HL Paper 2

a. The probability of extinction of a species increases if the population is small with low genetic variation. [2]

State **two** processes that cause population size to decrease.

b. Explain how meiosis promotes variation. [3]

Markscheme

a. a. mortality / fatal disease / predation / competition / other cause of death;

b. emigration;

b. a. (in prophase I) crossing over/chiasmata formation (between homologous chromosomes);

b. random alignment of homologues/bivalents in metaphase I / independent assortment of homologues / chromosomes;

c. second division of meiosis separates alleles further;

d. combinations of alleles in gametes is unlimited/2^n;

Examiners report

a. Many students were able to state examples of conditions that led to increases in mortality. Better prepared candidates identified emigration as a cause of population decrease.

b. A surprising number could not correctly link the events of meiosis to the correct phase indicating a lack of understanding of the necessary sequence of events. Many did not recognize that the second stage of meiosis also resulted in an increase of variety.

---

a. List **two** causes of variation within a gene pool. [2]

b. Describe how variation contributes to evolution by natural selection. [3]

c. Outline what is required for speciation to occur. [3]

Markscheme

a. a. sexual reproduction / random fertilization / meiosis

b. mutation

No mark for crossing over unqualified.
Reject natural selection/evolution as causes of variation.

b. a. (variation is) different phenotypes/differences between individuals in a population/species

b. struggle/competition for survival

c. some individuals have advantageous characteristics/are better adapted/have greater chance of survival/reproduction (than others)

d. favourable alleles/genetic variations passed on/inherited by offspring/next generation

Reject "pass on phenotypes".

c. a. divided species/gene pool / part of species/gene pool becomes separated / species splits into separate populations

b. reproductive isolation / lack of interbreeding

Mark point b refers to a lack of interbreeding between separated populations in a species, not the lack of interbreeding after speciation.

c. may be due temporal/behavioural/geographic isolation

d. different natural selection/different selective pressures

Examiners report

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

The biological insights of Mendel and Darwin in the 19th century remain important to this day.

a. Discuss the role of genes and chromosomes in determining individual and shared character features of the members of a species. [7]

b. Outline the process of speciation. [4]

c. Describe, using **one** example, how homologous structures provide evidence for evolution. [4]

Markscheme

a. *Genes*

a. mutation changes genes/causes genetic differences

b. genes can have more than one allele/multiple alleles
OR
alleles are different forms/versions of a gene

c. different alleles «of a gene» give different characters
OR
variation in alleles between individuals

d. eye colour/other example of «alleles of» a gene affecting a character

e. alleles may be dominant or recessive
OR
dominant alleles determine trait even if recessive allele is present

f. both alleles influence the characteristic with codominance
OR
reference to polygenic inheritance

g. all members of a species are genetically similar/have shared genes
OR
certain genes expressed in all members of a species

h. reference to epigenetics/methylation/acetylation / not all genes are expressed «in an individual»

i. genes are inherited from parents/passed on to offspring/passed from generation to generation

Chromosomes

j. same locus/same position of genes
OR
same sequence of genes/same genes on each chromosome «in a species»

k. same number of chromosomes «in a species»/all humans have 46 chromosomes/differences in chromosome number between species

l. some individuals have an extra chromosome/Down syndrome/other example of aneuploidy
OR
polyploidy divides a species/creates a new species

m. X and Y/sex chromosomes determine the sex/gender of an individual

n. meiosis/independent assortment/fertilization/sexual reproduction give new combinations «of chromosomes/genes»

b. a. speciation is the splitting of a species «into two species»

b. reproductive isolation/lack of interbreeding

c. isolation due to geography/«reproductive» behavior/«reproductive» timing

d. polyploidy can cause isolation

e. gene pools separated

f. differences in/disruptive selection cause traits/gene pools to change/diverge

g. gradualism / speciation/changes accumulating over long periods

h. punctuated equilibrium / speciation/changes over a short time period

c. a. similar structure but different function «in homologous structures»

b. pentadactyl limbs/limb with five digits/toes / other example

c. similar bone structure/example of similarity of bones «in pentadactyl limbs» but different uses/functions

d. two examples of use of pentadactyl limb by a vertebrate group

e. suggests a common ancestor «and evolutionary divergence»

f. process called adaptive radiation

Examiners report

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

---

a. Outline the processes that occur during the first division of meiosis. [6]

b. Prior to cell division, chromosomes replicate. Explain the process of DNA replication in prokaryotes. [8]

c. Outline outcomes of the human genome project. [4]

Markscheme

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

a. (consists of) prophase, metaphase, anaphase and telophase;
b. chromosome number halved/reduced/(diploid) to haploid;
c. homologous chromosomes pair up/form a bivalent/synapsis in prophase;
d. crossing over between non-sister chromatids/chromatids of different homologues;
e. nuclear envelope breaks down (at end of prophase/start of metaphase);
f. tetrads/bivalents/homologous pairs move to/align on equator/cell centre/on metaphase plate in metaphase; (accept homologous chromosomes without pairs if pairing has already been described)
g. attachment of spindle fibres/microtubules to centromeres/kinetochores;
h. (homologous) chromosomes separate/pulled to opposite poles in anaphase;
i. nuclear envelopes reform/do not reform (because of meiosis II) in telophase;
Accept the above points in a series of annotated diagrams. Reject answers with single chromatids forming pairs in metaphase or separating or moving to opposite poles in anaphase.

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

a. DNA replication is semi-conservative;
b. each (molecule formed) has one new strand and one from parent molecule;
c. helicase uncoils DNA;
d. helicase separates the two strands by breaking hydrogen bonds between bases; (reject unzips as an alternative to uncoils but accept as alternative to separates if breakage of hydrogen bonds is included)
e. RNA primase adds primer / primase adds (short) length of RNA;
f. DNA polymerase III binds to/starts at (RNA) primer;
g. DNA polymerase (III) adds nucleotides/bases in a 5' → 3' direction;
h. bases according to complementary base pairing / A–T and C–G;
i. (leading strand) built up continuously (towards the replication fork);
j. (lagging strand) built up in pieces/short lengths/Okazaki fragments;
k. DNA polymerase I removes RNA/primers and replaces them with DNA;
l. ligase seals gaps between nucleotides/fragments/makes sugar-phosphate bonds;
m. nucleoside triphosphates provide the energy to add nucleotides;
Accept the above points in annotated diagrams.

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

a. complete human DNA/chromosomes sequenced;
b. identification of all human genes / find position/map (all) human genes;
c. find/discover protein structures/functions;
d. find evidence for evolutionary relationships/human origins/ancestors;
e. find mutations/base substitutions/single nucleotide polymorphisms;
f. find genes causing/increasing chance of/develop test for/screen for diseases;
g. develop new drugs (based on base sequences) / new gene therapies;
h. tailor medication to individual genetic variation / pharmacogenomics;
i. promote international co-operation/global endeavours;

Examiners report

a. First division of meiosis

Most candidates knew the names of the four phases and many knew some of the events in them, but there were few really convincing accounts and some confusion between mitosis and meiosis. Few candidates made it clear in their answer than the two nuclei produced in the first division are haploid. The chromosome/chromatid terminology in mitosis and meiosis is rather awkward, but was expected to be used correctly in answers to this question. In past mark schemes there has often an easy mark for simply mentioning crossing over, whether in context or not. In this case candidates had to say that it occurs between non-sister chromatids.

b. DNA replication in prokaryotes

Some candidates were confused by the specification that replication should be described in prokaryotes. This is of course the only type of replication included in the IB Biology program. There were some very good answers and stronger candidates did not have difficulty in reaching full marks. Abler candidates seemed to have chosen question 5, perhaps because they knew they could cope with the complexities of DNA replication and knew that they had enough to say for 8 marks.

c. Outcomes of the human genome project

There were some good answers to this question also. Candidates often referred to the complete sequencing of the genome, evidence on human ancestry and the discovery of genes causing diseases or of genes that increase the incidence of a disease.

---

a. Draw a labelled diagram of a mature sperm. [5]

b. Outline the formation of chiasmata during crossing over. [5]

c. Explain how an error in meiosis can lead to Down syndrome. [8]

Markscheme

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

head and midpiece/mid-section/body;

tail/flagellum; (*at least four times length of the head and containing fibres*)

acrosome; (*shown as distinct structure near front of head*)

nucleus; (*occupying more than half the width or length of head*)

mitochondria; (*as repetitive structures inside membrane of mid piece*)

centriole; (*between head and midpiece*)

(plasma) membrane; (*shown as single line covering whole cell*)

microtubules; (*in 9 plus 2 array*)

b. crossing over/chiasmata formed during prophase I of meiosis;

pairing of homologous chromosomes/synapsis;

chromatids break (at same point); (*do not accept chromatids overlap*)

non-sister chromatids join up/swap/exchange alleles/parts;

X-shaped structure formed / chiasmata are X-shaped structures;

chiasma formed at position where crossing over occurred;

chiasmata become visible when homologous chromosomes unpair;

chiasma holds homologous chromosomes together (until anaphase);

Accept the above points in an appropriately annotated diagram.

c. non-disjunction;

chromosomes/chromatids do not separate / go to same pole;

non-separation of (homologous) chromosomes during anaphase I;

due to incorrect spindle attachment;

non-separation of chromatids during anaphase II;

due to centromeres not dividing;

occurs during gamete/sperm/egg formation;

less common in sperm than egg formation / function of parents' age;

Down syndrome due to extra chromosome 21;

sperm/egg/gamete receives two chromosomes of same type;

zygote/offspring with three chromosomes of same type / trisomy / total 47 chromosomes;

Accept the above points in an appropriately annotated diagram.

Examiners report

a. In part (a) the sperm drawings were mostly neat but few candidates scored full marks. Five structures shown realistically and correctly labelled were needed. The nucleus was often shown insufficiently large. Fibres and microtubules were missing from the tail. Centrioles were missing from many drawings and the plasma membrane, head and mid-piece of the sperm were often not labelled

b. Many candidates also lost marks in part (b) by giving insufficient detail or by including errors in their answers. Candidates were expected to use the terms *meiosis*, *homologous chromosomes* and *non-sister chromatids*. A frequent error was to suggest that the tight linkage between sister chromatids that exists when crossing over takes place is broken prior to crossing over, and that regions of non-sister chromatids become linked instead. This would of course not result in the chiasmata that remain clearly visible throughout metaphase I of meiosis.

Candidates should be taught that crossing over occurs by breakage of non-sister chromatids and their connection to each other, forming a knot-like chiasma. Chiasmata serve the essential function of preventing non-disjunction by holding homologous chromosomes together when the tight pairing or synapsis has ended.

c. Answers to part (c) were good in most cases. Diagrams were often included, candidates need to label them fully if they are to help answer the question. Some included more details of the normal process of meiosis than was expected and also symptoms of Down syndrome that were not really relevant.

.

In the red squirrel (*Tamiasciurus hudsonicus*), the allele for grey fur colour (G) is dominant to the allele for red fur colour (g) and the allele for a fluffy tail (F) is dominant to hairless tail (f).

a. The genes described above form a linkage group. Define *linkage group*. [1]

b. A cross is made between squirrels of the following genotypes. [2]

$$\frac{G\ F}{g\ f} \times \frac{g\ f}{g\ f}$$

Using a similar format, identify the genotypes of offspring which are recombinants.

c. Explain how the recombinants are formed during meiosis. [3]

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

Markscheme

a. genes that are located on the same chromosome (form a linkage group)

b. $\frac{G\ f}{g\ f}$;

$\frac{g\ F}{g\ f}$;

*Award **[1 max]** if the candidate does not use the same format, but gives the correct letters Ggff and ggFf.*

c. (recombination) occurs in prophase 1 of meiosis;

homologous chromosomes come together in pairs;

chiasmata form between the (non-sister) chromatids;

chromosomes exchange segments / crossing over takes place;

d. tRNA attaches to (specific) amino acid;

tRNA (with amino acid) moves to the ribosome;

anticodon of tRNA binds with codon of mRNA;

Examiners report

a. This was surprisingly poorly known, with only the better candidates being able to state that the genes are located on the same chromosome.

b. As was shown in part c, the candidates seemed to know the theory of crossing over and recombination. However part b showed that very few really understood the products. In addition, in spite of comments from last year's report, the format used in the syllabus and the instruction of “using a similar format”, most did not.

c. This was well answered, the theory was known.

d. Weaker candidates seemed to recall that tRNA had something to do with ribosomes, amino acids and protein synthesis, but were unable to explain any further and gain some marks.

---

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

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

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

Markscheme

a. a. mitosis is the division of a nucleus to produce two genetically identical daughter nuclei

b. consists of four phases: prophase, metaphase, anaphase, telophase

c. cytokinesis occurs after mitosis

d. interphase is the metabolically active phase between cell divisions *OWTTE*

e. the interphase consists of the S phase, G1 and G2

f. DNA replicates in the S phase

g. cell growth
OR
preparation for mitosis
OR
duplication of organelles in G1 and G2

b. a. «crossing over/chiasmata shown between» homologous chromosomes

b. centromere drawn and labelled

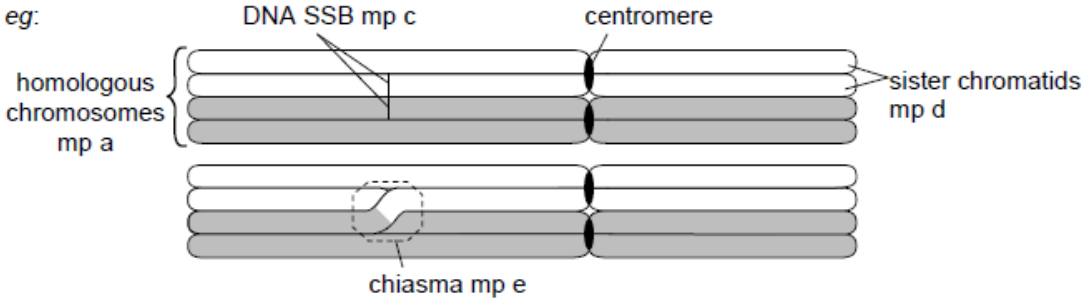
c. single strand break «SSB»/DNA cut between homologous chromosomes

d. non-sister chromatids labelled
OR
sister chromatids labelled

e. chiasma between homologous chromosomes labelled «shown forming after SSB»

Homologous chromosomes must be labelled and correctly drawn.

It is likely that more than one diagram will need to be included to demonstrate the stages.



c. a. mRNA conveys genetic information from DNA to the ribosomes «where it guides polypeptide production»

b. gene expression requires the production of specific mRNA «through transcription»

c. most genes are turned off/not being transcribed at any one time/regulated
OR
some genes are only expressed at certain times

d. some genes are only expressed in certain cells/tissues
OR
«cell» differentiation involves changes in gene expression

e. transcription factors/proteins can increase/decrease transcription

f. hormones/chemical environment of cell can affect gene expression

g. example of cell environment
eg: auxin/insulin/cytoplasmic gradient in embryo

h. transcription factors/proteins may prevent or enhance the binding of RNA polymerase

i. nucleosomes limit access of transcription factors to DNA/regulate gene expression/transcription
OR
activate or silence genes

j. DNA methylation/acetylation appears to control gene expression «as epigenetic factor»
OR
methylated genes are silenced

k. «some» DNA methylation patterns are inherited

l. introns may contain positive or negative gene regulators
OR
gene expression can be regulated by post-transcriptional modification/splicing/mRNA processing

Examiners report

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

---

a. Describe the causes of Down syndrome. [5]

b. Describe how human skin colour is determined genetically. [5]

c. Explain the causes of sickle-cell anemia. [8]

Markscheme

a. Down syndrome is caused by non-disjunction;

occurs during meiosis;

chromosome pairs fail to separate in meiosis I / chromatids in meiosis II / anaphase II;

some gametes have an extra chromosome;

can lead to zygotes/individuals with an extra chromosome / individual has 47 chromosomes;

in Down syndrome this would be trisomy 21/extra chromosome 21;

increased probability with increased age of mother/ages of parents;

b. skin colour is an example of polygenic inheritance;

many/more than two genes contribute to a person's skin colour;

due to the amount of melanin in the skin;

combination of alleles determines the phenotype;

allows for range of skin colours / continuous variation of skin colour;

phenotypes do not follow simple Mendelian ratios of dominance and recessiveness;

the environment also affects gene expression of skin colour / sunlight/UV light stimulate melanin production;

the more recessive alleles there are, the lighter the skin colour; (*vice versa*)

c. caused by gene mutation;

(sickle-cell anemia) due to a base substitution (mutation);

changes the code on the DNA;

which leads to a change in transcription / change in mRNA;

DNA changes from CTC to CAC/GAG to GTG / mRNA changes from GAG to GUG; (*accept DNA changes from CTT to CAT/GAA to GTA / mRNA changes from GAA to GUA*)

which (in turn) leads to a change in translation / change in polypeptide chain/ protein;
(the tRNA) adds the wrong amino acid to the polypeptide chain;
glutamic acid replaced by valine;
produces abnormal hemoglobin;
causing abnormal red blood cell/erythrocyte shape / sickle shape;
which lowers the ability to transport oxygen;
sickle-cell allele is codominant;
homozygote/Hb^S Hb^S have sickle cell anemia/is lethal / heterozygote/Hb^S Hb^A has the sickle trait/is carrier (and is more resistant to malaria);

Examiners report

a. In part (a) most candidates got several marks but few the full five for describing the causes of Down syndrome. There was confusion as to when

this occurs and how,. The most common statements were mp e, f and g.

b. Many candidates lost marks in part (b) by not knowing skin colour is an example of polygenic inheritance and describing a dihybrid inheritance.

Others simply gave an incomplete account for 5 marks and many were confused as to the difference between alleles and genes.

c. Answers to part (c) were good in many cases. In these scripts, there was complete detail on the cause, the DNA and amino acid changes and the effect on haemoglobin. This is obviously a topic that is well taught in many centres although some students are confused about the effect of the mutation on haemoglobin and its subsequent effect on the shape of the red blood cell.

---

a. Describe the process of crossing over. [2]

b. Explain the reason for linked genes **not** following the pattern of inheritance discovered by Mendel. [2]

Markscheme

a. a. occurs during prophase I/during meiosis

b. homologous chromosomes form bivalents/pair up

c. breakage and rejoining of chromatids

d. exchange «of DNA/alleles» between non-sister chromatids/homologous chromosomes

[Max 2 Marks]

b. a. «linked genes are» on the same chromosome

b. Mendel's genes were on different chromosomes

c. linked genes are inherited together

OR

no independent assortment

d. «linked genes» only separated by crossing over

OR

fewer recombinants than with unlinked genes

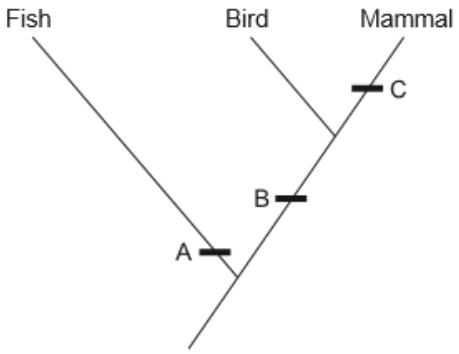
Reject sex-linkage

Examiners report

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

---

a. The image shows part of a cladogram. [3]



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

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

b. Starting from the concept of gene pool, explain briefly how populations of early vertebrates could have evolved into different groups. [3]

c. Mitochondria are thought to have evolved from prokaryotic cells. Describe **two** adaptations of the mitochondria, each related to its function. [2]

Markscheme

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

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

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

b. Gene pool is all genes/all alleles. *Reject all alleles/genes in a species.*

Geographic isolation *Reject isolation if no type of isolation given*.
OR
migration to different areas
OR
temporal isolation
OR
behavioural isolation

Speciation/gene pool split if populations are reproductively isolated/do not interbreed

In different environments there are different selection pressures/opportunities/natural selection/adaptations/niches «to exploit»

Allele frequencies change/diverge *Reject gene frequencies*.

c. Double membrane/small intermembrane space/small gap between inner and outer membrane for a gradient «of protons» to develop

Accept only the first two adaptations in the answer.

Cristae/folds in inner membrane/large surface area of inner membrane for ATP synthesis/chemiosmosis/proton pumping/electron transport chains

ATP synthase/stalked particles generates ATP from ADP + phosphate/Pi. *Reject ATPase. Allow ATP* synthetase.

Electron transport chains for generating a proton gradient/for releasing energy from reduced NAD

Matrix contains enzymes for Krebs cycle/link reaction/oxidation of fats/oxidation of substrates/aerobic respiration

Ribosomes/DNA for protein synthesis/replication

Examiners report

a. There was much criticism of the cladogram from teachers in G2 forms and predictions that candidates would not understand it. In practice, most candidates realized for point A, they were expected to give a feature of fish that is absent in birds and mammals, the reverse of this for B, and for C a characteristic of mammals that is absent in birds and fish. This was an effective test of candidates' knowledge of the characteristics of these three chordate groups.

b. In this question candidates were expected to apply their understanding of evolution and speciation to the context of the early evolution of vertebrates. All that was expected was a methods of reproductive isolation, differential natural selection and divergence until the differences between populations and their gene pools were great enough to prevent interbreeding. Candidates mostly got at least part of this.

c. Question setters try to include some stimulus material to make questions more interesting but the first sentence of this question proved to be a distraction rather than a help. Candidates only really needed to think about the second sentences and so describe two structures and explain how they help the mitochondrion to carry out its function of producing ATP.

---

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

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

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

Markscheme

a. a. can be sympatric or allopatric

b. temporal isolation by members of difference populations reproducing at different times *OWTTE*

c. behavioural isolation by difference in courtship behaviours *OWTTE*

d. geographic isolation by a population being separated by river/mountain/barrier to contact
An example of a geographic barrier is required.

e. polyploidy

b. a. spermatogonia «2n» are undifferentiated germ cells *OWTTE*

b. spermatogonia mature and divide «by mitosis» into primary spermatocytes «2n»

c. primary spermatocytes divide by meiosis I into secondary spermatocytes «1n»

d. secondary spermatocytes divide by meiosis II into spermatids «1n»

e. spermatids differentiate/mature into spermatozoa/sperm

f. Sertoli/nurse cells provide nourishment/support to these developing cells

g. Leydig/interstitial cells produce testosterone

c. a. anterior pituitary/hypophysis secretes FSH which stimulates ovary for follicles to develop

b. follicles secrete estrogen

c. estrogen stimulates more FSH receptors on follicle cells so respond more to FSH

d. increased estrogen results in positive feedback on «anterior» pituitary

e. estrogen stimulates LH secretion

f. estrogen promotes development of endometrium/uterine lining

g. LH levels increase and cause ovulation

h. LH results in negative feedback on follicle cells/estrogen production

i. LH causes follicle to develop into corpus luteum

OR

follicle cells produce more progesterone

j. progesterone thickens the uterus lining

k. high progesterone results in negative feedback on pituitary/prevents FSH/LH secretion

l. progesterone levels drop and allow FSH secretion

m. falling progesterone leads to menstruation/degradation of uterine lining

*Award **[5 max]** if no reference to feedback is made*.

Examiners report

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

---

b. Explain, using a **named** example, how polygenic inheritance gives rise to continuous variation. [2]

c. Describe the inheritance of colour blindness in humans. [3]

Markscheme

b. human skin colour can vary from pale to very dark / amount of melanin varies;

skin colour/melanin controlled by (alleles from) at least three/several genes;

no alleles are dominant / alleles are co-dominant / incomplete dominance;

many different possible combinations of alleles;

skin colour controlled by cumulative effect/combination of genes/alleles;

Award the above marking points for any other valid example.

c. sex linked condition;

carried on an X chromosome / absent from Y chromosome;

if present in male causes colour blindness;

(allele is) recessive so heterozygous females are not colour blind;

homozygous females are colour blind;

Do not allow carried on sex chromosome.

Examiners report

b. Answers were varied in quality. Some candidates were not clear about the nature of continuous variation and therefore either described how a small number of skin colours could arise, or described another example of variation with only a small number of phenotypic variants. The best answers explained how continuous variation results from the alleles of different genes acting in combination, with no single allele being dominant over the others. As there is considerable uncertainty about the number of genes influencing the quantity of melanin in human skin, the mark scheme accepted a wide range of answers.

c. This was well known by the stronger candidates, who had no difficulty in scoring three marks. There were some long answers describing particular mating and the offspring that they could produce, which sometimes scored few marks, as they did not make general points about the inheritance of colour blindness. Where crosses are used in an answer to a general question about the inheritance of a trait, they should be used to exemplify the pattern of inheritance, with annotation to make general points, rather than focusing too much on specific ratios.

In some maize plants the seed is enclosed in a green sheath called a tunica. The allele (T) for this is dominant to the allele (t) for normal, unenclosed seeds. The endosperm of the seed can be starchy (allele E) or sugary (allele e). The genes for these two characteristics are linked. The table below shows the outcome of crosses between a plant heterozygous for both characteristics and one that is homozygous recessive for both characteristics.

Phenotype	Number
Tunica present, starchy	326
Unenclosed seeds, starchy	111
Tunica present, sugary	118
Unenclosed seeds, sugary	295

a (i) State the genotype of the heterozygous parent using the correct notation. [1]

a (ii) Identify which individuals are recombinants in this cross. [1]

a (iii) Explain what has occurred to cause these results. [2]

b. Maize belongs to the group of plants known as angiospermophyta. Distinguish between angiospermophytes and bryophytes. [2]

Markscheme

a (i). $\frac{T \quad E}{t \quad e}$

a (ii) unenclosed seeds, starchy <u>and</u> tunica present, sugary /

$\frac{T\ \ e}{t\ \ e}$ and $\frac{t\ \ E}{t\ \ e}$ *(both needed)*

a (iii) crossing over;

between non-sister chromatids (in prophase I);

results in exchange of alleles / change in linkage groups;

so some gametes are T e or t E; (*linkage notation not expected*)

test cross expect ratio of two phenotypes / correct Punnett Square showing test cross;

but instead get four phenotypes with smaller percentage of recombinants;

Above points can be shown in diagrams.

b.

angiospermophytes	bryophytes
flowering	non-flowering;
(true) roots	rhizoids/no true roots;
(true) leaves	scales / thallus/no true leaves;
seeds produced	spores produced (in capsule);
waxy cuticle	no cuticle;
vascular (tissue)	non-vascular / no vascular tissue

Examiners report

a (i) Most candidates gave the heterozygous genotype but could not express it using the correct notation.

a (ii) Candidates were generally able to identify the recombinants, but explanation of the cause was often incorrectly attributed to independent assortment.

a (iii) Some mentioned crossing over, but could not accurately describe what this involves.

b. The structure of answers was not always what was expected in response to the command term; i.e., a list of features of one group was followed by a list of features of a second group. Some candidates accurately described the characteristics of one group but did not distinguish them from the other group. Lack of familiarity with terminology such as rhizoids etc. was common. Bryophytes were commonly equated with gymnosperms and pteridophytes.

In the pea plant (*Pisum sativum*), the allele for tall plants is A and the allele for short plants is a. The allele for green plants is B and the allele for yellow plants is b.

a. Determine the phenotype of Aabb. [1]

b. Compare the information that could be deduced when the genotypes are presented as AaBb or [2]

$$\frac{A\ B}{a\ b}.$$

c. Deduce **one** possible recombinant offspring of individual $\frac{A\ B}{a\ b}$. after a test cross. [1]

Markscheme

a. tall and yellow

b. both indicate the same phenotypes / both represent tall green plants;

(AaBb indicates unlinked genes and) $\frac{A\ B}{a\ b}$ linked genes;

AaBb indicates genes on different chromosomes and $\frac{A\ B}{a\ b}$ on the same chromosome;

independent assortment/AB, Ab, aB and ab (gametes) with AaBb but not independent assortment/only AB and ab (gametes) with $\frac{A\ B}{a\ b}$ (unless there is crossing over);

c. Aabb ***or*** aaBb ***or*** $\frac{A\ b}{a\ b}$ ***or*** $\frac{a\ B}{a\ b}$ ***or*** tall yellow ***or*** short green

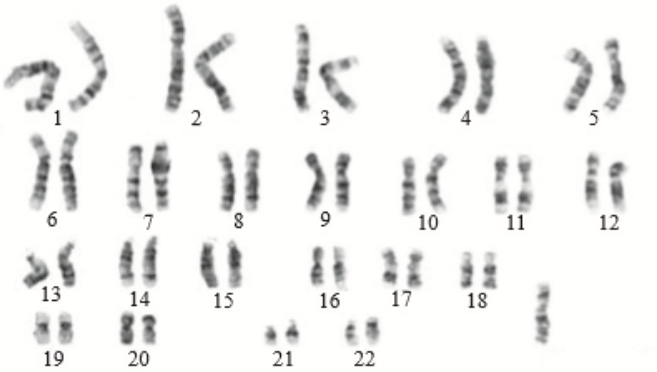
Examiners report

a. Nearly all candidates successfully determined the phenotype.

b. Answers were variable, with some excellent ones that distinguished between linked and unlinked genes, their position on the same or different chromosomes and the implications for recombination.

c. About half of candidates knew that the double recessive parent in a test cross would contribute a chromosome with the alleles ab and that recombinants would have new combinations of genes on their other chromosome, either Ab or aB.

The image shows the karyotype of a person who developed as a female.



[Source: http://en.wikipedia.org/wiki/File:45,X.jpg]

a (i) In a strain of soybeans, high oil content (H) in seeds is dominant to low oil content (h) and four seeds in a pod (F) is dominant to two seeds in a pod (f). A farmer crosses two soybean plants, both with high oil content and four seeds in a pod. The offspring have a phenotypic ratio of 9 : 3 : 3 : 1. [1]

Identify the genotypes of the soybean plants with high oil content and four seeds in a pod that were used in the cross.

a (ii) In a strain of soybeans, high oil content (H) in seeds is dominant to low oil content (h) and four seeds in a pod (F) is dominant to two seeds in a pod (f). A farmer crosses two soybean plants, both with high oil content and four seeds in a pod. The offspring have a phenotypic ratio of 9 : 3 : 3 : 1. [2]

Determine the genotypes of the gametes and offspring using a Punnett grid.

a (iii) In a strain of soybeans, high oil content (H) in seeds is dominant to low oil content (h) and four seeds in a pod (F) is dominant to two seeds in a pod (f). A farmer crosses two soybean plants, both with high oil content and four seeds in a pod. The offspring have a phenotypic ratio of 9 : 3 : 3 : 1. [2]

Identify the phenotypes of each part of the phenotypic ratio.

Ratio	Phenotypes
9	
3	
3	
1	

b (i) Deduce the reason for the person developing as a female. [1]

b (ii) Determine, with a reason, whether this karyotype shows that non-disjunction has occurred. [1]

Markscheme

a (i). HhFf HhFf □ / (both) HhFf;

a (ii).

gametes	HF	Hf	hF	hf
HF	HHFF	HHFf	HhFF	HhFf
Hf	HHFf	HHff	HhFf	Hhff
hF	HhFF	HhFf	hhFF	hhFf
hf	HhFf	Hhff	hhFf	hhff

all gametes shown correctly on Punnett grid;
all offspring genotypes correct;

a (iii).

	ratio	*phenotypes*
a.	*9*	high oil four seeds;
b.	*3*	high oil two seeds;
c.	*3*	low oil four seeds;
d.	*1*	low oil two seeds;

*Award **[1]** for any **two** correct phenotypes.*

b (i). no Y chromosome.

b (ii). yes as there is only one X chromosome/chromosome missing/only 45 chromosomes

Examiners report

a (i). Most wrote the correct genotype, though there were a surprising number that did not follow notation conventions such as writing HFhf or using linkage notation.

a (ii). The majority of students could answer this question. Where students were not answering correctly, it was due to a lack of conceptual understanding of segregation; i.e. writing gametes as HH or ff for example.

a (iii). This question was most commonly answered correctly.

b (i). Approximately half of students answered this correctly. A number did not recognize the condition for determining a female was the absence of the Y chromosome rather than the presence of the X chromosome.

b (ii). This was more commonly answered correctly than i). Here a common misunderstanding was that nondisjunction could only be present if additional chromosomes were present rather than if one were missing.

The diagram shows a human karyotype.

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

a. Analyse this karyotype. [2]

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

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

Markscheme

a. Male has (one X and) one Y chromosome / X chromosome is bigger than Y chromosome;

non-disjunction leads to three copies of chromosome 13/trisomy 13.

b. sex-linked/on X chromosome;

recessive allele / Xh;

more common in males than females;

heterozygous females are carriers / only females can be carriers;

c. more than one gene contribute to/control same characteristic;

as number of genes increase so does possible number of phenotypes;

leads to continuous variation;

specific example; *(eg human skin color (due to differing amounts of melanin))*

*Award **[2 max]** for general points with no example.*

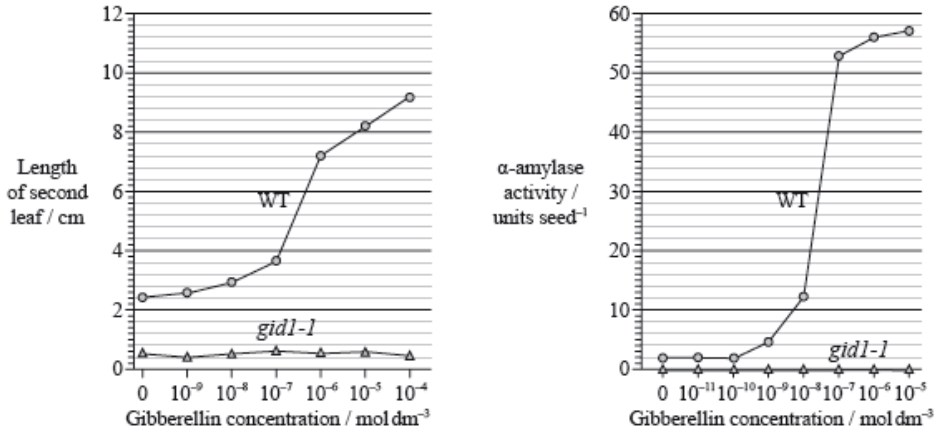
Examiners report

a. The fact that there was a trisomy 13 as a result of non-disjunction eluded the majority, who seemed to register that pair 21 was OK, therefore nothing else could be wrong. Many lost a mark for not explaining why it was a male. Better prepared candidates were able to explain haemophilia and polygenic inheritance. For some candidates it seemed to be the first time that they had encountered them.

b. The fact that there was a trisomy 13 as a result of non-disjunction eluded the majority, who seemed to register that pair 21 was OK, therefore nothing else could be wrong. Many lost a mark for not explaining why it was a male. Better prepared candidates were able to explain haemophilia and polygenic inheritance. For some candidates it seemed to be the first time that they had encountered them.

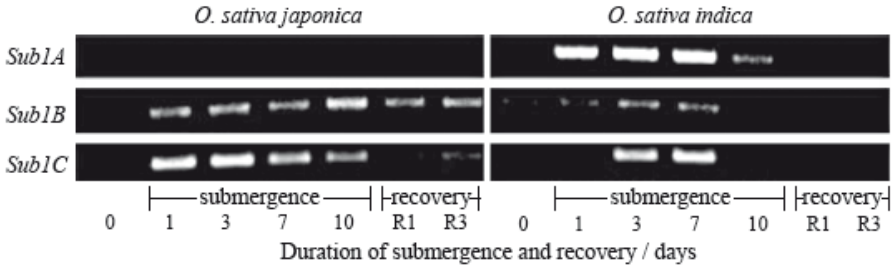
c. The fact that there was a trisomy 13 as a result of non-disjunction eluded the majority, who seemed to register that pair 21 was OK, therefore nothing else could be wrong. Many lost a mark for not explaining why it was a male. Better prepared candidates were able to explain haemophilia and polygenic inheritance. For some candidates it seemed to be the first time that they had encountered them.

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



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

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

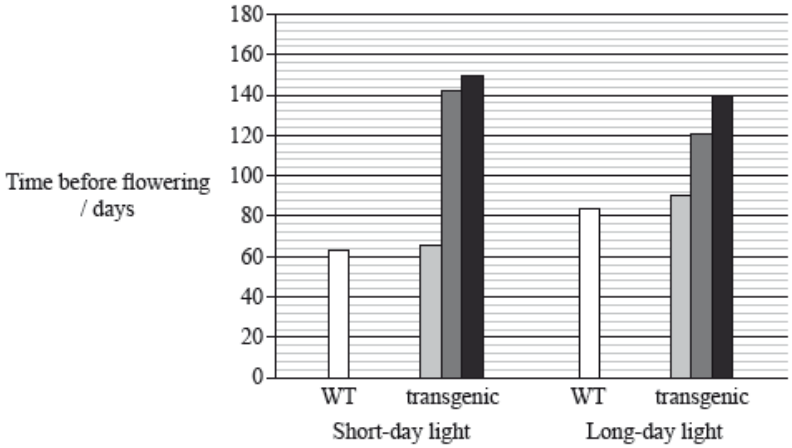


[Source: Adapted from "Sub1A is an ethylene-response-factor-like gene that confers submergence tolerance to rice" (2006) Kenong Xu, Xia Xu, Takeshi Fukao, Patrick Canlas, Reycel Maghirang-Rodriguez et al. Nature, 442, pp. 705—708. Adapted by permission from Macmillan Publishers Ltd (c) 2006.]

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

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

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



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

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

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

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

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

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

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

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

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

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

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

Markscheme

a(i) *gid1-1*

a(ii) between 10^{-8} and 10^{-7} mol dm^{-3} *(units required)*

b. a. 25% / 1 in 4 / 1:3 seeds produced would be homozygous recessive;

b. no response to/inhibits gibberellin in homozygous recessives results in less germination;

c. less growth / dwarf plants produced; *(must be in context)*;

d. would produce plants with infertile flowers that cannot produce rice grains;

e. would lower rice production/less yield because infertile plants cannot produce seeds (that humans can eat);

c(i) *Sub1C*

c(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;

d. a. *Sub1A*;

b. is only expressed in *indica* / *Sub1B* and *SubC* are expressed in both rice varieties;

c. *indica* is the variety showing submersion tolerance / vice versa for *japonica*;

e(i) it increases the length of time <u>before</u> flowering

e(ii) a. long-day light exposure increases time before flowering only if (*OsGI*) gene is not overexpressed/in WT and –/–;

b. long-day light exposure decreases time before flowering for +/– and/or +/+;

c. length of day does not make much difference/makes least difference for +/+;

d. overexpression for +/– reduces time before flowering;

e. –/– acts as a control / has nearly the same length of time before flowering as WT;

Accept numerical answers if they are making a clear comparison.

e(iii) is a short-day plant <u>because</u> WT has shortest time/shorter time before flowering in shorter days than longer days / as it takes less time to flower under short day conditions;

g. a. the mutant *gid1-1* would not be useful because it produces sterile plants;

b. genetically modified rice/rice with *Sub1A* is more tolerant to submersion/can withstand seasonal flooding/torrential rain;

c. *OsGI*+ varieties adapted to different latitudes / day length could be produced (to overcome food shortages);

d. short flowering time possibly means more crops per year;

Examiners report

a(i). The word “increment” seemed to confuse the weaker candidates who stated a value rather than a range. In addition there were a large number who omitted or misquoted the units. In spite of being clearly stated in topic 9.3.5, very few candidates correctly gained the mark in part (iii) for saying that the amylase catalysed the breakdown of starch to maltose. Many answered glucose instead of maltose, but a surprising number did not even realise that amylase is an enzyme.

a(ii). The word “increment” seemed to confuse the weaker candidates who stated a value rather than a range. In addition there were a large number who omitted or misquoted the units. In spite of being clearly stated in topic 9.3.5, very few candidates correctly gained the mark in part (iii) for saying that the amylase catalysed the breakdown of starch to maltose. Many answered glucose instead of maltose, but a surprising number did not even realise that amylase is an enzyme.

b. Most of the better candidates realised that it was a simple monohybrid cross (although several thought it was dihybrid) and realised that 25% would produce dwarf plants, but did not explain the consequences on potential yield in sufficient detail for the third mark.

c(i). In spite of doubts from the G2 forms, candidates had little difficulty in interpreting the photograph.

In part (i) most correctly answered *Sub1C*.

c(ii). The answers to (ii) tended to be descriptive, not making clear <u>differences</u>, as asked.

d. Most candidates correctly identified *Sub1A* with a correct reason.

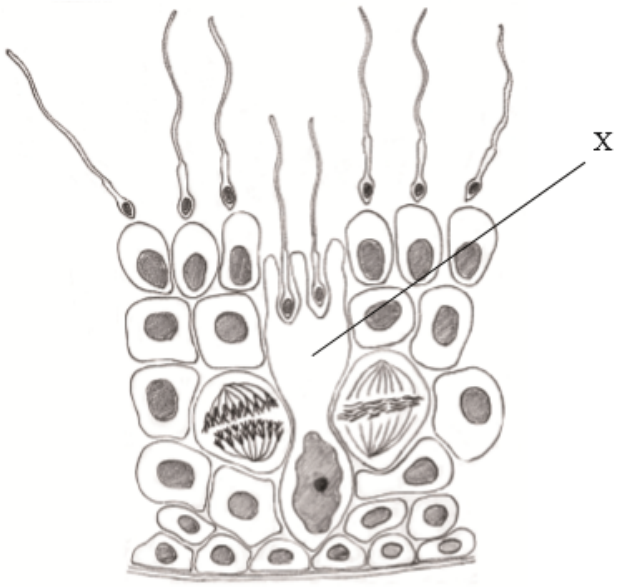
e(i). Most answered correctly that it increased the time <u>before</u> flowering.

e(ii). In (ii) almost every correct answer was from the first two mark points.

e(iii). In (iii) most candidates identified it as a short-day plant with reasons.

g. In spite of the stem saying “using all the data”, most of the answers were very vague and did not use the data. The ideas that the mutant *gid1-1* should be avoided as it produces sterile plants and those modified with *Sub1A* would withstand seasonal flooding were missed by most candidates.

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



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

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

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

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

Markscheme

a. mother receives hormone treatment/FSH to stimulate egg development;

eggs and sperm collected/harvested / eggs taken from ovary;

egg fertilized outside the body/in a dish/in a lab;

develops into embryo;

embryo(s) implanted (artificially) in mother's body/uterus;

Do not accept egg/fertilized egg/zygote implanted.

b (i). Sertoli cell / nurse cell

b (ii). nourishes maturing sperm(atozoa) / protects sperm from lymphocytes

c. crossing over in prophase 1/between chromatids;

random orientation of bivalents/homologous pairs in metaphase 1;

random orientation of chromatids/chromosomes in metaphase 2;

Examiners report

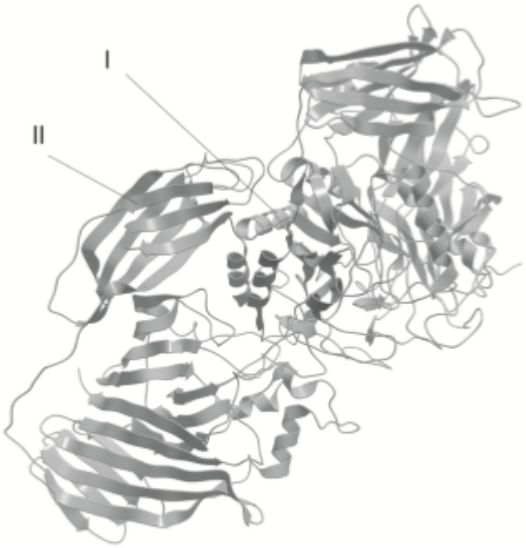
a. *In vitro* fertilization was understood well by many, though some answers were too vague to score some of the marks. The main area of misunderstanding was over what is put into the mother"s uterus. Many candidates thought that it was fertilized eggs or zygotes and others thought that it was blastocysts. The latter was accepted as they are at least embryos, but much older than the stage usually implanted; embryos at the four cell stage.

b (i) Many candidates were able to identify X as a Sertoli cell.

b (ii) Many candidates were able to identify X as a Sertoli cell, but not all could then state the function correctly.

c. This is a question that has often been asked but it is still an area that many candidates find difficult. Crossing over and independent orientation have sometimes been awarded marks in previous papers, if the terms are stated without any understanding of them being shown. In this paper the stage of meiosis was also required or some details of what the processes involve. As a result many candidates scored one mark only or none. Candidates should be encouraged to develop deep understanding of biological processes and not merely learn names; this will very much be the focus of the new IB Biology programme currently under development.

The diagram below shows the structure of lactase



[Source: Kindly provided by RL Miesfeld, The University of Arizona, Tucson, AZ USA]

a (i) A study of 600 adolescents in Sweden showed that milk consumption has a positive effect on height which shows continuous variation. However, milk contains lactose which some people can digest but some cannot. [1]

State the pattern of inheritance that contributes to continuous variation.

a (ii) Explain the production of lactose-free milk. [3]

b (i) Identify the protein structures indicated by I and II. [1]

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

b (ii) Describe how structure I is held together. [2]

b (iii) This protein is described as a globular protein. Distinguish between globular and fibrous proteins. [2]

Markscheme

a (i) polygenic / more than one gene

Accept polygenetic. Mark only first answer if more than one answer given.

a (ii) lactase added to milk / lactase immobilised;

lactose hydrolysed/broken down into glucose and galactose;

for people who are lactose intolerant/lack lactase;

increases sweetness/solubility/smooth texture (in processed foods);

b (i) I is alpha helix and II is beta pleated sheet

Reject (α) double helix but accept α/A/a and β/B/b instead of alpha and beta.

b (ii) hydrogen bonds;

Reject hydrogen and covalent bonds unqualified and hydrogen bonds between bases.

(hydrogen bonds) between N–H and C=O (on different amino acids);

Reject between amine and carboxyl groups.

(hydrogen bonds) between adjacent turns of the helix/every fourth amino

acid;

Accept above points in an annotated diagram.

b (iii).

Globular	*Fibrous*
water soluble (mostly)	not (water) soluble;
rounded shape/tertiary structure	long/narrow shape / no tertiary structure;
enzymes/hormones/catalysis/transport /defence functions	structural/movement functions;

A table is not required but for each feature the difference between globular and fibrous proteins must be made clear.

Examiners report

a (i) About half of candidates knew that polygenic inheritance contributes to continuous variation.

a (ii) This question was generally well answered with stronger candidates able to score full marks. A few confused lactase with lactose and the products of lactose hydrolysis were not always known.

b (i) About a quarter of candidates knew the names of the two secondary structures.

b (ii) Few candidates stated that hydrogen bonds stabilise secondary structures and even fewer earned a second mark for giving a detail of the hydrogen bonding.

b (iii) N/A