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]

Markscheme

a. a. *codominant allele*: (pair of) alleles that both affect the phenotype when present in a heterozygote / both alleles are expressed;

b. *recessive allele:* an allele that produces its characteristic phenotype only when present in homozygous state / is expressed when dominant allele not present;

c. *locus:* the (particular) position of a gene on a chromosome/homologous chromosomes;

d. *sex linkage:* a gene located on a sex chromosome/X/Y/X or Y chromosome;

b. *Example / annotated Punnett grid showing a cross between blood groups showing:*

a. parental genotype (for example I^Ai and I^Bi therefore A and B phenotypes);

b. gametes of one parent; (shown in Punnett grid)

c. gametes of other parent; (shown in Punnett grid)

d. genotypes of offspring; (shown in Punnett grid)

e. phenotypes of offspring expressed as a ratio or possibly in the Punnett grid;

f. blood group different to parent shown and identified (ie ii is blood group O);

*Award **[4 max]** if correct notation not used.*

*Award **[2 max]** if Punnett grid is not used.*

***NB** Other possible crosses could be used as long as the offspring include one or more offspring of a different phenotype from either of the parents.*

c. a. hemophilia is due to a recessive allele/is a recessive trait / X^H is normal allele and X^h is hemophilia allele;

b. hemophilia is sex linked;

c. allele/gene is on the X chromosome;

Reject disease/hemophilia carried on X chromosome.

d. (sex chromosomes in) females are XX while males are XY;

e. Y chromosomes do not have the allele/hemophiliac males are X^hY;

f. males inherit their X chromosome from their mother/do not pass the allele to sons;

g. males have only one copy so recessive trait/allele is not masked;

h. males have a 50 % chance of hemophilia/receiving the allele if mother is a carrier;

i. carrier is heterozygous for the gene/is X^HX^h;

j. dominant/normal allele masks the recessive allele (so clotting is normal);

k. females inherit one X chromosome from father and one from mother;

l. affected/hemophiliac males have carrier daughters;

m. hemophilia allele could have been inherited from either parent;

Accept the points above explained either in text or clearly using a Punnett grid or genetic diagram but not for simply reproducing an unlabelled Punnett grid or diagram without explanation.

Examiners report

a. Question 7 was by far the most popular questions and it was answered well by many.

Codominant allele, recessive allele and locus are all specifically defined in the guide so answers were only awarded credit when they closely matched the guide. For example, in locus allele was not accepted for gene. However, for sex linkage the guide offers no definition so trait and gene were equally accepted as being located on a sex chromosome.

b. Question 7 was by far the most popular questions and it was answered well by many.

ABO blood group inheritance seemed to be well understood. Through the use of Punnett grids with different examples, candidates were usually able to show how a child could have a different blood group from either parent. However answers were often penalized because of notation errors. This meant that in some cases Punnet grids seemed to show phenotypes rather than genotypes.

c. Question 7 was by far the most popular questions and it was answered well by many.

This hemophilia question presented an organizational challenge to candidates. Often candidates had the knowledge to answer the question but struggled to connect meaningful statements to produce a coherent passage. Instead of splitting their answer into two sections (how males inherit hemophilia and how females can become carriers) candidates just tended to write on and on about hemophilia. Many carelessly said that hemophilia is carried on the X chromosome rather than the allele/gene for hemophilia.

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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]

Markscheme

a. *Remember, up to TWO "quality of construction" marks per essay.*

a. meiosis reduces a diploid cell into (four) haploid cell(s);
b. (during prophase I) homologous chromosomes pair up/synapsis;
c. chromatids (break and) recombine / crossing over
d. (metaphase I) (homologous chromosomes) at the equator of the spindle / middle of cell;
e. (anaphase I) (homologous) chromosomes separate and move to opposite poles;

f. (telophase I) chromosomes reach poles and unwind *WTTE*;
g. (prophase II) chromosomes (condense and) become visible, new spindles form;
h. (metaphase II) chromosomes line up at the centre of the cells/equator;
i. (anaphase II) sister chromatids separate;
j. (telophase II) chromatids reach the poles and unwind;

b. *Remember, up to TWO "quality of construction" marks per essay.*

a. differentiated/somatic/diploid cells taken from donor animal/sheep udder;
b. (diploid) nucleus from donor cells removed;
c. ova/eggs cells removed from (donor) animal/female sheep;
d. (haploid) nucleus removed from eggs/ova;
e. (diploid/donor's) nucleus is fused with/inserted into egg/ovum (to form zygote);
f. embryo (from cell with donor nucleus and egg from surrogate) implanted in uterus of surrogate mother;
g. normal pregnancy and birth is completed;
h. offspring is a genetic copy/clone of the donor mother/diploid nucleus *WTTE*;

c. *Remember, up to TWO "quality of construction" marks per essay.*

a. therapeutic cloning involves producing embryos from which embryonic stem cells can be harvested for medical use;

argument in favour:
b. (to many people) any procedure that reduces pain and suffering is ethically/morally justified;
c. stem cells can be used to replace organs/tissues that have been lost/damaged in a patient;
d. (thus) pain and suffering can be reduced/lives can be saved/life quality improved;
e. cells can be removed from embryos that have stopped developing and would have died anyway;
f. cells are removed at a stage when no pain can be felt by the embryo;
g. use embryos from IVF that would otherwise be destroyed;

Accept up to one additional reasonable argument in favour.

argument against:
h. embryonic stem cells are no longer needed as adult stem cells can be used without causing loss of life;
i. there is danger of embryonic stem cells developing into tumour cells/harmful effects are not yet known;
j. every human embryo is a potential human with the right to development;
k. more embryos may be produced than can be used and so some would be killed;
l. (to many people) any procedure that harms a life/kills is unethical/morally wrong;
Accept up to one additional reasonable argument against.

To award [8] at least one pro and one con must be addressed.

Examiners report

a. Most had an idea that four haploid cells formed from one diploid and were able to outline the stages of meiosis.

b. The technique of cloning was not well understood, with many mixing it up with IVF. The origins of the differentiated cells and the ova were often confused.

c. Therapeutic cloning was not well understood, and again confused with IVF. Many answers conjured up ideas of human clones kept in laboratory cupboards from which organs could be harvested when needed. The answers seemed to be centre specific, with students from centres where it was discussed in detail scoring well. There were several comments about the fact that it was allocated 8 marks for ethical issues, whereas the other two parts were only awarded 5 each. It is an extremely important topic, which may have far reaching consequences for the students in the future.

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]

Markscheme

a. a. translation converts a sequence of mRNA nucleotides/codons to a sequence of amino acids/polypeptide/protein

b. «triplets of» nucleotides/bases on «activated» tRNAs pair with complementary «triplets of» nucleotides/bases on mRNA / *vice versa*

c. base pairing occurs when adenine/A pairs with uracil/U and guanine/G pairs with cytosine/C

d. specific amino acids are attached to specific of tRNA

e. mRNA has codons ***AND*** tRNA has anticodons

b. a. PCR is process by which a small sample of DNA can be amplified/copied many times

b. PCR involves repeated cycling through high and lower temperatures «to promote melting and annealing of DNA strands»

c. «mixture» is heated to high temperatures to break «hydrogen» bonds between strands of DNA/to separate the double-stranded DNA

d. Taq DNA polymerase can withstand high temperatures without denaturing

e. primers bind to «targeted» DNA sequences at lower temp

f. Taq DNA polymerase forms new «double-stranded» DNA by adding «complementary» bases/nucleotides

c. *Environment benefits:*

a. pest-resistant crops can be made

b. so less spraying of insecticides/pesticides

c. less fuel burned in management of crops

d. longer shelf-life for fruits and vegetables so less spoilage

e. greater quantity/shorter growing time/less land needed

f. increase variety of growing locations / can grow in threatened conditions

Environment risks:

g. non-target organisms can be affected

h. genes transferred to crop plants to make them herbicide resistant could spread to wild plants making super-weeds

i. GMOs (encourage monoculture which) reduces biodiversity

j. GM crops encourage overuse of herbicides

Health benefits:

k. nutritional value of food improved by increasing nutrient content

l. crops could be produced that lack toxins or allergens

m. crops could be produced to contain edible vaccines to provide natural disease resistance

Health risks:

n. proteins from transferred genes could be toxic or cause allergic reactions

o. antibiotic resistance genes used as markers during gene transfer could spread to «pathogenic» bacteria

p. transferred genes could cause unexpected/not anticipated problems
OR
health effects of exposure to GMO unclear

Examiners report

a. [N/A]
b. [N/A]
c. [N/A]

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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]

Markscheme

a. a. scrotum – *shown around testes*;

b. testis/testis/testicle – *shown inside scrotum*;

c. epididymis – *shown adjacent to testis and connected to sperm duct*;

d. sperm duct/vas deferens – *double line connecting testis/epididymis to urethra*;

e. seminal vesicles – *sac shown branched off sperm duct (not off the urethra);*

f. prostate gland – *shown positioned where sperm duct connects with urethra*;

g. urethra – *shown as double line linking bladder to end of penis*;

h. penis – *with urethra passing through it*;

*Award **[1]** for each structure clearly drawn and labelled that conforms to the italicized guidelines given*.

b. a. DNA from child, mother and possible father(s) used to establish paternity;

b. (DNA profiling is done) for legal reasons / divorce / inheritance;

c. (DNA profiling is done) for personal reasons / self-esteem issues for children/fathers/parents;

d. DNA copied/amplified using PCR;

e. DNA cut using restriction enzymes;

f. (gel) electrophoresis used to separate DNA fragments;

g. pattern of bands is produced (in gel);

h. analysed for matches between child with mother and possible father;

i. (about) half the child's bands will match the father (while the other half will match the mother);

c. a. colour blindness caused by recessive allele / colour blindness is recessive;

b. gene located on X chromosome/sex-linked;

c. X^b is allele for colour blindness and X^B is allele for normal colour vision/dominant allele;

d. male has one X and one Y chromosome;

e. male has only one copy of gene(s) located on X chromosome;

f. X chromosome (in males) comes from female parent;

g. any male receiving allele from mother will express the trait;

h. X^bY is genotype for colour blind male;

i. many more males have colour blindness than females;

j. female will express colour blindness only if is homozygous recessive/$X^b X^b$;

k. heterozygous/$X^B X^b$ female is a carrier;

l. colour blind female could be born to colour blind father and carrier mother;

*Marks may be earned for use of **annotated** diagram/Punnett square to show points given above.*

*Accept use of letters other than B and b as long as capital letter is used for dominant and lower case letter for recessive alleles. For using other improper notation (not showing X or Y), award **[0]** for the first misuse and then apply ECF to additional notation as long as usage is consistent.*

*(Plus up to **[2]** for quality)*

Examiners report

a. There were many good drawings. However, there were too many sloppy ones. Often the sperm duct and urethra were shown without double lines. The physical proximity and connections of sperm duct, prostate gland, and urethra were usually drawn incorrectly. In a few cases the female reproductive system was drawn.

b. DNA profiling for paternity cases was answered well by many candidates. However, many had the procedures quite poorly sequenced. Little attention was given to selectively breaking up the DNA, or use of restriction enzymes. Weaker answers would have benefitted from more precise terminology such as DNA fragments or DNA bands rather than just DNA. There was fair understanding of gel electrophoresis. Many candidates missed out as they failed to mention DNA from the mother must be used as well as DNA from father and child. Almost no responses included why one might do this process.

c. Inheritance of colour blindness seemed to be pretty well answered by many. There was better attention to correct notation than in the past. There was good use of annotated Punnett grids to clarify answers. However, the candidate needed to label or explain the Punnett grid in order to earn marks. It was surprising that many did not include the genotypes in their explanations. Marks were lost by incorrect use of the term gene when allele should have been used.

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

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

Markscheme

a. *allele*: one specific form of a gene (occupying the same gene locus as other alleles of the same gene)

b. I^BI^B and I^Bi

Examiners report

a. Most candidates could recall a definition of an allele.

b. Many candidates did not use appropriate notation and did not score a mark. The Biology subject guide is very clear that candidates must use the I^A, I^B, i notation for the relevant alleles

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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]

Markscheme

a. has the ability to differentiate (into specialized tissue)

b. only some genes are expressed in each cell type/tissue;

tissues therefore develop differently/become differentiated;

example of differentiated cell and the function of tissues;

c. knowledge of location of human genes / position of human genes on chromosomes;

knowledge of number of genes/interaction of genes / understanding the mechanism of mutations;

evolutionary relationships between humans and other animals;

discovery of proteins / understanding protein function / detection of genetic disease;

leads to the development of medical treatment/enhanced research techniques;

knowledge of the base sequence of genes/study of variation within genome;

Examiners report

a. Candidates either seemed very clear that differentiation was the process that produced specialized tissue or not aware of it at all.

b. Again, candidates found it difficult to explain how specialized tissue develops. The best answers explained how cells used genes selectively and gave specific examples of specialized tissue and their functions.

c. Many candidates confused the human genome project with karyotyping of individuals. However most candidates gained marks by mentioning that the project had been valuable in increasing our knowledge of and ability to treat diseases of genetic origin.

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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]

Markscheme

a. *habitat*:

the environment in which a species normally lives / the location of a living organism / *OWTTE*;

population:
a group of organisms of the same species who live in the same/specific area at the same time/interact; (*some reference to common place and time is required*)

community:
a group of populations/species living and interacting with each other in an area / *OWTTE*;

ecosystem:
a community and its abiotic environment / *OWTTE*;

b. producers/plants/autotrophs convert light energy into chemical energy/make food by photosynthesis;

such as sugars/organic compounds;

producers eaten by primary consumers, these by secondary consumers, (these by tertiary consumers)/energy moves up trophic levels;

only a small percentage/10–20 % of the energy is passed along food chain;

energy lost in the form of heat;

energy lost by (cell) respiration;

energy lost as not digested/lost in feces;

energy lost through death of organisms;

passed to detritivores/saprophytes/decomposers;

energy is not recycled;

c. DNA is universal (genes can be transferred among species);

gene modification is the transfer of genetic material between species;

named example; (*e.g. glyphosate resistant crops*)

source of gene; (*e.g. bacteria*)

function of gene; (*e.g. resistance to herbicides*)

modified organisms; (*e.g. soya beans*)

argument in favour/benefit of named example; (*e.g. increase in crop yield*)
argument in favour/benefit of named example; (*e.g. reduction in use of herbicides)*
argument in favour/benefit of named example; *(e.g. glyphosate breaks down into naturally occurring components so glyphosate resistant crops are justified)*

argument against/risk of named example; *(e.g. (application of) glyphosate could cause cancer in future)*
argument against/risk of named example; *(e.g. could be transferred to wild plants)*
argument against/risk of named example; *(e.g. genetically modified crops may cause allergies)*

Examiners report

a. Many candidates were correct with all of their definitions in 6(a). Since these involved pure recall, it showed that candidates had studied the topic.

Where trouble occurred, it was confusion between population and community

b. Overall, 6(b) was well answered with very few outright errors. Energy flow was well understood with accurate terminology being used. The ideas most frequently missed were: sugars/organic compounds as products of photosynthesis and the loss of energy. The latter included loss by (cell) respiration, loss as undigested material/feces and loss through death of organism. Also, not many candidates wrote that energy is not recycled.

c. Although 6(c) asked for the benefits and possible harmful effects of genetic modification using one example, it was appropriate to begin the answer by explaining that genetic modification involves the transfer of genes among different species based on the universality of DNA. This was rarely done. When naming the example, the source of the gene was usually not included, whereas its function and the modified organism were often given. Several examples of non-existent GMOs were cited. Some have ceased to be manufactured while others have not got out of the research

laboratory. Pros and cons tended to be generic instead of true applications of the arguments to the named GMO. Some candidates used different examples for different points in favour and against as opposed to discussing with one relevant named example. Finally, a few candidates confused GMOs with selective breeding or cloning.

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]

Markscheme

a. 32

b. a. because the chromosome number is not an even number/63

b. (so) cannot divide by two during meiosis/cannot perform meiosis/chromosomes cannot pair up during meiosis

c. one chromosome has no homologue/WTTE

d. because unlikely to/cannot produce viable gametes/sperm/egg cells

c. a. to be in same species two organisms must have the same genes arranged on the same chromosomes

OR

must have the same number of chromosomes

b. members of same species produce fertile offspring and a mule is not fertile

d. non-disjunction

Accept description of non-disjunction.

Examiners report

a. [N/A]
b. [N/A]
c. [N/A]
d. [N/A]

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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]

Markscheme

a. cells undergoing mitosis are used for karyotyping;

process of mitosis is stopped at (mitotic) metaphase;

chromosomes (cut from photographs) are arranged in pairs of similar structure/ homologous chromosomes;

allows abnormalities in the chromosome number/appearance to be seen;

any valid example *(e.g. in Down syndrome / gender of fetus)*;

detected by identifying unique feature (*e.g.* trisomy 21 / one extra chromosome / 47 chromosomes);

*Award **[3 max]** for an example with no description of karyotyping*.

b. restriction enzymes/endonucleases cut a small fragment of DNA from an organism;

same restriction enzymes used to cut DNA of plasmid / *e.g. E. coli*;

sticky ends are the same in both cases;

fragment of DNA is inserted into the plasmid;

spliced together by ligase;

to make recombinant DNA/plasmids;

recombinants can be inserted into host cell and cloned;

c. genetic modification is when the DNA/genotype of an organism is artificially changed;

genetic modification alters some characteristic/phenotype of the organism;

named example with modification (*e.g.* salt tolerance in tomato plants);

*benefits: **[5 max]***

allows crops to be grown where they would not grow naturally;

provides more food;

economic benefits;

expands world's productive farmland;

reduces the need to clear rainforests to grow crops;

lowers cost of production;

less pesticides/fertilizers/chemicals needed so better for environment;

*Award marks for any valid benefit consistent with a **named** example.*

*harmful effects: **[5 max]***

may be released into natural environment;

may affect food chains / unintended effects on other organisms;

may affect consumers e.g. allergies/health risks;

unfair to smaller farmers who cannot compete;

long-term effects are unknown; risk of cross-pollination;

risk of long-term contamination of soil;

*Award marks for any harmful effect consistent with the **named** example.*

Examiners report

a. Few candidates could give much accurate information about karyotyping. Especially overlooked was the importance of selecting cells undergoing mitosis and stopping mitosis at metaphase. Candidates did better in describing an application. Most often, abnormalities in chromosome number or the example of Down syndrome was given.

b. Candidates tended to do either very well or quite poorly on describing gene transfer. Those who blundered often confused gene transfer with cloning.

c. Those few who could name an example of genetic modification often struggled to identify specific benefits or harmful effects resulting in generalizations and fictitious accounts. Many answers were incomplete or vague.

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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]

Markscheme

a. *Award **[1]** for each of the following structures clearly drawn and correctly labelled.*

Adjacent structures mentioned in each marking point must be recognizable in the drawing for the mark to be awarded, but need not be correctly labelled.

testes/testis – shown inside scrotum;

scrotum – shown around testes;

sperm duct/vas deferens – shown connected to urethra;

penis/erectile tissue – penis shown with erectile tissue inside;

urethra – shown linking bladder / upper side of prostate gland to end of penis;

epididymis – shown connected to sperm duct;

seminal vesicle – shown branched off sperm duct (not off the urethra);

prostate gland – shown positioned where sperm duct connects with urethra;

bladder – showing urethra leading away;

b. two sex chromosomes are X and Y;

one sex chromosome inherited from each parent;

XX results in female;

XY results in male;

sex determined by sperm/father;

sex-linked genes are those located on the sex chromosomes / usually refers to genes on X chromosome;

recessive sex-linked traits appear more frequently in males since they only have one X chromosome;

hemophilia is an example of a gene located on the X chromosome/sex-linked;

female carriers are heterozygous / X^HX^h;

males with hemophilia are X^hY / normal males are X^HY;

sons (of carrier females) have 50 % probability of showing the trait (even if father is normal);

daughters (X^hX^h) of hemophiliac father and carrier mother can be affected / daughters who receive an affected X from each parent will have hemophilia;

The points above can be gained by annotated Punnett squares.

Candidates may introduce a lettering system for haemophilia genotypes which does not include H and h. Accept other letters for superscripts, but same alphabetical letter should be used throughout, dominant form should appear as upper case letter and recessive as lower case letter.

c. *To award full marks, discussion must contain both pro and con considerations.*

pros/positive considerations: ***[3 max]***
chance for infertile couples to have children;
decision to have children is clearly a conscious one due to difficulty of becoming pregnant;
genetic screening of embryos could decrease suffering from genetic diseases;
spare embryos can safely be stored for future pregnancies/used for stem cell research;

cons/negative considerations: ***[3 max]***
IVF is expensive and might not be equally accessible;
success rate is low therefore it is stressful for the couple;
it is not natural/cultural/religious objections;
could lead to eugenics/gender choice;
could lead to (unwanted) multiple pregnancies with associated risks;
production and storage of unused embryos / associated legal issues / extra embryos may be used for (stem cell) research;
inherited forms of infertility might be passed on to children;
Accept any other reasonable answers.

Examiners report

a. The drawings of the male reproductive system were generally poor. Organs were suspended and not connected to one another in many drawings, while in others they were improperly connected. The relative sizes of structures showed little sense of proportion.

b. Candidates usually knew the role of sex chromosomes in controlling gender but were weak explaining how sex-linkage affects the inheritance of hemophilia. Some stated that dominance changed depending on the gender of the person; others put the gene on the Y chromosome. Punnett squares were evident but had irrelevant crosses. Confusion was apparent over whether hemophilia was a recessive trait, and subsequent lettering systems for genotypes were unclear and muddled.

c. Since this question involved a discussion of ethical issues associated with IVF, both positive and negative arguments should have been included. This did not always happen. Some candidates limited their answers to only negative arguments such as why IVF was not natural or why it was against religious beliefs and did not expand this. Several candidates wrote about the process of IVF while others confused IVF with artificial insemination or even cloning. Fortunately, there were a few candidates who wrote thoughtful and balanced discussions.

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]

Markscheme

a. (stem cells) have/retain the capacity to divide;

can be used to produce cell cultures/large number of identical cells;

can be used to repair/replace damaged/lost cells/tissue;

(stem cells) are undifferentiated / have not yet differentiated/specialized;

can differentiate/specialize in different ways / are pluripotent/totipotent;

can be used to form a variety of different tissues / form organs;

used in medical research;

used in treatment of (named) disease;

b. genes that are located on just one of the sex chromosomes/X or Y are sex-linked;

(sex-linked) genes present on the X chromosome are absent from the Y chromosome / *vice versa*;

named recessive X-linked condition (e.g. colour blindness / haemophilia / other valid example);

sex-linked conditions tend to be more commonly expressed in males;

female can be homozygous or heterozygous/carrier for a sex-linked/X-linked condition;

affected males have only one copy of the gene / have carrier daughters but cannot pass the condition on to sons;

carrier/heterozygous females can have affected sons/carrier daughters;

for a female to be affected (homozygous recessive) the father must be affected;

If the example used is of a recessive X-linked condition, use marking points c–h.
Make appropriate adjustments if the example is of a dominant X-linked trait or a Y-linked trait.
Accept any of the above points shown in a suitable diagram/chart/Punnett square/pedigree.

c. *Definition and construction of karyotypes:*

karyotype is the number and type / image of chromosomes in a cell;

cells collected from chorionic villus / by amniocentesis;

requires cells in metaphase / stimulate cells to divide and reach metaphase;

burst cells and spread chromosomes / photo taken of chromosomes;

chromosomes are arranged in pairs;

according to size/structure/position of centromere/banding pattern;

Uses for karyotypes:
karyotypes used to identify sex/gender;
male is XY and female XX;

used to identify chromosome mutations/abnormal numbers/non-disjunction;
Down syndrome due to extra chromosome 21 / other trisomy/aneuploidy example;
used for pre-natal diagnosis of chromosome abnormalities;
may lead to a decision to abort the fetus;
prepare for consequences of abnormality in offspring;

Examiners report

a. Many candidates knew that stem cells retain the capacity to divide and can differentiate into different tissues. It was frequently mentioned that stem cells can replace damaged cells and form a variety of tissues. Candidates knew about medical applications for stem cells such as in treatment for leukemia and for growing skin to help burn victims.

b. Many candidates showed excellent knowledge about sex linked inheritance, using hemophilia as their example. Although many candidates gained the max of 5 marks, the importance of the X chromosome in sex-linked conditions was not always understood. There was a lack of understanding of “carrier” vs “affected.” A few candidates gained marks with annotated Punnet Squares. For those who failed this question, there was an inability to explain the genetics of inheritance and the inaccurate choice of sickle cell anemia as the example. Some regarded alleles as chromosomes. There appears to be weakness in the learning of Topic 4 among more than a few candidates.

c. There were many strong answers to this question. The technique and the uses of karyotypes were well stated. Collectively, candidates answered all the marking points. Some candidates failed to point out the obvious e.g. XY is male and XX is female. Some candidates referred to Down syndrome as inherited on chromosome 23. Others did not use the term chromosome for the abnormality and referred to genes instead. As mentioned earlier in this report, karyotyping was confused with a variety of other laboratory procedures from DNA fingerprinting to gel electrophoresis.

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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]

Markscheme

a. *eg source:* pancreas;

substrate: triglycerides / lipids / fats / oils;

product: glycerol and (three) fatty acids; (*both needed*)

optimal pH: 8; (accept answers in the range of 7 to 8)

Accept other correct examples.

b. a. plasmids are removed/obtained from bacteria;

b. endonuclease/restriction enzymes cut the plasmids at target sequences;

c. DNA fragments of other organism are cut with the same restriction enzymes;

d. in both DNA and plasmid, complementary sticky ends/staggered cut are produced;

e. DNA segment added to the opened plasmid;

f. spliced together by ligase;

g. reverse transcriptase makes DNA copies of mRNA / DNA polymerase to increase the amount of DNA;

h. recombinant plasmids inserted into new/host cells;

i. cultured/cloned to produce the new genes/more genetically modified cells;

Award [3 max] if no specific enzyme names are given.

Do not accept the word "enzyme" on its own.

c. *pH:*

a. enzymes have an optimal pH/work best at a given pH;

b. activity increases as pH gets closer to optimal pH;

c. extreme pH denatures enzymes;

d. by breaking bonds / changing enzyme shape/structure / active site shape/structure;

substrate:
e. as substrate concentration increases, activity increases;
f. as substrate concentration increases, the collisions between substrate and enzyme increase;
g. up to a maximal level of action / reaching a plateau;
h. all active sites are saturated/occupied;

temperature:
i. enzymes have an optimal temperature (where they work most effectively);
j. activity increases as it gets closer to optimal temperature;
k. high temperatures stop enzyme activity due to irreversible changes in structure / denaturation;
l. by breaking bonds / changing enzyme shape/structure / active site shape/structure;
Award any of the above points in an annotated graph.
*Award up to **[8]** if all three addressed and **[6 max]** if only two addressed.*

Examiners report

a. Clear answers were given by most of the students that had the knowledge.

b. Some students got confused with other biological techniques, making reference to PCR for example, apart from explaining correctly some steps in gene transfer. There was often no mention of reverse transcriptase.

c. Most of the students scored marks for this answer, some of them confused the graphs of temperature and pH with the one of substrate concentration, consequently their explanations were incorrect. A number of students incorrectly wrote that the enzyme denatures once it reaches its optimal temperature or pH, so marks were not awarded.

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]

Markscheme

a. a. mitochondria and chloroplasts are similar to prokaryotes

b. «host» cell took in another cell by endocytosis/by engulfing «in a vesicle»

Allow "taking in" in place of "engulfing"

c. but did not digest the cell/kept the «ingested» cell alive

OR

symbiotic/mutualistic relationship «between engulfed and host cell»

d. chloroplasts and mitochondria were once independent/free-living «organisms»

e. DNA «loop» in chloroplast/mitochondrion

f. division/binary fission of chloroplast/mitochondrion

g. double membrane around chloroplast/mitochondrion

h. 70s ribosomes «in chloroplast/mitochondrion»

*Award up to **[2]** for evidence from mpe to mph*

[Max 4 Marks]

b. a. FSH stimulates the development of follicles

b. follicles produce estrogen

c. estrogen stimulates the repair of the uterus lining

d. estrogen stimulates LH secretion

e. LH causes/stimulates ovulation

f. LH causes/stimulates the development of the corpus luteum

g. corpus luteum secretes progesterone

h. progesterone causes/stimulates thickening of the uterus lining

OR

prepares uterine lining for implantation

OR

maintains the endometrium

i. progesterone/estrogen inhibits the secretion of LH/FSH

j. falling progesterone levels at the end of the cycle allow FSH production/menstruation

k. negative/positive feedback «control» described correctly

l. LH/FSH are pituitary hormones

[Max 8 Marks]

c. a. clones are genetically identical organisms

OR

group of cells derived from a single parent cell

b. asexual reproduction in plants such as tubers/runners/bulbs

Allow other verifiable examples of plants

c. common in non-vertebrates such as budding in hydra

Allow other verifiable examples of invertebrates

d. budding in yeast/fungi

Allow other verifiable examples of fungi

e. identical twins «in humans» are clones because they originate from the same cell

Examiners report

a. [N/A]
b. [N/A]
c. [N/A]

---

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]

Markscheme

a. a. growth (of cells);

b. transcription/protein synthesis/translation;

c. DNA replication / genetic material copied;

d. production of organelles/mitochondria/chloroplasts;

e. named normal activity of cell (*eg active transport, movement, secretion*);

NB *Do not accept G1, S, G2 unless linked to correct process.*

c. a. sexual reproduction promotes variation in species;

b. independent assortment of genes / random orientation of chromosomes in metaphase/meiosis;

c. crossing-over provides new combinations of alleles;

d. production of great variety of gametes (by meiosis) / different combinations of chromosomes in gametes;

e. (random) combination of gametes from both parents (in fertilization);

f. (genetic) variation allows natural selection which leads to evolution;

Examiners report

a. Various cellular processes occur during interphase. Any three of the following were accepted: growth (of cells), protein synthesis/translation, DNA replication, production of organelles or named normal activity (e.g. active transport, movement, secretion etc.). It was not necessary to name the sub phases such as G1, S or G2. If that was done the sub phase had to be linked to a correct process to achieve a mark. It should be noted that cells grow in all three phases by producing proteins and organelles. DNA replication, however, only occurs in the S phase.

c. Explaining how sexual reproduction can lead to variation and then evolution challenged many candidates. Some candidates began with the premise that sexual reproduction produces variation, but did not explain how the variation occurs.This was the heart of the question. Others tried to answer what evolution is, instead of explaining how sexual reproduction allows it to occur. Too many answers just stated the terms independent assortment, crossing over, random fertilization and natural selection without further developing them, i.e. their effect on genes, allele combination or gametes. Sometimes mutation was mixed into the answer gaining no credit.

---

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]

Markscheme

b. populations produce more offspring than can survive;

individuals show variation;

limited resources;

create a struggle for survival/competition;

survival of the fittest / some are better suited to the environment and survive;

variation/characteristic must be heritable;

best fitted individuals survive to reproduce;

advantageous variation/characteristic/allele passed on;

over time advantageous variation/characteristic/allele increases in the population;

c. altering a base (in DNA) is a (point) mutation;

only has an effect if base is in a gene;

when mRNA is produced by transcription one mRNA base is different;

one codon in mRNA is different;

one amino acid is different in the polypeptide;

polypeptide produced by translation of mRNA;

some base changes do not change the amino acid coded for;

structure of polypeptide /protein may be altered;

usually the polypeptide/protein does not function as well;

example given:
disease: sickle cell anemia;
mutation: GAG to GTG;
consequence in translation: glutamic acid to valine;
consequence for protein: hemoglobin altered so sickle cell formed;
consequence for individual: less oxygen can be carried;

Examiners report

b. The role of natural selection in evolution was not well answered even though it is a fundamental concept in biology. The best answered laid out a step-wise sequence of events that lead to evolution with real life examples to illustrate the explanation such as Galapagos Island Finches.

c. The consequences of altering a base in the genome of an organism should be a straightforward question to answer but many candidates rambled without giving specifics. The best answers laid out a step-wise sequence of events that explain the consequences with real life examples to illustrate the explanation such as Sickle cell anaemia.

---

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]

Markscheme

a. *The diagram must show four nucleotides shown with two on each side showing phosphate-sugar backbones and nitrogen base pairs bonded between them.*

*Award **[1]** for each of the following clearly drawn and correctly labelled.*
phosphate – shown connected to deoxyribose;
deoxyribose – shown connected to phosphate;
(nitrogenous) bases – shown bonded to deoxyribose;
base pairs – shown with labels adenine/A bonded to thymine/T and cytosine/C bonded to guanine/G;

hydrogen bonds – shown connecting bases;
covalent bonds – shown connecting deoxyribose to phosphates;
nucleotide – clearly identified by the candidate;
*Award **[4 max]** if diagram is not shown double stranded.*

b. DNA samples are taken from crime scene, suspects and victims;

polymerase chain reaction/PCR used to increase the amount of DNA;

restriction enzymes used to cut DNA;

electrophoresis involves electric field/placing sample between electrodes;

used to separate DNA fragments according to size;

creating DNA profiles/unique patterns of bands;

comparison is made between the patterns;

criminals/victims can be identified in this way;

DNA is (quite) stable / DNA can be processed long after the crime;

c. DNA codes for a specific sequence of amino acids/polypeptide;

the DNA code for one polypeptide is a gene;

DNA is transcribed into mRNA;

mRNA moves to a ribosome;

where mRNA is translated into a polypeptide;

originally it was thought that one gene always codes for one polypeptide;

some genes do not code for a polypeptide;

some genes code for transfer RNA/tRNA/ribosomal RNA/rRNA;

some sections of DNA code for regulators that are not polypeptides;

antibody production does not follow this pattern (of simple transcription-translation); (*allow other examples*)

change in the gene/mutation will affect the primary structure of the polypeptide;

Examiners report

a. Most candidates correctly answered this question with diagrams that were well done and appropriately labelled.

b. Many candidates did this question well; most candidates did not mention that DNA samples are taken from the crime scene, the victims and the suspects however; they only mentioned suspects. Many of the candidates were not fully familiar with the actual technique involved in DNA profiling; this might be due to lack of exposure of students to the laboratory working with steps involved in DNA profiling.

c. This was one of the tough questions for most of the candidate since candidates thought "one gene one polypeptide" scope was only up until explaining the DNA-Gene-codon-polypeptide, most of the students did not mention the involvement of transcription and translation and exceptions to one gene one polypeptide hypothesis. In other cases, candidates went into great detail to explain transcription and translation (which was not asked for) and completely forgot about the purpose of the question.

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.

Markscheme

a (i).

	recessive allele	*dominant allele*	*codominant allele*
heterozygous genotype	no	yes	both/yes;
homozygous genotype	yes	yes	yes;

Award [1] for each correct row.

a (ii) *(alleles for blood groups) A and B / I^A and I^B*

b. a. a correct representation of the alleles eg X^N normal, X^n dark and Y;

b. Punnett grid including four cubs' correct genotypes, showing sex linkage;

c. female genotype $X^N X^n$;

Do not allow ECF.

Accept other suitable alternatives for ^{Nn} on the X.

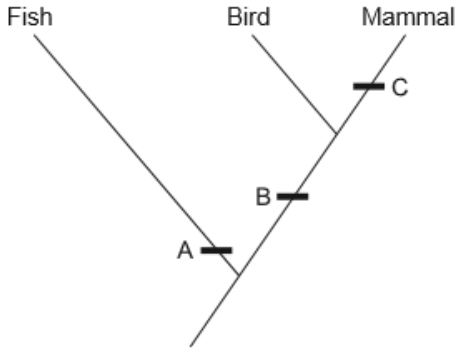
Examiners report

a (i) Some did not receive a mark for mentioning "both" for the codominant allele in the homozygous genotype.

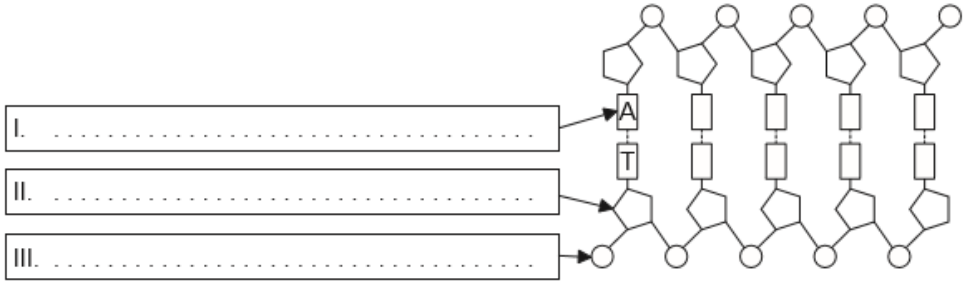
a (ii) Many of the candidates did not receive the mark for making reference to the blood groups instead of correctly identifying the alleles. Some put the correct letters and symbols but placed them next to each other so implying it was a genotype and lost the mark.

b. Many candidates drew a correct Punnett Square, for which they scored two marks but failed to show the genotype of the mother clearly. Some failed to use appropriate sex-linkage allele symbols. Many simply used uppercase and lowercase, yet did not use X and Y symbols. Y was also wrongly associated with a gene in many cases.

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]

Markscheme

a. *I*: nitrogenous base

OR

adenine

OR

purine base

II: deoxyribose

///: phosphate

b. A: gills ***or*** fins ***or*** scales ***or*** no limbs ***or*** external fertilization

B: homeothermic ***or*** endothermic ***or*** warm-blooded ***or*** lungs ***or*** tetrapod ***or*** four limbs ***or*** pentadactyl limbs ***or*** internal fertilization

C: hair ***or*** fur ***or*** mammary glands ***or*** milk

c. Eukaryotes

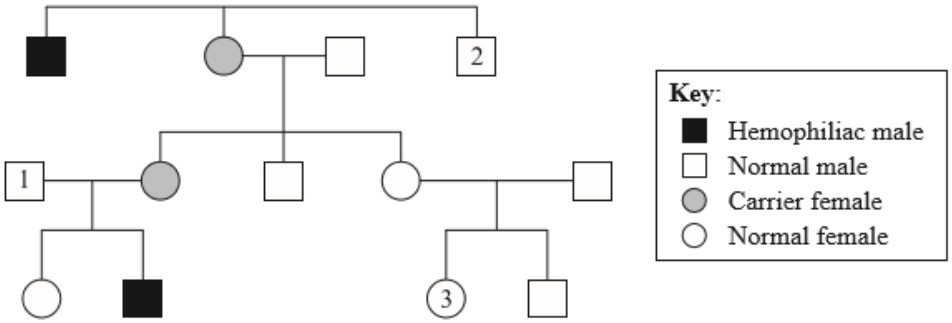
Examiners report

a. Most candidates gained two marks, the most common mistake being to label the deoxyribose as ‘sugar’ or ‘ribose’

b. Again this seems to be an area that escaped some teachers in their reading of the new specification and resulted in a large number of G2 comments, most of which seemed to think that the oversimplification of the cladogram led to confusion. In the end better prepared candidates had no problem with the question, managing to state a fish characteristic for A, something in common between birds and mammals, e.g. homeothermic for B and a general mammalian feature for C (but not forgetting the monotremes)

c. If candidates had been taught this section, they knew that the domain was eukaryotes.

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) If 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]

Markscheme

a (i) X^HY

a (ii) X^HX^h

Apply ECF if upper case and lower case forms of another letter are used to correctly denote hemophilia in female genotype.

a (iii) normal (male) / not affected / no hemophilia

Do not accept X^HY by itself, since question asks for phenotype.

b. genetically modify sheep to produce (blood) clotting factors (e.g. factor IX) in milk

Examiners report

a (i) Needed the genotype X^HY; no credit was awarded to a word description such as normal male;

a (ii) Again the genotype is needed but easier to get than in i) since in X^HX^h it's not necessary to know if h is dominant or recessive;

a (iii) Description of the boy's phenotype was needed e.g. normal or not affected or no hemophilia.

b. Almost no candidate could answer this question to the extent of gaining the mark. Though genetically modifying sheep to produce clotting factors was sometimes known, candidates failed to mention how the clotting factors became available to humans. That the clotting factors could be harvested from the sheep milk was a necessary piece of additional information. Surprisingly, some extremely weak candidates gave accurate thorough answers to this question (A.S.4.4.9).

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.

Markscheme

a.i. a. radiation

b. chemical mutagens/carcinogens/papilloma virus/cigarette smoke

a.ii. base substitution/insertion/deletion/frameshift

b. a. jointed appendages

b. «chitinous» exoskeleton

c. segmented body
OR
bilateral symmetry
OR
mouth ***AND*** anus
OR
paired appendages

b.ii a. «scientists would accept» hypothesis A as the better one as mutations are random

b. scientists would reject hypothesis B because characteristics acquired during the lifetime of the individual being inherited is Lamarckian/not part of the evolution by natural selection theory/not all mutations are heritable

c. «the resistance» mutation would be present in the population initially and not caused by the shampoo «as hypothesis B states»

d. both hypotheses include variation in the population of lice «resistant and non-resistant»

e. variation is necessary for natural selection to occur

f. frequency of the best adapted increases and these individuals reproduce/pass on resistance to their offspring, so the resistant population increases «so hypothesis A is better»

OWTTE can be used for any of the answers in this part.

Examiners report

a.i. [N/A]
a.ii. [N/A]
b. [N/A]

b.ii. [N/A]

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

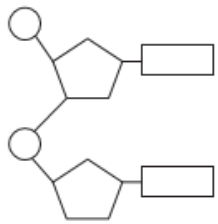
b. Outline a basic technique for gene transfer. [6]

c. Explain the process of translation. [9]

Markscheme

a.

e.g.



phosphate;

deoxyribose;

(nitrogenous) base / specific name *e.g.* adenine, thymine, guanine, cytosine;

covalent bond;

*Award **[1]** for each labelled item shown above.*
*Award **[2 max]** if the two nucleotides are not shown in a single strand.*

b. plasmid removed from bacteria;

plasmid cleaved/cut open by restriction enzymes;

desired gene/DNA extracted from donor;

DNA from donor cleaved using same restriction enzyme;

results in sticky ends;

with complementary base sequences;

pieces of DNA from two organisms mixed;

ligase used to splice pieces (DNA);

recombinant plasmids formed;

insertion into host cells;

c. translation is the synthesis of proteins/polypeptide chain/specific sequence of amino acids;

translation occurs in cytoplasm/ribosomes;

uses information on the mRNA;

mRNA carries the genetic information of DNA;

mRNA binds to ribosome;

mRNA contains series of codons/base triplets;

tRNA binds with an amino acid and carries it to the ribosome;

tRNA has the anticodon that is complementary to the codon on the mRNA;

two tRNAs bind to a ribosome/mRNA at the same time;

(peptide) bond forms between two amino acids (carried by tRNA molecules to the ribosome);

the first tRNA detaches, ribosome moves along mRNA and another tRNA carrying an amino acid binds;

process repeats forming chain of amino acids/polypeptides;

Examiners report

a. Many candidates gained full marks for their diagrams of joined DNA nucleotides. As mentioned earlier, the problem for some candidates was their misinterpretation of “a single strand of DNA.” Though appropriate shapes were given, the bonding was improper.

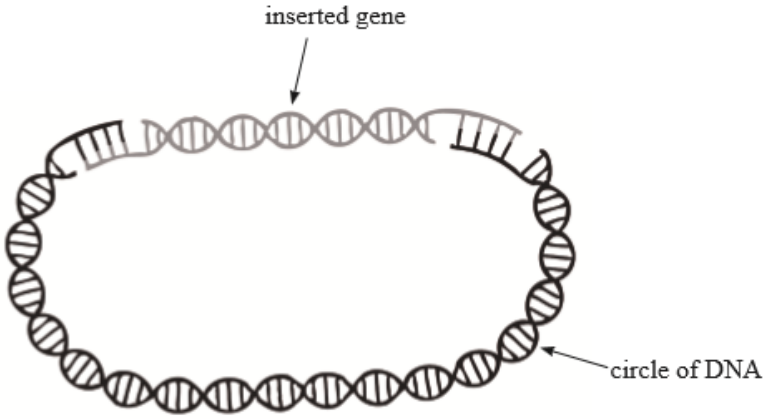
b. In their outlines of gene transfer, candidates (as a group) eventually included each of the ten marking points. A number of candidates thoroughly understood the topic, while others wrote about meiosis and crossing over! The nature of the topic allowed candidates to express their ideas in a logical sequence.

c. The process of translation has been examined frequently on past papers. Though the topic involves many different molecular structures and events, some candidates seemed to correctly grasp much of the detail and overall result. Some excellent answers appeared. However, as in previous years, there were candidates who confused translation with transcription (perhaps a reading error after glancing at the question?) and those who mixed accurate with inaccurate information.

---

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]

Markscheme

a. plasmid

b. DNA ligase involved; (DNA *required to be consistent with syllabus*)

seals gaps/nicks in DNA (strands);

makes sugar-phosphate bonds;

c. named example of DNA source and organism to which it is transferred;

benefit of the example of gene transfer;

possible harm from the example of gene transfer;

Example:
gene transfer details ***[1 max]***
e.g. Bt gene transferred from bacterium/Bacillus to maize
specific benefit ***[1 max]***
e.g. corn borer/insect pest killed by Bt toxin increasing crop production;
e.g. less pesticides/fertilizers/chemicals needed so better for environment;
specific harmful effect ***[1 max]***
e.g. non-target insects may be killed as well;
e.g. risk of cross-pollination may introduce gene to unintended species;

Examiners may have to consult resources for legitimate alternative examples.

Examiners report

a. Many candidates identified DNA circle as a plasmid, although some called it mRNA or used names of enzymes.

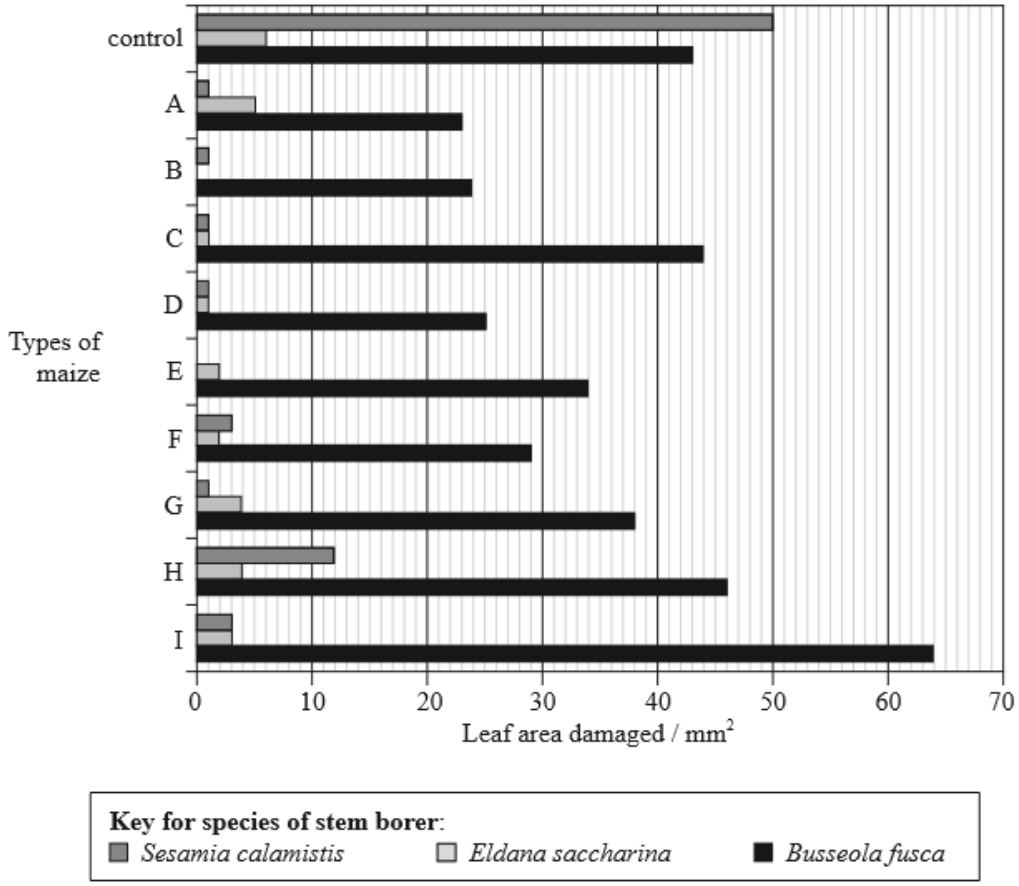
b. Ligase was frequently given but very few used the term DNA ligase, as seen in Assessment Statement 4.4.8 of the IB biology guide. Very few spoke of sealing nicks or gaps, or mentioned joining sugar phosphate bonds. It was not realized that the sticky ends were already joined i.e. complementary base pairing had already occurred.

c. This question was answered poorly. Actual examples (not hypothetical or unsuccessful) of gene transfer were required. Transfer details such as source of gene and transgenic species were rarely mentioned. Sometimes, the cited potential benefit and possible harm of the gene transfer did not relate to the example provided.

Gene transfer was also confused with cloning, cross-breeding, IVF, gene mutation or even bone marrow transplant. Some candidates gave only very general answers that gained no marks. Others left the answer space entirely blank.

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.

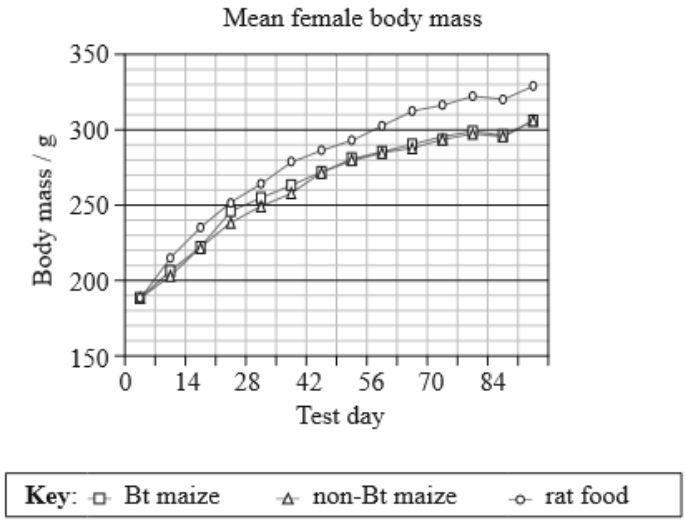


[Source: adapted from S Mugo, *et al.*, (2005), *African Journal of Biotechnology*, **4**(13), pages 1490–1504]

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]

Markscheme

a (i) maize not modified/transformed with Bt (genes) / maize that did not have Bt gene added / not genetically modified / untreated maize

b. there was a decrease in damage by all three types of stem borers compared to control;

there was almost no change in damage by *Eldana* compared to control;

there was almost no damage/little effect (to Bt maize type A) by *Sesamia* (and *Eldana*);

Busseola caused the most damage (to Bt maize type A);

c. very efficient at controlling *Sesamia*;

type B is the most effective against the three stem borers collectively;

no type of Bt maize controlled *Busseola* well / vice versa i.e. *Busseola* not well controlled by any types of Bt maize;

all types of Bt maize decreased *Sesamia* damage (significantly) / Bt maize type E not damaged by *Sesamia* / vice versa;

Bt maize types C/H/I had more damage caused by *Busseola* (than was caused in the control) / vice versa;

all types of Bt maize decreased *Eldana* damage (to some extent) / type B was not damaged by *Eldana* / vice versa;

Eldana damage low in control / less effect;

cannot determine efficiency since data is about leaf damage and stem borers may feed (preferentially) on other structures/stems/roots;

e. mass increases in all three groups;

increase is more rapid in beginning and tapers off later in the study;

mass seems to be levelling off in rats fed Bt and non-Bt maize / rate of increase in mass is slowing down;

rats fed rat food always have higher mass/greater mass increase than those fed either type of maize;

f. all three foods result in the same pattern of growth/mass gain / highest rate of growth at start of study / tapering off later in the study;

Bt maize causes same amount of growth as non-Bt maize / appears to be as good a food source as non-Bt maize / there is no significant difference between Bt and non-Bt maize (in terms of mass gain);

corn (both types) appears to cause less growth/mass gain than rat food / vice versa;

genetic modification does not affect growth/mass gain;

no evidence to support risk of Bt maize to growth/mass gain;

study does not investigate other possible risks of Bt maize to rats;

sample size is small / only 12 rats (in each group) so this may not be enough to give trends;

only female rats tested, no males;

Examiners report

a (i)The best answers identified the control as maize that did not have Bt gene added, rather than just untreated maize.

b. Weaker candidates misread the question (perhaps a language issue) and wrote how maize type A damaged the three species of stem borers instead of how the stem borers affected maize type A. This caused a variety of ambiguous answers which caused difficulty in awarding marks

c. Few candidates analyzed the data in its entirety. They didn't consider that no type of Bt maize controlled *Busseola* well or that all types of BT maize decreased *Sesamia* damage. An astute evaluation made by some candidates who recognized that type B maize was most efficient in controlling all three species if they were considered together as a group.

e. Though the question used the term “female rats,” there three lines on the graph because there were three different groups of female rats depending on which diet they were fed. Candidates needed to qualify their answers by naming the group(s) of female rats which correlated to the change they were describing.

f. Most candidates answered that Bt maize causes the same amount of growth as nonBt maize and that both types appeared to have caused less growth or mass gain than the rat food. No candidates mentioned the small sample size being too small to give trends of that only female rats were tested.

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.

Markscheme

a. (i) amniocentesis/sampling amniotic liquid/fluid (via needle)/chorionic villus sampling

(ii) chromosomes are grouped by pairs according to size and structure/band pattern/location of centromeres

(iii) metaphase/late prophase of mitosis

c. (i) Punnett grid shows the gametes (A and a) on one axis and the gametes (A and a) on the other axis and genotypes (AA, Aa, Aa, and aa) of offspring;

AA/homozygous dominant and Aa/heterozygous (show normal pigmentation); *Both needed*

Do not award marks to any answer suggesting sex linkage.

(ii) 1/4 /25 %/0.25 probability of albinism / 1 in 4 chance

Examiners report

a. (i) A broad range of inaccurate answers were given, e.g. karyotyping, polymerase chain reaction, or just no response at all.

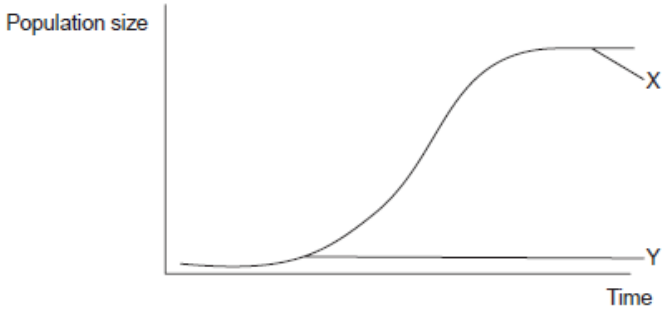
(ii) This question proved to be difficult because three components (pairs, size, structure/banding) were needed for the one mark. Many candidates forgot that chromosomes are placed in pairs in a karyotype. Some just mentioned ‘karyotyping’. In this case, candidates should realize that just repeating a term (karyotyping) from the question stem will not get them credit.

(iii) Few mentioned metaphase; interphase, which was commonly given, lost the mark. Several answers suggested meiosis.

c. i) A Punnett grid usually given with correct genotypes and correct genotypes of sister with normal pigmentation. Confused answers gave pedigree charts or introduced sex linkage.

ii) Often the correct percentage or ratio was given. In some cases, this occurred despite an incorrect Punnett grid in (i).

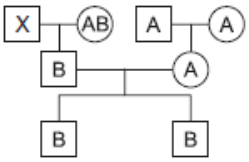
The graph shows a sigmoid population growth curve.



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]

Markscheme

a. X: plateau phase

Y: exponential growth / log phase

(both needed)

b. a. the sequence in which fossils appear matches the expected sequence of evolution;

b. comparisons with fossils and living organisms (morphology) shows change in characteristics from an ancestral form / *OWTTE*;

Vestigial organs and homologous structures are acceptable answers.

c. fossils of extinct species show that (evolutionary) change has occurred;

d. fossils can be dated with radioisotopes / geological depth/strata indicates (relative) age/date of organism;

e. can yield DNA for molecular clock analysis;

f. example of any of the above can earn one mark (*eg*: reptiles follow amphibians);

c(i). genotype is the genetic make-up/set of alleles (of an organism) while phenotype is the characteristics (expressed/shown in an organism)

c(ii). chromosome from bacteria has no protein associated/naked DNA / bacteria is circular, H. sapiens is linear / (chromosomes of) H. sapiens are much bigger/have <u>many</u> more base pairs than bacteria

N.B.: Answer must refer to "chromosomes" not genomes of the two organisms.

c(iii). 20 %

d(i). A, B, AB and O

All four phenotypes must be shown to award the mark.

d(ii). allele I^A and the allele I^B are (co)dominant as they are both expressed in the heterozygote/AB type blood / *OWTTE*

Examiners report

a. Well prepared candidates could state ‘plateau phase and exponential growth or log phase’. A surprising number reversed the answers, probably due to carelessness.

b. There were many convoluted answers without substance. Most gained the marks by stating that fossils can be compared with living organisms with an example.

c(i). Most managed to give a reasonable explanation of genotype and phenotype.

c(ii). Many missed the word 'chromosomes' in the stem. The knowledge of naked v proteins or circular v linear was expected from the core. Using the data it was expected that the candidates could state that the human chromosomes were <u>much</u> bigger (divide by 46) or that there were many more base pairs as there was about 3 X 10^3 difference.

c(iii). Considering that everyone on the IB diploma course studies maths at some level, a surprising number left (iii) blank or gave answers that did not make sense.

d(i). A pleasing number were able to state that all 4 blood groups were possible in (i), and most had a reasonable attempt at explaining codominance in part (ii).

d(ii). A pleasing number were able to state that all 4 blood groups were possible in (i), and most had a reasonable attempt at explaining codominance in part (ii).

---

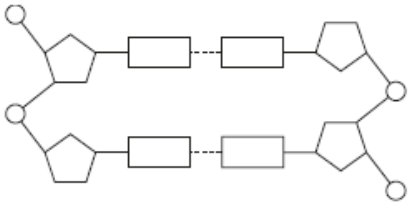
a. Draw a labelled diagram of a section of DNA showing four nucleotides. [5]

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

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

Markscheme

a. Award [1] for each labelled item shown correctly connected.



a. phosphate;

b. deoxyribose;

c. (nitrogenous) base / specific name *eg*: adenine/thymine/guanine/ cytosine shown connected to carbon-1;

d. covalent bond / phosphodiester bond;

e. hydrogen bond;

f. nucleotide shown to include phosphate, sugar and base by (shape or label);

g. diagram shows complementary base pairing or A bonded to T, C with G.

*Award **[3 max]** if the nucleotides are shown in a single strand.*
*Award **[4 max]** if antiparallel structure is not shown.*

b. a. plasmid used for gene transfer/removed from bacteria;

b. plasmid is a small/extra circle of DNA;

c. restriction enzymes/endonucleases cut/cleave DNA (of plasmid);

d. each restriction enzyme cuts at specific base sequence/creates sticky ends;

e. same (restriction) enzyme used to cut DNA with (desired) gene;

f. DNA/gene can be added to the open plasmid/sticky ends join gene and plasmid;

g. (DNA) ligase used to splice/join together/seal nicks;

h. recombinant DNA/plasmids inserted into host cell/bacterium/yeast;

c. a. (genetic) variation in population;

b. (variation is) due to mutation / sexual reproduction;

c. valid example of variation in a specific population;

d. more offspring are produced than can survive / populations over-populate;

e. competition / struggle for resources/survival;

f. example of competition/struggle for resources;

g. survival of fittest/best adapted (to the changed environment)/those with beneficial adaptations / converse;

h. example of changed environment and adaptation to it;

i. favourable genes/alleles passed on / best adapted reproduce (more) / converse;

j. example of reproduction of individuals better adapted to changed environment;

k. alleles for adaptations to the changed environment increase in the population;

l. example of genes/alleles for adaptations increasing in a population;

m. evolution by natural selection;

n. evolution is (cumulative) change in population/species over time / change in allele frequency;

Suitable examples are antibiotic resistance and the peppered moth but any genuine evidence-based example of adaptation to environmental change can be credited.

Examiners report

a. Most gained some marks for the diagram. As it was DNA the nucleotides should be in two strands joined by H bonds. Many drew only one strand.

b. Marks were lost through lack of precision. The names of the enzymes were expected. Few stated that the same restriction enzyme was required for the plasmid and gene.

c. This was answered well by the better candidates. There were also disappointing numbers of Lamarkian answers from weaker candidates trying to explain the adaptation of individuals. Many answers were very general and would have benefitted from concrete examples.

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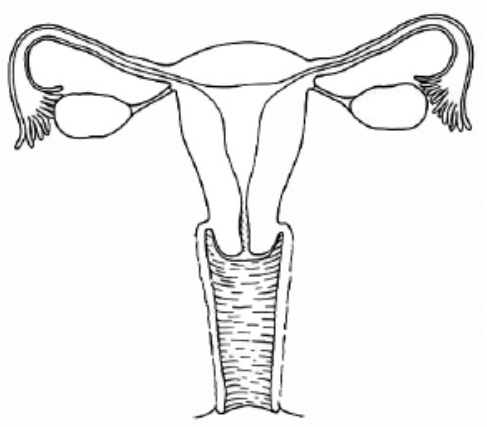
a. The diagram below shows the female reproductive system. [1]



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]

Markscheme

a. letter U marked/labelled on uterus

Accept in lumen or on wall.

b. formation of the corpus luteum

c. allows characteristics from both parents to appear in offspring;

crossing over (during prophase 1) changes chromosome composition;

produces gametes which are all different;

random chance of which sperm fertilizes ovum;

greater variation (resulting from sexual reproduction) favours survival of species through natural selection;

Accept independent assortment during meiosis from AHL.

Examiners report

a. Almost all candidates could identify the uterus.

b. An extremely difficult question for most candidates as evidenced by many blank answer spaces. The role of LH after ovulation was just not known. The corpus luteum was rarely mentioned.

c. A common knowledge among candidates was their understanding of independent assortment and crossing over. However, for the latter event, some candidates only mentioned the process without any comment on what it accomplished.

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

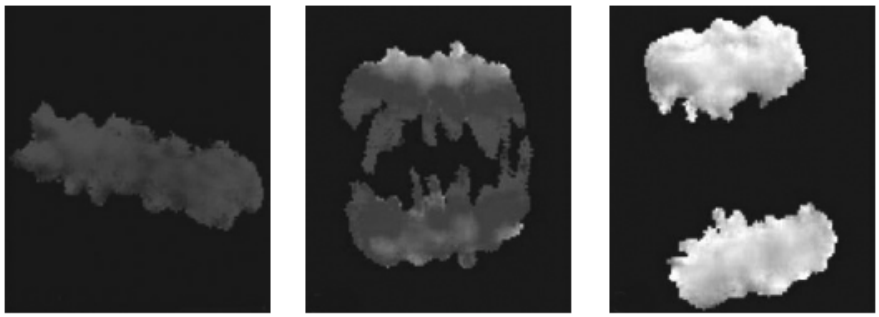


Image I Image II Image III

[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]

Markscheme

a. anaphase

b. a. growth (through increasing cell number);

b. embryonic development;

c. tissue production/repair;

d. (asexual) reproduction;

c. uncontrolled mitosis/cell division

d. a. pair of homologous chromosomes moves in same direction/does not separate during anaphase I / chromatids move in same direction/do not separate during anaphase II;

b. leaving a cell with an (some) extra chromosome(s)/missing chromosome(s);

c. an example; *(e.g. Down syndrome where there is an extra chromosome number 21);*

Examiners report

a. Anaphase was usually given, perhaps Image II had not been studied in relation to Images I and III.

b. Some candidates understood the question to mean phases of mitosis. Others wrote ambiguous answers such as “repair” instead of “tissue repair”.

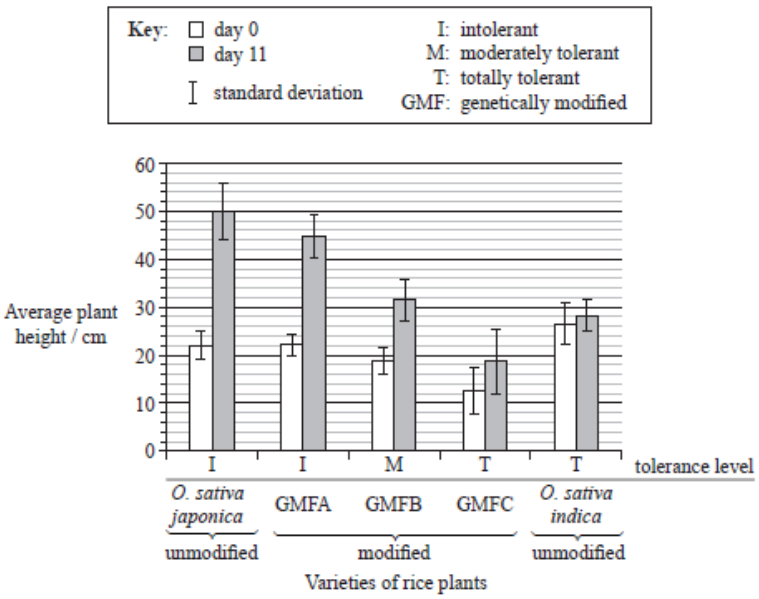
c. Mainly correct. It was essential to include the term “uncontrolled”. A few candidates were unclear about tumour formation and answered “mutation”.

d. There were very few descriptions of how non-disjunction in meiosis can produce a change in the chromosome number. However, the example of Down syndrome where there is an extra chromosome 21 was almost always given.

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.

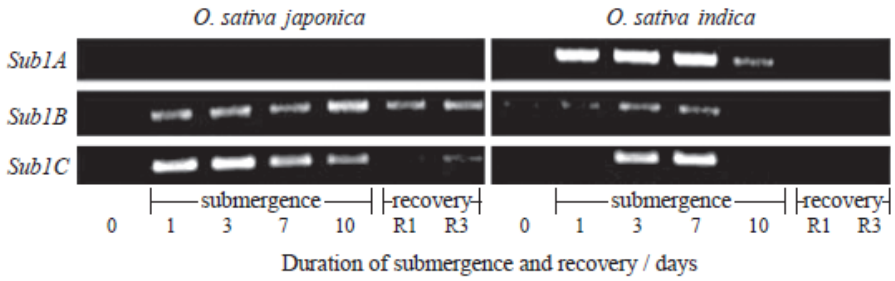
Three genetically modified forms of *O. sativa japonica*, GMFA, GMFB and GMFC, were made using different fragments of DNA taken from *O. sativa indica*.

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]

Markscheme

a(i). (GMF) C

a(ii). $\frac{(50-22)}{22} \times 100$;
$= 127\%$; *(units required) (allow answers in the range of 127 to 127.3)*

c. inversely proportional / the higher the tolerance, the less the growth / *vice-versa*

d. a. first name/*Oryza* for genus / second name/*sativa* for species;

b. (all) members of *Oryza satica* share special/unique features;

c. two names make a unique combination to designate species / worldwide recognizable nomenclature;

d. varieties (*japonica* and *indica*) have some (consistent) differences (in tolerance);

e(i). *Sub1C*

e(ii) a. *Sub1A* is expressed strongly/the most / *Sub1A* produces the most RNA;

b. *Sub1B* (always) has the lowest expression/produces least mRNA;

c. *Sub1A* expressed/produces mRNA for the longest time/days 1 to 10;

d. *Sub1C* expressed/produces mRNA for the shortest time/days 3 to 7;

e(iii) a. *Sub1A* only expressed/produces mRNA in *indica* / not/never expressed/ never produces mRNA in *japonica*;

b. *Sub1C* expressed/produces mRNA from day 1 in *japonica*, but not *indica*;

c. *Sub1B* has lower expression/production of mRNA than *Sub1C* in both varieties;

*Award **[1 max]** for other accurate comparisons between japonica and indica*.

f. a. *Sub1A*;

b. is only expressed in *indica*;

c. *indica* is the variety showing submersion tolerance;

g. a. genetically modified rice/rice with *Sub1A* is more tolerant to submersion;

b. can withstand seasonal flooding/torrential rain;

c. GMF/tolerant rice ensures greater harvest/provides more food during flooding;

Examiners report

a(i). Generally well done. A few wrote only GMF.

a(ii) Little understanding shown. Many divided the difference in height by 50 instead of 22.

c. Many candidates worded generalized relationships such as the higher the tolerance, the less the growth or growth and tolerance were inversely proportional. Sometimes “height” was given rather than “growth”.

d. The designation of *Oryza* as genus and *sativa* as species was the only marking point that many candidate got correct in this question, although some candidates mixed up the terms calling *Oryza* the species and *sativa* the genus. Very few candidates went beyond to mention that *O. sativa* shared special features. Even fewer candidates mentioned that the varieties *japonica* and *indica* had differences in tolerance. Occasionally, a candidate mentioned that binomial nomenclature helps scientists communicate about the same plant or the worldwide acceptance for the terminology.

e(i). Some candidates did not appreciate that the actual production of each gene was indicated by the intensity of the bands shown on the photograph of electrophoresis.

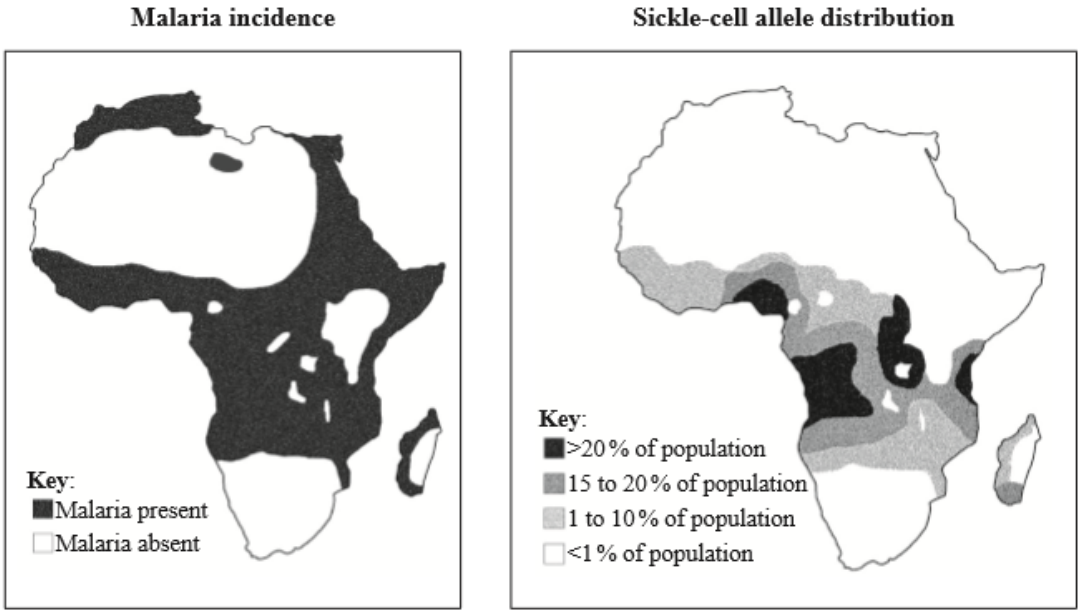
e(ii) Since the question asked for differences in mRNA production for the three genes, it was important that candidates used quantitative wording such as *Sub1A* produces the “most” mRNA or that *Sub1B* produces the “lowest” or “least” mRNA to convey a sense of comparison. A few candidates noted that *Sub1A* produced mRNA for the “longest” time/days 1 to 0 and/or that *Sub1C* produced mRNA for the “shortest” time/days 3 to 7.

e(iii) Many valid comparisons could be made comparing the mRNA production for the three genes. Most often given was that *Sub1A* only produced mRNA in *japonica* and/or never in *indica*. The two mark maximum was achieved frequently.

f. The question was poorly answered. Though *Sub1A* was sometimes correctly identified as the gene to modify GMFC, reasoning to support that answer was usually incorrect or missing.

g. Many candidates missed the question by trying to relate GMFs to drought conditions rather than flooding. GMFs offered tolerance to submersion enabling them to withstand flooding so that greater harvests/food production were ensured during flooding.

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:

Markscheme

a. offspring compete/environment cannot support all offspring;

(genetic) variation in the offspring;

natural selection /survival of better adapted/fittest organisms;

reproduction passes characteristics to other generations;

allele frequencies change;

malaria causes selection pressure (in Africa/worldwide);

different hemoglobin/sickle-cell genotypes exist / normal hemoglobin and sicklecell alleles exist;

natural selection/resistance to malaria of sickle-cell heterozygotes/allele;

survivors pass on sickle-cell allele to offspring; (*do not accept sickle-cell anemia*)

frequency of sickle-cell allele highest in areas of high malaria incidence;

b. change in the codon (of the mRNA);

tRNA with a different anticodon attaches;

(if codon changed) wrong/different amino acid is joined to peptide/glutamic acid replaced by valine;

distorted hemoglobin molecule alters red blood cell shape/reduces ability to carry oxygen;

c. (*genotypes shown in a Punnett grid eg*)

	Hb^A	Hb^S
Hb^A	$Hb^A Hb^A$	$Hb^A Hb^S$
Hb^S	$Hb^A Hb^S$	$Hb^S Hb^S$

;

(*phenotypes*)
($Hb^A Hb^A$) normal and ($Hb^A Hb^S$) normal carrier/intermediate/sickle-cell trait and ($Hb^S Hb^S$) sickle-cell anemia/diseased / ($Hb^A Hb^A$ and $Hb^A Hb^S$) normal /symptomless and ($Hb^S Hb^S$) sickle-cell anemia/diseased;
To award the mark all phenotypes must be mentioned.

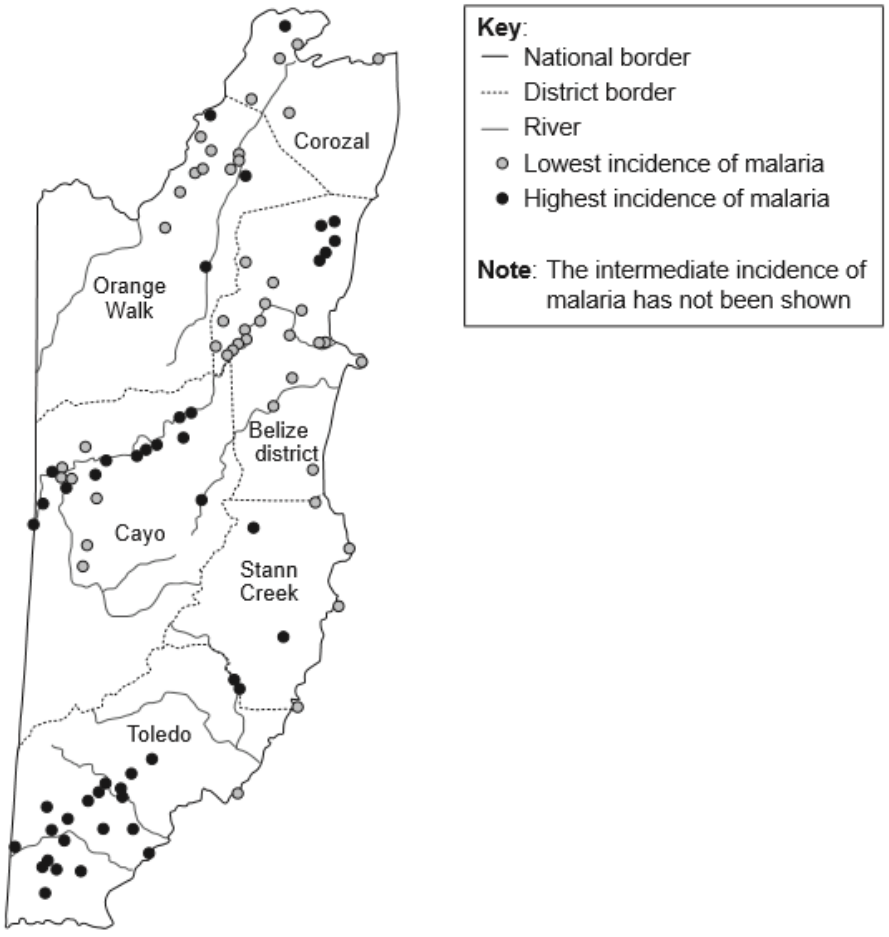
Examiners report

a. Much stimulus material is given about malaria and sickle-cell anemia in the stem for 4(a), yet the final question can be answered without any reference to the stem. This may have caused uncertainty among candidates. An effort was made to accommodate general answers about natural selection leading to evolution as well as those that included the malaria information given in the stem. Some candidates inaccurately used the term “sickle-cell anemia” when they should have written “sickle-cell allele.”

b. Few candidates recognized that a base substitution mutation causes the structural defect in hemoglobin which causes sickle-cell anemia for 4(b). Hemoglobin was rarely mentioned. A change in the codon of mRNA and the consequent attachment of a tRNA with a different anticodon and amino acid was just not given. There was almost no reference to codon or anticodon. Candidates proffered less detailed answers such as “a different amino acid is joined to the peptide” or “glutamic acid is replaced by valine”.

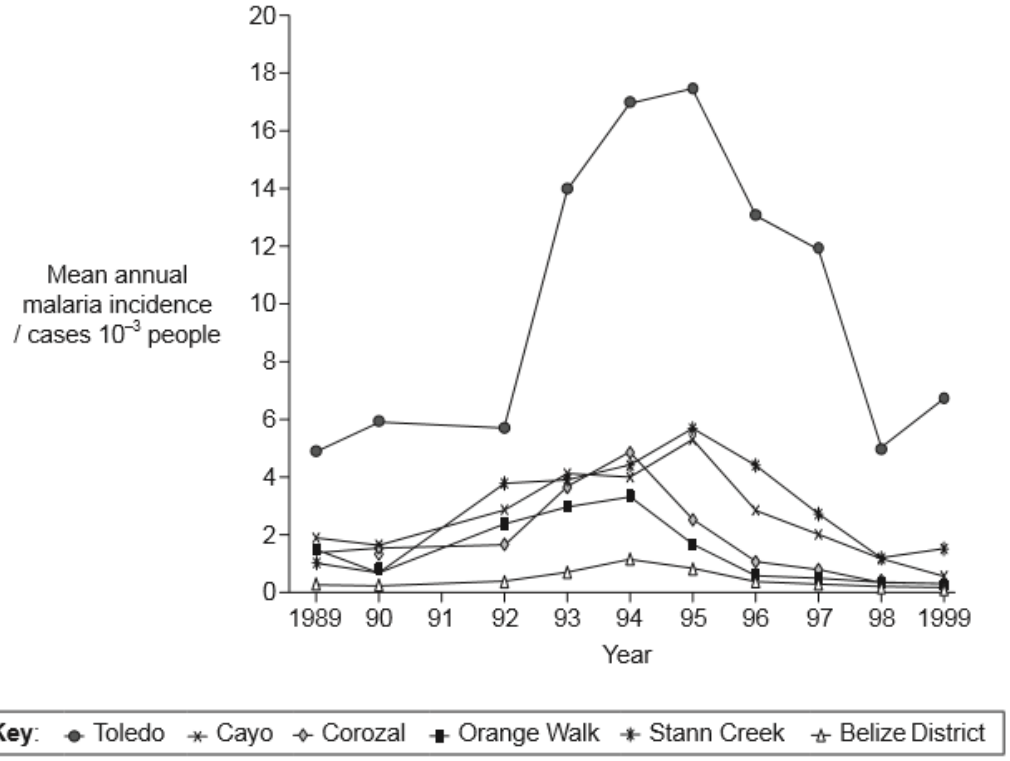
c. A few candidates confused sickle-cell anemia and Hb inheritance with sex-linkage in 4(c), perhaps because of wording in the stem. Some listed genotypes instead of describing phenotypes for the second part of the answer. All phenotypes had to be given for the mark. Since the guide (4.3.12) regards Hb^A and Hb^S as codominant alleles, describing or stating the phenotype of the carrier is problematic since carrier status "appears" the same as homozygous normal. This problem was covered by the mark scheme as each of the following was accepted to describe the carrier phenotype: normal, normal carrier, intermediate, sickle-cell trait and symptomless. Regardless of how the carrier phenotype was described the phenotype of sickle-cell anemia/diseased had to be mentioned. Those who drew a correct Punnett grid usually did well in describing the 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.



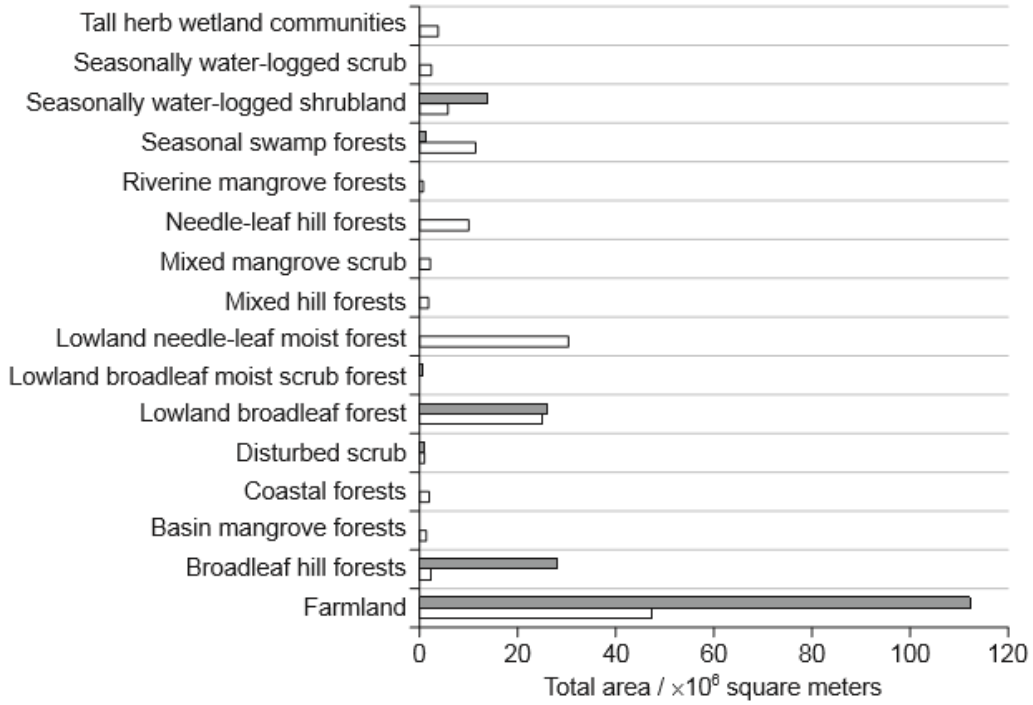
[Source: adapted from S. Hakre *et al.* (2004) *International Journal of Health Geographics*, **3** (6). Spatial correlations of mapped malaria rates with environmental factors in Belize, Central America. Shilpa Hakre, Penny Masuoka, Errol Vanzie and Donald R. Roberts © 2004 Hakre *et al*; licensee BioMed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

Markscheme

a. Toledo

b. a. in Cayo and/or Toledo the high incidence seems to be associated with rivers;

b. however, along one river in Toledo there is no high incidence;

c. in Belize District there is low incidence along the river / high incidence away from the river;

d. Orange Walk/Stan Creek there is no clear association;

e. (consequently) association of rivers with high incidence of malaria is inconclusive OWTTE;

c. a. both are stable from 1989 to 1992;

b. both see upward spike in 1992;

c. Corozal reaches its peak (one year) earlier / vice versa;

d. Toledo rises after 1998 but Corozal continues to decline / Corozal at the end decreases almost to 0, while Toledo still have incidence at the end of the decade;

e. Toledo has a higher incidence (throughout the decade) / vice versa;

f. Toledo changes more rapidly than Corozal / vice versa;

Do not award numerical comparisons.

d (i) insecticides used to kill mosquitoes / more anti malarial drugs / drought/less water for mosquito breeding / increased drainage / improved education / more mosquito nets / other reasonable change in conditions

Do not accept vaccines as they do not exist.

d (ii) drier climate/less rainfall / more predators / vegetation/ecology not favourable to mosquitoes / higher rainfall so faster flowing rivers/more educated inhabitants so more aware of dangers.

e. lowland broadleaf forest and broadleaf hill forests *(both required)*

f. Toledo because it has the highest incidence of malaria in map/graph (and farmland has highest correlation to incidence of malaria in the table).

g. a. if farming provides habitat for mosquitoes, then reducing it could reduce malaria / *OWTTE*;

b. natural habitats provide predators, but farmland does not;

c. changing native vegetation is not practical since plants are adapted to their environment/organisms have specific adaptations to their environments;

d. might work to change broadleaf forest into mixed hill forest as much of broadleaf forest has high incidence of malaria and no part of mixed hill forest has high incidence of malaria / *OWTTE*;

e. loss of habitat/loss of biodiversity results in less stable environment;

f. the value of maintaining natural habitat must be balanced with the value of reduced malaria;

g. farmland feeds the population, so cannot be replaced / *OWTTE*

Examiners report

a. Some G2 comments seemed to think that Question 1 was too long, containing too many marks for one concept. Others felt that it was too biased towards geography due to the map analysis. Really the map reading required should have been within the capabilities of all students. Perhaps a geography student may have been at some advantage, but it could be argued that sometimes a chemistry student is advantaged in other years. Nearly all students identified Toledo correctly.

b. Some G2 comments seemed to think that Question 1 was too long, containing too many marks for one concept. Others felt that it was too biased towards geography due to the map analysis. Really the map reading required should have been within the capabilities of all students. Perhaps a geography student may have been at some advantage, but it could be argued that sometimes a chemistry student is advantaged in other years.

Good candidates were able to analyse the data, quoting specific districts. Weaker ones did not mention any districts or tried to make the data fit the association.

c. Some G2 comments seemed to think that Question 1 was too long, containing too many marks for one concept.

Better students were able to compare the trends correctly and easily scored all three marks. Weaker students wrote about Toledo and then Corazol, hoping that the examiner would make the comparison for them. Very weak students just quoted numbers without considering trends. There were some G2 comments that it was difficult to make out the lines. However the students seemed to have no trouble, and some well organized students drew over it to highlight the correct line.

d (i) Some G2 comments seemed to think that Question 1 was too long, containing too many marks for one concept.

In part (i) an answer in terms of reducing the number of mosquitos or an increase in education about mosquitos was looked for. Simply "the mosquito population went down" was not deemed good enough; it needed a because… or due to…. Similarly in part (ii) "fewer mosquitoes" was too weak. Vaccines are nowadays near to becoming a reality, but certainly did not exist between 1995-1999. Similarly cures for malaria, and an increase in the number with sickle cell forest were discounted.

d (ii) Some G2 comments seemed to think that Question 1 was too long, containing too many marks for one concept.

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e. Some G2 comments seemed to think that Question 1 was too long, containing too many marks for one concept.

Nearly everyone gave broadleaf forest and broadleaf hill forest.

f. Some G2 comments seemed to think that Question 1 was too long, containing too many marks for one concept.

Most correctly stated Toledo with the correct reason.

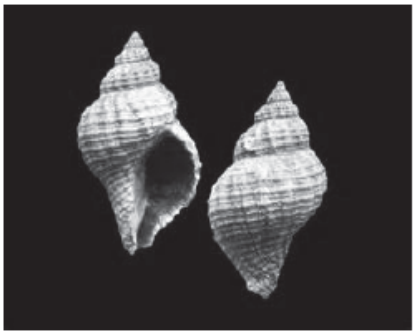
g. Some G2 comments seemed to think that Question 1 was too long, containing too many marks for one concept.

This proved to be a testing question, and as several pointed out, would have benefitted from a larger answer box as it was worth 4 marks. Many gained the mark for pointing out that if farming does provide the habitat for mosquitoes, then replacing would be beneficial, and that no part of mixed hill forest has high incidence, so that could work. Few got beyond these and discussed biodiversity and adaptation.

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]



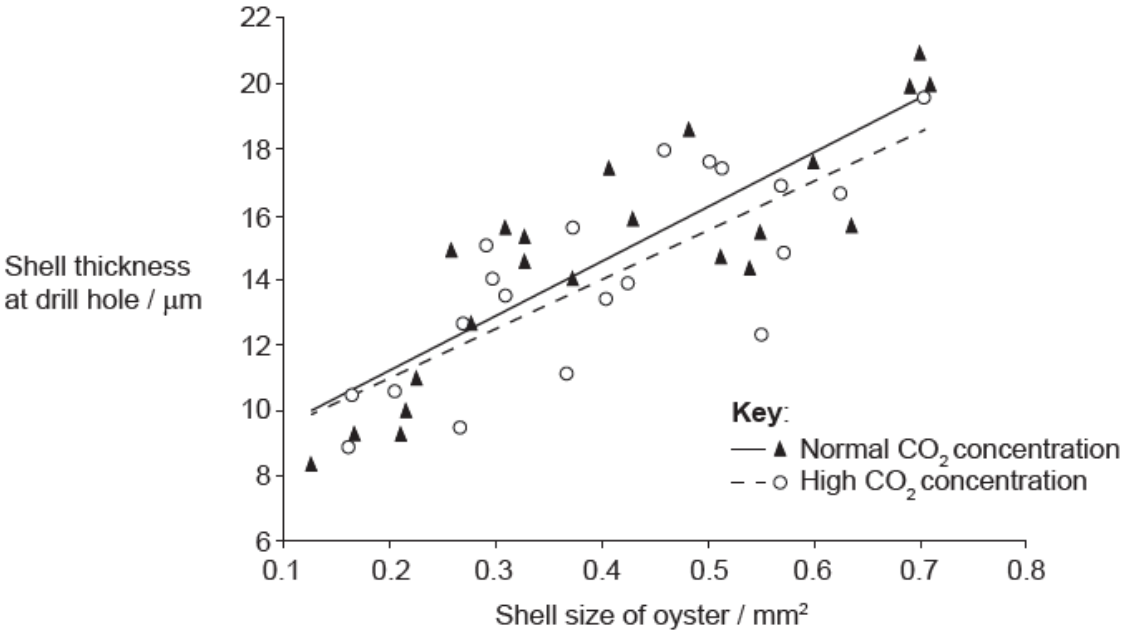
Adult gastropod shell, *Urosalpinx cinerea*

[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.

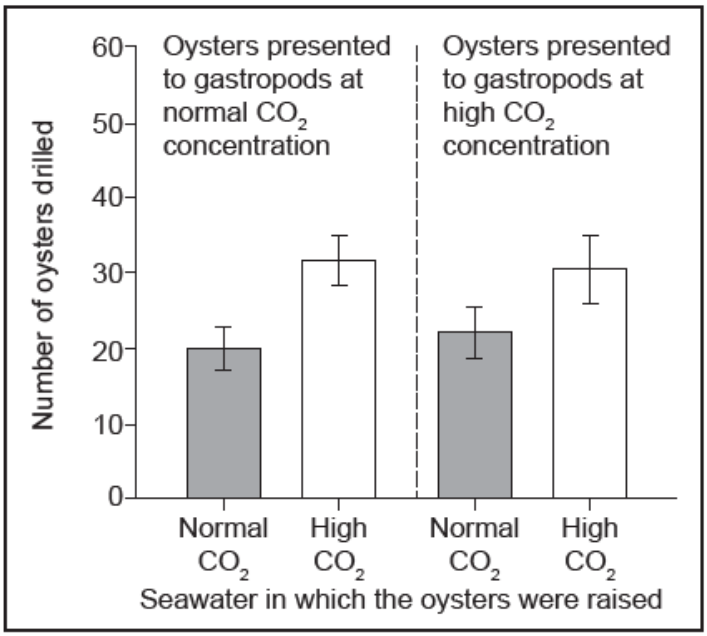
The first step was to raise oysters in two different mesocosms. One had seawater at a normal concentration of CO_2 and the other had sea water with a high concentration of CO_2. Gastropods were raised in two further mesocosms with normal and high CO_2 concentrations respectively.

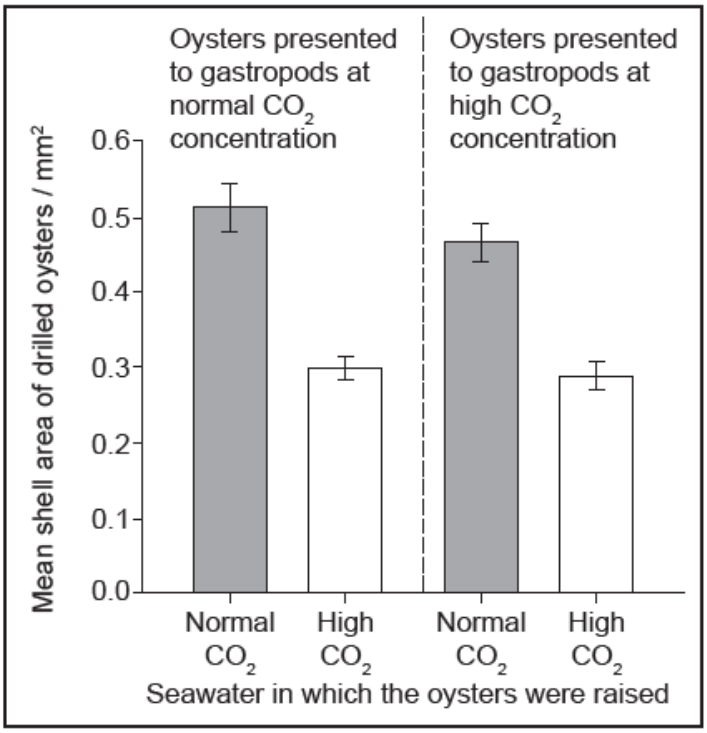
A juvenile gastropod will attack a juvenile oyster by using its tongue-like structure (radula) to drill a hole through the oyster shell. Once the hole has been drilled, the gastropod sucks out the soft flesh. Researchers investigated the shell thickness at the site of the drill hole in relation to the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

Markscheme

a. Shells might dissolve/deteriorate / become smaller/thinner/weaker / OWTTE

OR

shell formation reduced / more difficult

b. a. positive correlation between shell thickness and shell size

OR

as shell thickness increases, shell size «also» increases

b. (positive correlation) occurs at two different CO_2 concentrations / both high and normal concentrations

c. trend for thickness is «slightly» lower with high CO_2

c. «approximately» 0.2 mm^2

OR

«approximately» 40 % «smaller»

unit required

d.i. a. significant factor: concentration of CO_2 in which oysters were raised

b. insignificant factor: concentration of CO_2 at which oysters were presented to gastropods

d.ii a. (because) shells are thinner/smaller when the oyster is raised in high CO_2/lower pH

OR

«because» lower pH/higher acidity prevents/reduces deposition of calcium carbonate

b. gastropods target smaller/thinner-shelled oysters more

c. gastropods can eat/drill thin-shelled/smaller oysters at a faster rate (and move onto another)

d. eating smaller oysters «from high CO_2 environments» means given population of gastropods require more oysters for same food intake

d.iii a. data shows that similar numbers are drilled regardless of conditions

b. since radulas are not affected by acidification

OR

radulas not made of calcium carbonate so (remain) strong/successful at drilling

e. a. the data/trend lines indicate that a higher CO_2 concentration diminishes the shell thickness, making gastropod predation more successful

OR

the bar graphs suggest that oysters raised in a higher CO_2 concentration are smaller, making gastropod predation more successful

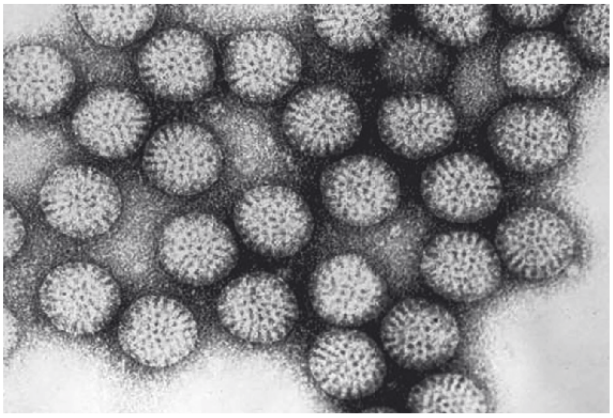
b. CO_2 concentrations «during feeding» do not change the occurrence of drilling/predation «by gastropods»

c. «limitation» no information about how exaggerated the CO_2 concentrations were
OR
«limitation» no information about numbers of gastropods used «in each setting»

Examiners report

a. [N/A]
b. [N/A]
c. [N/A]
d.i. [N/A]
d.ii. [N/A]
d.iii. [N/A]
e. [N/A]

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]

Markscheme

a. electron microscope has greater resolution/magnification

OR

70 nm is too small/viruses are too small to be viewed by a light microscope

b. a. viruses are not living

b. viruses lack metabolism/lack enzymes «for metabolism»/lack cell walls

c. antibiotics target metabolic «pathways»/cell wall production

[Max 2 Marks]

c. transfer/vector of genetic material/genes/DNA fragments

OR

to produce insulin/useful protein

Examiners report

a. [N/A]
b. [N/A]
c. [N/A]