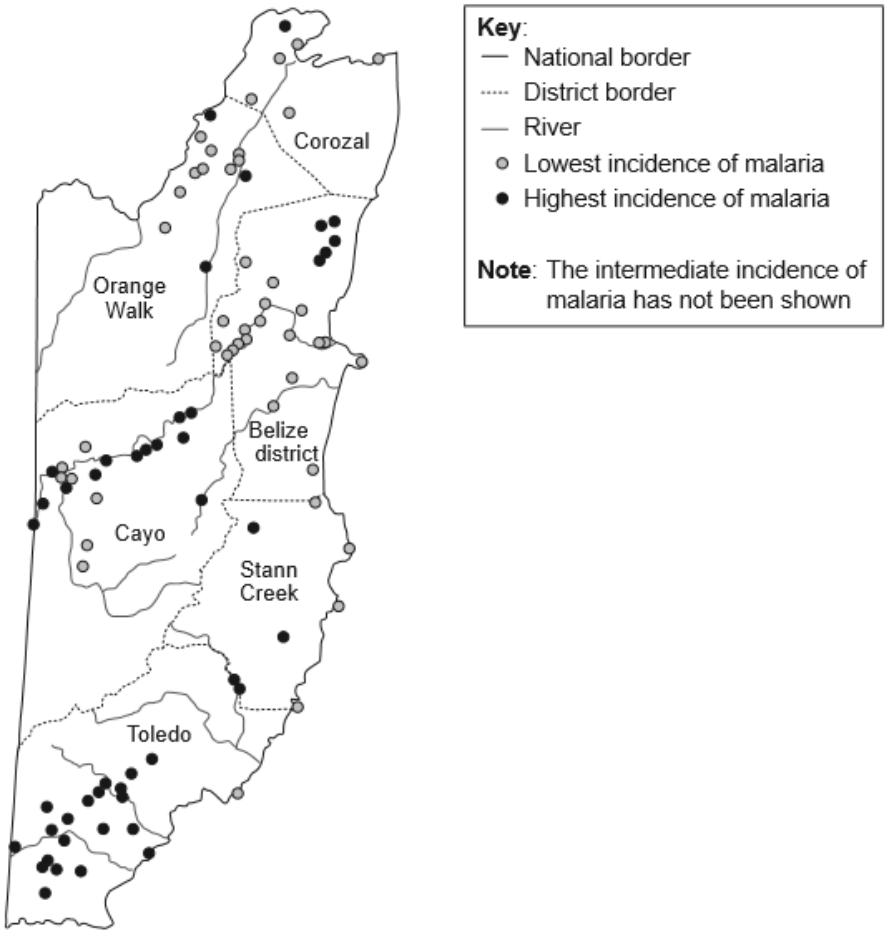
a. The correlation shown in the data above can be explained by natural selection. Outline how the process of natural selection can lead to evolution. [3]

b. Explain how a base substitution mutation, such as GAG to GTG, can lead to a disease like sickle-cell anemia. [2]

c. Using a Punnett grid, determine the possible genotypes and phenotypes of a cross between a man and a woman who are both carriers of the sickle-cell allele. Use the symbol Hb^S for the sickle-cell allele and Hb^A for the normal allele. [2]

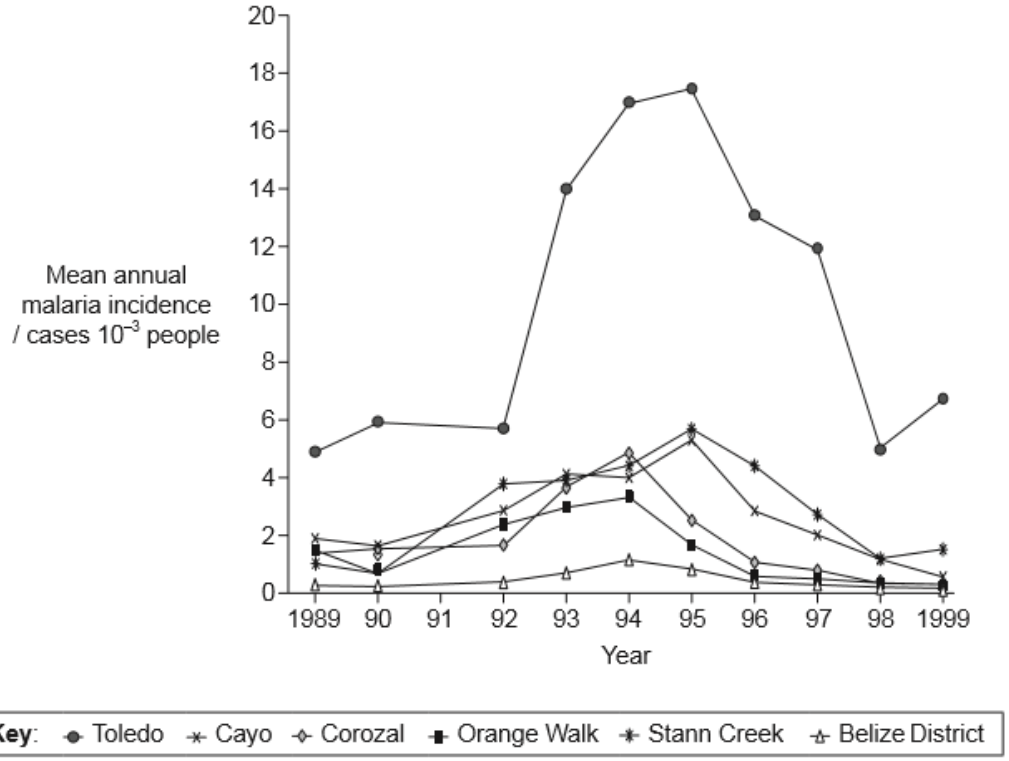
Phenotypes:

Malaria is a mosquito-borne disease caused by a unicellular organism, *Plasmodium*. *Plasmodium* is a parasite that spends part of its life in a mosquito and part in a human. The mosquito transmits the *Plasmodium* to a human when it feeds on human blood. Mosquitoes hatch in water and are flying insects as adults. In the country of Belize, where malaria is a serious problem, studies have been made to determine what environmental factors affect the incidence of the disease. 156 villages were studied over a ten-year period.



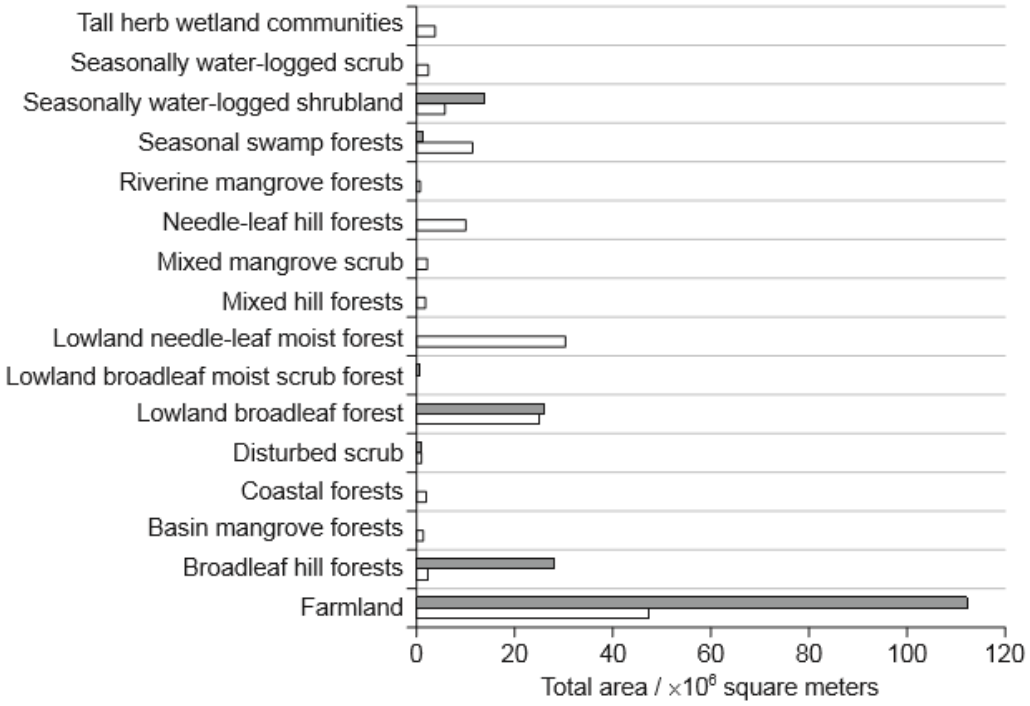
[Source: adapted from S. Hakre *et al.* (2004) *International Journal of Health Geographics*, **3** (6). Spatial correlations of mapped malaria rates with environmental factors in Belize, Central America. Shilpa Hakre, Penny Masuoka, Errol Vanzie and Donald R. Roberts © 2004 Hakre *et al*; licensee BioMed Central Ltd]

Each of the six districts of Belize was studied from 1989 to 1999. The graph shows the mean number of people in each district to be affected by malaria per year per 1000 people.



[Source: adapted from S. Hakre *et al.* (2004) *International Journal of Health Geographics*, **3** (6). Spatial correlations of mapped malaria rates with environmental factors in Belize, Central America. Shilpa Hakre, Penny Masuoka, Errol Vanzie and Donald R. Roberts © 2004 Hakre *et al*; licensee BioMed Central Ltd]

The country of Belize has many different ecosystems. These ecosystems are shown in the bar chart. The white bars indicate the total area within each ecosystem with the lowest incidence of malaria. The dark grey bars indicate the total area within each ecosystem with the highest incidence of malaria. The total area with an intermediate incidence of malaria is not shown.



[Source: adapted from S. Hakre *et al.* (2004) *International Journal of Health Geographics*, **3** (6). Spatial correlations of mapped malaria rates with environmental factors in Belize, Central America. Shilpa Hakre, Penny Masuoka, Errol Vanzie and Donald R. Roberts © 2004 Hakre *et al*; licensee BioMed Central Ltd]

a. State the district where there is the highest number of villages with the highest incidence of malaria. [1]

b. Analyse the data in the map to find whether there is an association between rivers and the incidence of malaria. [2]

c. Compare the trends in incidence of malaria for Toledo and Corozal. [3]

d (i) Suggest a reason for the decreases in the incidence of malaria from 1995 to 1999. [1]

d (ii) Suggest a reason why the incidence of malaria is so low in the Belize District. [1]

e. Besides farmland, identify which two ecosystems have the greatest total area with a high incidence of malaria. [1]

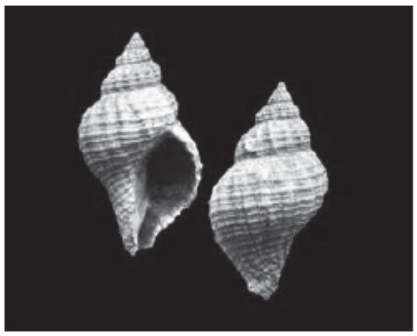
f. Predict with a reason, using the data, which district has most farmland. [1]

g. Discuss whether malaria could be reduced by replacing farmland with natural ecosystems and replacing broadleaf hill forest with mixed hill forest. [4]

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]



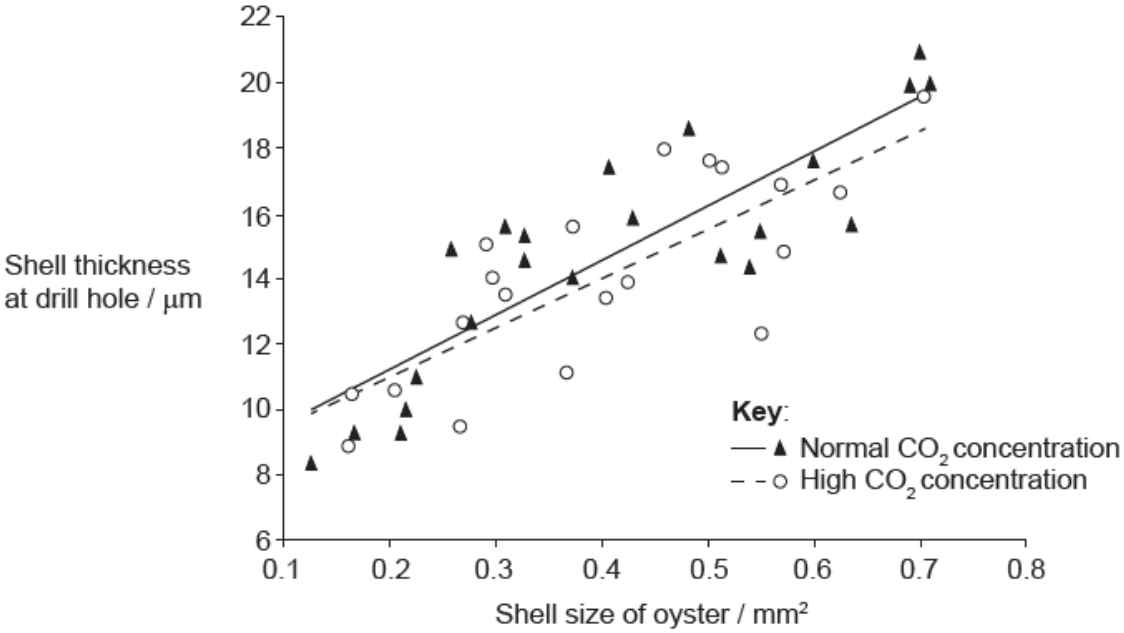
Adult gastropod shell, *Urosalpinx cinerea*

[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.

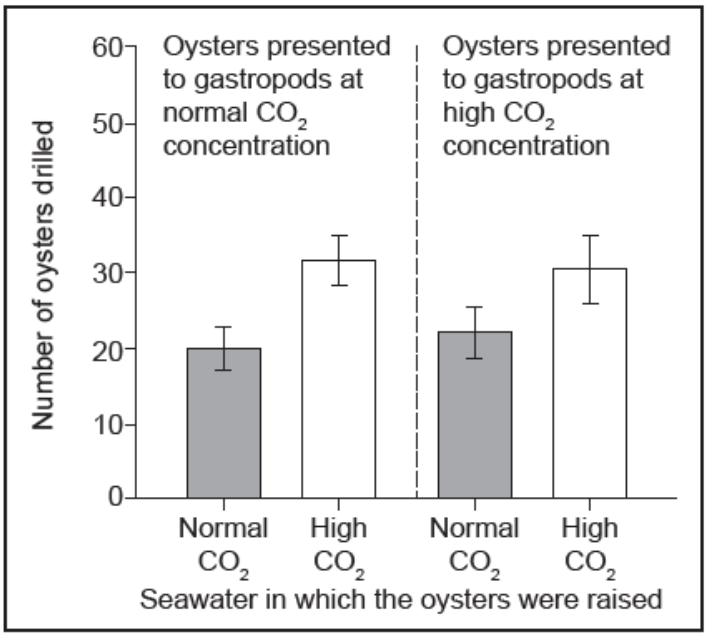
The first step was to raise oysters in two different mesocosms. One had seawater at a normal concentration of CO_2 and the other had sea water with a high concentration of CO_2. Gastropods were raised in two further mesocosms with normal and high CO_2 concentrations respectively.

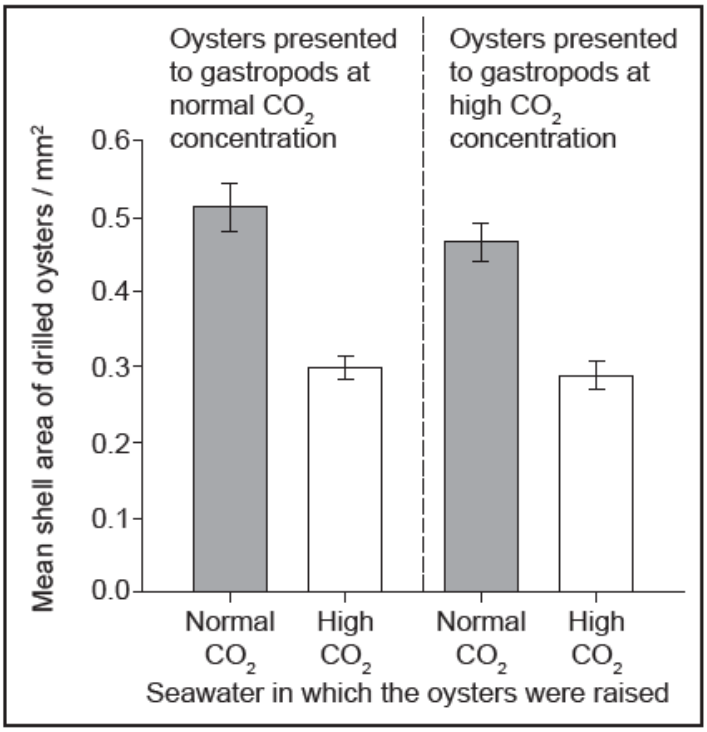
A juvenile gastropod will attack a juvenile oyster by using its tongue-like structure (radula) to drill a hole through the oyster shell. Once the hole has been drilled, the gastropod sucks out the soft flesh. Researchers investigated the shell thickness at the site of the drill hole in relation to the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

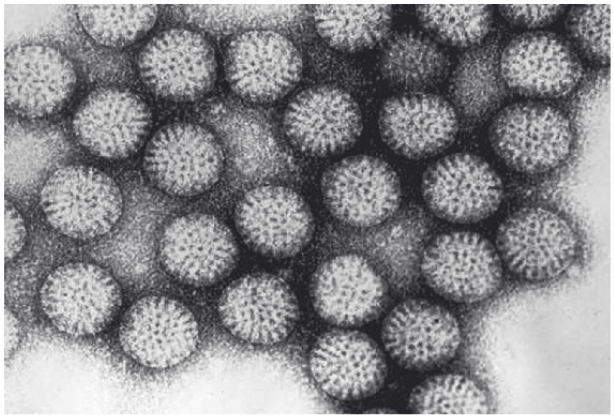
d.i. Deduce from the data in the bar charts which factors were and were not correlated significantly with the number of oysters drilled by the gastropods. [2]

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]

The figure shows a transmission electron micrograph of rotavirus particles. Each rotavirus is about 70 nanometres in diameter.



[Source: CDC / Dr. Erskine L. Palmer]

a. State a reason for using an electron microscope to view this virus rather than a light microscope. [1]

b. Rotavirus causes diarrhea and vomiting. Explain why viral diseases cannot be treated using antibiotics. [2]

c. State an application of plasmids in biotechnology. [1]