HL Paper 2

a. Distinguish between autotrophs and heterotrophs. [2]

b. Define *saprotroph*. [1]

c (i) State an external feature that is different in: [1]

Cnidaria and Mollusca.

c (ii) State an external feature that is different in: [1]

Mollusca and Annelida.

Markscheme

a. autotrophs make their own food/organic molecules/organic matter and heterotrophs feed on/obtain their food/organic molecules from other organisms;

autotrophs use/require inorganic molecules/CO_2 and heterotrophs require (complex) organic molecules;

b. an organism that lives on/in non-living/dead (organic) matter and secretes digestive enzymes/digestive juices into it / *OWTTE*

c (i) Cnidaria have radial symmetry while Mollusca have bilateral symmetry;

Cnidaria have tentacles/nematocysts/stinging cells while Mollusca do not;

Mollusca (may) have a (hard) shell while Cnidaria do not;

Mollusca have a mouth and anus while Cnidaria have only one opening;

Mollusca have a muscular/large foot while Cnidaria do not;

other valid external difference;

c (ii) Annelida are segmented while Mollusca are not (visibly segmented);

Annelida may have bristles/chetae/chaetae while Mollusca do not;

Mollusca (may) have a (hard) shell while Annelida do not;

Mollusca have a muscular/large foot while Annelida do not;

other valid external difference;

Examiners report

a. Nearly all candidates knew something about autotrophs and heterotrophs but answers tended to be too loose to score many marks. A common error was to suggest that plants make energy.

b. Fewer than half of candidates were able to state what a saprotroph is. Answers had to make it clear that saprotrophs feed on dead organic matter by external digestion, to exclude detritivores that ingest dead matter.

c (i) Candidates were evenly divided between those who had no idea of the external features of Cnidaria, Annelida and Mollusca, those who knew some of their features but failed to score marks because they did not give both sides of the comparison and those who gave correct and full comparisons.

c (ii) Candidates were evenly divided between those who had no idea of the external features of Cnidaria, Annelida and Mollusca, those who knew some of their features but failed to score marks because they did not give both sides of the comparison and those who gave correct and full comparisons.

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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. Draw a labelled diagram of a mature human egg. [5]

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

c. Explain how evolution may happen in response to environmental change with evidence from examples. [8]

Markscheme

a. *Award **[1]** for each structure accurately drawn and correctly labelled.*

a. haploid nucleus;
b. cytoplasm – with nucleus-to-membrane distance >4 times nucleus diameter;
c. centrioles – two must be shown but only one needs to be labelled;
d. cortical granules – needs to be drawn in vicinity of plasma membrane;
e. plasma membrane – shown as a single line and approximately circular overall;
f. polar cell / (first) polar body – needs to be drawn outside the egg cell;
g. zona pellucida / layer of gel (outside the cell membrane);
h. follicle cells / corona radiata (outside the cell membrane);
i. size shown as 100 μm/0.1mm; *(accept 90 μm to 120 μm)*

b. a. plasmid used for gene transfer/removed from bacteria;
b. plasmid is a small/extra circle of DNA;
c. restriction enzymes/endonucleases cut/cleave DNA (of plasmid);
d. each restriction enzyme cuts at specific base sequence/creates sticky ends;
e. same (restriction) enzyme used to cut DNA with (desired) gene;

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

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

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

c. a. variation in population;

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

c. valid example of variation in a specific population;

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

e. competition / struggle for resources/survival;

f. example of competition/struggle for resources;

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

h. example of changed environment and adaptation to it;

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

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

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

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

m. evolution by natural selection;

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

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

Examiners report

a. Of the four drawings on this exam, the egg drawings were in general the weakest. The nucleus was in almost all cases far too large and cortical granules were often distributed throughout the cytoplasm rather than being located close to the plasma membrane. Structures outside the plasma membrane were often muddled, perhaps because it was necessary to use three or more concentric circles to represent them.

b. Strong candidates had no difficulty in scoring full marks here by describing gene transfer using plasmids, restriction enzymes and DNA ligase. The weakest candidates wrote on a wide range of other topics.

c. Answers ranged from impressive, with a secure understanding of evolution by natural selection and effective use of examples, to very confused. In contrast to some previous exams most candidates chose appropriate examples such as the evolution of antibiotic resistance in bacteria or the development of melanism in peppered moths. Descriptions of the development of the giraffe's neck or speciation in Galapagos finches were not accepted because they do not correspond with any specific environmental change for which we have good evidence. It is particularly important to base accounts of evolution on strong evidence rather than speculation, because of the objections to the theory that are still being raised.

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a. Describe the relationship between the rise in the concentration of atmospheric carbon dioxide and the enhanced greenhouse effect. [5]

b. Outline the precautionary principle. [5]

c. Antibiotic resistance in bacteria is an example of evolution in response to environmental change. Using another example, explain how an environmental change can lead to evolution. [8]

Markscheme

a. CO_2 is a greenhouse gas;

increases in CO_2 increase/enhance the greenhouse effect;

greenhouse effect is a natural phenomenon but not its increase;

Earth receives short wave radiation from the sun;

reradiated from Earth as longer wave radiation/infra red/heat;

CO_2 /greenhouse gases trap/absorb longer wave radiation/infra red/heat;

global warming happened during same time/period as CO_2 rise;

CO_2 concentration correlated (positively) with global temperature / global temperature increases as CO_2 concentration increases;

(causal) link accepted by most scientists;

no proof that man-made increases in CO_2 have caused global warming;

b. those proposing something must prove that it causes no harm;

before they start to do it;

objectors do not have to prove that there will be harm;

activities that risk/threaten/may cause harm are banned;

trials/tests must be done first;

precautionary principle is applied when possible consequences are severe;

precautionary principle should be used in the case of global warming;

action should be taken to reduce CO_2 emissions before proved it is the cause;

another example of implementation of the precautionary principle;

c. natural selection (in correct context);

better-adapted individuals survive/more likely to survive;

more reproduction/genes passed on by better adapted individuals;

name of species; (*accept even if remainder of answer is invalid*)

description of original/decreasing phenotype;

type of environmental change that led to evolution;

consequence of environmental change

description of new/increasing phenotype;

genetic basis of phenotypes;

reason for new phenotype being better adapted;

detail of reason for adaptedness of new phenotype;

The following has been provided as an example answer.
great tit;
bird that lays its eggs in spring;
global warming/climate change;
more caterpillars (on trees) in early spring;
laying eggs earlier in spring;
time of egg laying is (partly) genetically controlled;
eggs laid early hatch at start of period of greatest food abundance;
more young can be fed/young grow faster/fewer deaths;

Examiners report

a. Answers to part (a) were varied but mostly were rather weak, with confusion about long wave and short wave radiation and between the greenhouse effect and ozone depletion. Most answers explained the greenhouse effect in general terms and only a few really described the relationship between the rise in atmospheric carbon dioxide and the enhanced greenhouse effect. The best answers explained that the greenhouse effect is a natural phenomenon but that there was been an anthropogenic increase in carbon dioxide concentrations that is positively correlated with global warming. Although not proven, almost all climate scientists accept that there is a causal link.

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b. Part (b) was also poorly answered on the whole, with much evidence of guesswork rather than secure understanding. The term precautionary principle has been used in different ways and a teacher"s note was therefore inserted in the current IB Biology programme, to make clear what is expected in answers to IB Biology questions. Teachers are encouraged to follow the guidance in that note.

c. Part (c) of this question was also poorly answered. Fewer than half of candidates gave an acceptable example of evolution in response to environmental change. Candidates were expected to give a real and well documented example, with the species named and the precise environmental change explained. Resistance to a named pesticide in a named pest species was acceptable for example, but not accounts of how resistance might develop in general. Giraffes were not accepted as an example, as their evolution cannot be tied in to any proven and specific environmental change. The human examples that were seen in candidates' answers were also not accepted.

Many candidates' answers were vague and confused and in some cases were based on guesswork, in the hope that examiners might not realise. It is of course unacceptable to fabricate examples and evidence in science, whether in an exam or any other situation. Particularly with evolution, any assertion that we make should be based on reliable evidence. Despite these negative comments about the quality of answers, some were excellent with a clear explanation of how the characteristics of a species can change by natural selection when the environment of a species has changed.

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a. Outline the types of evidence that can be used to support the theory of evolution. [4]

c. Explain **two** examples of evolution in response to an environmental change. [8]

Markscheme

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

a. fossils (give evidence of evolution);
b. fossils show different species existed in the past/species changed over time;
c. selective breeding of (domesticated) animals/crop plants;

d. selective breeding shows that (artificial) selection can cause rapid change;
e. homologous (anatomical) structures/vestigial organs (give evidence of evolution);
f. homologous structures/pentadactyl limbs/other example show common ancestry;
g. DNA/base/amino acid sequences show (common) ancestry/species diverged;

Do not award marks for examples of evolution in response to environmental change such as melanism as this is tested in part (c) of this question.

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

For each example:
a. a named example of a species that has evolved in this way;
b. description/clear statement of the change that occurred in the environment;
c. description/clear statement of different varieties (that existed at the same time);
d. explanation of/reason for one variant having a selective advantage;
e. the change in the population/species due to natural selection/evolution;
Do not award the last mark if the change is explained using Lamarckism rather than natural selection.

Example:
f. *Staphylococcus aureus*/MRSA/*Clostridium difficile*/other named species;
g. introduction/use of an antibiotic/named antibiotic;
h. some bacteria were resistant and others were not;
i. resistant bacteria survived (and multiplied) while non-resistant were killed;
j. percentage of the population showing resistance increased;

***[8]** can be awarded if the candidate scores **[5]** for one example and **[3]** for the other.*
Do not accept examples where the evidence of evolution comes from fossils, or where the variation is not heritable.

Examiners report

a. There were some good accounts of the types of evidence for evolution. Nearly all mentioned fossils and many also included homologous structures. One fault in some answers was to include examples where natural selection can be used to explain phenomenon but which in themselves do not provide convincing evidence for evolution because there are other possible explanations.

c. Answers to this part of the question were also poor in many cases. Science must be based on evidence that is as strong as possible. This is especially true with evolution, where many non-scientists remain to be convinced. Much of the evidence presented by candidates here would convince no-one, with inaccurate and in some cases invented examples. Only cases based on known environmental change were accepted, so for example supposed increases in the height of trees and a consequent lengthening of the necks of giraffes was not accepted, nor hypotheses about human evolution. There were many very vague accounts of Galapagos finches which did not include any reference to environmental change. El Niño and La Niña cause environmental change in the Galapagos archipelago and evolution in response is well researched but this evidence was rarely included in answers. The case of the peppered moth was often cited and some answers described it well. The other case that was successfully described was the development of antibiotic resistance in bacteria.

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]

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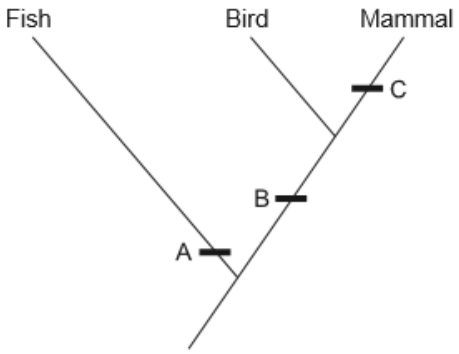
a. The image shows part of a cladogram. [3]



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** <u>four</u> 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.

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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]

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a. Outline how antibiotic resistance in bacteria can arise in response to environmental change. [5]

b. Outline the principle of immunity. [6]

c. Discuss the benefits and dangers of vaccination. [7]

Markscheme

a. antibiotic resistance can be inherited;

alleles for resistance can be passed from one cell to another by exchange of plasmids/conjugation;

some varieties are more resistant than others;

bacteria reproduce very rapidly and have high mutation rate;

evolution can occur rapidly;

increased exposure to antibiotics is the environmental change that selects for resistant varieties;

for example, in hospitals / animal feed / inappropriate prescriptions / not finishing prescriptions;

bacteria without resistance die / resistant bacteria survive and pass on genes to next generation;

results in change in genetic makeup of population;

b. immunity is the ability of an organism to resist infection;

due to presence of (specific) antibodies;

immunity can be active or passive;

passive due to receiving antibodies from external sources/across placenta/from breast milk/injection;

active results from facing an infection directly/through vaccination;

pathogen/foreign cell invades body;

leads to clonal selection/formation of B memory cells;

B-cells produce specific antibodies;

if same pathogen enters body again memory cells activated/stimulated to divide;

antibodies produced faster and in greater amounts;

c. *Benefits:* ***[4 max]***

immunity results

can limit pandemics/epidemics/spread of (infectious) diseases;

diseases can be eradicated/smallpox eliminated;

reduces mortality/deaths due to disease;

can protect vulnerable groups/young/old/with other conditions;

decrease crippling effects of diseases (such as polio);

decreased health care costs;

Dangers: ***[4 max]***
may produce (mild) symptoms of the disease;
human error in preparation/storage/administration of vaccine;
individual may react badly to vaccine / defective immune system / hypersensitive/allergic reaction;
immunity may not be life-long/booster required;
possible toxic effects of mercury-based preservatives/thimerosal;

Examiners report

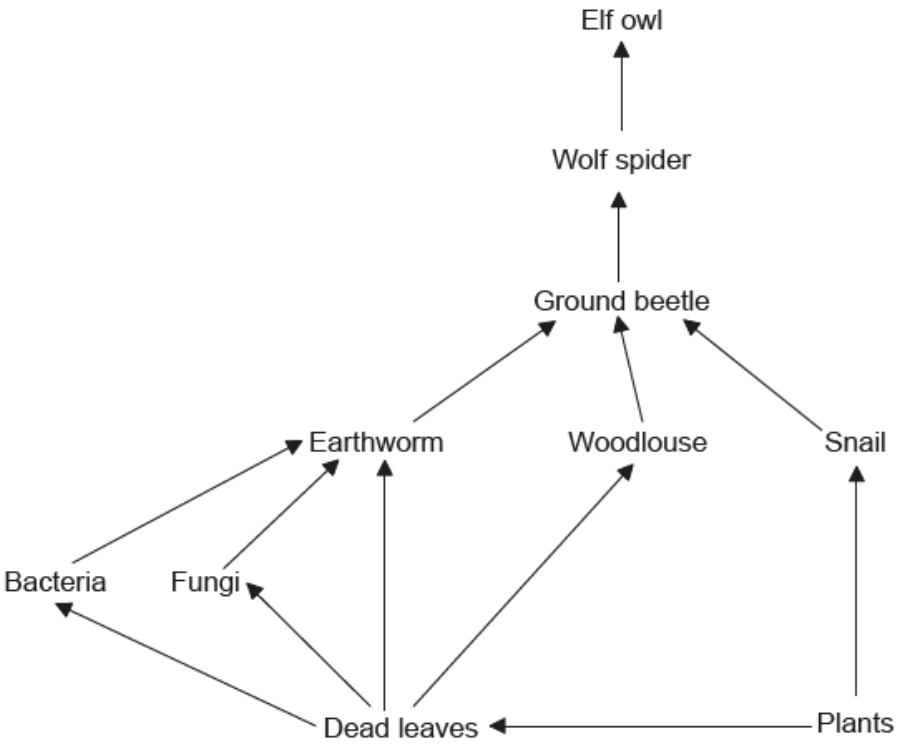
a. Most candidates scored few marks, failing to mention gene transmission in bacteria, variation, or widespread use of antibiotics as the environmental change.

b. Surprisingly few candidates could define immunity well. Some detailed accounts of how immunity is gained were given, but failure to describe accurately what happens if the same pathogen enters again or the different types of immunity meant that many candidates gained a low score.

Vague, rambling accounts about T and B cells were provided quite often. There was too much detail on the sequence of events leading to the development of memory cells (named as T or B) and less on how this resulted in immunity. Antibodies and antigens were sometimes confused.

c. Candidates were generally better at giving the benefits rather than the dangers, but few candidates could give four of both. Misunderstanding about vaccinations was common which is quite a worry for candidates who have been through an advanced biology course. Many mentioned autism without substantiation.

The image shows a food web.



[Source: © International Baccalaureate Organization, 2017]

a.i. Using the food web, identify a detritivore. [1]

a.ii. Using the food web, identify a saprotroph. [1]

b. State the name of the domain to which birds, such as the Elf owl, belong. [1]

c. Outline the energy flow through this food web. [3]

Markscheme

a.i. earthworm/woodlouse

a.ii. bacteria/fungi

Do not accept protozoans or nematodes as they are consumers.

b. eukaryote/eukaryota/eukarya

c. a. light energy of Sun is converted by plant/autotroph to chemical energy «in carbon compounds through photosynthesis»

b. detritivores/saprotrophs decay plant material «that accumulates in the soil» to obtain energy *OWTTE*

c. consumers release energy from the carbon compounds by cell respiration energy lost as heat

d. energy is used by organisms for metabolism

e. energy is transferred between organisms/trophic levels through the food chains/web
For mp e, accept specific example such as energy is transferred from primary to secondary consumer etc.

f. energy is lost at each trophic level «so lengths of food chains/web are restricted»
OR
approximately 80/90 % of energy is lost «between trophic levels»
Vice versa

Award mark points that refer to the specific organisms from this food web.

Examiners report

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

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 and tunica present, sugary /

$\frac{T \quad e}{t \quad e}$ and $\frac{t \quad E}{t \quad e}$ *(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.

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

b. Compare the processes of spermatogenesis and oogenesis [8]

c. Describe the consequences of the potential overproduction of offspring. [5]

Markscheme

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

b. testes/testis/testicles – *shown inside scrotum*;

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

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

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

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

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

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

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

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

a. both produce haploid cells / both produce (mature/male/female) gametes;
b. both have mitosis at start/in epithelium / both involve mitosis and meiosis;
c. both have cell growth before meiosis;
d. both involve differentiation (to produce a specialised gamete);

	Comparison	Oogenesis	Spermatogenesis
e.	what is produced where	eggs/ova produced in the ovaries	sperm (atozoa) produced in the testes;
f.	when the process starts/is initiated	during development of embryo/fetus	during puberty/adolescence;
g.	if there are breaks in meiosis	breaks occur in prophase I/ prophase II/ metaphase II	no breaks;
h.	if cytokinesis during meiosis is equal	cytoplasm split unequally / larger cell and smaller cells	equal division of cytoplasm;
i.	number of gametes per meiosis	one cell/egg (per meiosis) / some become polar bodies	four sperm (per meiosis) / all cells become sperm;
j.	number of gametes produced/released	one (usually) at a time/per month/per menstrual cycle	many/far more/(hundreds of) millions daily/at a time;
k.	timing of release	on about Day 14/in middle of menstrual cycle/at ovulation	continuously (from testis) / by ejaculation/intercourse;
l.	if gametogenesis ever stops	stops (at menopause)	goes on (throughout adult life/until death);

A table is not required but both statements in one row of the table above must either be explicitly stated or clearly implied for each mark awarded.

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

a. more (offspring) than the environment can support / carrying capacity reached;
b. increased mortality/lower life expectancy/more deaths;
c. competition (for resources) / struggle for survival;
d. food/mates/nest sites/territory/other example of resource shortage / example of greater need;
e. variation between members of population / example of variation;
f. better adapted more likely to survive / converse; (reject Lamarckian statements such as those who adapt survive)
g. better adapted reproduce / pass on (favourable) genes/traits / converse;
h. natural selection / (survival of fittest) leads to evolution;

Examiners report

a. Structure of the male reproductive system

As so often in past papers, the diagrams of the male reproductive system were very poor. Many candidates were worryingly ignorant about the internal structure, with organs shown incorrectly or not at all. Connections between the parts of the reproductive system were often incorrect and the position of the prostate gland was almost always wrong. Many male students in later life will suffer from an enlarged prostate with difficulties in urination because the urethra passes through the prostate. For this and other obvious reasons, students should learn in detail about the structure of the male and female reproductive systems. Too many students are too ignorant in this area, despite what they and their teachers may think they know.

b. Spermatogenesis and oogenesis compared

Most candidates found at least one or two similarities or differences between gamete production in males and females but very few scored really highly on this question. Many answers were constructed in the form of a table with two columns, which made it easier to confine the answer to genuine comparisons, but even so in some answers the statements in the left and right column did not correspond. Other answers consisted of long paragraphs about spermatogenesis and then separate paragraphs about oogenesis. The onus is then on the examiner to find the comparisons within the answer when this is actually the candidate's task. Few candidates reached 8 marks on this question, which was a challenge but perfectly possible.

c. Consequences of overproduction of offspring

Some candidates wrote only about humans, with the focus on large families and overcrowded housing. They should have realised that this is not a biological answer to the question and that a general answer about all species was expected. There were some very good answers that tied in populations rising above the carrying capacity to competition for resources, increased mortality, variation and the survival and reproduction of the better adapted individuals, hence evolution of the species by natural selection.

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a. Cell biologists play an important role in research into disease, fertility, evolution and many other areas of science. [4]

Describe the origin of eukaryotic cells according to the endosymbiotic theory.

b. Cell biologists play an important role in research into disease, fertility, evolution and many [8]

other areas of science.

Compare and contrast the processes of spermatogenesis and oogenesis.

c. Cell biologists play an important role in research into disease, fertility, evolution and many [3]

other areas of science.

Outline the evidence for evolution provided by selective breeding.

Markscheme

a. a. mitochondria and chloroplasts are similar to prokaryotes

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

Allow "taking in" in place of "engulfing"

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

OR

symbiotic/mutualistic relationship «between engulfed and host cell»

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

e. DNA «loop» in chloroplast/mitochondrion

f. division/binary fission of chloroplast/mitochondrion

g. double membrane around chloroplast/mitochondrion

h. 70s ribosomes «in chloroplast/mitochondrion»

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

[Max 4 Marks]

b. a. both result in haploid cells/gametes

b. both involve mitosis at the start/in the «germinal» epithelium

c. both have cell growth «before meiosis»

d. both involve «two divisions of» meiosis

e. both involve differentiation to produce a gamete

f. both are stimulated by hormones

OR

spermatogenesis stimulated by testosterone and oogenesis stimulated by FSH

	Oogenesis	***Spermatogenesis***
g.	in the ovaries	in the testes
h.	starts «in germinal epithelium» during embryo/fetus development	starts during puberty/adolescence ***OR*** continuously starting «in germinal epithelium»
i.	pauses occur in prophase I/prophase II/ metaphase II	no pauses
j.	large quantity of cytoplasm in egg/ cytoplasm split unequally	small quantity of cytoplasm «per sperm»/equal division of cytoplasm
k.	one cell/egg «per meiosis» ***OR*** some become polar bodies	four sperm «per meiosis» ***OR*** all cells become sperm
l.	one «usually» at a time/per month/per menstrual cycle	many/far more/millions daily
m.	released on about Day 14/in middle of menstrual cycle/at ovulation	released continuously «from testis» ***OR*** by ejaculation/intercourse
n.	stops at menopause	goes on throughout adult life/until death

A table is not required but both statements in one row of the table must either be explicitly stated or clearly implied to award the mark

[Max 8 Marks]

c. a. crop plants/domesticated animals/livestock produced by selective breeding

b. specific example of a domesticated animal/crop plant and the wild species from which it was developed

OR

specific example of a domesticated animal/crop plant and the features in it which have been improved «compared with the wild species»

For example dogs have been developed from wolves

c. artificial selection/crossing selected varieties/eliminating undesirable varieties

d. «selective breeding/artificial selection can cause» significant/rapid change over time/from the original wild species

e. «changes due to selective breeding/artificial selection» shows natural selection can cause change/evolution «in a species»

[Max 3 Marks]

Examiners report

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

The Chinese soft-shelled turtle, *Pelodiscus sinensis*, lives in salt water marshes. The turtle can live under water and out of water.

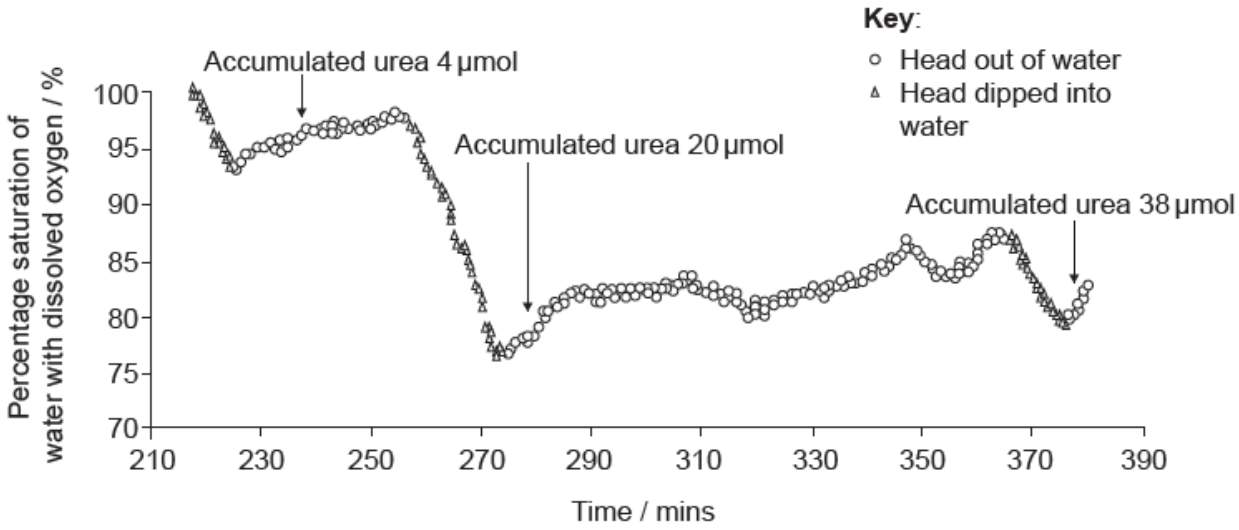
These turtles have fully developed lungs and kidneys, however, many microvilli have been discovered in the mouth of *P. sinensis*. A study was undertaken to test the hypothesis that oxygen uptake and urea excretion can simultaneously occur in the mouth.

Initial experiments involved collecting nitrogen excretion data from *P. sinensis*. The turtle urinates both in water and out of water. When in water it allows waste products to be washed out of its mouth. When out of water it regularly dips its head into shallow water to wash its mouth. The table shows the mean rates of ammonia and urea excretion from the mouth and kidney over six days.

	Excretion of nitrogen by the mouth / μmol day^{-1} g^{-1} turtle		Excretion of nitrogen by the kidney / μmol day^{-1} g^{-1} turtle	
	Turtle submerged in water	Turtle out of water	Turtle submerged in water	Turtle out of water
Ammonia	0.29	0.30	0.63	0.54
Urea	0.90	1.56	0.07	0.73

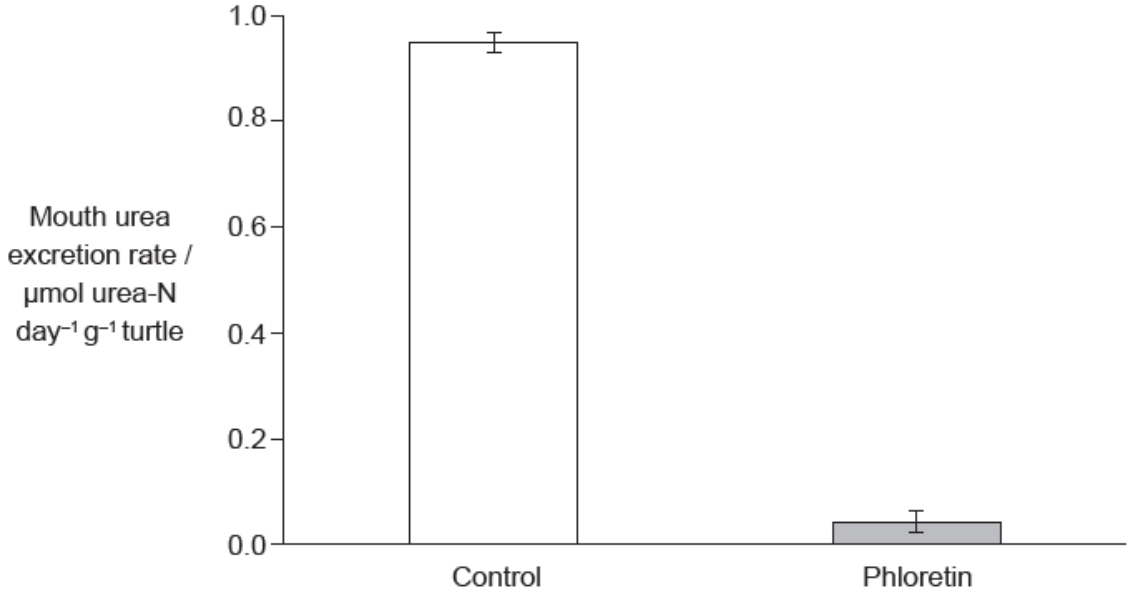
[Source: Reproduced with permission, Y. Ip *et al.* (2012) *The Journal of Experimental Biology*, 215, pages 3723—3733. jeb.biologists.org. doi: 10.1242/jeb.068916]

It was noted that during long periods out of water, turtles rhythmically moved their mouths to take in water from a shallow source and then discharge it. Changes in the dissolved oxygen and the quantity of accumulated urea in the rinse water discharged by the turtles were monitored over time as shown in this graph.



[Source: adapted with permission from Y. Ip *et al*. (2012) *The Journal of Experimental Biology*, 215, pages 3723–3733.]

In order to test whether a urea transporter was present in the mouth tissues of the turtles, phloretin (a known inhibitor of membrane proteins that transport urea) was added to the water in which a further set of turtles submerged their heads. The results of that treatment are shown.

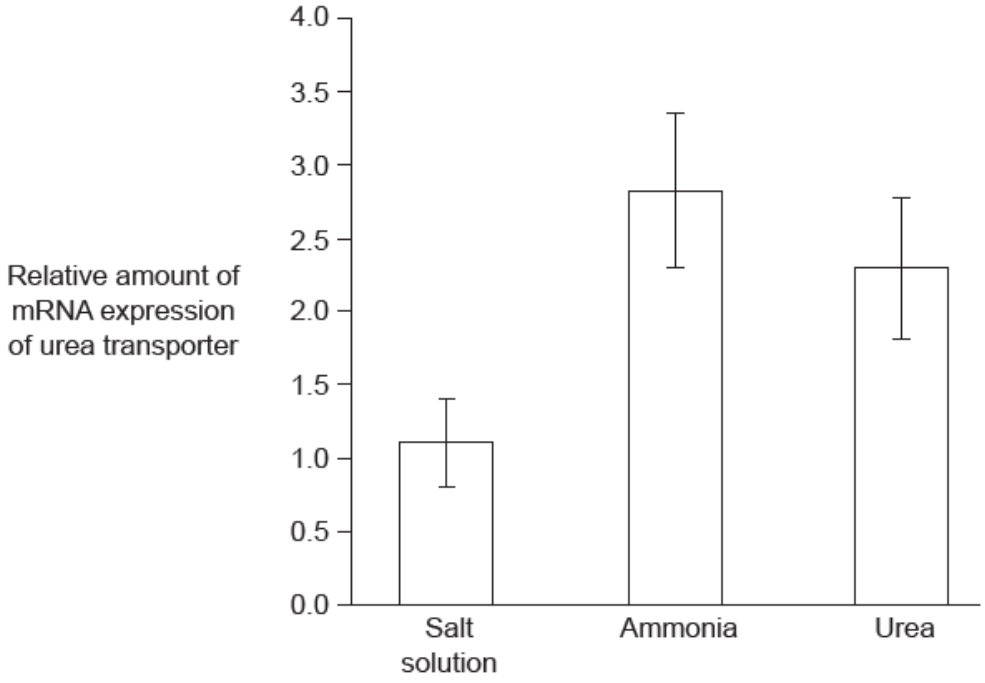


[Source: Reproduced with permission from Y. Ip *et al*. (2012) *The Journal of Experimental Biology*, 215, pages 3723–3733. jeb.biologists.org.]

Further research was conducted to determine where mRNA expression of a urea transporter gene might be occurring in *P. sinensis*. Gel electrophoresis was used to analyse different tissue samples for mRNA activity.

[Source: Reproduced with permission from Y. Ip *et al.* (2012) *The Journal of Experimental Biology*, 215, pages 3723–3733. jeb.biologists.org.]

Expression of the urea transporter gene by cells in the turtle's mouth was assessed by measuring mRNA activity. Turtles were kept out of water for 24 hours and then injected with either a salt solution that matched the salt concentration of the turtle, dissolved ammonia or urea, followed by another 24 hours out of water.



[Source: © International Baccalaureate Organization 2017]

a. Deduce whether the excretion of ammonia or urea changes more when a turtle emerges from water. [2]

b. Compare and contrast the changes in urea excretion in the mouth with the changes in urea excretion in the kidney when a turtle emerges from the water. [3]

c.i. Describe the trends shown by the graph for dissolved oxygen in water discharged from the mouth. [1]

c.ii. Suggest reasons for these trends in dissolved oxygen. [2]

d. Deduce with a reason whether a urea transporter is present in the mouth of *P. sinensis*. [2]

e. Outline the additional evidence provided by the gel electrophoresis results shown above. [2]

f.i. Identify which of these turtle groups represent the control, giving a reason for your answer. [1]

f.ii. Suggest a reason for the greater expression of the gene for the urea transporter after an injection with dissolved ammonia than an injection of urea. [2]

g. The salt marshes where these turtles live periodically dry up to small pools. Discuss the problems that this will cause for nitrogen excretion in the turtles and how their behaviour might overcome the problems. [3]

Markscheme

a. a. urea

b. for both mouth and kidney

c. percentage change/change in μmol day^{-1} g^{-1} greater with urea/other acceptable numerical comparison

b. a. both higher/increased on emergence from/with turtle out of water

b. both increased by 0.66 «μmol^{-1} g^{-1} when turtle emerges from water»

c. % increase is higher in kidney / kidney 940% versus mouth 73/75% / increase is higher proportionately higher in kidney / kidney x10 versus mouth nearly double/x1.73

d. urea excretion by mouth greater than kidney out of water «despite larger % increase in kidney excretion»

c.i. decrease «when head is submerged» and increase when head is out of water

c.ii. a. oxygen absorbed from water/exchanged for urea when head dipped in water«so oxygen concentration decreases»

b. lungs cannot be used with head in water / can «only» be used with head out of water

c. oxygen from water «in mouth» used in «aerobic cell» respiration

d. oxygen from air dissolves in water when head out of water «so oxygen concentration increases»

d. a. urea transporter is present

b. less urea «excreted»/ lower rate «of urea excretion» / excretion almost zero when phloretin/inhibitor was present

e. a. mRNA only in mouth and tongue/in mouth and tongue but not esophagus intestine kidney or bladder

b. bands / lines indicate mRNA for/expression of urea transporter gene

c. urea transporter gene expressed / urea transporters in mouth/tongue / not expressed/made in esophagus/intestine/kidneys/bladder

d. mRNA/transcription/gene expression/urea transporters higher in tongue/more in tongue «than mouth»

f.i. salt solution is control because it does not contain a nitrogenous/excretory waste product / it matches the salt concentration of the turtle / the turtle's body already contains salt / because the turtle lives in salt water/salt marshes / because nothing has been altered

f.ii. a. ammonia is «highly» toxic/harmful

b. ammonia is more toxic than urea/converse

c. ammonia converted to urea

d. urea concentration raised «by injecting ammonia»

e. difference between ammonia and urea «possibly» not «statistically» significant

g. *Problems:*

a. urea becomes more concentrated «in small pools» / lower concentration gradient «between tongue/mouth and water»

b. less water available for urine production/excretion by kidney

OR

less water in ponds for mouth rinsing/more competition for pools (to use for mouth rinsing)

Behaviour to overcome problems:

c. «still able to» dip mouth into/mouth rinse in water/pools

d. «still able to» excrete urea «though the mouth» in the small pools

e. more conversion of ammonia to urea/urea excretion rather than ammonia

f. more urea transporters/expression of urea transporter gene

g. urea excreted «in mouth/via microvilli» by active transport/using ATP

h. excretion with little/no loss of water

Examiners report

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

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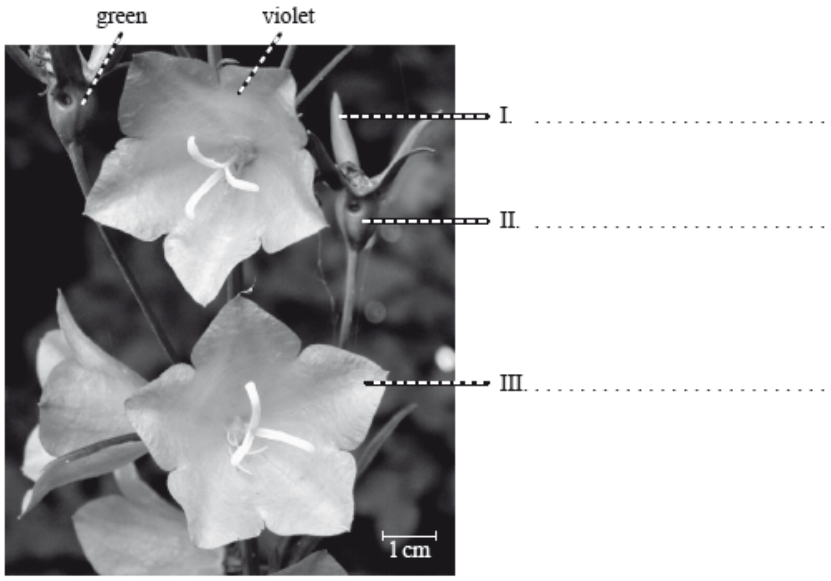
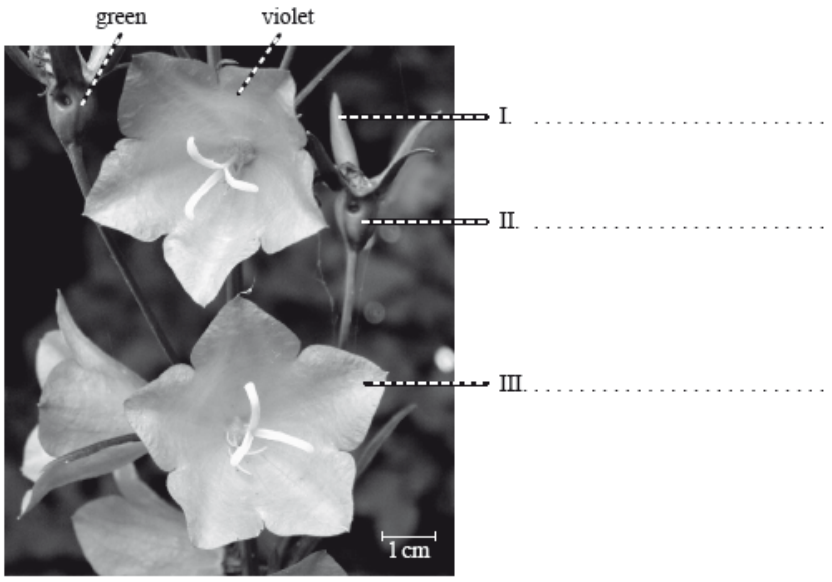
a. The photograph below shows the flowers of *Campanula persicifolia*. Label structures I, II and III. [3]



[Source: photograph provided by IB examiner]

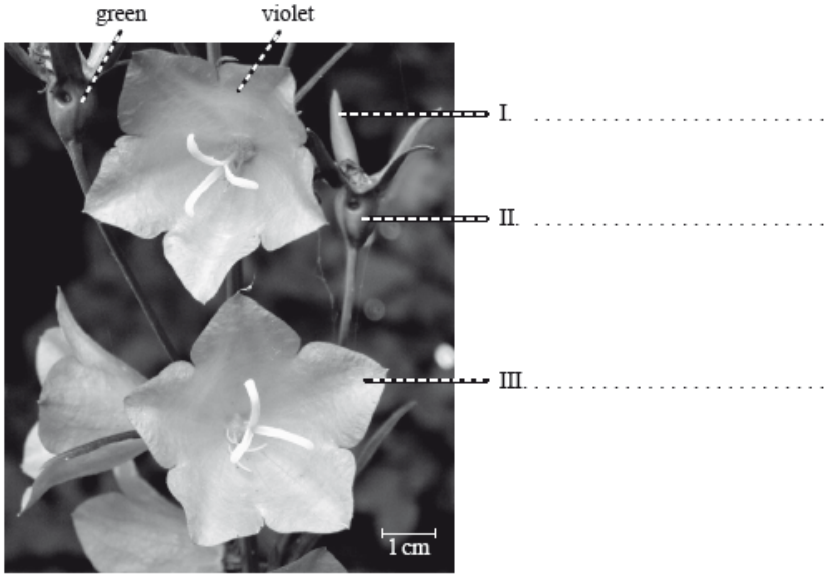
b(i). [1]



[Source: photograph provided by IB examiner]

Using the external features shown in the photograph, state the phylum to which this plant belongs.

b(ii). [2]



[Source: photograph provided by IB examiner]

Comment on the hypothesis that the plant shown in the photograph could be pollinated by an animal.

c. Outline the use of the binomial system of nomenclature in *Campanula persicifolia*. [2]

Markscheme

a. I. sepal;

II. ovary / receptacle;

III. petal;

b(i) Angiospermophyta / Angiospermophytes / Angiosperms

Do not accept flowering plants.

b(ii) a. confirms the hypothesis;

b. stigma/anther inside the flower/ring of petals so as visiting animal enters it brushes past them;

c. colourful petals (provide contrast) so that flowers can be seen by animals;

d. (slightly) cone-shaped flowers so animals come in;

c. a. first name/*Campanula* for genus / second name/*persicifolia* for species;

b. (all) members of *Campanula persicifolia* share special/unique features;

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

Examiners report

a. Of all the comments received from the G2 forms, question 2 received by far the most. Most said that the photograph was difficult to interpret. If it had been in colour then it would have been far easier. However, as none of the candidates would have seen it in a book, it was fair for everyone.

A surprising number of candidates failed to gain any marks at all, not managing to identify I as the sepal, II as the ovary or receptacle and III as the petal. At the other end of the scale there were several centres whose candidates gained full marks. It seems that the teaching of Topic 9, Plant Science is very varied.

b(i) About half of the candidates correctly stated that the plant was an angiosperm, with most of the other half saying that the phylum was dicotyledons.

b(ii) Most stated that the violet petals would attract animals/insects, but did not “comment on the hypothesis” as instructed. Many mentioned nectaries which could not be seen in the photograph. Few stated that the stigma was inside the flower (not evident from the central two flowers, but evident from the one shown in profile), so the pollen could be rubbed off as the animal entered. A surprising number replied that it was not due to animals, but due to insects.

c. Only about half of candidates were able to gain the mark for stating genus for *Campanula* and species for *persiciflora*. Fewer gained a second mark for saying that all members of *C. persiciflora* share unique features or that is a worldwide nomenclature.