16.1

Investigating the effect of hormones on plant growth

1 **Advantage:** You can identify the effect of different concentrations of hormone on plant growth, helping you build a model of the concentrations involved in the plant (1). **Any other sensible suggestion.** **Disadvantage:** You might use concentrations that are nothing like those involved in the plant cells – the concentrations effective in the cells might be so low that it is difficult to work at those levels experimentally. **Any other sensible suggestions.**

2 Significant increase means the increase in fresh mass was statistically significant – in other words the increase in fresh mass observed is very unlikely to have arisen by pure chance (1); to calculate whether a difference is significant you need to apply the most appropriate statistical test. With the information given in this case it is most likely that the Student’s t-test will be the test to use, to compare means (1); applying the formula for the test gives a test statistic result, this is then compared with the critical value (1); with the relevant confidence level (95% / p = 0.05) and the correct degrees of freedom given the details of the experiment (1); if the test statistic is equal to or greater than the critical value, the difference is reported as being significant (1).

Summary questions

1 Plants are multicellular and often large so need coordination (1); plants don’t appear to have nervous systems so no electrical coordination system (1); chemicals can be carried in plant transport systems and move from cell to cell to coordinate responses (1).

2 a Any three hormones and functions from Table 1 – must have correct hormone and function for the mark (3).

2 b Analogous to animal hormones (1); involved in coordination and control of the plant (1); made in one place (1); and carried through the transport system to another region where they have an effect (1) (max 3)

3 a There are a variety of examples students could choose. One example is given here to show the level of detail required for the marks: Auxin produced in tip of growing shoot stimulates growth in some regions of the plant and inhibits growth in others – the apical shoot grows and lateral shoots are inhibited (1); if tip of leading apical shoot is removed, growth in that shoot slows as stimulation of auxin removed (1); lateral shoots grow faster as auxin inhibition removed (1); replace auxin artificially on leading shoot (1); and apical shoot stimulated and grows fast again (1); while lateral shoots inhibited again and growth slows (1).

3 b One chemical can exert control in different ways in different parts of the plant, allowing for complex coordination without production of huge numbers of different chemicals (2).

4 Current model: Auxin molecules bind to specific receptor sites in the plant cell membrane, activating process which pumps hydrogen ions into cell wall spaces, lowering pH to about 5, the optimum pH for the enzymes that break down bonds between cellulose microfibrils, so they slide past each other easily and the walls remains very flexible and plastic allowing cells to stretch and grow (2); graph shows decrease in pH of cell wall from almost 6 to below 5 after the application of auxin (1); this is followed by increased rate of shoot elongation from 1–2 microns per minute (1); to approximately 6 microns per minute (1); appears to confirm both change in pH and resulting increase in stretching of cell wall and growth (1).

16.2

Summary questions

1 They are rooted to the ground so cannot move their bodies (1); therefore very important that they are sensitive so they can grow in the right direction and make the best of the circumstances where they have germinated (1).
2 The amount of photosynthesis that can take place decreases as day length is reduced and temperatures fall (1); so the amount of glucose produced by photosynthesis falls (1); the amount of glucose needed for respiration to maintain leaves through the winter (1); and produce chemicals to prevent freezing damage increases (1); it becomes more efficient to lose the leaves and become dormant until the days lengthen and temperatures increase again (1).

3 Falling light levels → decreased concentration of auxin → leaves produce hormone ethene → ethene initiates gene switching in abscission zone at base of leaf stalk → gene switching causes production of new enzymes → new enzymes digest and weaken cell walls in outer layer of abscission zone (separation layer) → vascular bundles sealed off, fatty material deposited in cells on stem side of separation layer → layer forms protective scar when leaf falls preventing pathogen entry → cells in separation zone respond to hormonal cues by retaining water and swelling putting more strain on outer layer → further abiotic factors finish process → strain is too much and leaf separates from plant leaving neat waterproof scar (max 6).

4 a Chemicals such as abscisic acid (1); trigger gene switching (1); so plants make chemicals such as sugars or proteins (1); which lower the freezing point of the cytoplasm (1); or protect the cells against damage by ice crystals if they do freeze (1).

b Water in intercellular spaces freezes and energy released raises temperature of cells (2); solute concentration in cytoplasm/vacuoles maintains lower freezing points (1).

c Protection mechanisms include leaf loss, production of chemicals to act as antifreeze or ice protection depend on gene switching, and production of new compounds in response to triggers of day length and temperature which take place over several weeks (2); sudden early frost – cold protection mechanisms not in place as plants move into summer mode (1); so levels of protection have fallen (1); and can't respond to freezing temperatures so cells destroyed (1).

5 Water stress induced experimentally by withholding water from plants (1); ABA content of leaves increases shortly after water stress induced (1); stomatal resistance increases (stomata close) as ABA levels increase (2); as soil rehydrates, ABA levels decrease rapidly in response (1); as ABA levels drop, stomatal resistance decreases as stomata reopen (2).

16.3

*Mimosa pudica* – nerves and muscles in plants

Initial folding fast to avoid herbivory – if it was slow it wouldn't frighten an animal away or make an insect fall off the leaf to have a selection value must be fast (1). In survival terms, it is worth expending ATP to save leaf (1). Recovery: if it recovers too fast herbivores may return and eat leaf again, no need for rapid recovery so can rely on concentration gradients, etc. to restore original levels and expend as little ATP as possible (1). *Any other sensible points.*

Summary questions

1 Herbivory is the process by which herbivores eat plants (1).

2 Any two can be chosen 1 mark for correct chemical, 1 mark for defensive role in plant, 1 mark for human uses. For example *tannins* (1); bitter taste puts animals off eating leaves OR toxic to insects (1); flavour tea and red wine (1). *Alkaloids* (1); affect metabolism, often poison animals OR prevent germination in plants OR stop roots of neighbouring plants spreading OR taste bitter (1); *insecticide terpenoids*; toxic to insects OR repel insects; used as insect repellent (1).

3 a A pheromone is a chemical made by an organism which affects the social behaviour of other members of the same species (1); plants are not mobile and do not behave socially so pheromones are not entirely appropriate (1).

b They must travel through the air inside or outside of the plant to carry their message (1); so they must be in the form of a gas or vapour (1).
c Any suitable examples chosen by student – the discussion about pheromones must include recognition that pheromones act between members of the same species to affect social behaviour (3 marks max for each example). For example, pheromone produced by maple tree when attacked by insects that is absorbed by leaves on other branches and nearby trees (1); that make protective chemicals such as callose (1); pheromone because acts between members of the same species to affect their behaviour (1); OR not a pheromone as does not affect behaviour, only biochemistry. Apple tree attacked by spider mites produce chemicals that attract predatory mites (1); that come and destroy the spider mites attacking the tree (1); NOT a pheromone as affects the social behaviour of a different species (the predatory mites) not the same species (apple trees).

16.4

Practical investigations into phototropisms
Any sensible points raised by students, for example, immediate pictorial record (1); able to make a series of photographs to record changes (1); time-lapse photography to show movement (1); have camera always same distance away and so make accurate measurements of growth movements (1); easy to save record, combine images and graphs. Disadvantages: Not everyone has access to smart phones/tablets, in experimental setting potential to get things wet/drop them etc (1); have to remember to always position in exactly same place at same angle or can introduce anomalies/false evidence (1); can lose data/hard delete by accident (1); if lose or break phone or tablet all data lost (1) **any other sensible points** (max 6).

Practical investigations into geotropisms
Plants respond to unilateral light by growing towards it (1); in dark or all round light they do not grow towards light specifically so can assume any responses will be due to gravity (1). **Any other sensible suggestion.**

Summary questions

1 a Plant growth responses to a directional stimulus (1)

b **Phototropisms:** Plant responses to unilateral light (1); **Geotropisms:** Plant responses to gravity (1).

c Shoots positively phototropic and negatively geotropic (1); roots negatively phototropic and positively geotropic (1).

2 Variety of ways students might do this but answers must include: Unilateral light causes lateral movement of auxin (1); across from the illuminated side to the shaded side (1); → low levels of auxins reach elongating cells on lit side and higher than usual levels of auxin reach elongating cells on shady side of shoot (1); → Reduced elongation and growth on lit side of shoot, extra elongation and growth on shady side of shoot (1); → shoot bends as it grows to face the light as a result of asymmetric growth (1); → auxin distribution becomes even again so shoot grows straight towards light (1).

3 Water soluble substances will pass through gelatin as it is made up of water (1); butter is a fat so water soluble substances will not pass through it, but fat soluble substances will (1); gelatine allows auxin to pass through it and so the response to unilateral light is maintained (1); butter prevents auxin moving through it so the response to unilateral light is lost (1); indicating that auxin is water soluble and not fat soluble (1).

4 Look for students commenting on some or all of the following (max 6): the importance of space flight in the investigation of geotropism should be mentioned for full marks (1); the role of the root cap (1); gravity perceiving cells (1); amyloplasts and sedimentation under gravity (1); role of calcium ions (1); work in space to remove gravity (1); possibility of magnetic gradients (1); role of auxin (1).

16.5

Summary questions
1 Ethene involved in natural fruit ripening (1); used to ripen fruit such as bananas, mangos, tomatoes etc. at desired time (1); cytokinins and gibberellins can be used to delay fruit ripening (2).
2 Ripe fruit is easily damaged in transport (1); once fruit is ripe it has a finite life before it goes off (1); if fruit is transported unripe and hard (1); much less likely to be damaged and doesn’t start to go off (1); controlled ripening when needed gives uniform product (1); and minimises waste (1).
3 Should include: Auxins – rooting powder, selective weedkillers, development of seedless fruit, leaf fall, (1.5 marks for at least 2 suggestions). Ethene – controlled ripening, fruit dropping, leaf fall (1.5 marks for at least 2 suggestions). Gibberellins: delays fruit ripening, increases fruit size, speeds up the brewing process (1.5 marks for at least two suggestions). Cytokinins: prevent ageing of ripened fruit and lettuces etc., and in micropropagation to control tissue development (1.5 marks for at least two suggestions) (max 6).
4 Ethene levels rise at rate of approximately 5 µl/kg h⁻¹ from day 2 to day 4 (1); and then remain at a steady level (1); carbon dioxide levels increase at a rate of approximately 15 ml/kg h⁻¹ from day 2 to day 4 (1); as ethene levels rise (1); as the ethene levels plateau, the carbon dioxide levels decrease steadily (1) at a rate of around 5ml/kg h⁻¹ for 5 days (1).

b Initial rise in ethene levels triggers start of ripening process (1); many different reactions take place to bring about fruit ripening (1); requires a lot of energy so respiration rates increase (1); and so carbon dioxide levels increase dramatically reflecting increased cellular respiration (1); raised ethene levels maintain ripening process (1); but reactions gradually slow down as aspects of ripening are completed so demands on respiration are less so amount of carbon dioxide produced is reduced (1). Any other sensible scenario can be given some credit. Link between metabolic increase in response to ethene, reflected by increased levels of carbon dioxide must be included.

c Ripening is the result of many enzyme-controlled reactions(1); at lower temperatures reactions occur more slowly (1); so ripening occurs more slowly even with ethene present (1).