Core practical 1

1 Independent: trypsin concentration. Dependent: rate of reaction in absorbance units, s^{-1}.

2 Because the reaction is rapid and the milk (substrate) concentration quickly declines. The rate slows as the substrate is used up. Comparisons can only be made at the start of the reaction where controlled variables such as substrate concentration are the same for all levels of the independent variable.

3 A systematic error, because it would cause absorbance readings to be higher than the true value for every measurement.

4 pH – the rate of reaction of enzymes varies with pH, due to changes in the shape of the active site. An enzyme would have the highest rate of reaction at its optimum pH. A buffer might be used to maintain pH at a suitable level. Temperature – the rate of reaction of enzymes varies with temperature. As temperature increases, particles gain more energy and more collisions take place between enzyme and substrate particles. Enzymes have an optimum temperature at which the rate of reaction is at its peak. Above that temperature, enzymes will begin to denature, changing the shape of the active site and preventing further catalysis. A water bath and thermometer could be used to maintain a suitable temperature.

Core practical 2

1 This will depend on the size of the drawing and the objective used. You should divide the image size (length of scale bar measured with a ruler, converted to μm) by the actual size (the length that the scale bar represents in μm).

2 A suitable summary might include the following points.

- Use a stage micrometer and eyepiece graticule (eyepiece micrometer).
- Calibrate the eyepiece graticule with the objective lens that will be used.
- Do this by measuring the eyepiece scale against the scale of the stage micrometer.
- Measure the cell using the eyepiece scale and convert into length units (μm).

3 Calculate a mean. Measure more cells to estimate a more reliable mean. The volume of the cells would be a better descriptor of size than the linear dimensions.

Core practical 3

1 The root tip is heated with acid to break up the tissues into individual cells. The cellulose walls of plant cells are held together by pectins such as calcium pectate. Treatment with hydrochloric acid breaks this down.

2 Pressing the preparation will separate the cells in the meristem tissue into individual cells in a single layer. This makes it easier to see the chromosomes and to identify the stages of division.

3 The cell counts show the relative duration of each stage in the cell cycle. The longer a phase, the more cells are likely to be going through that phase at any point in time.

4 Mitosis produces identical daughter cells for growth, replacement and repair.

Core practical 4

1 Advantage: the use of pollen from the same flower improves the validity of the results because the maturity of the flower is a controlled variable. This means that any differences in the results between treatments are more likely to be a result of the differences in sucrose concentration.

Disadvantage: the results may not be reliable. Different results may arise if the experiment is repeated because of differences between flowers. Flowers may differ slightly in maturity or there may be genetic differences in pollen tube growth. Ideally, the investigation would be repeated with a large number of flowers and a mean would be taken.

2 The pollen tube carries the male gametes to the ovule for double fertilisation.

3 Pollen tube growth may be attracted towards the micropyle by chemicals secreted by the embryo sac. The pollen tube may be positively chemotropic.

Core practical 5

1 The variables controlled during the experiment are:

- the volume of bathing water in each tube (10 cm)
- the surface area and volume of the beetroot cylinders (dependent on size of cork borer; 1 or 2 cm in length)
- the equilibration time (5 minutes)
- the soaking time for the cylinders (15 minutes)
- the volume of coloured liquid in the cuvettes (e.g. 4 cm^3)
- the colorimeter filter/wavelength used (blue/green)
- the part of the beetroot the core was taken from (e.g. the centre)
- the age, variety and storage time of the beetroot (the same beetroot or beetroots from the same batch may have been used).

2 The temperature must be equilibrated to ensure the tubes contain water at the correct temperature before starting the experiment. This allows confidence that the effect of the correct temperature is being assessed.

3 The cylinders are washed and dried to remove excess surface pigment from the cut cells at the edge. This excess pigment would distort the transmission readings, giving inaccurate results.

4 The percentage transmission decreases as the temperature rises. Initially there is little increase, but at around 40–60 °C the percentage transmission decreases sharply. You should use values from your own graph. At higher temperatures, the rate of decrease usually levels out.

5 At lower temperatures the tonoplast and plasmalemma are intact and betalain molecules are too large to pass through these membranes easily, meaning light transmission remains high (note that if cells freeze, damage to membranes may cause pigment release). The higher the temperature, the greater the kinetic energy and the faster the movement and diffusion of pigment molecules. Greater kinetic energy also causes phospholipids of the membrane to become more fluid and bonds between the fatty acid tails can begin to separate so that some pigment molecules can pass through. Therefore, more pigment passes through the membrane, decreasing the amount of light that can pass through the liquid (percentage transmission). The point of sudden increase in percentage transmission occurs when proteins in the membrane begin to lose their tertiary structure. At higher temperatures, the protein molecules in the membrane become completely denatured and the membrane develops gaps through which the pigment can flood out. Eventually, the change in transmission levels out as the concentration of pigment is the same inside and outside the cells.

Core practical 6

1 The solution closest to 50% plasmolysis will vary according to the tissue used.

2 This will depend on your results; you should read off the concentration that would give 50% plasmolysis.

3 Water potential is described by the equation $\psi = P + \pi$. At the point of incipient plasmolysis, the cell membrane is just beginning to peel away and exerts no pressure on the cell wall, so $P = 0$. Therefore, ψ must equal π. There is no net movement of water by osmosis at this point.

4 This will depend on your results. You will need to estimate between points on the table.

Core practical 7

1 a The chitin spirals support the tracheae. They hold the tracheae open if they are squashed as the insect moves.

b Ventilation movements actively pump air into the tracheal system and increase the supply of oxygen to very active tissues. Expansion of the abdomen increases the volume and therefore decreases the pressure inside the body so that pressure in the tracheae becomes lower than atmospheric pressure, drawing air in through open spiracles. Compression of the abdomen decreases the volume and increases the pressure inside the body so that air moves out of the tracheae through open spiracles.

c Air sacs act as air reservoirs or bellows. They increase the volume of air moved through the respiratory system. They have flexible walls so that changes in pressure caused by ventilating movements of the abdomen (or the thorax when in flight) inflate and deflate them.

2 Opening and closing of the spiracles allow the rate of gas exchange to be controlled. But water vapour also diffuses out of spiracles, so sphincters allow spiracles to be kept closed as much as possible to minimise the amount of water lost.

3 Suitable approaches that you might describe include reducing the number of animals used by working in groups or observing a teacher demonstration, any steps taken to reduce suffering of animals or prevent them experiencing stress (e.g. humane killing). This may be based around the three 'R's: Replacement, Reduction and Refinement. You may also describe steps you took to derive maximum benefit from the use of animals.

Core practical 8

1 Without an airtight seal, water will not be drawn up the capillary tube and no air bubble movement will be possible. Water movement in the capillary tube and in the xylem relies on cohesive forces between water molecules. Air bubbles prevent the cohesive forces and stop the upward tension being transmitted through the entire water column.

2 Limitations may include:
- factors that influence transpiration and are difficult to control, such as the size of the shoot, the number of leaves on the shoot, the total surface area of the leaves, leaves that have not been dried fully or differences in density of stomata between leaves
- factors that reduce the accuracy of the equipment, such as the difficulty in making a seal between the shoot and the apparatus.

3 The limitations may have the following effects.
- Transpiration rate will increase if a larger leaf surface area is used or if there are more leaves present. Wet leaves reduce the diffusion gradient for water.
- The lack of an airtight seal will slow air bubble movement and may stop transpiration altogether. This will produce a lower value for the water uptake rate.

4 The limitations could be reduced in the following ways.
- Shoots should be the same size, with the same number of leaves. Leaf area should be measured so that water loss per unit area can be calculated.
- The seal between the shoot and the apparatus must be as airtight as possible. This may be achieved by using a flexible material and adding a sealant.
- Repeating the experiment a large number of times will give a measure of reliability and will allow a mean to be calculated.

Core practical 9

1 Both plants and animals respire to produce ATP for cellular processes, but animals also move around and require additional ATP for muscle contraction. Respiration rates are therefore usually higher in animals.

2 Some variables may not have been effectively controlled, such as temperature, amount of movement, age or stage of development of organisms. The low resolution of the manometer scale will also cause some uncertainty in readings.

3 Temperature could be controlled using a water bath. Organisms could be matched between groups for size or stage of development.

4 **a** A decrease in temperature or an increase in atmospheric pressure would cause movement towards the respirometer. An increase in temperature or a decrease in atmospheric pressure would cause movement in the opposite direction.

b Movement towards the control respirometer would be subtracted from results; movement away from the control respirometer would be added to results.

5 Soda lime is used to absorb any carbon dioxide produced by the respiring organisms. The gas volume will reduce as oxygen is removed for respiration.

6 A reduction in gas volume will reduce the pressure inside the tube. As it becomes lower than atmospheric pressure, the fluid bubble will move towards the respirometer chamber.

Core practical 10

1 We assume that the gas is oxygen and that the rate of bubble formation will be directly proportional to the rate of photosynthesis.

2 Oxygen will be produced by photosynthesis but there could be a small amount of carbon dioxide in the bubbles from respiration. Some of the oxygen produced will be used internally in respiration. Nitrogen may also come out of solution in the water. The rate of respiration is likely to be constant and is unlikely to be affected by altering the wavelength of light. Providing the temperature remains constant, the assumption that any change in rate of gas production is due to changes in the rate of photosynthesis is therefore probably valid.

3 Ideas could include longer test periods, better ways of ensuring that no ambient light influences results, repeating the procedure with different pieces of pondweed, greater control of factors such as temperature, measurement of light wavelength and quantification of light intensity or plant biomass.

4 The absorption of CO_2 per unit time; the increase in biomass or production of carbohydrate per unit time.

Core practical 11

1 The R_f value of a particular substance should always be the same provided the chromatogram is treated in the same manner in each case. Different paper, solvent and running conditions may affect the R_f values. While the values in this table are for the same solvents, there may be slight differences.

2 It would be more accurate to use pure extracts of the pigments as reference standards and test them alongside the leaf extract in an identical chromatography procedure then compare R_f values.

3 Some substances do not move at all because they are insoluble in the mobile phase/solvent.

4 Each of the pigments absorbs and captures energy from light from particular areas of the spectrum. As a result, far more of the energy from the light falling on the plant can be used than if only one pigment was present.

Core practical 12

1 Calibrate OD readings using either dilution plating or direct counting (using a haemocytometer). Produce a calibration curve for a range of OD readings and use the graph to estimate the number of microorganisms present.

2 The method is valid because most of the change in turbidity will be a result of microorganism cells in suspension. However, the method does not distinguish between live cells and other particles in suspension such as dead cells, spores or cell fragments, which reduces the validity.

3 The magnetic stirrer keeps cells in suspension and ensures that nutrients are evenly distributed. It also oxygenates the culture to allow aerobic respiration.

Core practical 13

1 Sets of streaks must cross over so that clumps of bacteria in the first streaks can gradually be spread out into subsequent streaks.

2 Temperatures above 30 °C are closer to human body temperature, so temperatures in this range would cause a risk of incubating human pathogens which could infect you.

3 The use of aseptic technique is vital in microbiology to ensure that there is no contamination of cultures by microorganisms from the environment and that people and the environment are not contaminated by the microorganisms being handled. Even cultures thought to be low risk should be treated with caution, as bacteria may mutate to form pathogenic strains, our knowledge of the hazards may be incomplete or the culture may have become contaminated.

4 *Micrococcus luteus* forms yellow colonies and *Escherichia coli* and *Bacillus megaterium* form white colonies.

5 Ideas might include overall shape, shape of the colony margin, whether colonies are shiny or dull, and height of colony (flat or raised).

Core practical 14

1 The embryos would produce gibberellin in unknown quantities, reducing the validity of the results.

2 Microorganisms such as fungi and bacteria may produce amylase, which would produce clear zones. If there had been contamination close to the seeds, this would make the measured results invalid.

3 Gibberellin at certain concentrations stimulates the production of amylase by the aleurone layer around the endosperm. This hydrolyses starch to maltose. Iodine only stains the areas that contain starch.

Core practical 15

1 Percentage cover is more appropriate because the grass plants are very abundant in this community and it is difficult to separate individual grass plants.

2 The more quadrat samples are taken, the more reliable the estimate of mean population will be. The number must be large enough to minimise the effect of anomalies, but not too large to be carried out in the time available. You could plot the cumulative mean population against the number of quadrat samples. When the mean has stabilised, meaning that it changes very little from one sample to the next, this indicates a sufficient sample size.

3 It is important to sample randomly to get a true representation of the population and avoid investigator bias. If plants are not evenly spaced throughout the study area, then it might be tempting to go to those places where the plants are or to throw a quadrat in that direction, resulting in a population estimate that is greater than the true population.

4 Answers will depend on your findings. A single large quadrat is likely to record more species than a small one. Small quadrats are quicker to count, so more samples can be taken and a wider range of the habitat can be covered. However, they would not be suitable for large species. It is difficult to keep a count of large numbers of plants in a big quadrat, so numbers may be under- or over-estimated.

5 Results gathered using point quadrats are more objective but may be less precise. Each point may account for several per cent within one quadrat; in a quadrat with 16 points each 'hit' is worth 25%. Point quadrats are more likely to miss the presence of species with low abundance. Frame quadrats rely on some estimation of percentage cover by eye, which may be subject to investigator bias.

Core practical 16a

1 Using an interrupted transect is quicker, or allows a greater distance to be covered in the same amount of time. Interpolation between quadrats can be used to estimate the overall trends.

2 We can only conclude that there is a relationship, we cannot conclude that changes in light intensity cause the changes in distribution. Any patterns could be the result of other abiotic factors such as soil moisture content, or the result of biotic factors such as competition.

3 Take all readings as close together in time as possible because light intensity can be very variable over short timescales, for example, due to clouds passing over. It would be better to take multiple sets of readings throughout the day.

Core practical 16b

1 Check the publication type. Is it subject to peer review, as scientific journals should be? Is there any possibility of bias, such as commercial interests? Is it up to date? Check the author(s). Can you tell who wrote the article? If so, are they experts in this topic? Have they published elsewhere? Check to see if the information is backed up by similar statements in other publications. Is the publication widely cited by other authors? If so, make sure it is cited for the right reasons!

2 A hazard is a potential source of harm. A risk refers to the likelihood that a person will be harmed, e.g. high risk or low risk.

3 Reliability: results are reliable if they can be repeated by other scientists to achieve similar results.

Validity: a measurement is valid if it measures what it is supposed to be measuring. This depends both on the suitability of the method and the equipment. For example, results are unlikely to be valid if variables other than the independent variable have not been controlled.