HL Paper 2

Angiospermophyta have vascular tissue (xylem and phloem) that bryophyta lack. Suggest advantages that vascular tissue confers.

Markscheme

would make it easier to stand upright (against gravity)/structural support / allows (angiospermophytes) to be bigger;

could put leaves higher in the air to get more sunlight;

transport of water supply/nutrients from roots to other tissues;

could (more efficiently) transport/translocate sugars/food from leaves for storage;

Examiners report

Many students stated the function of vascular tissue, but did not adequately discuss why it allows for functionality not present in bryophytes. Bryophytes can also move water and carbohydrates into cells. Vascular plants are able to move these across greater distances from source tissues to sink tissues.

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. Explain how abiotic factors affect the rate of transpiration in terrestrial plants. [8]

c. Describe the importance of water to living organisms. [5]

Markscheme

b. a. less transpiration/water loss as (atmospheric) humidity rises;

b. air spaces inside leaf are saturated/nearly saturated (with water vapour);

c. smaller concentration gradient with higher atmospheric humidity;

d. more transpiration/water loss as temperature rises/with more heat;

e. faster diffusion / more kinetic energy (of water molecules);

f. faster evaporation (due to more latent heat available);

g. more transpiration/water loss as wind (speed) increases;

h. humid air/water vapour blown away from the leaf;

i. increasing the concentration gradient (of water vapour);

j. more transpiration/water loss in the light;

k. light causes stomata to open / stomata closed in darkness;

l. low CO_2 concentration inside leaf in bright light so stomata open wider;

Accept any of the points if clearly made on an annotated graph.

c. a. coolant in sweat/in transpiration;

b. water has a high heat of vaporisation / heat taken when hydrogen bonds break;

c. water is cohesive so can pulled up/so can be moved under tension in xylem;

d. water is an excellent/universal solvent/dissolves many different substances;

e. medium for transport in blood/xylem/phloem;

f. medium for metabolic reactions / (metabolic) reactions happen dissolved in water;

g. surface tension due to cohesion allows organisms to live on water surface;

h. water has high heat capacity so much energy required to change its temperature;

i. ice floats so lakes/oceans do not freeze allowing life under the ice;

j. high heat capacity so stable habitat/so temperature of water changes slowly;

k. used in chemical reactions/photosynthesis/hydrolysis in organisms;

Examiners report

b. Accounts of the effects of abiotic factors on the rate of transpiration were mostly good. Few candidates made the point that the air spaces inside the leaf are at or close to saturation with water vapour and very few knew that carbon dioxide concentration can influence transpiration rates through changes in stomatal aperture. Many accounts could have been improved by mentioning how steep concentration gradients are between the air spaces in the leaf and the air outside. This was relevant in relation to both atmospheric humidity and wind speed.

c. There were a lot of possible answers to this question on the importance of water so strong candidates had no difficulty in reaching five marks. Weaker answers were vague and incomplete and sometimes muddled up the properties of water such as coherence and adherence and the various thermal properties.

a. State the role of **four named** minerals needed by living organisms. [4]

b. Explain the processes by which minerals are absorbed from the soil into the roots. [8]

c. In anaerobic conditions, plants release energy by glycolysis. Outline the process of glycolysis. [6]

Markscheme

a. sulfur – part of amino acids / proteins;

calcium – strengthening/formation of bones / muscle contraction / synaptic transmission;

phosphorus – formation of nucleic acids / ATP / GTP / NADP / phospholipids;

iron – formation of hemoglobin / transport of oxygen;

sodium – nerve impulse / sodium-potassium pump / osmoregulation;

potassium – nerve transmission / sodium-potassium pump / osmoregulation;

magnesium – part of chlorophyll molecule;

b. plants absorb minerals in ionic form/mineral ions;

nitrate / phosphate / potassium / other example of mineral;

minerals can be absorbed by (facilitated) diffusion;

(diffusion is) movement of ions from high to low concentration/down concentration gradient;

root hair cells provide a large surface area for absorption;

fungal hyphae help to absorb minerals/phosphate;

minerals absorbed by active transport;

as mineral ion concentration is smaller outside the root than inside / absorbed against a concentration gradient;

active transport requires energy/ATP;

occurs through pump/carrier proteins;

proton pump transports hydrogen ions/H^+ out of cell (allowing mineral movement in);

c. occurs in cytoplasm (of cell);

substrate is hexose/glucose/fructose;

phosphorylation of glucose/fructose/hexose;

to form hexose diphosphate/glucose 6-phosphate;

requires ATP;

glucose/fructose/hexose (diphosphate) converted into (two) pyruvates/three carbon compounds;

oxidation;

to produce (two) NADH + H^+/ (two) reduced NADs;

net gain of two ATP (per glucose);

Examiners report

a. In part (a), most candidates had no difficulty in naming four mineral elements that are needed by living organisms and giving a role for each. Carbon was not accepted as an answer, as conventionally it is not regarded as a mineral. In plants minerals are absorbed from soil or water. In animals minerals are absorbed in an inorganic form from food or drinking water.

b. Part (b) of the question was not answered as well as expected. There was some confusion between absorption from the soil into roots and movement through the soil to the roots. As a result, many candidates suggested that minerals could be absorbed by mass flow along with the water that was being absorbed. This shows that the selective nature of mineral absorption has not been understood. Another common fault was to suggest that diffusion is the main method of mineral absorption. If plants are able to absorb water by osmosis, they must have higher solute concentrations inside their cells than outside and this can only be achieved by active transport.

c. There was generally good knowledge of the stages of glycolysis in part (c). To make the marking of this question fair in relation to other choices, there was a restricted set of points on the marking scheme, but the more able candidates were still easily able to score full marks.

---

a. Outline how **three** properties of water enhance its use by living organisms. [6]

b. Describe the role of ADH in osmoregulation. [4]

c. Explain how water is moved from roots to leaves in terrestrial plants. [8]

Markscheme

a. cohesive properties help in transpiration pull/movement of water in plants;

high surface tension allows some animals to stride across its surface;

high latent heat of evaporation/large amounts of energy required for evaporation makes it a good coolant;

high specific heat capacity causes it to maintain environmental temperatures;

low density as ice forms insulation of lakes allowing life below;

transparency for photosynthesis;

transparency for vision in animals;

solvent properties make it the medium for metabolic reactions;

solvent properties allow transport of (soluble) molecules/food;

b. osmoregulation is control of water balance in organisms/blood/tissues/ cytoplasm;

ADH regulates water levels/solute concentration of the blood;

produced/released when water in blood is too low;

it increases the permeability of the collecting ducts / increase in the reabsorption of water;

leads to more aquaporins (in collecting duct cell membranes);

lower volume/less urine is produced/urine more concentrated;

c. water enters roots through the root hairs by osmosis;

root hairs provide an extended surface area (for active transport and osmosis);

active transport of ions from soil into the roots (enhances osmotic pressure);

osmotic pressure moves water into the xylem;

water is carried (in a transpiration stream) in the xylem;

adhesion of water to the inside of the xylem helps move water up;

cohesion of water to itself enhances water movement up the xylem;

water diffuses into air spaces (in spongy mesophyll) of leaves;

it passes out through the stomata by evaporation/transpiration;

evaporation sets up a transpiration pull that keeps the water moving;

guard cells control the rate of transpiration pull/evaporation;

xylem vessels are tubes with helical rings to enhance water movement/resist low pressure;

Examiners report

a. Many did not understand the difference between heat capacity and specific heat capacity. Heat capacity is a property of a quantity of matter. For example, two litres of water has a greater heat capacity than one litre of water. Specific heat capacity is a property of certain substance. Water has a greater specific heat capacity than iron. Nor did they understand why water made for a good coolant. Many focused too narrowly on an aspect of thermal, cohesive or solvent properties rather than discussing these properties from a more "big picture" perspective.

b. The role of ADH was well described an many candidates scored full marks here. Students need to take greater care when using the term concentration as water represents the solvent.

c. This question was generally well answered.

---

a. Draw the absorption spectrum of chlorophyll. [4]

b. Explain the process of photophosphorylation in chloroplasts. [8]

c. Outline how the glucose produced as a result of photosynthesis is transported and stored in plants. [6]

Markscheme

a. *labelled x-axis*: wavelength / colour;

labelled y-axis: absorbance / % absorption;

peak between 400 and 500 nm / blue light;

peak between 600 and 700 nm / red light;

blue peak higher than red peak;

b. using energy from light to provide energy;

absorbing light/photoactivation produces an excited/high energy/free electron;

absorption of light in photosystem II gives electron to chain of carriers;

photolysis;

H^+ pumped across thylakoid membrane;

protons pass through ATP synthetase/synthase;

producing ATP;

chemiosmosis;

(chlorophyll/antenna of) photosystem I absorbs light;

cyclic and non-cyclic photophosphorylation;

(in non-cyclic photophosphorylation) photolysis of water produces $H^+/O_2/e^-$;

in cyclic photophosphorylation electron returns to photosystem I;

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

c. glucose transformed to sucrose;

translocation of sugars/sucrose;

by phloem;

active process / requires energy;

from source to sink;

source is photosynthetic tissue/leaves;

sink is fruits/seeds/roots/storage organs;

(sucrose) converted to starch;

stored in storage organs/roots/tubers;

Examiners report

a. The syllabus statement for 8.2.7 does say "explain" as a command term for absorption spectrum. Draw is a lower level skill, and students should be able to draw the typical absorption spectrum. The x-axis is commonly not understood conceptually. If the axis is "wavelength", then red should be shown as longer wavelength than blue. This was commonly reversed. The y-axis was often insufficiently labelled as absorption. Absorbance or percent absorption was required.

b. Most of the better students who attempted this question explained photophosphorylation very well. Students who had done poorly on the rest of the paper avoided this question.

c. As mentioned before, some centres seem to have regarded the plant topic as optional, so the function of phloem was not well known. Many did not demonstrate awareness that sugars are translocated as sucrose, not glucose.

Photosynthesis and transpiration occur in leaves. Explain how temperature affects these processes.

Markscheme

photosynthesis rate increases as temperature rises (up to an optimum temperature);

(due to) increase in the rate of enzyme catalysed reactions/light independent reactions/the Calvin cycle;

(steep) drop in rate of photosynthesis above the optimum;

at high temperatures enzymes/Rubisco/RuBP carboxylase denature(s);

graph with correctly labelled axes showing relationship between temperature and rate of photosynthesis;

transpiration rate increases as temperature rises;

(energy/heat leads to more) to more evaporation of water (in the leaf);

faster diffusion of water vapour at higher temperatures;

relative humidity falls as temperature rises / warmer air can hold more water vapour;

stomata may close at very high temperatures reducing the transpiration rate;

some plants open their stomata at very high temperatures to cool by transpiration;

Examiners report

Here candidates were able to outline the effects of temperature on photosynthesis and transpiration, but explanations failed to adequately address mechanisms such as the role of enzymes in photosynthesis and the role of evaporation in transpiration.

A very high number of candidates stated that higher temperatures meant more light and it was this that increased the rate of photosynthesis. Others went off into the idea that transpiration was a type of sweating and was used **normally** by plants to keep them cool. Few linked increased rate to enzyme activity and a further increase beyond optimum to a decrease in rate because of denaturation.

---

a. Describe how plants carry out gas exchange in the leaves. [5]

b. Outline the causes and consequences of the enhanced greenhouse effect. [5]

c. Explain the role of limiting factors in photosynthesis. [8]

Markscheme

a. gases/O_2 and CO_2 enter/exit the leaf through the stomata;

by diffusion / down the concentration gradient;

photosynthesis maintains concentration gradients/high O_2 and low CO_2 in the leaf;

guard cells open the stomata during the day / close the stomata at night;

gases/O_2/CO_2 move through air spaces in the spongy (mesophyll);

CO_2 dissolves in moisture in (mesophyll) cell walls;

b. burning of (fossil) fuels/coal/oil/gas releases carbon dioxide;

deforestation/loss of ecosystems reduces carbon dioxide uptake;

methane emitted from cattle/livestock/melting permafrost/waste dumps;

heating of the atmosphere/global warming/climate change;

melting of ice caps/glaciers/permafrost / sea level rise / floods / droughts / changes in ocean currents / more powerful hurricanes / extreme weather events / other abiotic consequence;

changes in species distributions/migration patterns / increased decomposition rates / increases in pest/pathogen species / loss of ice habitats / other biotic consequence;

c. factor nearest its minimum/furthest from its optimum is limiting;

increasing a limiting factor with other factors constant increases the rate;

increasing a non-limiting factor with other factors constant has no effect on rate;

light intensity is limiting in dim/low intensity light / at night;

photosynthesis (directly) proportional to intensity up to plateau / graph to show this;

light intensity affects the light-dependent reactions/production of ATP/NADPH;

temperature limiting at low and high temperatures;

optimum temperature with lower rates above and below plateau / graph to show this;

low temperatures limit the rate of light-independent reactions/Calvin cycle;

RuBP carboxylase/rubisco does not fix carbon dioxide at high temperatures;

carbon dioxide concentration is limiting in bright light and warm temperatures;

photosynthesis is (directly) proportional to CO_2 concentration up to plateau / graph to show this;

low CO_2 concentration limits carbon fixation/reaction between CO_2 and RuBP;

Examiners report

a. This question was based on assessment statement 9.1.3, which includes the relationship between the structure of the leaf and its role in gas exchange. All that was needed was an outline of the structure of the spongy mesophyll, guard cells and stomata, in relation to the diffusion of carbon dioxide into the leaf and oxygen out. Scores were typically poor, with many candidates missing the basic points. More candidates for

example for example seemed to state that CAM plants open their stomata for gas exchange at night than that most plants open their stomata in the day.

b. Scores were mostly much better in this part of the question, with nearly all candidates at least mentioning warming due the enhanced greenhouse effect and an example of the abiotic and biotic consequences. The cause of the enhanced greenhouse effect was less well understood, with vagueness about what is causing carbon dioxide levels to increase and other greenhouse gases often not mentioned. There was considerable confusion, as so often, between ozone depletion and the greenhouse effect. It is easy to assume that candidates will be able to distinguish between these two phenomena easily and that little teaching is required, but all those who marked this exam will know that careful teaching is very much required.

c. This was another area of relatively poor understanding, perhaps because weaker candidates tended to choose question 7. A basic minimum was to know that light intensity, temperature and carbon dioxide concentration are the three main limiting factors of photosynthesis. Many failed at this first hurdle, omitting one or more of the main three and including instead pH, water availability or various other biotic and abiotic factors. Perhaps some candidates were confusing enzyme activity with photosynthesis. What was required for each of the three factors was a clear statement of the relationship between the level of the variable and the rate of photosynthesis, ideally by means of an annotated sketch graph, and then some details of the reasons for the rate of photosynthesis changing as the level of the variable changed. A common misconception was to say that the rate reduces at higher temperatures because of enzyme denaturation when in fact the rate reduction occurs at much lower temperatures than those at which this would happen. The problem at higher temperatures is due to RuBP carboxylase failing to fix carbon dioxide effectively.

---

a. Explain how minerals move into plants. [8]

b. Outline the conditions needed for the germination of a typical seed. [3]

c. Following germination of seeds, plants undergo a rapid increase in the number of cells. Describe stages in the cell cycle that result in this increase of cells. [7]

Markscheme

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

a. minerals bound to soil particles;
b. examples of three nutrients from: phosphate, nitrate, magnesium, iron, calcium, potassium, sodium, magnesium;
c. minerals dissolve in water;
d. mass flow causes movement of minerals with movement of water through soil;
e. minerals diffuse down a concentration gradient towards roots (as the mineral concentration next to the roots is continuously decreasing);
f. minerals enter the plant through roots;
g. by active transport / use of ATP;
h. branching of roots increases surface area for absorption of minerals;
i. root hairs increase surface area (for the absorption of minerals);
j. hypha of (mutualistic) fungi may enhance movement of selected ions into roots / increase surface area;
k. root hairs have many mitochondria to provide energy/ATP for active transport;

l. export of H+ creates electrochemical gradient / displaces ions bound to soil/clay;
m. that causes positive mineral ions to diffuse into (root) cells;
n. negative mineral ions cross membrane linked to H+ ions moving down (H+) gradient;

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

a. water to rehydrate the seed / activate metabolic processes;
b. oxygen for aerobic respiration as seed germinates;
c. suitable temperature for enzyme activity;
d. each type of seed has specific temperature requirements / temperature requirements ensure that seeds germinate at the correct time of year;
Do not accept a simple list of factors without details.

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

a. growth phase/G-1: synthesis of proteins/cytoplasm/organelles;
b. synthesis phase/S-phase: replication of DNA;
c. second growth phase/G-2: continued growth of cytoplasm/molecular synthesis/duplication of organelles;
d. prophase: chromosomes super-coil to prepare for mitosis / nuclear envelope disappears / spindle fibres form;
e. metaphase: chromosomes line up at equatorial/metaphase plate / spindle fibres attach to centromeres/chromosomes;
f. anaphase: chromatids move along microtubules/spindle fibres move chromatids toward opposite poles;
g. telophase: nuclear membranes form around each cluster of chromosomes;
h. cytokinesis: new plasma membrane forms between the nuclei / cell plate forms;
i. a new cell wall forms;
j. (mitosis) results in two cells with identical nuclei;

Names of phases are required to earn the mark.
Award marks for a clearly drawn correctly annotated diagram.

Examiners report

a. Students tended to perform well on this question though it was rare for students to demonstrate detailed knowledge of the mechanism of active transport in terms of ion exchange.

b. Students found it easier to list the conditions required for germination rather than outlining the conditions required.

c. Many students earned marks by outlining the stages of mitosis though a number were not clear on when spindle fibres form and when they attach, commonly indicating that this occurs in metaphase. Some students muddled the mechanisms of meiosis and mitosis. The distinctions between cytokinesis in plant and animal cells does not seem to be well understood. The events that occur in the different stages of interphase appears to be less well known.

---

a. Draw a labelled diagram of a eukaryotic plant cell as seen in an electron micrograph. [4]

b. Outline how the energy flow through food chains limits their length. [3]

c. In hot, dry conditions plants lose water rapidly due to transpiration. Explain how the structures and processes of the plant allow this water to be replaced. [8]

Markscheme

a. Cell wall shown with two continuous lines to indicate the thickness

Plasma membrane/cell membrane shown as a single continuous line

Accept inner line of wall as membrane if clearly labelled.

Nuclear membrane/nucleus shown with double membrane and nuclear pores

Vacuole «membrane»/tonoplast shown as a single continuous line

Chloroplast/plastid shown with a double line to indicate the envelope and thylakoids/grana

Mitochondrion shown with double membrane/cristae

b. Only a small proportion/20 %/10 % «of energy» can pass from one trophic level to the next *Accept named trophic levels or named stages in a food chain in place of "trophic levels"*.

OR

large proportion/80 %/90 % lost between one trophic level and the next *Accept if clearly shown in a diagram such as a pyramid of energy*.

Energy released by respiration ***AND*** lost as heat *Not just respiration or heat*.

Energy losses due to uneaten parts/undigested parts/feces/egestion

Not enough energy for 4th/5th/later stages of a food chain
OR
more energy available if feeding at an earlier stage in a food chain

c. Evaporation of water «in leaf/mesophyll» creates tension/low pressure/negative pressure «potential»/pulling force/transpiration pull

Water drawn through cell walls/out of xylem «in leaf» by capillary action/adhesion «to cellulose»

Low pressure/tension/suction/pulling force in xylem

Hydrogen bonds make water cohesive/allow water to be pulled up under tension/allow the transpiration pull «to move water»

Xylem resists tension/low pressure/collapse with thickened/lignified walls

Water travels from the roots to the leaves in xylem

Water absorbed in roots by osmosis

Active transport of ions/solutes into roots «enabling osmosis»

Deep/wide ranging/extensive root systems/taproots/many root hairs

Thick/waxy cuticle reduces transpiration/water loss/evaporation

Small/no leaves/reduced surface area of leaves/thorns instead of leaves

Few stomata/stomata in pits/rolled leaves

Hairs on leaf surface «to reduce air flow near the leaf/reflect sunlight»

Stomata open at night/CAM physiology to reduce water loss

Examiners report

a. Diagrams of plant cell structure were mostly rather poor and few candidates scored full marks. The question specified 'as seen in an electron micrograph'. Many diagrams showed the appearance of plant cells in a light micrograph. This allowed marks for cell wall and cell membrane to be awarded, but not for internal structures such as the nucleus as their representation was not detailed or accurate enough. In contrast to the

membrane diagrams in 6(a), many of these cell diagrams were carelessly drawn with overlapping, multiple or discontinuous lines used for structures that have a single continuous edge.

b. This is a familiar question, though there was a slight twist in that candidates were expected to explain specifically why food chains cannot be long. Nearly all candidates wrote about energy losses between trophic levels and many mentioned the '10% rule' though in some cases got it the wrong way round and stated that 10% of energy is lost. Too few candidates mentioned the most important idea – that release of energy by cell respiration and its use is accompanied by loss of energy from a food chain in the form of heat.

c. This question caused some problems. It was another case where a sentence had been added to set the scene, but it proved a distraction rather than an aid to focus. The wording of the question as a whole was clear, but many candidates seemed not to have read to the end of the second sentence and they did not therefore explain how losses of water by transpiration are replaced. Some answers were concerned exclusively with xerophytic adaptations. An extensive markscheme was devised that allowed these answers to score up to five marks. Those candidates who did actually describe the uptake and transport of water within the plant were able to score full marks. There were few really strong answers and many misunderstandings. One in particular is worth mention: capillary action due to adhesion of water to xylem walls only helps to refill xylem vessels when they are air-filled. If a plant is transpiring the xylem will be filled with water under tension and adhesion cannot cause upward movement.

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]

---

a. Draw a labelled diagram of the structure of a chloroplast as seen with an electron microscope. [4]

b. Describe how water is carried by the transpiration stream. [7]

c. Explain how flowering is controlled in long-day and short-day plants. [7]

Markscheme

a. *Award **[1]** for each of the following clearly drawn and correctly labelled. Label lines must be unambiguous in terms of what they are indicating.*

double/inner and outer membrane/envelope – shown as two concentric continuous lines close together;

granum/grana – shown as a stack of several disc-shaped subunits;

(intergranal) lamella – shown continuous with thylakoid membrane;

thylakoid – one of the flattened sacs;

stroma;

(70S) ribosomes/(circular) DNA / lipid globules / starch granules / thylakoid space;

b. transpiration is water loss (from plant) by evaporation;

flow of water through xylem from roots to leaves is the transpiration stream;

evaporation from spongy mesophyll cells;

replaced by osmosis from the xylem;

(diffusion of water vapour) through stomata;

water lost replaced from xylem / clear diagram showing movement of water from xylem through cell(s) (walls) to air space;

water pulled out of xylem creates suction/low pressure/tension; transpiration pull results;

water molecules stick together/are cohesive;

due to hydrogen bonding/polarity of water molecules;

xylem vessels are thin (hollow) tubes;

adhesion between water and xylem due to polarity of water molecules;

creates continuous column/transpiration stream;

c. flowering affected by light;

phytochrome;

exists in two (interconvertible) forms/P_{fr} and P_r;

P_r (red absorbing/660 nm) converted to P_{fr} (far-red/730 nm absorbing) in red or day light;

sunlight contains more red than far red light so P_{fr} predominates during the day;

gradual reversion of P_{fr} to P_r occurs in darkness;

P_{fr} is active form / P_r is inactive form;

in long-day plants, flowering induced by dark periods shorter than a critical length / occurs when day is longer than a critical length;

enough P_{fr} remains in long-day plants at end of short nights to stimulate flowering;

P_{fr} acts as promoter of flowering in long-day plants;

short-day plants induced to flower by dark periods longer than a critical length/days shorter than a critical value;

at end of long nights enough P_{fr} has been converted to P_r to allow flowering to occur;

P_{fr} acts as inhibitor of flowering in short-day plants;

Examiners report

a. Diagrams were variable in quality. The poorest were very unclear and labelling was often inaccurate. The double membrane, grana, stroma and thylakoid were most often correctly labelled. The connection between the thylakoid and intra-lamellar membrane was often not shown.

Failing to close lines when drawing membranes was also problematic. In some cases thylakoids were coloured in obscuring connections.

b. The importance of adhesion and cohesion was covered well, although these were not often related to the molecular properties of water.

It was the process of transpiration and the resultant force created that was less often mentioned or just given a brief treatment, losing marks for many candidates. Commonly, how water moves from soil into the root was detailed.

c. Phytochrome was known about and that it exists in 2 interconvertible forms. A number showed evidence of memory of facts but with lack of understanding because details were confused and terms interchanged.

---

b. Most of the surface of the Earth is covered with a wide diversity of ecosystems. Outline **two** general characteristics of all ecosystems. [2]

c.i. Vascular plants can be found in a wide variety of ecosystems. [2]

Outline active transport in phloem tissue.

c.ii. Vascular plants can be found in a wide variety of ecosystems. [3]

Explain how a plant replaces the water it loses in transpiration.

Markscheme

b. a. organisms/community plus the environment / biotic and abiotic «components»

b. interactions

c. ecosystems show sustainability

d. nutrients are recycled in ecosystems

e. energy flows through ecosystems

f. producers «are part of all ecosystems»

g. decomposers/saprotrophs «are part of all ecosystems»

c.i. a. active transport/pumps used to load sugars/sucrose into phloem/companion cells/sieve tubes

b. loading in sources/unloading in sinks
OR
sucrose/sugars moved from source to sink

c. active transport moves H^+ out of phloem/sieve tubes «to make H^+ gradient in the leaf/source»

d. H^+ gradient used for co-transport of sucrose into phloem/sieve tubes/companion cells

Accept protons or hydrogen ions instead of H+ ions.

Accept the equivalent of mpc and mpd for unloading in the sink.

c.ii. a. transpiration/evaporation of water causes suction/tension

b. water sucked/drawn out of xylem «in leaf»

c. water moves up in xylem

d. due to suction/tension/pulling forces

e. cohesion of water/hydrogen bonds between water molecules

f. movement from roots to leaves

g. water enters root by osmosis/due to higher solute concentration inside root

Examiners report

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

c.ii. [N/A]

a. Outline the various stages of the cell cycle. [4]

c. Define the term *transpiration* and explain the factors that can affect transpiration in a typical terrestrial plant. [9]

Markscheme

a. G_1 the cell grows/duplication of organelles;

S is synthesis stage when DNA is synthesized/replicated;

G_2 the chromosomes begin condensing/preparation for cell division;

G_1 , S and G_2 make up interphase;

during mitosis nuclear division occurs/all four stages listed;

during cytokinesis cytoplasm/cell divides/daughter cells formed;

c. (transpiration is) loss of water vapour from the leaves/stomata (and stems) of plants;

temperature, humidity, light (intensity) and wind <u>all affect</u> transpiration;

high temperatures increase evaporation rate of water/transpiration; *(accept converse)*

high humidity lowers the rate of water evaporation/transpiration; *(accept converse)*

air currents/wind increase water evaporation/transpiration; *(accept converse)*

high light (intensity)/sunlight (usually) increases photosynthesis/water evaporation through the stomata/transpiration;

stomata open to allow gaseous exchange/entry of CO_2;

abscisic acid stimulates closing of stomata;

guard cells open/close the stomata;

adaptations of (xerophyte) plant structures reduce water loss/transpiration;

one example;

(thicker leaf cuticle / reduced surface area/rolled leaves/spines / sunken/reduced stomata / close stomata in day / low growth form / CAM / C4 physiology)

second example; *(of above)*

*Award **[8 max]** if definition is missing.*

Examiners report

a. In part (a) many students knew the cell cycle and its parts, but did not fully describe each one. Some students went into very detailed descriptions of the stages of mitosis, only worth one mark, instead of describing the others.

c. Part (c) was often well answered with candidates write detailed accounts of the effects of the different factors on plant transpiration. However, some described the effects of evaporation of the water in anthropogenic terms of cooling the plant. Also some students wasted valuable time describing the transpiration stream in great detail.

---

a. Describe **four** properties of water that are due to hydrogen bonding and polarity. [4]

b. Describe how water is carried through a flowering plant. [6]

c. Some of the water carried to the leaves of a plant is used in photosynthesis. Explain the role of water in the light-dependent reactions of photosynthesis. [8]

Markscheme

a. *Descriptions of properties expected not lists of properties.*

hydrogen bonding:
a. high specific heat capacity requiring large amounts of energy to break the H-bonds/to raise the temperature;
b. boiling point is high/100°C as H-bonds must be broken to change from liquid to gas;
c. cooling effect of evaporation due to H-bonds taking energy from liquid water to break / high latent heat of evaporation;
d. water molecules on surface resistant to forces because of surface tension;
e. water is most dense at 4°C due to more regular hydrogen bonding;

polarity:
f. water molecules stick together through cohesion; (*full idea required*)
g. water molecules stick to other polar molecules through adhesion; (*full idea required*)
h. good solvent of polar organic molecules

b. a. active transport of solutes from soil into roots;

b. draws water by osmosis

c. root hairs provide a large surface area for water uptake;

d. carried through xylem vessels;

e. transpiration is the loss of water (vapour) from leaves and stems / stomata;

f. (transpiration) creates suction/pull/negative pressure;

g. cellulose wall with rings of lignin give strength to resist (low) pressure;

h. water pulled up due to capillary action/cohesion/adhesion;

i. continuous column of molecules/transpiration stream;

c. a. water only plays a role in non-cyclic photophosphorylation;

b. chlorophyll absorbs light/photons and activates electrons of photosystem II;

c. excited/active electrons of photosystem II are passed to carriers;

d. photolysis is the splitting of water;

e. produces O_2 and H^+/proton and electrons;

f. O_2 released (as waste);

g. electrons (from water) replace lost electrons in photosystem II;

h. electrons from photosystem II pass (through carriers) to photosystem I;

i. electrons from photosystem I pass to $NADP^+$ (in stroma);

j. $NADP^+$ accepts H^+/proton (from water) to form NADPH;

k. electron flow causes protons pumped across thylakoid membranes/into the thylakoid space;

l. creating a proton concentration gradient;

m. chemiosmosis couples electron transport to ATP synthesis;

n. protons pass through ATP synthase/synthetase;

o. NADPH/H^+/proton is passed to the light-independent reactions (to fix carbon);

Examiners report

a. This was a popular question.

7a, few completely related hydrogen bonding to surface tension. In discussing solvent properties, a number neglected to draw in that water performed best at dissolving polar substances. When discussing adhesion, students should have referenced the polarity of molecules.

b. This was a popular question.

In part b, many referenced the role of xylem. Many used terminology correctly in this section making reference to transpiration pull, cohesion, adhesion and the transpiration stream. The stages of water uptake that occur in the root was covered in less detail and with less accuracy in general.

c. This was a popular question.

Part c was in general poorly done as the question required students to discuss the role of water. The details of photolysis were often excluded as were the correct details of chemiosmosis.

---

b. Outline the metabolic processes that occur in starchy seeds during germination. [6]

c. Explain the light-independent processes of photosynthesis in plants. [8]

Markscheme

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

a. water absorbed by the seed / seed rehydrated;
b. water activates metabolism;
c. gibberellin synthesized/produced/secreted;
d. gibberellin stimulates the production of amylase;
e. amylase digests/hydrolyses starch to maltose;
f. maltose converted/hydrolysed to glucose (by maltase);
g. glucose used in aerobic respiration;
h. glucose used in synthesis/production of cellulose;

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

a. occurs in stroma (of chloroplast);
b. energy/ATP and NADPH provided by the light-dependent reactions;
c. Calvin cycle;
d. carbon dioxide fixed to RuBP / carboxylation of RuBP/ribulose bisphosphate;
e. by RuBP carboxylase/rubisco;
f. forms unstable 6C compound / forms 6C compound which splits;
g. glycerate 3-phosphate (is produced by carbon fixation);
h. (glycerate phosphate) to triose phosphate/3C sugar by reduction/adding hydrogen;
i. using NADPH/reduced NADP;
j. triose phosphate/3C sugar converted to form hexose/glucose (phosphate);
k. most/$^{5}/_{6}$ of triose phosphate used for regeneration of RuBP;
l. ATP used to regenerate RUBP/convert glycerate 3-phosphate to triose phosphate;

Examiners report

b. Well prepared candidates gave thorough and high scoring accounts of metabolic processes that follow water uptake in geminating seeds.

c. This was another high scoring part of the question for stronger candidates. A few misread the question and wrote about light-dependent reactions.

The use of the abbreviation GP is discouraged as it is ambiguous in accounts of the Calvin cycle.

---

a. Outline how and where energy is stored in plants. [4]

b. Ecologists sometimes display data from an ecosystem using a diagram called a pyramid of energy. Describe what is shown in pyramids of energy. [6]

c. Explain the control of body temperature in humans. [8]

Markscheme

a. a. glucose (from photosynthesis) stored as starch;

b. starch stored (as granules) in chloroplast/in plastids;

c. (starch stored) in seeds/storage roots/stem tubers;

d. stored as lipids/oils;

e. (lipid/oils storage) in seeds;

f. lipids store twice as much energy per gram as starch;

b. a. pyramid of energy shows the flow of energy from one trophic level to the next (in a community);

b. units of pyramids of energy are energy per unit area per unit time/kJ m^{-2} yr^{-1};

c. bar width is proportional to the energy stored (in the biomass) in that trophic level;

d. the first/lowest trophic level is producers;

e. second level is primary consumers/herbivores;

f. third level of secondary consumers/carnivores;

g. only a small amount (10 to 20 %) of energy of one level is passed to the next;

h. bar width/energy stored in the trophic level decreases (proportionally) as you go up each level;

i. pyramid shows that there is a limit to the length of food chains;

Award any of the above marking points to a correctly drawn and clearly labelled pyramid.

c. a. normal body core temperature constant/36.5 to 37.5°C; (*accept single values within this range*)

b. regulated by negative feedback/homeostatic mechanisms;

c. hypothalamus is the centre of thermoregulation;

d. hypothalamus sends impulses to the body to increase/decrease temperatures;

e. release of sweat (by sweat glands in the skin) if skin temperature rises;

f. evaporation of water cools the body; (*concept of evaporation must be mentioned*)

g. heat is transferred by blood;

h. transfer of heat from body core in blood to surface;

i. if temperature rises, increased flow of blood/heat to the skin/vasodilation of skin blood vessels/arterioles; (*do not accept veins, arteries or capillaries*)

j. if temperature drops, decreased flow of blood/heat to the skin/vasoconstriction of skin blood vessels/arterioles; (*do not accept veins, arteries or capillaries*)

k. shivering increases heat production (in muscles);

l. example of one behavioural mechanism; (*eg reducing activity (to lower body temperature) / reducing exposed surfaces (to reduce heat loss*)

Examiners report

a. This was a popular question among candidates.

For part a, many did not earn full marks and this appeared to be due to a lack of knowledge of this part of the syllabus.

b. This was a popular question among candidates.

For b, many candidates easily earned the marks for parts d, e and f requiring them to identify examples of organisms that occupy the various trophic levels of organisms. A number lost marks due to poorly constructed diagrams especially in relation to the bars not being drawn proportionately. Few correctly indicated the correct units for productivity of the various trophic levels.

c. This was a popular question among candidates.

Part c was generally well done. Most used the term homeostasis and negative feedback in their answers. A number have a misconception regarding vasodilation and vasoconstriction as they are writing that arterioles move toward and away from the skin surface. Few discussed the role of the hypothalamus in regulated body temperature.

---

a. Plants have widespread influences, from food chains to climate change. [3]

Draw a labelled diagram of the internal structure of a seed.

b. Plants have widespread influences, from food chains to climate change. [8]

Explain the process of water uptake and transport by plants.

Markscheme

a. a. radicle/embryo root shown tapering to a root tip

b. plumule/embryo shoot shown with embryonic leaves «in a dicot seed» drawn and labelled

OR

plumule/embryo shoot shown tapering to a shoot tip «in a monocot seed»

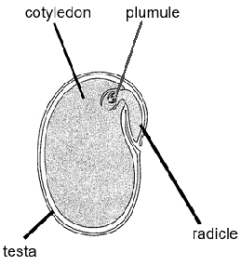
c. seed coat/testa shown with a double line

d. cotyledon/endosperm shown as a large structure «for food storage»

e. embryo shown with both embryo root and shoot visible

Accept any dicot or monocot seed

eg:



*Award **[1]** for any of the structure clearly drawn and labelled*

Award mpe only if mpa and mpb have not been awarded and the labelling line points clearly to the plumule or radicle or both.

[Max 3 Marks]

b. a. roots/root hairs absorb water

b. water is absorbed by osmosis

c. solute concentration inside the root is higher/water potential is lower «than in the soil»

d. due to active transport of ions/minerals into the root

e. transport of water in xylem vessels

f. flow/stream of water from roots to leaves

g. water movement in xylem due to pulling force/transpiration pull/suction/negative pressure potential

h. cohesion/hydrogen bonds between water molecules «allows water to be pulled up in xylem»

i. transpiration in leaves generates tension/pulling forces/suction

j. evaporation of water from «leaf» cell walls

k. adhesion of water to «leaf» cell walls/cellulose creates tension «forces»

Not adhesion to xylem walls in mpk and the adhesion must be linked to creating tension

l. lignin in xylem walls/thickened xylem walls prevent collapse/resist tension

m. «movement of water in xylem is a» passive process

[Max 8 Marks]

Examiners report

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

---

a. Outline pollination, fertilization and seed dispersal. [4]

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

Markscheme

a. pollination is the transfer of pollen to the stigma/carpel/pistil of a flower;

pollen grains grow a pollen tube down the style to the ovule;

male and female gametes/nuclei join/fuse (in the ovule/ovary) during fertilization;

the ovary matures into a fruit;

dispersal of seeds depends on the fruit;

example of seed dispersal; (*e.g. pods split open to scatter seeds, e.g. animal eats fruit / ingests and egests seed*)

b.

	spermatogenesis	***oogenesis***
a.	both start with germ cells/germinal epithelium (of gonad);	
b.	both start with mitosis to produce many cells;	
c.	both involve cell growth before mitosis;	
d.	both involve meiosis/reduction division/create haploid cells;	
e.	occurs in testes	occurs in ovaries;
f.	millions/large numbers produced daily	one/few produced per month;
g.	released during ejaculation	released during ovulation/mid-way through cycle;
h.	begins during puberty	egg production begins before birth;
i.	continues throughout life	production stops at menopause;
j.	four sperm made per meiosis	only one egg produced per meiosis;
k.	polar bodies not produced/equal division	polar bodies produced/uneven division of cytoplasm;
l.	cytoplasm is reduced in sperm	cytoplasm is enhanced in eggs;
m.	sperm are motile	eggs are not motile;

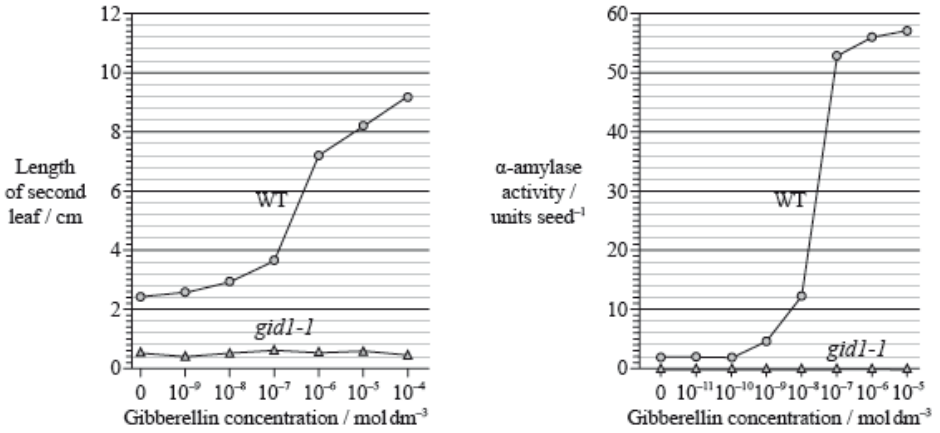
*To award **[8 max]**, responses must provide at least one similarity. Responses do not need to be shown in a table format.*

Examiners report

a. This part of the question was an area of strength in terms of student understanding of concepts and structure of answers. The most likely aspect to cause problems was the distinction between pollination and fertilization.

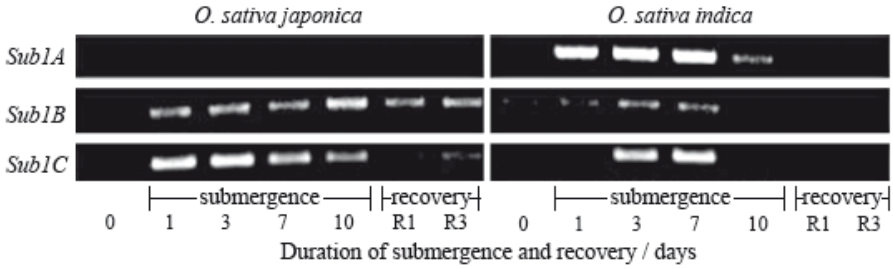
b. This question was answered reasonably well with improvements seen over previous years in terms of the degree to which candidates carried out a comparison throughout. There was occasionally a digression into irrelevant aspects of the menstrual cycle.

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.

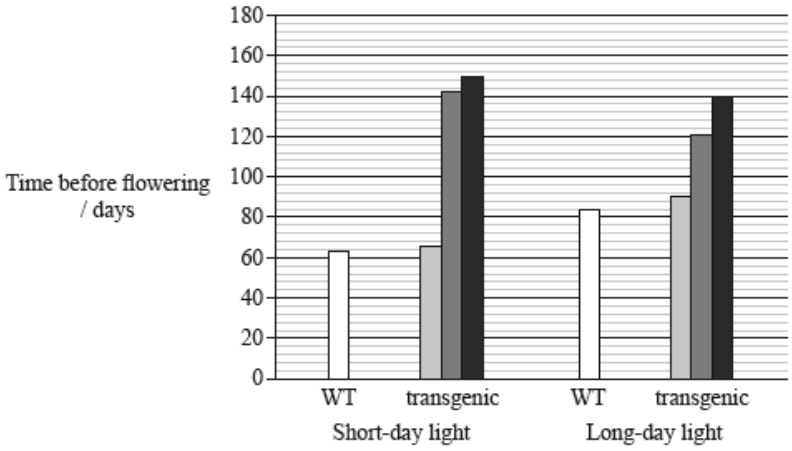


[Source: Adapted from "Sub1A is an ethylene-response-factor-like gene that confers submergence tolerance to rice" (2006) Kenong Xu, Xia Xu, Takeshi Fukao, Patrick Canlas, Reycel Maghirang-Rodriguez et al. Nature, 442, pp. 705—708. Adapted by permission from Macmillan Publishers Ltd (c) 2006.]

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 differences, as asked.

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

e(i). Most answered correctly that it increased the time before flowering.

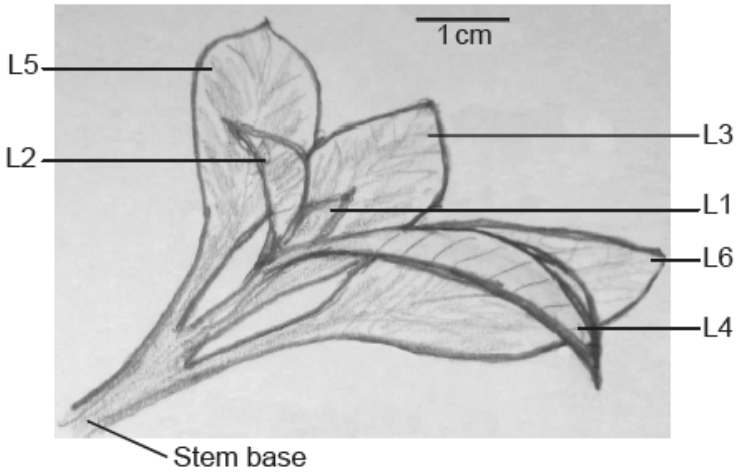
e(ii). In (ii) almost every correct answer was from the first two mark points.

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.

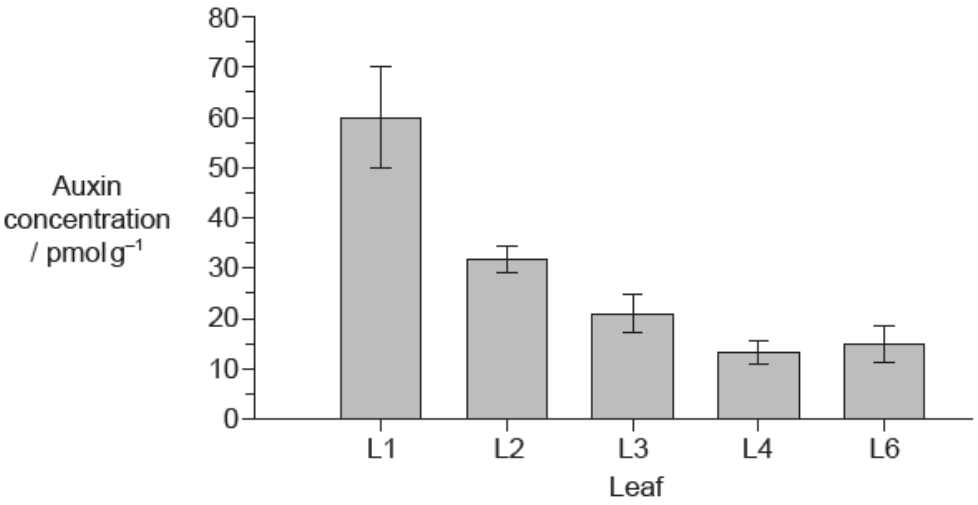
Auxin can be used to promote the development of roots from stem and leafy cuttings in some plants. In a study into the distribution of auxin in the development of these roots, scientists measured the amount of auxin in different leaves of a shoot tip of *Petunia hybrida*.

The figure indicates the numbering of leaves on the shoot, from L1 as the youngest and smallest to L6 as the largest and oldest leaf. The developmental stage of L5 and L6 was very similar, so L5 was not analysed. The stem base is the lowest part of the cutting where roots may form.



[Source: A. Ahkami *et al.* (2013) *Planta*, 238, pages 499–517]

The graph shows the auxin concentration in the different leaves.



[Source: A. Ahkami *et al.* (2013) *Planta*, 238, pages 499–517]

N-1-naphthylphthalamic acid (NPA) is an inhibitor used to block auxin transport. NPA was sprayed onto the leaves of a set of cuttings for 14 days.

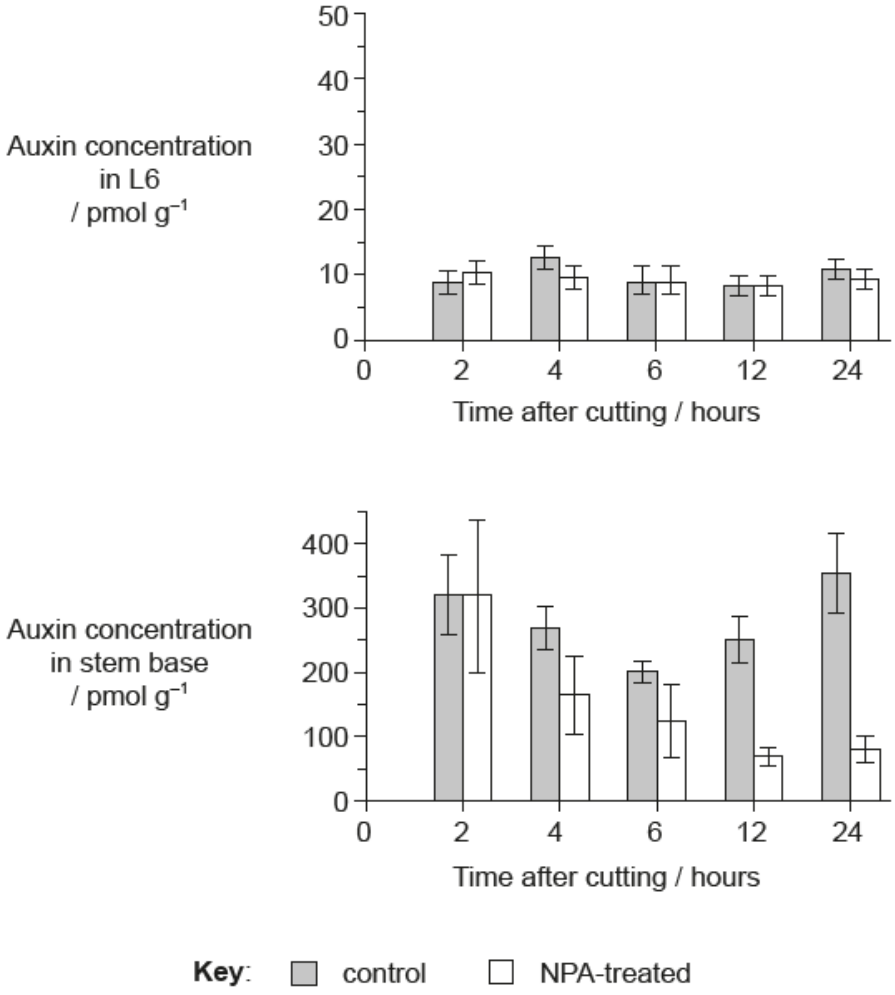
Development of the roots in control (non-treated) and NPA-treated cuttings was measured 14 days after taking the cuttings.

The table shows the influence of NPA on rooting.

	Mean number of roots per cutting	**Mean root length / cm**	**Mean total root length per cutting / cm**
Control	53.2	1.4	47.7
NPA-treated	8.0	0.6	1.0

[Source: adapted from A Ahkami, *et al.*, (2013), *Planta*, **238**, pages 499–517]

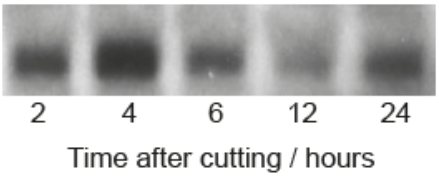
The scientists also measured the changes in auxin concentration in L6 and the stem base during the early period of root formation. They recorded the concentration in the control and NPA-treated cuttings for 24 hours after taking the cuttings.



[Source: adapted from A Ahkami, *et al*., (2013), *Planta*, **238**, pages 499–517]

The scientists wanted to know whether the accumulation of auxin over time in the stem base of the controls affected expression of the *GH3* gene, known to have a role in growth regulation in different plants. The technique that was used to quantify the level of transcription of the *GH3* gene was Northern blotting. In this procedure the darkness

and thickness of the band is an indicator of the level of transcription of a particular gene. The image shows the result of the Northern blot from 2 hours to 24 hours after cutting.



[Source: adapted from A Ahkami, *et al*., (2013), *Planta*, **238**, pages 499–517]

a. Calculate the difference in the concentration of auxin found in L1 and L6. [1]

. . . . . pmol g^{-1}

b. Identify the relationship between the concentration of auxin and the age of the different leaves. [2]

c. Analyse the effect of NPA on the formation of roots. [2]

d.i. Compare and contrast the changes in auxin concentration in the stem base over time for the control and NPA-treated cuttings. [2]

d.ii. Deduce the effect of NPA on auxin transport between L6 and the stem base. [2]

e. Based on all the data presented and your knowledge of auxin, discuss the pattern of auxin production and distribution in the leaves and the possible relationship to root formation in leafy cuttings of *Petunia hybrida*. [3]

f.i. State the name of the molecule which is produced by transcription. [1]

f.ii. Compare the pattern of *GH3* transcription with the pattern of auxin concentration in the stem base control cuttings. You may use the table provided to help you to record the patterns before you compare them. (Please note: a simple comparison in the table will not gain marks) [2]

	2–4 hours	4–6 hours	6–12 hours	12–24 hours
Auxin concentration				
***GH3* bands**				

f.iii. The scientists concluded that auxin activates the transcription of the *GH3* gene. Using the information on the auxin concentration in the stem base in the graph and the Northern blot, evaluate whether this conclusion is supported. [2]

Markscheme

a. 45 «pmol g^{-1}»

Allow answers in the range of 44 «pmol g^{-1}» to 46 «pmol g^{-1}».

b. less auxin as the leaves become older/larger *Vice versa*

OR

negative correlation from L1 to L4

L4 and L6 leaves have least auxin concentration
OR
L4 and L6/older leaves have about the same concentration of auxin/do not have significantly different concentrations

c. a. NPA decreased the «mean» number of roots per rooted cutting «by about 5» *OWTTE*

b. NPA decreased the «mean» length per root «by more than half»

c. NPA decreased the «mean» total root length per planted cutting «to about 2 % of control» *OWTTE*

d. NPA inhibited the formation of roots
OR
decreased all three measures

Accept other correct statements of overall changes in values.
The word "mean" is not required.

d.i. a. both decrease up to 6 hours/initially

b. NPA-treated decrease more/at a faster rate than control «up to 6 hours»

c. after 6 hours, control increases while NPA treated continues to fall

d.ii a. NPA «appears to have» no effect on concentrations/transport of auxin in L6 as control and NPA-treated remain at same «low» level

OWTTE

A valid reason must be given for the mark.

b. NPA «probably» inhibits the auxin efflux pumps/transport «in the leaves» as the levels drop in NPA-treated in stem base «but not in control»

OWTTE

A valid reason must be given for the mark.

c. the transport of auxin to the stem base must occur from younger leaves
OR
L6 is not the source of auxin in the stem base

d. NPA inhibits the auxin pumps/transport «in the leaves» as the levels drop in NPA-treated in stem base

e. a. L1 has the highest concentration of auxin so appears to be/is the main source/the producer of auxin

b. as leaves age, they «appear to» decrease the production of auxin

Vice versa

c. the stem base is an auxin sink as seen by the accumulation in the control stem base «where roots form»
OWTTE

d. high concentration of auxin «in the stem base» promotes root formation
Vice versa

f.i. mRNA/RNA

f.ii. a. at 2 and 24 hours, auxin levels are similar and at 2 and 24 hours *GH3* levels are similar

b. the pattern for the formation of auxin is similar to the pattern of transcription of the *GH3* gene
OR
both decrease and then increase

c. «however» there is a lag between the peaks of the *GH3* transcription and the peaks of auxin

A comparison must be made to award marks. Do not award marks for simple completion of the table.

f.iii a. the data «partially» supports the conclusion

OR

the relationship is not clear

b. the auxin concentration «seems to» rise before the transcription level increases

OR

there is a lag between auxin concentration changing and transcription level changing

OR

the auxin concentration falls before the transcription level falls

To award mp b, awareness of the lag should be demonstrated

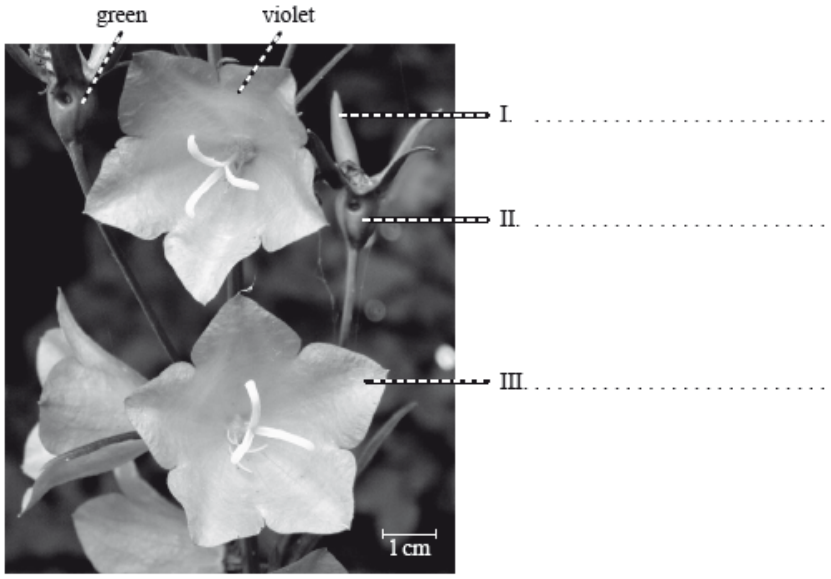
c. more data is needed «before two hours/after 24 hours»
OWTTE

Examiners report

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

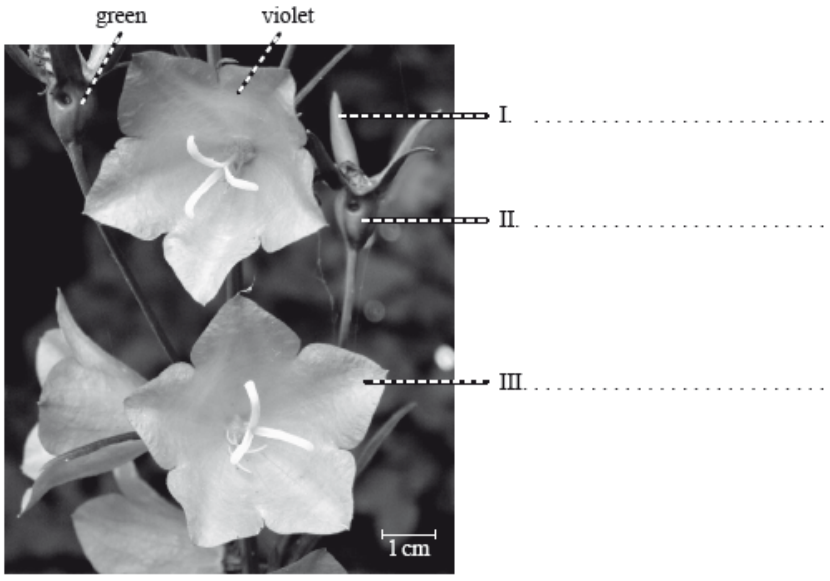
---

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



[Source: photograph provided by IB examiner]

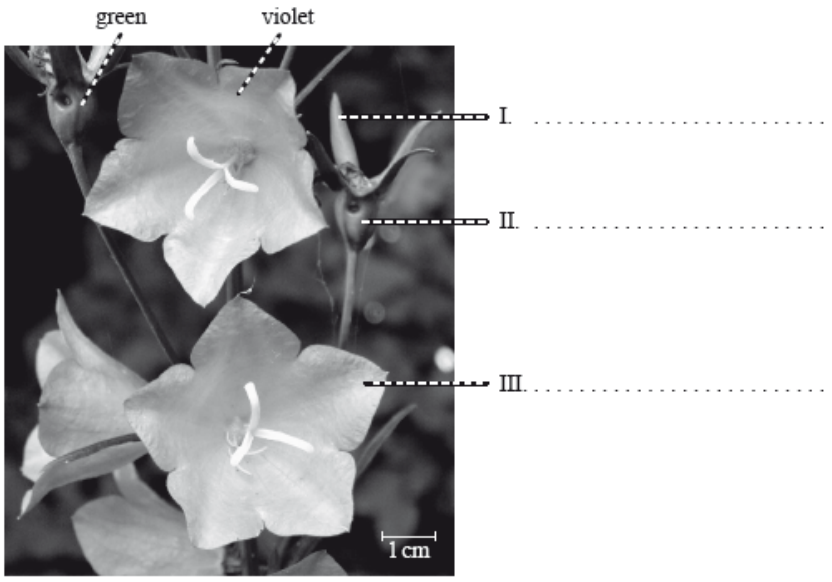
b(i). [1]



[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.