# HL Paper 2

a.i. Nucleosomes help to regulate transcription in eukaryotes. [1]

State the components of a nucleosome.

a.ii. Nucleosomes help to regulate transcription in eukaryotes. [1]

State a chemical modification of a nucleosome that could impact gene expression.

# Markscheme

a.i. DNA and histone

a.ii. methylation/acetylation/phosphorylation/epigenetic tags/modification of nucleosome tails/N-terminal tails

# Examiners report

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

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a. Distinguish between RNA and DNA. [3]

b. Explain the process of DNA replication. [8]

c. Outline how enzymes catalyse reactions. [7]

# Markscheme

a. DNA is double-stranded while RNA is single-stranded;

DNA contains deoxyribose while RNA contains ribose;

the base thymine found in DNA is replaced by uracil in RNA;

one form of DNA (double helix) but several forms of RNA (tRNA, mRNA and rRNA);

b. occurs during (S phase of) interphase/in preparation for mitosis/cell division;

DNA replication is semi-conservative;

unwinding of double helix / separation of strands by helicase (at replication origin);

hydrogen bonds between two strands are broken;

each strand of parent DNA used as template for synthesis;

synthesis continuous on leading strand but not continuous on lagging strand;

leading to formation of Okazaki fragments (on lagging strand);

synthesis occurs in 5'→3' direction;

RNA primer synthesized on parent DNA using RNA primase;

DNA polymerase III adds the nucleotides (to the 3' end)

added according to complementary base pairing;

adenine pairs with thymine and cytosine pairs with guanine; (*Both pairings required. Do not accept letters alone.*)

DNA polymerase I removes the RNA primers and replaces them with DNA;

DNA ligase joins Okazaki fragments;

as deoxynucleoside triphosphate joins with growing DNA chain, two phosphates broken off releasing energy to form bond;

*Accept any of the points above shown on an annotated diagram.*

c. they increase rate of (chemical) reaction;

remains unused/unchanged at the end of the reaction;

lower activation energy;

activation energy is energy needed to overcome energy barrier that prevents reaction;

annotated graph showing reaction with and without enzyme;

substrate joins with enzyme at active site;

to form enzyme-substrate complex;

active site/enzyme (usually) specific for a particular substrate;

enzyme binding with substrate brings reactants closer together to facilitate chemical reactions (such as electron transfer);

induced fit model / change in enzyme conformation (when enzyme-substrate/ES complex forms);

making the substrate more reactive;

# Examiners report

a. Many of the candidates scored full marks.

b. Despite some confusion about which enzyme does what and confusing DNA replication with transcription/translation, many candidates managed to gain full marks. A good number indicate that an RNA primer begins replication on the lagging strand only. Another common error was to refer to the gaps rather than the fragments as Okazaki fragments. Some candidates confused replication with translation.

c. Many candidates lost marks by focusing on factors affecting the rate of enzyme controlled reactions and inhibition and missed the basics. Nearly all mentioned the lowering of activation energy, but many were not able to describe how this is done. Diagrams that were included could have earned more marks if they were more carefully drawn, with axes labels being more carefully included and differences in energy between reactants and products being more accurately represented. Few indicated that the enzyme was not used up in the reaction.

a. Outline the action of enzymes. [4]

b. Explain the roles of specific enzymes in prokaryote DNA replication. [7]

c. Many genetic diseases are due to recessive alleles of autosomal genes that code for an enzyme. Using a Punnett grid, explain how parents who do not show signs of such a disease can produce a child with the disease. [4]

# Markscheme

a. Catalyse/speed up reactions

Substrate-specific

Lower the activation energy «of a chemical reaction»

Substrate collides with/binds to active site

Enzyme–substrate complex formed
***OR***
transition state formed
***OR***
bonds in substrate weakened

b. «DNA» gyrase/topoisomerase «II» prepares for uncoiling/relieves strains «in the double helix»

Helicase uncoils/unwinds the DNA/double helix

Helicase separates/unzips/breaks hydrogen bonds between the two strands of DNA

«DNA» primase adds an RNA primer/short length of RNA *Accept RNA primase.*

DNA polymerase III adds «DNA» nucleotides/replicates DNA/synthesizes complementary strand in a 5' to 3' direction

DNA polymerase III starts replication/adding nucleotides at the primer

DNA polymerase I removes the primer
***OR***
replaces RNA with DNA

«DNA» ligase seals the nicks
***OR***
links sections of replicated DNA
***OR***
links Okazaki fragments

DNA polymerase I/DNA polymerase III proofreads for mistakes

c. Key or text giving alleles with upper case for dominant allele and lower case for recessive allele/allele causing disease

Reject key showing a sex linked gene such as hemophilia.
*Reject if X or Y chromosomes are shown with the alleles.*
*Accept Aa or any other upper and lower case letters.*

Punnett grid showing that both parents can pass on either a dominant or a recessive allele in their gamete

*For example row and column headings with A and a.*
*This mark can be awarded if X or Y chromosomes are shown but each parent has one recessive and one dominant allele as if for autosomal inheritance.*

Four possible genotypes for child correctly shown on grid

*AA, Aa, aA and aa for example.*
*This mark can be awarded if X or Y chromosomes are shown but the genotypes are correct for autosomal inheritance.*

Double/homozygous recessive shown having the disease

*Cannot be awarded with sex linkage.*

25 % or 0.25 or 1/4 chance of inheriting the disease

*This mark can be awarded if X or Y chromosomes are shown but the ratio is correct for autosomal inheritance.*

# Examiners report

a. This was generally well answered with most candidates able to give enough of the important features of enzyme action to score well. One mistake seen in a number of responses was to state that the active site is on the substrate rather than on the enzyme.

b. Knowledgeable candidates had no difficulty in scoring full marks by giving an accurate description of the role of enzymes in DNA replication. It was not necessary to focus on the leading and lagging strands as the action of the various enzymes is largely the same, though of course primers are repeatedly added to the lagging strand and then replaced. Some candidates were obviously concerned that they were being asked about prokaryote DNA replication. This is of course the type of DNA replication that is specified by the programme and has been for many years. It is worth making sure that candidates know that they have learned about this rather than eukaryote replication.

c. This part was very well answered with many candidates scoring full marks. There were a few errors in notation with different letters of the alphabet used for alleles of the same gene or X and Y chromosomes indicating confusion between autosomal and sex-linked genes.

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a. Outline the structure and functions of nucleosomes. [4]

b. Explain how DNA is used to pass on genetic information to offspring accurately but also produce variation in species. [8]

c. Accurate transmission of base sequences to offspring depends on successful gamete production. Describe how spermatogenesis occurs in humans. [6]

# Markscheme

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

a. found in eukaryotes;
b. consists of DNA wrapped around proteins/histones;
c. histones are in an octamer/group of eight;
d. are held together by another histone/protein;
e. in linker region;
f. help to supercoil chromosomes / to facilitate DNA packing;
g. (function is to) regulate transcription / gene expression;

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

a. DNA is replicated/copied semi-conservatively/from a template;
b. mutations can be a source of variation / resulting protein has new or different functions;
c. mutations/changes in the DNA may not result in changes in the amino acid for which the triplet codes;
d. genetic code is redundant;

e. genes occur as paired alleles which can be different;
f. crossing-over occurs;
g. recombines linked alleles producing new combinations;
h. random orientation of bivalents / homologous chromosomes (in metaphase I);
i. large genetic variation in (haploid) gametes / $2^n$ / $2^{23}$;
j. random recombination of alleles during fertilization (leads to variation);
k. different phenotypes among members of the same population;
l. natural selection may lead to enhanced survival of recombinants;

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

a. germinal cells / spermatogonia undergo mitosis to keep a supply of germinal cells present;
b. some germinal cells / spermatogonia grow larger to become primary spermatocytes;
c. primary spermatocytes go through meiosis I;
d. to form secondary spermatocytes;
e. these secondary spermatocytes go through meiosis II;
f. to produce spermatids;
g. spermatids differentiate/grow a tail and reduce their cytoplasm
h. spermatids associated with nurse cells (Sertoli cells);
i. sperm detach from Sertoli cells and enter lumen of the seminiferous tubule;
j. testosterone stimulates sperm production;

# Examiners report

a. It was common for four marks to be awarded. Students knew this topic well.

b. Many candidates appeared to be giving memorized responses from past mark schemes without recognizing the subtleties of what the question demanded. Better prepared candidates used language carefully. Some muddled the discussion by referring to mitosis.

c. Candidates struggled to use terminology correctly. The greatest confusion occurs in discussing the beginning stages of spermatogenesis.

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a. Describe the relationship between genes, polypeptides and enzymes. [4]

b. Outline control of metabolic pathways. [6]

# Markscheme

a. gene is a sequence of DNA bases;

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

enzymes are proteins/composed of polypetides;

sequence of amino acids determines tertiary structure/folding/shape of active site;

change in the gene/mutation will affect the active site/function of an enzyme;

enzymes are involved in replication/transcription of genes;

enzymes are involved in synthesis of polypeptides;

b. metabolic pathways can be a sequence/chain of reactions;

they can be cycles of reactions;

different enzymes control each reaction in the sequence/cycle;

accumulation of an end-product can inhibit the first enzyme of the sequence/ pathway;

(an end-product inhibitor) joins an allosteric site/a site separate from active site;

attachment at the allosteric site changes the shape of the active site;

preventing the binding of substrate;

until the level of the end-product is reduced (and the inhibition removed);

this is an example of negative feedback;

# Examiners report

a. This part of the question was poorly answered. Candidates were usually able to relate genes to translation but were less likely to adequately relate their responses specifically to polypeptides beyond that.

b. Aspects of allosteric inhibition were usually a strength within student responses to this question. Answers for this question were generally not very well constructed.

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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]

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

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

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

*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.

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

b. Explain the process of DNA replication. [8]

c. Outline how the structure of the ribosome is related to its function in translation. [6]

# Markscheme

a. *Award any of the following clearly drawn and correctly labelled.*

cell wall; (*shown as a double line*)

plasma membrane; (*less than the width of wall*) (*reject inner surface of cell wall labelled as cell membrane*)

nucleoid/(region containing) naked DNA (distinguished from rest of cytoplasm)

ribosome; (*dots in cytoplasm*)

cytoplasm;

flagella; (*at least a quarter as long as the cell*)

pili; (*less than a quarter as long as the cell*)

*Award **[3 max]** if any specifically eukaryotic structure shown.*

b. helicase uncoils DNA/splits DNA into two strands;

(RNA) primase adds short length of RNA/primer;

primer allows attachment of (DNA) polymerase;

DNA polymerase III copies DNA;

adds nucleotides in the 5′ to 3′ direction;

uses deoxynucleoside triphosphates/nucleotides that are free in cell;

two phosphates removed to release energy (required for the process);

(complementary base pairing of) adenine with thymine and guanine with cytosine; (*reject A with T and C with G*)

(leading) strand replication towards the replication fork;

short pieces of daughter DNA / Okazaki fragments (on lagging strand);

DNA polymerase I removes the RNA primers/replaces them with DNA;

(DNA) ligase joins short fragments/seals nicks;

by making sugar-phosphate bond;

c. translation is protein/polypeptide synthesis;

formed by (ribosomal) RNA and proteins; (*both needed*)

about 20nm/30nm / 80S in eukaryotes;

organized into a tertiary structure/globular shape;

a small subunit and a large one;

(three) binding sites for tRNA on/in large subunit;

A, P and E sites;

binding site for mRNA on surface/in small subunit;

two tRNA can bind at the same time;

ribosomal RNA catalyses formation of peptide bond;

# Examiners report

a. In part (a), most candidates drew an appropriate diagram of a prokaryote cell and there was a continuation of the improvement in the quality of diagrams that has been seen over recent years. In a few cases, eukaryote structures such as mitochondria had been included. Pili and flagella were not always distinguishable.

b. Replication is a complicated process and candidates were expected to be able to describe it in detail in (b). The strongest candidates did this admirably well, but weaker ones tended to reveal misunderstandings or gaps in knowledge. It is usually possible for examiners to distinguish between those who have developed a genuine understanding and others who may have memorized some key phrases but are unable to use them correctly in context.

c. The emphasis in the answer to part (c) of the question needed to be on ribosome structure, rather than the process of translation. There were some detailed descriptions of translation that made only passing reference to structure and so scored poorly. Diagrams were often included but they needed to be annotated fully to gain marks for a particular idea. Some of the best answers included the idea that ribosomes are composed of both protein and ribosomal RNA, with the RNA having a catalytic role in translation.

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a. Draw a labelled diagram showing **two** different complementary pairs of nucleotides in a molecule of DNA. [4]

b. Outline the structure of nucleosomes. [2]

c. Explain primary structures and tertiary structures of an enzyme. [3]

# Markscheme

a. *The structures underlined must be labelled.*

at least one nucleotide with deoxyribose linked to base and phosphate;{ *Labels need not be on the same nucleotide. Do not allow sugar.*

phosphate and deoxyribose linked $C_3$ to $C_5$;{ *Position required, not label. Straight line from $C_4$ to phosphate is acceptable. Do not penalize if the second strand is not antiparallel and the bonding is therefore incorrect on it.*

(complementary) bases labelled with at least one of each of A, G, T and C correctly linked to $C_1$;

hydrogen bonds between correct complementary bases;{ *Bond numbers not required.*

correct antiparallel orientation shown; (*as seen by shape or orientation of sugar*)

b. (eight) histone (proteins);

DNA wrapped around histones/nucleosome;

further histone holding these together;

*Do not allow histone wrapped around DNA.*

c. primary structure is (number and) sequence of amino acids;

joined by peptide bonds;

tertiary structure is the folding of the polypeptide/secondary structure/alpha helix;

stabilized by disulfide/ionic/hydrogen bonds/hydrophobic interactions;

tertiary structure gives three dimensional globular shape/shape of active site;

# Examiners report

a. This was often well answered, with many candidates scoring four marks. The sugar was sometimes labelled as ribose rather than deoxyribose, or simply as sugar. Another common error was to link the phosphate groups to the oxygen in the sugar ring, rather than to $C_4$ via $C_5$.

   Stronger candidates often drew impressively detailed and accurate diagrams, with the antiparallel orientation of the strands, the numbers of hydrogen bonds and the molecular structure of deoxyribose and phosphate groups correctly shown. It was possible to score four marks without all of this detail, but it was good to see such high quality answers.

b. This was also well answered by properly prepared candidates. A few misread the question and outlined the structure of nucleotides rather than nucleosomes.

c. This was more poorly answered than expected. Perhaps candidates who knew about the primary and tertiary structure of proteins were unable to transfer this knowledge to a question about enzymes, though they surely knew that enzymes are globular proteins. Many of the candidates who did write about primary and tertiary structure failed to include the essential detail that primary structure is the sequence or order of amino acids. There was some confusion between secondary and tertiary structure and also some over-simplified accounts of tertiary structure. Some candidates stated simply that tertiary structure is three-dimensional structure. It was expected that candidates should at least include the idea that enzymes are globular in their three-dimensional structure.

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Angiospermophyta are vascular flowering plants.

a. Describe the transport of organic compounds in vascular plants. [4]

b. The flowers of angiospermophyta are used for sexual reproduction. Outline **three** processes required for successful reproduction of angiospermophyta. [3]

c. Growth in living organisms includes replication of DNA. Explain DNA replication. [8]

# Markscheme

a. a. phloem transports organic compounds/sucrose

   b. from sources/leaves/where produced to sinks/roots/where used

   c. through sieve tubes/columns of cells with sieve plates/perforated end walls

   d. loading of organic compounds/sucrose into /$H^+$ ions out of phloem/sieve tubes by active transport/using ATP

   e. high solute concentration causes water to enter by osmosis (at source)

   f. high (hydrostatic) pressure causes flow (from source to sink)

   g. companion cells help with loading / plasmodesmata provide a path between sieve tubes and companion cell

   h. translocation/mass flow

b. a. meiosis / production of male and female gametes

b. pollination / transfer of pollen from anther to stigma

c. fertilization happens after pollination / fertilisation is joining of gametes

d. seed dispersal / spread of seeds to new locations

*Reject fruit dispersal.*

c. a. helicase unwinds the double helix

b. gyrase/topoisomerase relieves strains during uncoiling

c. helicase separates the two strands of DNA/breaks hydrogen bonds

*Accept unzips here but not for mark point a.*

d. each single strand acts as a template for a new strand / process is semi-conservative

e. DNA polymerase III can only add nucleotides to the end of an existing chain/to a primer

f. (DNA) primase adds RNA primer/short length of RNA nucleotides

g. DNA polymerase (III) adds nucleotides in a 5’ to 3’ direction

h. complementary base pairing / adenine to thymine and cytosine to guanine

*Do not accept letters.*

i. DNA polymerase (III) moves towards the replication fork on one strand and away from it on the other strand

j. continuous on the leading strand and discontinuous/fragments formed on the lagging strand

k. DNA polymerase I replaces primers/RNA with DNA

l. ligase joins the fragments together/seals the nicks

# Examiners report

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

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a. Outline the structure of a ribosome. [4]

b. Distinguish between fibrous and globular proteins with reference to **one** example of each protein type. [6]

c. Auxin is a protein. Explain its role in phototropism. [8]

# Markscheme

a. small subunit and large subunit;

mRNA binding site on small subunit;

three tRNA binding sites / A, P and E tRNA binding sites;

protein and RNA composition (in both subunits);

b. fibrous proteins are strands/sheets whereas globular proteins are rounded;

fibrous proteins (usually) insoluble whereas globular proteins (usually) soluble;

globular more sensitive to changes in pH/temperature/salt than fibrous;

fibrous proteins have structural roles / other specific role of fibrous protein;

globular proteins used for catalysis/transport/other specific role of globular protein;

another role of globular protein;

named fibrous proteins *e.g.* keratin/fibrin/collagen/actin/myosin/silk protein;

named globular protein *e.g.* insulin/immunoglobulin/hemoglobin/named enzyme;

*Do not accept statements about fibrous proteins having only secondary structure and globular proteins having only tertiary structure.*

c. auxin is a plant hormone;

produced by the tip of the stem/shoot tip;

causes transport of hydrogen ions from cytoplasm to cell wall;

decrease in pH / $H^+$ pumping breaks bonds between cell wall fibres;

makes cell walls flexible/extensible/plastic/softens cell walls;

auxin makes cells enlarge/grow;

gene expression also altered by auxin to promote cell growth;

(positive) phototropism is growth towards light;

shoot tip senses direction of (brightest) light;

auxin moved to side of stem with least light/darker side

causes cells on dark side to elongate/cells on dark side grow faster;
*Accept clearly annotated diagrams for phototropism marking points.*

# Examiners report

a. Part (a) was generally well answered with many candidates scoring marks by including annotated drawings of ribosomes.

b. Part (b) was also answered well in many cases with most giving acceptable examples of globular and fibrous proteins and their roles. There were some doubtful statements about levels of protein structure. Although tertiary structure is more significant in globular than in fibrous proteins, it is not true to say that fibrous proteins have secondary structure and globular proteins have tertiary and quaternary structure. Most globular proteins have regions of secondary structure. Collagen, perhaps the best example of a fibrous protein, has neither α-helices nor β-pleated sheets within its structure and as it has three polypeptides wound together collagen has quaternary structure.

c. There was an error in (c) for which the examiners apologise: auxin is of course not a protein and is instead indole ethanoic acid in its naturally occurring form. Unfortunately this mistake was propagated in many candidates" answers. Knowledge of the physiology of phototropism was good. The best answers included details of how auxin is moved between cells and its effects on cell walls and growth of cells.

b. Outline, with an example, the process of exocytosis. [5]

c. Translation occurs in living cells. Explain how translation is carried out, from the initiation stage onwards. [9]

# Markscheme

b. vesicles carry material to plasma membrane;

vesicle fuses with membrane;

(by joining of) phospholipid bilayers;

aided by the fluidity of the membrane;

material released/expelled from the cell;

membrane flattens;

name of example e.g. exocytosis of neurotransmitter / exocrine secretion/endocrine secretion / hormone secretion / release of cortical granules;

outline of example: (in the presence of calcium), neurotransmitter vesicles release their contents into the synapse / hormones released from one cell have an effect on another cell etc.;

*Accept these points if clearly made in an annotated diagram.* ***[4 max]*** *if no example given.*

c. translation involves initiation, elongation/translocation and termination;

mRNA binds to the small sub-unit of the ribosome;

ribosome slides along mRNA to the start codon;

anticodon of tRNA pairs with codon on mRNA:

<u>complementary base pairing</u> (between codon and anticodon);

(anticodon of) tRNA with methionine pairs with start codon / AUG is the start codon;

second tRNA pairs with next codon;

peptide bond forms between amino acids;

ribosome moves along the mRNA by one codon;

movement in 5' to 3' direction;

tRNA that has lost its amino acid detaches;

another tRNA pairs with the next codon/moves into A site;

tRNA activating enzymes;

link amino acids to specific tRNA;

stop codon (eventually) reached;

# Examiners report

b. There were some very good answers to this section which included all possible marking points, but far too many only knew one fact, that it expelled material form a cell. A large number of candidates summarized intracellular vesicle traffic which again suggests that candidates have memorized mark schemes rather than applying what they know to novel questions. In this question, the details of a specific example were rarely included.

c. It was surprising that so many managed to omit the basic facts on codon/anticodon binding by complementary base pairing. Some explained DNA replication and transcription instead. Answers were in general, poorer on this topic than they have been in the past which suggests that teachers are not spending adequate time on this topic.

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a. State **four** functions of proteins, giving a **named** example of each. [4]

b. Outline the structure of ribosomes. [6]

c. Explain the process of transcription leading to the formation of mRNA. [8]

# Markscheme

a. a. structure – collagen;

b. transport – transthyretin / hemoglobin;

c. enzyme/catalyst – lysozyme;

d. movement – actin / tubulin;

e. hormones – insulin;

f. antibodies – immunoglobulin;

g. storage – albumin;

*Accept any other valid function of proteins with a named example.*

*For example sodium potassium pump, but do not accept simply "in membranes" without a clear function.*

*To award [4 max], responses need a function of protein and a named example.*

*Only accept the first four answers*.

b. a. made of protein;

b. made of rRNA;

c. large subunit <u>and</u> small subunit;

d. three tRNA binding sites;

e. Aminacyl/A, Peptidyl/P and Exit/E;

f. mRNA binding site (on small subunit);

g. 70S in prokaryotes / 80S in eukaryotes;

h. can be free / bound to RER (in eukaryotes);

c. a. <u>RNA</u> polymerase; *(polymerase number is not required)*

b. binds to a promoter on the DNA;

c. unwinding the DNA strands;

d. binding nucleoside triphosphates;

e. to the antisense strand of DNA;

f. as it moves along in a 5'→3' direction;

g. using complementary pairing/A-U and C-G;

h. losing two phosphates to gain the required energy;

i. until a terminator signal is reached (in prokaryotes);

j. RNA detaches from the template and DNA rewinds;

k. RNA polymerase detaches from the DNA;

l. many RNA polymerases can follow each other;

m. introns have to be removed in eukaryotes to form mature mRNA;

# Examiners report

a. Most candidates gained some marks here with knowledge of functions of proteins with examples. However many answers were very descriptive rather than “stating with an example” as asked.

b. Most knew about the two ribosome subunits and the mRNA binding site. Very few knew that they were made from protein and rRNA. Several answered that there were 3 binding sites, but not what was bound there (tRNA) or what they were called.

c. The process of transcription was well known by most candidates who attempted this question.

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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.

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a. Most of the DNA of a human cell is contained in the nucleus. Distinguish between unique and highly repetitive sequences in nuclear DNA. [5]

b. Draw a labelled diagram to show **four** DNA nucleotides, each with a different base, linked together in **two** strands. [5]

c. Explain the methods and aims of DNA profiling. [8]

# Markscheme

a. *Award **[1]** for each pair of statements in the table and **[1]** for any statement below the table.*

| Unique sequences | Highly repetitive sequences |
|---|---|
| occur once in genome | occur many times; |
| long base sequences | short sequences/5–300 bases; |
| (may be) genes | not genes; |
| (may be) translated / coding sequences | never translated; |
| small differences between individuals | can vary greatly; |
| exons (are unique sequences) | introns (may be repetitive); |
| smaller proportion of genome | higher proportion of genome; |

satellite DNA is repetitive;
repetitive sequences are used for profiling;
prokaryotes do not (usually) contain repetitive sequences

b. *Award **[1]** for each of these structures clearly drawn and labelled.*

four nucleotides shown in diagram with one nucleotide clearly labelled;

base, phosphate and deoxyribose (shown as pentagon) connected between the correct carbons and labelled at least once;

backbone labelled as covalent bond between nucleotides correctly shown as 3' to 5' bond;

two base pairs linked by hydrogen bonds drawn as dotted lines and labelled;

two H bonds between A and T and three H bonds between C and G;

adenine to thymine and cytosine to guanine; *do not accept initials of bases*

antiparallel orientation shown;

c. DNA sample obtained;

from hair/blood/semen/human tissue;

DNA amplified / quantities of DNA increased by PCR/polymerase chain reaction;

satellite DNA/highly repetitive sequences are used/amplified;

DNA cut into fragments;

using restriction enzymes/restriction endonucleases;

gel electrophoresis is used to separate DNA fragments;

using electric field / fragments separated by size;

number of repeats varies between individuals / pattern of bands is unique to the individual/unlikely to be shared;

*Award **[5 max]** for methods*

forensic use / crime scene investigation;
example of forensic use *e.g.* DNA obtained from the crime scene/victim compared to DNA of suspect / other example of forensic use;
paternity testing use *e.g.* DNA obtained from parents in paternity cases;
biological father if one half of all bands in the child are found in the father;
genetic screening;
presence of particular bands correlates with probability of certain phenotype / allele;
other example;
brief description of other example;
*Award **[4 max]** for aims*

# Examiners report

a. Knowledge of the nature of unique and repetitive sequences of DNA was very poor. Very few scored anywhere near full marks. Often odd marks could be picked up by linking widely separated comments, as descriptions of the two types were attempted. Where candidates possessed knowledge, some did not follow the command to distinguish the two types of sequences.

b. This was a difficult diagram to draw unless it had been well learnt and many showed that this had not been achieved. A few were good enough to get every possible mark and exceed the maximum. The antiparallel nature of the two strands, arrangement of base, phosphate and deoxyribose and the base pairing relationship were widely known. Individual nucleotides were almost never identified. Hydrogen bonds were indicated with a solid line suggesting that they were equivalent to covalent bonds. Sometimes the bases were only given as letters. Commonly, more than four nucleotides were shown.

c. It was clear that this was a popular section but accounts were still rather vague and unscientific. “Suspects can be identified” and “paternity can be decided” but without any indication of having a DNA sample first and then another with which to compare.
Very few mentioned using satellite /repetitive sequences in creating a DNA profile. Gel electrophoresis was often outlined but specifics were missing such as the use of restriction enzymes and the creation of a pattern of DNA fragments. Some accounts confused karyotyping and amniocentesis with DNA profiling.

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a. Draw a labelled diagram of *Escherichia coli* as an example of a prokaryote. [4]

b. Explain the process of transcription in prokaryotes. [8]

c. Some prokaryotes cause infectious diseases which stimulate the body’s immune system. Outline the principles that form the basis of immunity. [6]

# Markscheme

a. *Award [1] for each structure clearly drawn and correctly labeled.*

cell wall; *(with some thickness)*

plasma membrane; *(shown as single line or very thin)*

cytoplasm;

pilus/pili; *(shown as single lines coming from the cell wall)*

flagellum/flagella; *(thicker and longer than pili and embedded in cell wall)*

70S ribosomes; *(shown as small dots)*

nucleoid / naked DNA;

approximate width 0.5 μm / approximate length 2.0 μm;

*Award [3 max] if the bacterium drawn does not have the shape of a bacillus (rounded-corner rectangle with length approximately twice its width).*

*Award [3 max] if any eukaryotic structures included.*

b. transcription, synthesis of RNA identical to one strand/coding strand of DNA;

antisense stand acts as template/is transcribed;

RNA polymerase attaches to sequence of DNA known as promoter (region);

RNA polymerase separates the two strands of DNA;

(unwinding) exposes (10–20) DNA bases for pairing with RNA nucleotides;

RNA nucleotides matched to complementary bases;

adenine with uracil and cytosine with guanine / uracil replaces thymine;

H bonds between RNA nucleotide and complementary base on DNA strand;

(RNA) nucleoside triphosphates used;

hydrolysis of (two) phosphate molecules provides energy for reaction;

adds nucleotides to the 3′ end of RNA molecule/in 5′ → 3′ direction;

terminator is sequence of DNA signaling end of transcription;

RNA molecule separates completely from DNA;

*Award any of the above points for a clearly drawn correctly annotated diagram.*

c. skin and mucous membranes form barriers to pathogens as first line of defence;

macrophage recognizes antigens and ingests pathogen (in blood/body tissues);

presents antigen/MHC on cell surface;

macrophage activates helper T-cells that are complementary to antigen;

complementary B-cell becomes activated/stimulated by T-helper cells;

activated B-cell increases in size and divides by mitosis / creates clone of B-cells;

B-cells differentiate into plasma cells and memory cells; (both needed) plasma cells secrete specific antibodies;

memory cells remain/form basis of long-term immunity;

polyclonal response / multiple B-cells activated by different molecules of antigen;

*Award any of the above points for a clearly drawn correctly annotated diagram.*

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

# Examiners report

a. Although the general level of diagrams has been improving, there were still a few poorly labelled ones, especially not distinguishing clearly between the cell wall and the plasma membrane. There were many pili and flagella seemingly floating in space, and many with eukaryotic structures. Most correctly drew the bacillus shape correctly.

b. Well prepared candidates gave a very clear and precise account of transcription. However some still remain confused between transcription, translation and replication, so described the wrong process. One common error was to say that helicase instead of RNA polymerase separated the strands. At the end, many forgot that they were explaining the process in prokaryotes and described the mRNA leaving the nucleus.

c. Most knew that the stimulation of the immune system involved macrophages, and T and B cells, but only the better candidates could explain the process clearly.

---

a. Nitrogen is part of many important substances in living organisms. [3]

Draw labelled diagrams to show a condensation reaction between two amino acids.

b. Nitrogen is part of many important substances in living organisms. [4]

Distinguish between transcription and translation.

c. Nitrogen is part of many important substances in living organisms. [8]

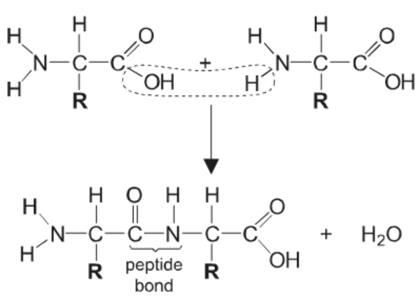
Explain how insects excrete nitrogenous wastes.

# Markscheme

a. a. at least one of the amino acid structures completely correct

b. peptide bond shown with N–C and C=O and N–H correct

c. release of water clearly shown




b. a. DNA is transcribed ***AND*** mRNA is translated

*Disallow the first mark, if a candidate gets transcription and translation the wrong way round, but allow marks after that up to **[3 max]***

b. transcription produces RNA ***AND*** translation produces polypeptide/protein

c. RNA polymerase used in only in transcription and ribosomes only in translation

d. transcription in the nucleus «of eukaryotes» and translation in the cytoplasm

e. tRNA needed for translation but not transcription

f. nucleotides linked in transcription and amino acids in translation

***OR***

sugar-phosphate/phosphodiester bonds in transcription and peptide bonds in translation

***[Max 4 Marks]***

c. a. excreted as uric acid

b. excretion by Malpighian tubules

c. nitrogenous waste/ammonia «accumulates» in hemolymph

d. nitrogenous waste/ammonia absorbed by Malpighian tubules

e. ammonia converted to uric acid

f. conversion to uric acid requires energy/ATP

g. high solute concentration in Malpighian tubules

***OR***

active transport of ions/Na+/K+ into Malpighian tubules

h. water absorbed by osmosis flushes uric acid/nitrogenous waste to «hind» gut

i. water/ions reabsorbed from the feces and returned to hemolymph

j. uric acid precipitates/becomes solid/forms a paste so can pass out with little water

k. uric acid excreted/egested with the feces

l. water conservation/osmoregulation

***OR***

reduces mass of water «in body»

m. uric acid is non-toxic

***[Max 8 Marks]***

# Examiners report

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

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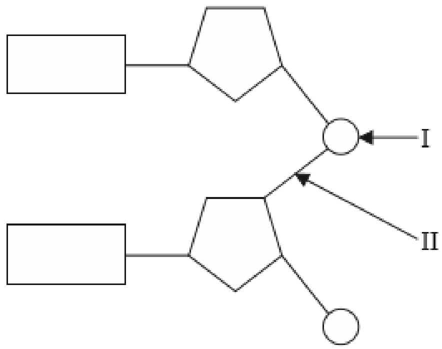
The diagram below shows two nucleotides linked together to form a dinucleotide.




a (i) Identify the chemical group labelled I. [1]

a (ii) State the type of bond labelled II. [1]

b. Distinguish between the sense and antisense strands of DNA during transcription. [1]

c. Compare the DNA found in prokaryotic cells and eukaryotic cells. [2]

# Markscheme

a (i) phosphate

a (ii) covalent / phosphodiester

b. only the antisense strand is transcribed / the antisense strand is transcribed to mRNA and the sense strand is not transcribed/has the same base sequence as mRNA (with uracil instead of thymine)

*To award [1], reference must be made to both strands and transcription.*

c.

| prokaryotic DNA | eukaryotic DNA |
|---|---|
| circular | linear; |
| in cytoplasm/nucleoid region | enclosed in nuclear membrane / in nucleus; |
| naked | associated with proteins/histones; |
| plasmids | no plasmids; |
| both prokaryotic and eukaryotic DNA consist of a double helix of (deoxy)nucleotides / phosphate, deoxyribose and base/ATC and G; | |

*Award marks for paired statements only. Answers do not need to be shown in a table format.*

# Examiners report

a (i) In part (i), virtually all students identified the phosphate group.

a (ii) Most were also able to identify the covalent or phosphodiester bond, although some stated it was an H bond.

b. This question was difficult for most students, although some wrote correct answers. In some scripts, students answered in terms of 3' → 5', whereas others did not refer to the two strands, nor did they relate them to transcription.

c. Few students got full marks as they did not compare relative characteristics. For example, it appears that many candidates interpret "naked" DNA as not being within a nuclear envelope. With this assumption, it is more difficult for them to gain mark on correct pairs of statements.

---

a. Draw a labelled diagram showing the ultra-structure of a liver cell. [4]

b. Distinguish between prokaryotic cells and eukaryotic cells. [6]

c. Explain prokaryotic DNA replication. [8]

# Markscheme

a. *Award **[1]** for each structure clearly drawn and correctly labelled. Whole cells not necessary.*

(plasma) membrane – single line surrounding cytoplasm;

nucleus – with a double membrane and pore(s) shown;

mitochondria(ion) – with a double membrane, the inner one folded into internal projections, shown no larger than half the nucleus;

rough endoplasmic reticulum – multi-folded membrane with dots/small circles on surface;

Golgi apparatus – shown as a series of enclosed sacs with evidence of vesicle formation;

ribosomes – dots/small circles in cytoplasm/ribosomes on rER;

lysosome;

*Award **[0]** if plant cell is drawn. Award **[2 max]** if any plant cell structure (e.g. cell wall) is present.*

b.

| prokaryotic | eukaryotic |
|---|---|
| naked DNA | protein associated with DNA; |
| DNA in cytoplasm / nucleoid / no nucleus | DNA in nucleus / nucleus present; |
| circular DNA | linear chromosomes/DNA molecules; |
| no mitochondria | mitochondria; |
| <u>70S</u> ribosomes present | <u>80S</u> ribosomes present; |
| no membrane bound organelles | internal membranes form organelles; |
| pili present | pili absent; |
| plasmids (sometimes) present | plasmids absent; |
| cell wall present | cell wall only present in <u>plants</u>/<u>fungi</u>;<br>*Do not accept cell wall sometimes present.* |
| flagella solid | flagella flexible/membrane-bound; |

c. DNA replication is semi-conservative / each strand of DNA acts as template;

(DNA) helicase separates two strands/forms a replication fork;

new strand built / nucleotides added in a 5' to 3' direction;

(deoxy)nucleoside triphosphates hydrolysed to provide energy for nucleotide formation/base pairing;

on one strand DNA polymerase III builds continuous strand;

on other strand short chains of DNA/Okazaki fragments are formed;

each short chain starts with RNA primer;

added by RNA primase;

then remainder of chain of DNA built by DNA polymerase III;

DNA polymerase I removes RNA primer and replaces it by DNA;

DNA ligase joins DNA fragments together forming complete strand;

replication only occurs at a single replication fork;

*Award credit for any of the above points clearly drawn and accurately labelled.*

# Examiners report

a. In the light of answers seen by examiners, perhaps the question should have given candidates a clearer pointer to what was expected. The quality of drawings was very variable. Marks were only awarded for structures clearly drawn and labelled. The mark scheme for this paper gives details of the criteria that examiners used. It was not necessary to draw a whole cell, as this would have involved drawing organelles repeatedly, but at least one of each organelle type, accurately drawn, was needed.

b. This was often answered by means of a table. This was particularly appropriate here as the question asked for prokaryote and eukaryote cell structure to be distinguished, rather than compared, so only differences were required. Tables help to ensure that candidates give both sides of a distinguishing feature. This approach only works if candidates fully understand the features, which they did not in some cases. For example, naked DNA in prokaryotes was often matched with DNA enclosed in a nucleus in eukaryotes, rather than with DNA associated with histone proteins. Mesosomes were given as an equivalent of mitochondria although most bacteriologists now regard the mesosome as an artefact of preparation for electron microscopy, rather than as a functionally significant structure. The current IB Biology programme does not refer to mesosomes.

c. This may also have discouraged answers from some candidates, as it referred to DNA replication in prokaryotes. This is how assessment statement 7.2.2 is phrased, so the wording of the question was acceptable, but there were some answers that showed some candidates had been confused. Some wrote about binary fission, about the replication of a circular DNA molecule, or even about the cell cycle and mitosis. However, stronger candidates coped extremely well and quickly amassed eight marks. The best answers explained the method of replication on the leading strand and then explained how and why the process was different on the lagging strand.

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a. Define the terms *chromosome*, *gene*, *allele* and *genome*. [4]

b. Compare the genetic material of prokaryotes and eukaryotes. [6]

c. Explain the process of DNA replication. [8]

# Markscheme

a. *chromosome:* structure formed by DNA and proteins;

*gene:* a heritable factor that controls a specific characteristic;

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

*genome*: the whole of the genetic information of an organism;

b.

| ***prokaryotic DNA*** | ***eukaryotic DNA*** |
|---|---|
| circular | linear; |
| one chromosome | many chromosomes; |
| not associated with proteins / naked DNA / no nucleosomes | associated with proteins / histones / nucleosomes; |
| plasmids present | no plasmids present; |
| no introns | introns and exons; |
| found in nucleoid region | contained in nucleus; |
| one replication/initiation point | many replication/initiation points; |
| mitochondrial and chloroplast DNA similar to prokaryotic DNA; | |
| both use DNA as their genetic material; | |

*Responses do not need to be shown in a table format.*

c. occurs during (S phase of) interphase/in preparation for mitosis/cell division;

DNA replication is semi-conservative;

unwinding of double helix/separation of strands by helicase;

hydrogen bonds between two strands are broken;

each strand of parent DNA used as template;

deoxynucleoside triphosphate provides energy;

synthesis continuous on leading strand but not continuous on lagging strand;

resulting in formation of Okazaki fragments (on lagging strand);

synthesis occurs in 5'→3' direction;

RNA primer synthesized on parent DNA using RNA primase;

DNA polymerase III adds the nucleotides (to the 3' end);

complementary base pairing;

adenine pairs with thymine and cytosine pairs with guanine; (*both pairings required*) (*do not accept letters alone*)

DNA polymerase I removes the RNA primers and replaces them with DNA;

DNA ligase joins Okazaki fragments/seals nicks (in sugar-phosphate backbone);

*Accept any of the above points shown in a clearly annotated diagram.*

# Examiners report

a. This was the most popular question by far. It also tended to be the best answered. Most candidates were attempting to describe chromosome, gene, allele and genome, rather than defining as asked. The definitions in the syllabus were expected or very close alternatives.

b. Better-prepared candidates scored well on part b, being able to competently compare the genetic material in prokaryotes and eukaryotes. Weak answers were caused by missing the word "genetic material" and just compared the two, scoring very few marks. A large number inappropriately defined naked DNA as being DNA that is not enclosed within a nucleus rather than DNA that is not associated with histones.

c. The explanation of DNA replication was well known by all but the least well prepared candidates. Many gave answers of textbook quality. It should be mentioned that if diagrams are included they should be clear and well labelled.

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a. Draw molecular diagrams to show the condensation reaction between two amino acids to form a dipeptide. [4]

b. Outline the roles of the different binding sites for tRNA on ribosomes during translation. [4]

c. Explain the production of antibodies. [7]

# Markscheme

a. a. each amino acid with a COO–/COOH group at one end ***AND*** a $NH_2/NH_3^+$ at the other

*Both needed*.

*mp a requires the double bond to be shown between the C and O*.

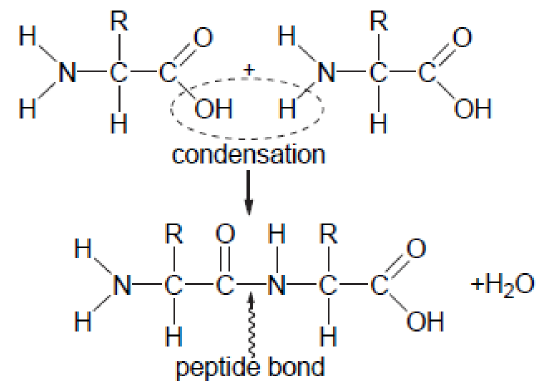
b. CH in middle with H or R group attached

c. peptide bond correctly drawn between N and C=0

d. COO–/COOH group at one end of dipeptide ***AND*** $NH_2/NH_3^+$ at other end
*Both needed*.

e. loss of water

*eg:*




b. a. A, P and E binding sites are on the large subunit of the ribosome

b. initiation of translation starts with binding of met-tRNA to the start codon

c. large sub-unit binds with «start» tRNA in the P site

d. A binding site holds the tRNA with the next amino acid to be added

e. peptide bond is formed between the amino acids of the A site and the polypeptide at the P site

f. polypeptide is transferred to the tRNA in the A site

g. the tRNA «with polypeptide» in A site then moves to P site
***OR***
P binding site holds the tRNA attached to the growing polypeptide

h. E binding site «exit» is where the tRNA «from P site without amino acid» leaves the ribosome

*Accept annotated diagrams of the sites*.

c. a. each antibody corresponds to a specific antigen

b. antibodies are necessary for immunity/resistance to «infectious» disease

c. macrophage/phagocyte ingests/engulfs pathogen

d. macrophage/phagocyte digests pathogen

e. macrophage/phagocyte displays antigen from pathogen

f. antigens of a pathogen correspond to a specific T lymphocytes/cells
***OR***
T lymphocytes/cells are activated by antigen binding

g. T lymphocytes/cells activate B lymphocytes/cells

h. «B cells» divide by mitosis to form many/clones of plasma cells

i. plasma cells secrete specific antibody

j. some «activated» B lymphocytes/cells act as memory cells

*Accept annotated diagrams of the process*

# Examiners report

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

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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

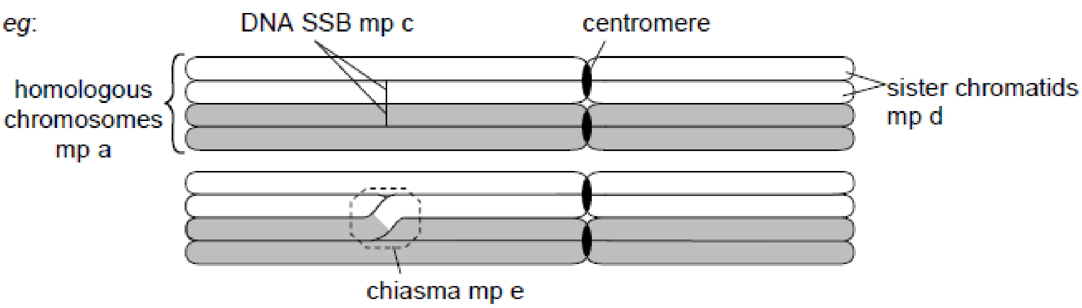
d. non-sister chromatids labelled
***OR***
sister chromatids labelled

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.*

*eg:*




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]

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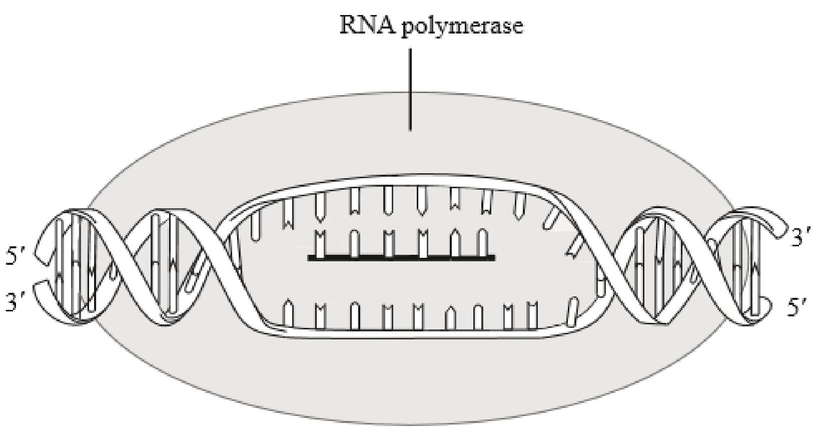
The diagram below shows the process of transcription.




a. DNA replication involves a number of enzymes including DNA polymerase. Identify **one** other enzyme involved in DNA replication. [1]

b. Explain the role of Okazaki fragments in DNA replication. [2]

c (i) Label the sense and antisense strands. [1]

c (ii) Draw an arrow on the diagram to show where the next nucleotide will be added to the growing mRNA strand. [1]

# Markscheme

a. helicase / RNA primase / (DNA) ligase

b. DNA fragments/sections (formed) on the lagging strand;

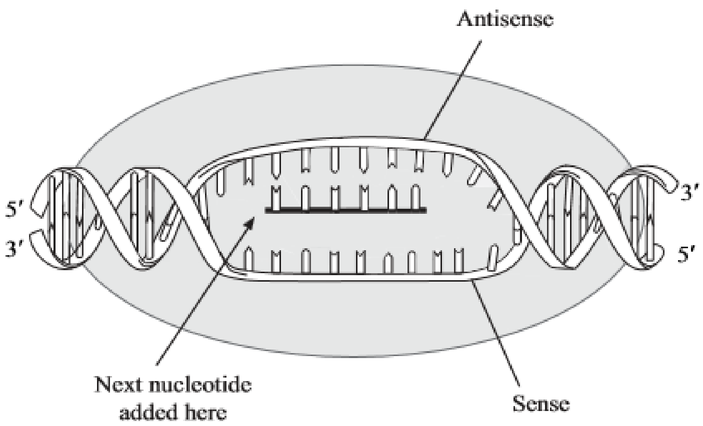
because replication must be in the 5' –3' direction;

replication starts repeatedly and moves away from replication fork;

c (i)both strands clearly labelled

*Check carefully whether the correct strand has been labelled if the labels are shown in helical parts of the DNA.*

*Reject if the sense strand label points to the mRNA.*




c (ii)a clearly drawn arrow pointing at the free 3' end of the mRNA strand or to the first free nucleotide on the antisense strand to the left of the mRNA or to a nucleotide added by the candidate to the left hand end of the mRNA

# Examiners report

a. All but the weakest candidates were able to name an enzyme involved in DNA replication.

b. This question discriminated very well with the best candidates writing authoritatively about Okazaki fragments, but weaker candidates struggling. Some teachers felt that the word role was inappropriate here, but any answer explaining that Okazaki fragments are formed on the lagging strand because nucleotides can only be added in a 5' to 3' direction would have scored both marks. A common error was to refer to the lagging strand as the antisense strand. This is not correct -on a DNA molecule the lagging strand is the antisense strand for some genes and the sense strand for others.

c (i)About half of the candidates knew that the transcribed strand is the antisense strand, with the others either getting the strands the wrong way round or thinking that the mRNA was either the sense or the antisense strand.

c (ii)When asked in part (ii) to show where the next nucleotide will be added to the mRNA strand the weakest candidates labelled various places other than an end of the mRNA; of the other candidates, more than half labelled the right hand end, whereas the left hand was the 3' terminal so that is where the 5' end of a nucleotide would be added.

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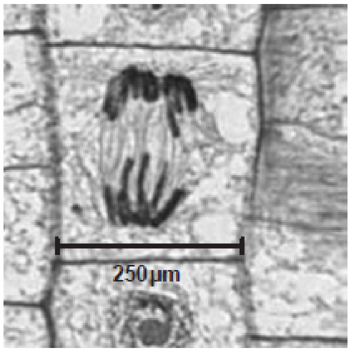
The micrograph shows a cell from the root of an onion (*Allium cepa*) during mitosis.




[Source: adapted from http://img.ehowcdn.com]

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

a(ii)Deduce the stage of mitosis shown in the micrograph. [1]

a(iii)The onion (*Allium cepa)* is an angiospermophyte. The honey bee (*Apis mellifera*) is an arthropod. State **three** structural differences between the cells of an onion and a honey bee. [2]

b. State what is indicated by the presence of polysomes in a cell. [1]

# Markscheme

a(i).136 *(accept answers in the range of 132 to 140)*

a(ii)anaphase

a(iii).

| onion cell | honey bee |
|---|---|
| cell wall | no cell wall; |
| chloroplast | no chloroplast; |
| large vacuole | no large vacuole; |
| fixed shape | no fixed shape; |
| starch stored | glycogen stored; |
| no centrioles/no centrosomes | has centrioles / has centrosomes; |

*Award **[1]** for two correct, **[2]** for three correct answers.*

*To award the mark both parts of a comparison must be stated explicitly or unambiguously implied.*

b. much protein of one type needed/produced by polysomes;

mRNA is being repeatedly translated;

# Examiners report

a(i).About half of candidates calculated the magnification of the image correctly. Those that did not were usually one more orders of magnitude away from the answer. A common problem was the use of centimetres rather than millimetres to measure the size of the scale bar image. This very often leads to an error of one order of magnitude.

a(ii)This was well answered with more than 90% of candidate recognising that the cell was in anaphase.

a(iii)This was also well answered by many candidates with each of the three statements in the answer referring both to honey bee cells and to onion cells. A few only mentioned one organism or the other so failed to score any marks. It is not enough to imply a difference in questions such as this – the difference should be stated explicitly.

b. This was very poorly answered with fewer than 25% of candidates knowing that polysomes are groups of ribosomes that are translating the same mRNA, which indicates that the cell needs multiple copies of one particular polypeptide.

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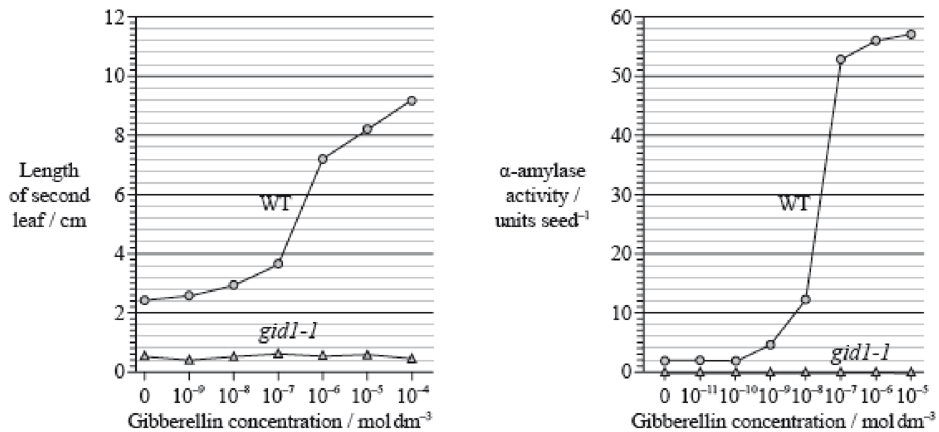
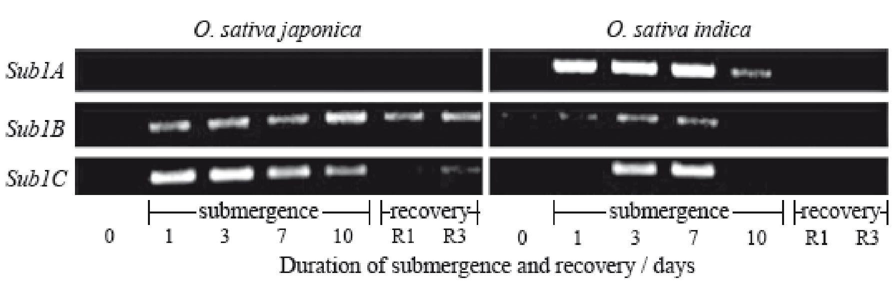
Gibberellin promotes both seed germination and plant growth. Researchers hypothesize that the gene *GID1* in rice (*Oryza sativa*) codes for the production of a cell receptor for gibberellin. The mutant variety *gid1-1* for that gene leads to rice plants with a severe dwarf phenotype and infertile flowers 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.

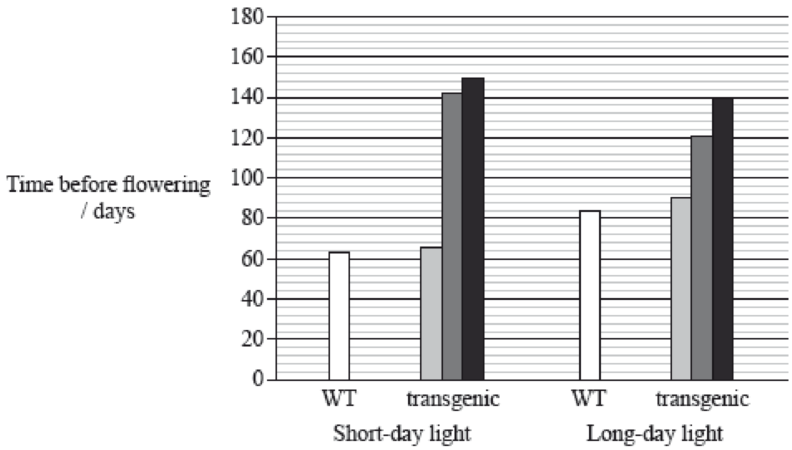



[Source: Adapted from "Sub1A is an ethylene-response-factor-like gene that confers submergence tolerance to rice" (2006) Kenong Xu, Xia Xu, Takeshi Fukao, Patrick Canlas, Reycel Maghirang-Rodriguez et al. Nature, 442, pp. 705—708. Adapted by permission from Macmillan Publishers Ltd (c) 2006.]

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.

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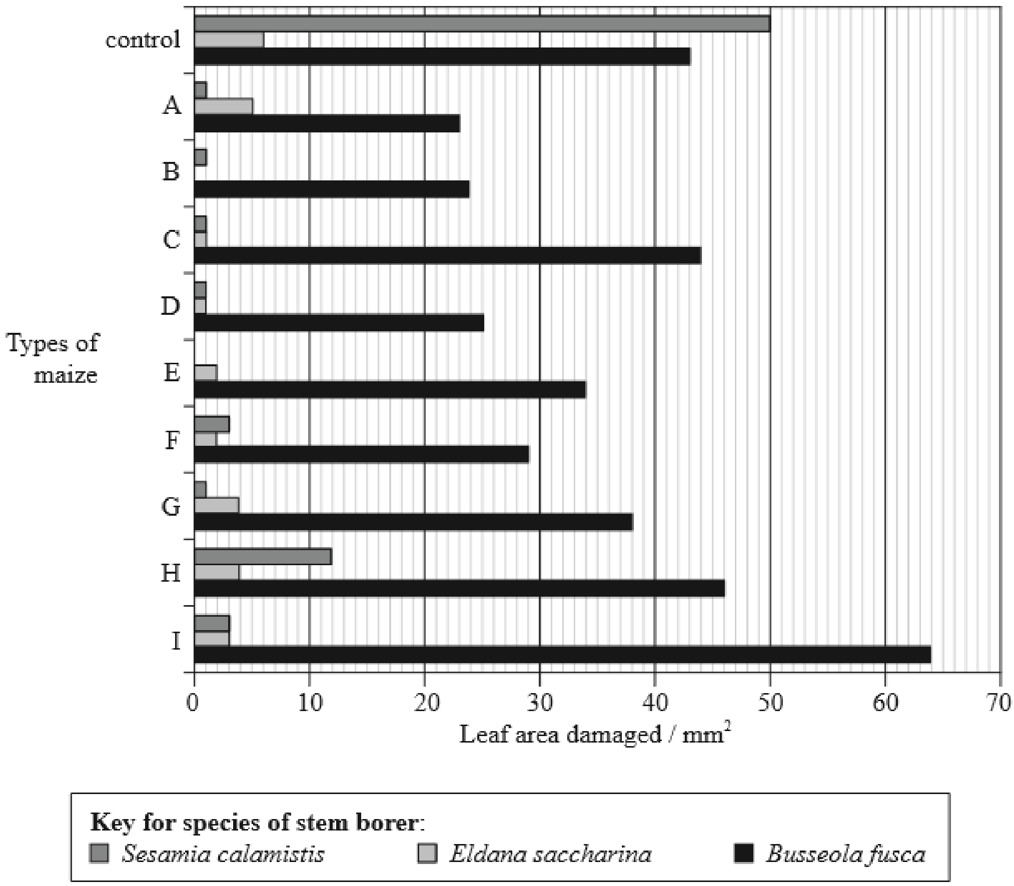
Genetic engineering allows genes for resistance to pest organisms to be inserted into various crop plants. Bacteria such as *Bacillus thuringiensis* (Bt) produce proteins that are highly toxic to specific pests.

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.

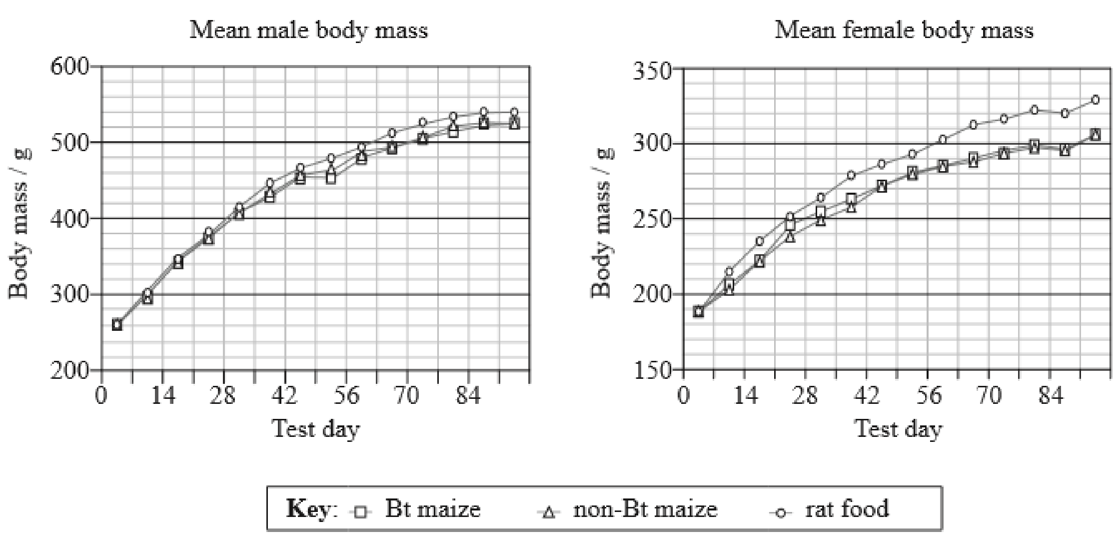



[Source: adapted from S Mugo, *et al.*, (2005), *African Journal of Biotechnology*, **4** (13), pages 1490–1504]

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 adult male and 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]

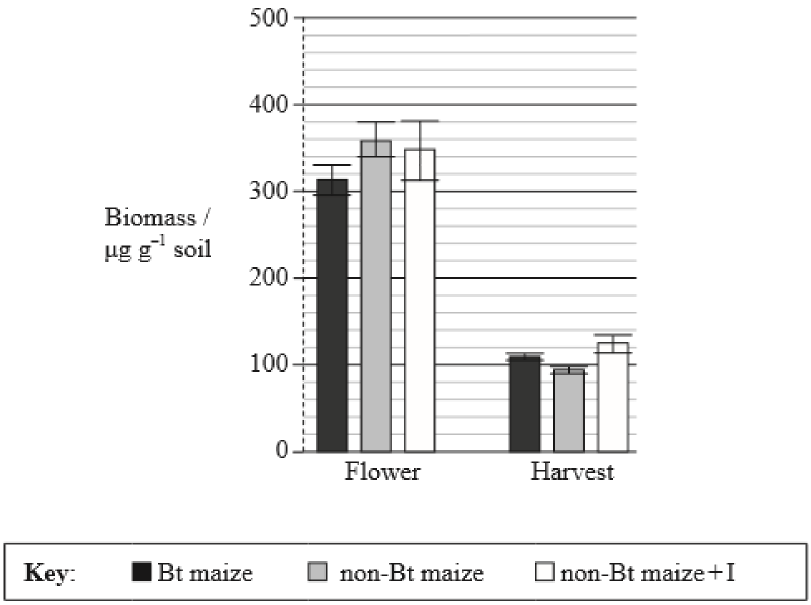
Studies have shown that Bt proteins are released by plant roots and remain in the soil. One study looked at the biomass of microorganisms in soil surrounding the roots of:

• Bt maize

• non-Bt maize

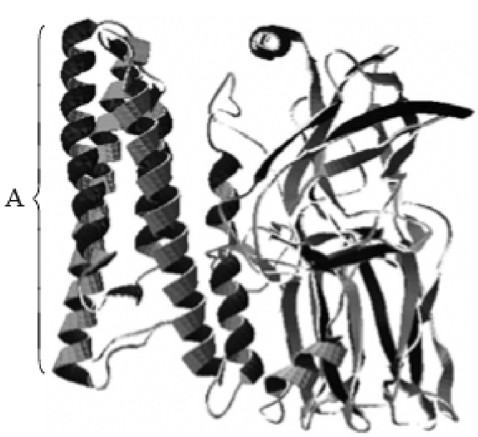
• non-Bt maize with an insecticide (I).

The graph below shows the biomass of microorganisms at two different times in the growth cycle of the plants (Flower and Harvest). Error bars represent standard error of the mean.




[Source: adapted from M Devare, *et al.*, (2007), *Soil Biology and Biochemistry*, **39**, pages 2038–2047]

Bt proteins act as toxins to insects, primarily by destroying epithelial cells in the insect's digestive system. Below is the three-dimensional structure of one such protein.




[Source: M Soberon, *et al.*, (2007), *Toxicon*, **49**, pages 597–600]

a. Calculate the percentage difference in leaf area damaged by *Sesamia calamistis* between the control and maize type H. Show your working. [2]

b. Discuss which species of stem borer was most successfully controlled by the genetic engineering of the maize plants. [3]

c. Calculate the change in mean mass of male and of female rats fed on Bt maize from day 14 to 42. [2]

d. Evaluate the use of Bt maize as a food source on the growth of the rats. [2]

e. Comment on the use of Bt maize as a food source compared to the other diets tested. [1]

g. Compare the biomass of microbes in the soils surrounding the roots of Bt maize and non-Bt maize. [2]

h. The researchers' original hypothesis stated that microorganisms would be negatively affected by the Bt protein released by the plant roots. [2]

Discuss whether the data supports the hypothesis.

i (i). State the type of structure shown in the region marked A in the diagram above. [1]

i (ii) Outline how this structure is held together. [2]

i (iii) Region A inserts into the membrane. Deduce, with a reason, the nature of the amino acids that would be expected to be found in this region. [2]

# Markscheme

a. 50 12 38 (mm ); *Accept 12 50 = 38*

(38 50) 100 ( )76(%); (ECF)

b. *Sesamia* (was most successfully controlled);

in control plants *Sesamia* caused most damage;

all types of Bt/genetically modified maize/A–I show (significant) decrease in damage by *Sesamia*;

mark for correct numerical <u>comparison</u>;

*Sesamia* caused no damage to type E/ in one instance;

*Busseola* not controlled/affected by Bt/genetically modified maize/caused largest amount of damage in types A–I/increased damage in some varieties;

*Eldana* controlled by some types of maize / B/C/D but not others / *Eldana* caused least damage in control and not much difference in many maize types;

c. *males*: (440 – 325 =)115g ; (*Accept answers in range 105–125 g*)

*females*: (268 – 215 =)53g ; (*Accept answers in range 51–57 g*)

*Units required, no workings required*.

d. (promotes) highest rate of growth at start of study / tapering off later in the study;

Bt maize appears to cause less growth/mass gain than rat food / vice versa;

more pronounced difference in females;

no difference in growth/mass gain between Bt and non-Bt maize;

e. (Bt) maize may not be as good as the (commercially prepared) rat food;

Bt maize appears to be as good a food source as non-Bt maize;

Bt maize an acceptable/safe food source;

*Answers require a judgement about Bt maize as a food source rather than a description.*

g. (for both groups) overall biomasses were higher during flowering than harvest / vice versa

the microbial biomass for the Bt crop was (slightly) lower than for the non-Bt crops at flower time;

the microbial biomass for the Bt crop was (slightly) higher than for the non-Bt crops at harvest time;

h. data does not support the hypothesis as there is little difference between biomass found in the soil (surrounding) roots (of the Bt and non-Bt) at either time;

data does not support the hypothesis as there is a slightly positive effect at harvest;

data supports hypothesis as there is a slightly negative effect at flowering;

i (i). helix / alpha helix

i (ii) hydrogen bonds;

between the turns of the helix (rather than between R-groups);

bonds between carboxyl and NH groups/C-O---H-N;

i (iii) non-polar amino acids/R-groups;

(inner part of phospholipid) bilayer is hydrophobic/non-polar;

# Examiners report

a. In comparison to similar questions in previous years, candidates were relatively successful in answering this question. Where candidates did not answer correctly, it was due to a lack of ability to calculate percent difference rather than a problem with interpreting the data.

b. Most candidates scored at least one mark. A common error was to interpret the results without comparison to the control.

c. Most candidates calculated the mean masses correctly and included the correct units.

d. Most candidates scored at least one mark. A common error was to focus on the difference between male and female rats rather than the food source and to not make reference to growth.

e. Most candidates gained the mark, but some simply repeated their answer to (d). The command term "comment" requires candidates to give a judgment. Commonly, candidates mistakenly described the data in response to this command term.

g. Most candidates gained both the marks by recognizing the difference between harvest and flowering. Like answer (f), word choice affected performance with candidates referring to the biomass of flowers for example rather than biomass of soil microbes.

h. Many candidates scored both marks. A common error was to answer without reference to the hypothesis.

i (i). Many candidates identified the alpha helix, though a surprising number referred to the double helix.

i (ii) Most candidates identified hydrogen bonds as stabilizing the structure but very few could identify the parts of the molecule that were connected by H-bonds.

i (iii) Only a minority of candidates recognized the importance of the hydrophobic nature of membrane proteins.