CHAPTER 2

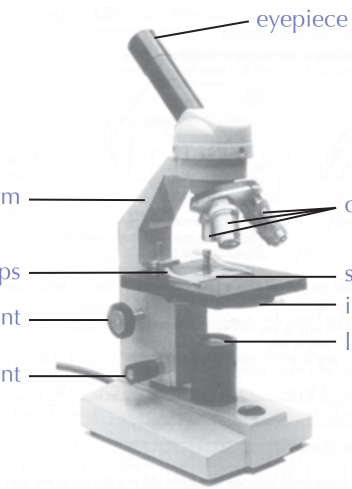
Biological material at the microscopic level

NCEA Level 2 Biology material covered in this chapter includes material for Achievement Standard 91160 (Biology 2.8) 'Investigate biological material at the microscopic level'. The chapter looks at:

- Preparing biological material for viewing under a light microscope – two different plant tissues and one unicellular organism needed.
- Viewing under the microscope to enable detail of cells and their structure to be seen.
- Recording observation in biological drawings.
- Identifying specialised features and explaining how they enable the cell(s) to carry out their specific functions.

Light microscope

The photo shows a standard light (or optical) **microscope** used in a school laboratory.



The microscope is called a *compound* microscope because it has two sets of lenses: the eyepiece and the objective lenses. The **magnification** of an object on the stage is given by *multiplying*:

magnification of eyepiece lens × magnification of objective lens

For school microscopes, the typical magnification of eyepiece lenses is 10 ×; typical magnifications of objective lenses are 4 ×, 10 ×, and 40 ×; therefore total magnifications are 40 ×, 100 ×, and 400 ×. *Always give the magnification with any biological drawings*.

Activity 2B: Biological drawings

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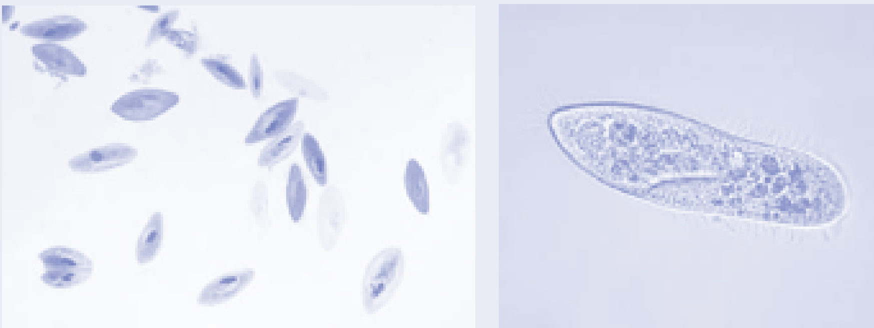
1. The following pictures are photomicrographs – photographs taken of sections as viewed under the microscope. The left photomicrograph shows cells from the lining of a human cheek stained with methylene blue; the right photomicrograph shows cells from the epidermis of an onion stained with iodine. Both are magnified 400 ×.
Make a biological drawing of each photomicrograph. Three structures or components should be identified and labelled in each drawing.

2. Make a biological drawing of the *Paramecium* shown in the following photomicrographs. Three structures or components should be identified and labelled.



Photomicrographs of unicellular organism* Paramecium *magnification 400 ×.
Left diagram shows several* Paramecia *stained; right diagram shows one living* Paramecium *(unstained).

a. Explain why the staining has been used.

b. Identify all the organelles visible from both photomicrographs.

c. Draw a large, clear, labelled diagram of *one Paramecium* to show its shape and main structures.

d. Give the function of the identified structures.

Photosynthesis by plants accounts for the high level (approximately 20%) of *oxygen* in the atmosphere. This gas is essential for the process of *aerobic respiration*.

Without photosynthesis, animal life could not exist.

Respiration

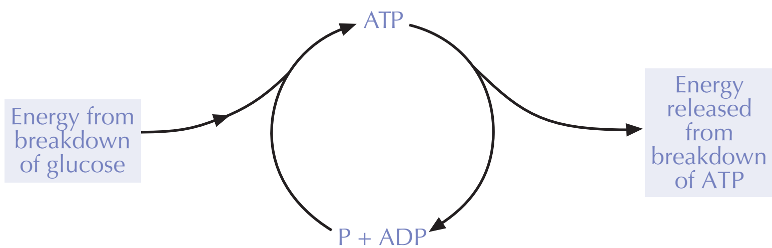
Respiration occurs in the mitochondria of the cells in *all* organisms *all* the time (both day and night). Refer pages 29, 30 for structure and occurrence of mitochondria. Respiration is the process by which the cell breaks down glucose to produce **ATP** – **adenosine triphosphate**; heat energy is a by-product. ATP is the so-called 'energy molecule' in all organisms and is used to fuel all the chemical reactions of the cell, including the following.

- Active transport of substances across membranes.
- Synthesis of molecules – e.g. proteins from amino acids.
- Movement – e.g. phagocytosis, action of cilia and flagella, action of actin and myosin in muscle contraction.
- Bioluminescence (light production) in cells of such animals as glow-worms and fireflies.

The breakdown of glucose may be *aerobic* or *anaerobic*; aerobic respiration produces much larger amounts of ATP per glucose molecule than anaerobic respiration does.

ATP is constantly made in cells from **ADP** – **adenosine diphosphate**. The energy from glucose metabolism adds a high-energy phosphate bond to ADP to make ATP:

When a cell needs energy, the high-energy phosphate bond is broken and ATP returns back to ADP (ADP could be thought of as a 'flat battery' and ATP as a 'charged battery'). The process is very rapid and ongoing.



ADP/ATP cycle in cells

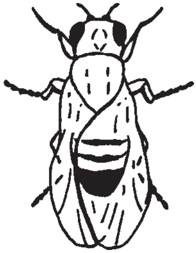
The heat energy produced as a by-product of respiration (aerobic respiration is approximately 45% efficient) is used in maintaining body temperature in homeotherms ('warm-blooded' animals – birds and mammals).

Aerobic respiration

Aerobic respiration needs *oxygen* for the complete breakdown of glucose into carbon dioxide and water; energy is released in the form of ATP and heat. There are three main

Lethal alleles

A **lethal allele** occurs when a mutation results in an allele that produces a non-functional version of an essential protein. If an individual inherits a lethal combination of mutated alleles it will die before or shortly after birth. For example, in fruit flies, *Drosophila*, a mutated allele produces 'curly' wings rather than normal wings. The mutated allele is dominant. Fruit flies that inherit a homozygous genotype for the curly-winged phenotype do not survive to hatch from the egg.



Normal wings

Curly wings

The expected 3 curly-winged : 1 normal-winged ratio of flies from a heterozygous cross becomes a 2 curly-winged : 1 normal ratio, because the homozygous dominant flies do not survive to hatch.

P cross **Cc** × **Cc**

	C	**c**
C	**CC** lethal	**Cc** curly wings
c	**Cc** curly wings	**cc** normal wings

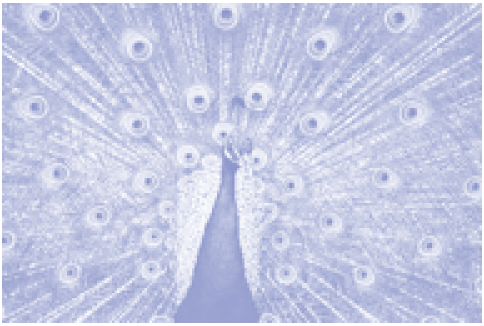
F1 individuals with **CC** die, so the expected 3 : 1 ratio becomes instead 2 curly wings (**Cc**) : 1 normal wing (**cc**).

The breed of cats known as Manx (from the Isle of Man) can be tailless. This results from a dominant autosomal mutation (**M**) that affects the spine, shortening the tail.

The homozygous dominant (**MM**) genotype is typically a lethal combination of alleles. Kittens with this genotype usually die and are aborted naturally before birth, because the spine is dangerously shortened, damaging the spinal cord.

Sexual selection

Sexual selection is a special case of natural selection, in which one sex (usually the female) acts as the *selecting agent*. The males in the species 'advertise' their fitness in some suitable way (e.g. displays, vocalisation, trials of strength) and the female selects the 'most impressive' male as her mating partner – he has the 'best' genes and therefore his alleles will enter the gene pool of the population in his offspring and become more frequent.



Artificial selection

Artificial selection, also known as **selective breeding**, is in contrast to natural selection in that *people* (not the environment) select the individuals that will breed. We do this because certain plant or animal individuals have features that we find desirable. By breeding from them, we increase the probability that the offspring produced will have the desirable features – e.g. faster racehorses, greater milk yield in dairy cows, less-fatty meat in pigs, crisper apples.

Humans have been carrying out artificial selection since the domestication of animals and cultivation of plants began, about 10 000 years ago.

By artificially selecting characteristics beneficial to humans, we have changed the gene pools of many plant and animal species dramatically, to the extent that today some species are radically different from their ancestral type.

By starting with small original gene pools, not allowing immigration, selecting only individuals with specific characteristics for breeding, and enforcing our rules for sexual selection, humans have developed **breeds** within species.

Example

People living in Herefordshire in England decided their 'ideal' type of cattle had to be a rounded, squat, beefy animal with a white face and a white stripe down the back, with the rest of the body being a burnt orange colour. These cattle are now known as Herefords. Conversely, breeders in County Ayr in Scotland wanted a larger, rangier animal that produced lots of milk. Picking individuals with brown spots scattered across a white body produced the breed now known as the Ayrshire. Similar scenarios explain Angus cattle, Friesians, Jerseys and other cattle breeds.

Hereford cattle

Ayrshire cattle

Jersey cattle

Friesian cattle

CHAPTER 13

Mutagens, mutations and phenotype

NCEA Level 2 Biology material covered in this chapter includes material for Achievement Standard 91159 (Biology 2.7) 'Demonstrate understanding of gene expression'.
The chapter looks at:

- Mutations, gene and chromosomal.
- Metabolic pathways.
- Phenotype – effect of mutations and environment.

Mutagens

A **mutagen** is an environmental factor that *changes the genetic material*, usually DNA, of an organism. A mutagen *increases the frequency* of mutations above the natural 'background' frequency – the so-called 'spontaneous mutations' that occur due to errors in DNA replication, repairs, and recombination. Many spontaneous mutations can be repaired by enzyme mechanisms in the nucleus. Since many mutations cause cancer, mutagens are typically also *carcinogens*.

Mutagens usually fall into one of two categories: radiation, and chemical compounds.

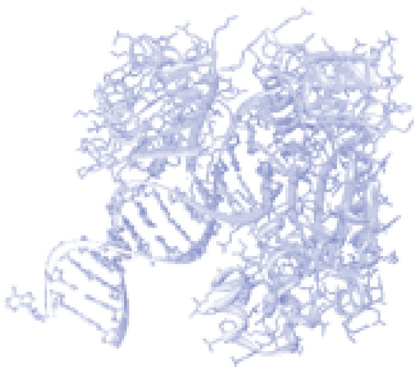
Radiation

Ionising radiation e.g. from X-rays, gamma rays, or alpha particles, and *UV radiation*, e.g. from the sun, can directly damage DNA by breaking the strands, causing loss of bases, and/or causing cross-linking of strands.

Chemical compounds

A large number of chemical compounds, of various sorts, act as mutagens.

Some (e.g. base analogues such as bromouracil) replace normal bases in DNA, others (e.g. ethidium bromide) become inserted between bases, while others (e.g. nitrous oxide) damage bases. Other chemicals (e.g. peroxides, benzene, formaldehyde) can break DNA strands or crosslink them. Note that some viruses can also act as mutagens, because they can invade cells and become integrated into the genome, triggering cancers. An example is the hepatitis B virus, which is a cause of liver cancer.



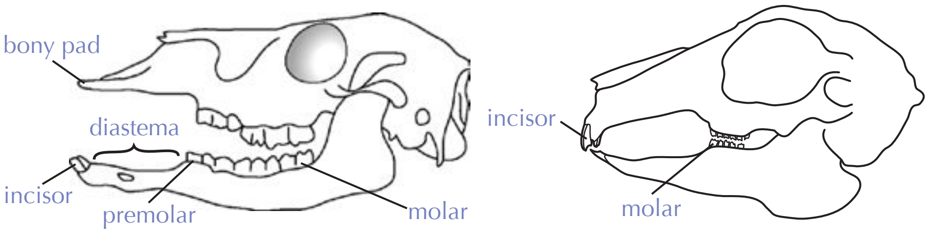
Carcinogen binding to DNA

Mutations

Mutations can be identified as either **gene mutations**, which occur within a gene and change the sequence of DNA bases, or **chromosomal mutations**, which involve changes to whole genes or chromosomes. Only gene mutations are assessed in Bio 2.7. Content on chromosomal mutations is at ▶ **ESA Online**.

In *herbivores,* such as cows and rabbits, canine teeth are typically absent, since they are not needed. Incisors are very large and blunt for tearing off grasses and vegetation. The top incisors can be missing (e.g. in cattle) and the lower incisors move against the bony pad of the upper jaw, which acts as a cutting board. A gap (the *diastema)* typically exists between the incisors and the large ridged, grinding molars at the back of the mouth. The diastema allows room to manipulate food with the tongue (e.g. when cows 'chew the cud') for thorough chewing. The large ridged molars provide an efficient grinding surface for tough plant material – plants have strong cellulose cell walls that must be broken by grinding to release the cell contents.

The large chewing, grinding molars and premolars of a herbivore (a deer)

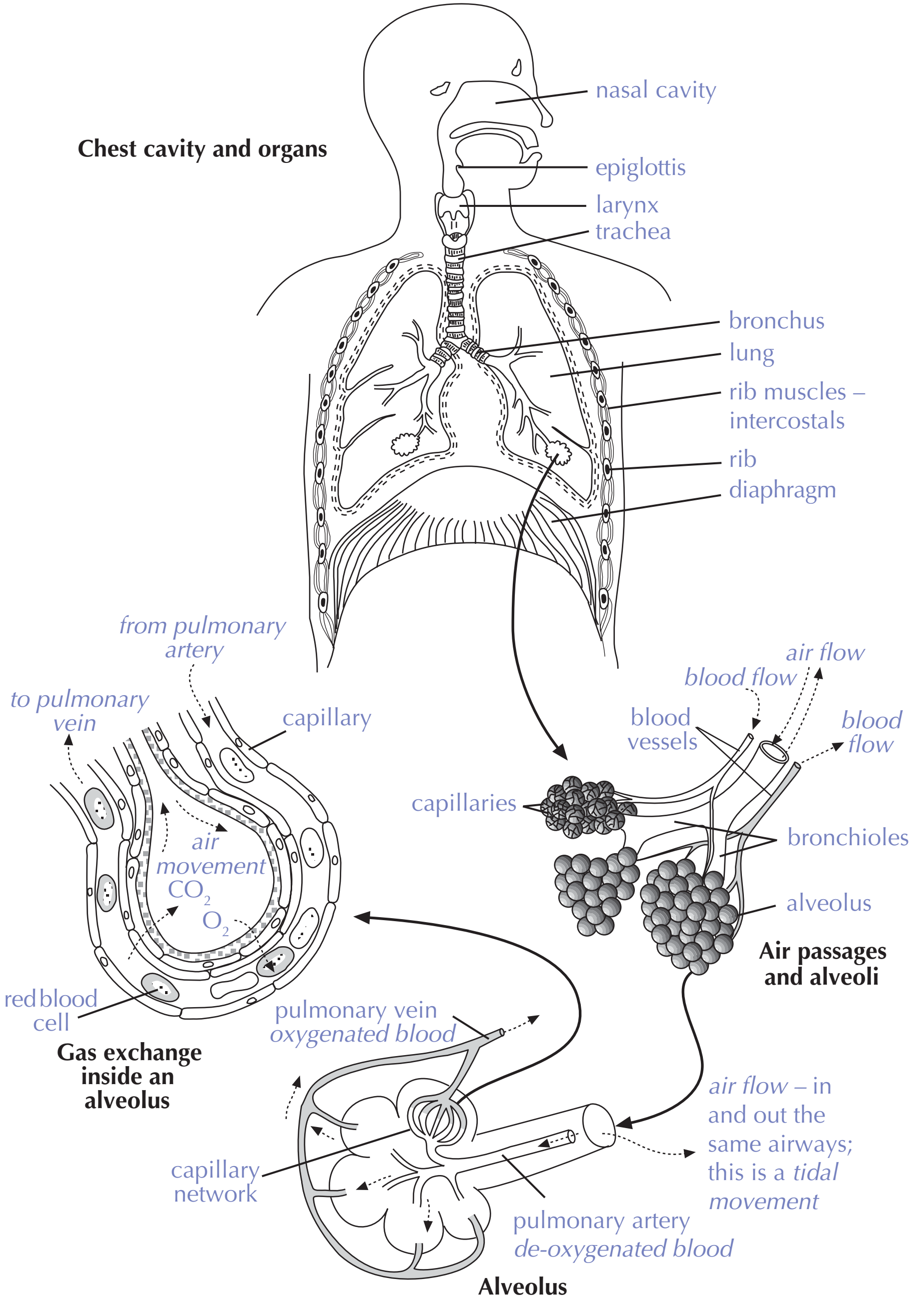


Herbivore teeth (cow (left) and rabbit)

A **dental formula** gives the number and type of teeth in one-half of an adult jaw. The formula gives clues to the diet of the animal.

- Human: I 2/2 C 1/1 PM 2/2 M 3/3
- Cow: I 0/4 C 0/0 PM 3/3 M 3/3
- Rabbit: I 2/1 C 0/0 PM 3/2 M 3/3
- Dog: I 3/3 C 1/1 PM 4/4 M 2/3

Teeth break food into smaller chunks, making food easier to swallow and increasing the surface area to facilitate *chemical digestion*. Saliva mixed with the food acts as a lubricant to help swallowing; in humans, saliva also contains the enzyme *amylase*, which begins the chemical digestion of starch.

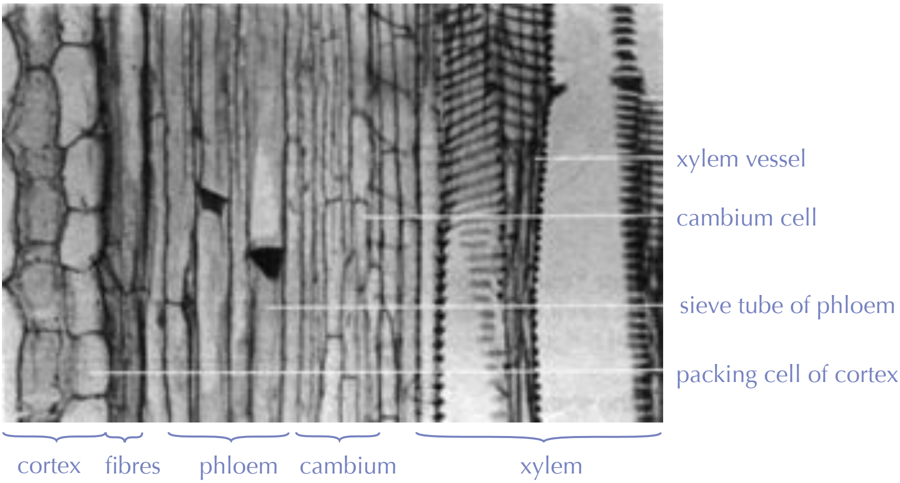


Gas exchange within the human lung

Angiosperms

The angiosperms continue the trend to terrestrial living shown by the ferns, and have beome completely adapted to a terrestrial existence (though some forms have become adapted again to an aquatic existence, e.g. water lilies). Angiosperms can be large and long lived. Angiosperms are broken up into two major divisions – the monocotyledons (monocots) and the dicotyledons (dicots). Though the two angiosperm groups show differences in the structure and location of tissues in the root and stem, transport in the two groups is essentially the same.

- Vascular tissue is continuous from roots to leaves.
- Water is transported from roots upwards to the leaves in the xylem vessels.
- Organic compounds are transported in the phloem both downwards (leaves to roots) and upwards (roots to areas of growth, e.g. buds).



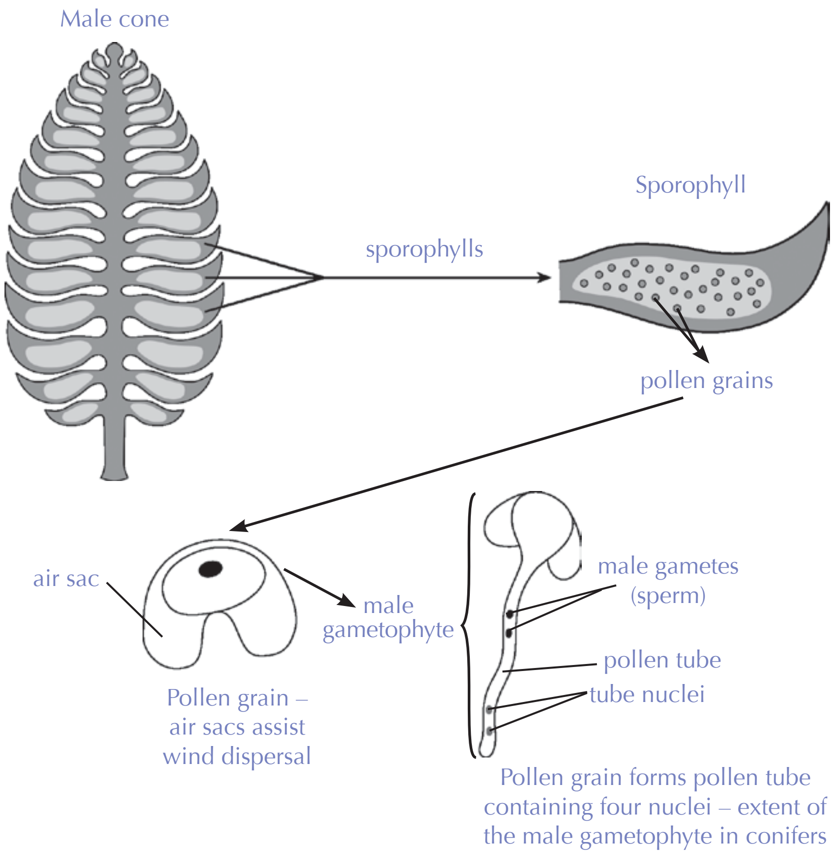
Photomicrograph of a longitudinal section (LS) of a stem through the vascular tissue

Roots

Dicotyledon roots

Under the epidermis, *dicotyledon* roots have a wide area of tissue (the cortex) made of general 'packing' cells (parenchyma cells), where starch is stored. In the centre of the root is an area called the *stele*, which contains the xylem and phloem.

- The xylem begins as a central, star-shaped bundle, with clusters of phloem in the 'arms' of the star.
- Thickening of the stem results in a complete round centre of xylem, surrounded by a complete circle of phloem.
- The outer layer of the stele is the **endodermis**, a ring of cells that controls the entry of minerals from the soil into the xylem.

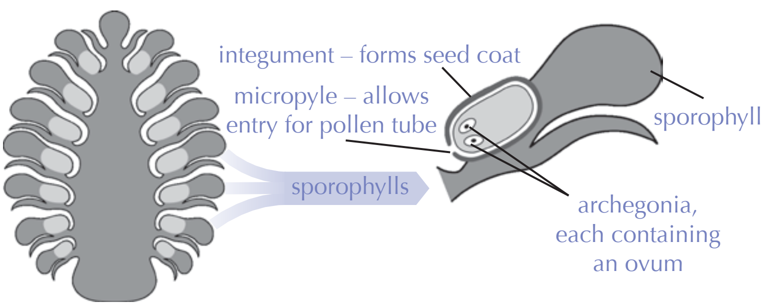


Female cones

Female cones have ovules enclosed in the sporophylls. Each ovule has two archegonia, each containing a haploid ovum/egg produced by meiosis. *The ovule and its ova are the extent of the female gametophyte*. A tiny opening called the **micropyle** leads into the ovule.

Female cones and sporophylls are much larger than male cones. Sporophylls spread to receive pollen and release seeds.

Ovule forms at base of each sporophyll on the upper side – extent of the female gametophyte in conifers.



CHAPTER

28

Carry out a practical investigation

NCEA Level 2 Biology material covered in this chapter includes material for Achievement Standard 91153 (Biology 2.1) 'Carry out a practical investigation in a biology context, with supervision'. The chapter looks at:

- Planning a practical investigation in a biology context.
- Carrying out the plan to collect (primary) data.
- Processing and interpreting the data to reach a conclusion.
- Writing a report on the investigation.

Each student must plan and carry out a practical investigation, then write a scientific report on it. It is this report that is assessed. The complete activity is an *individual* one; however, the constraints of time and equipment in schools usually mean that students may work together in doing the practical component of the investigation.

The investigation may be a *stand-alone* one (the student does the complete investigation without sharing or contributing findings to others) or it may be an investigation that can contribute findings to an investigation by a large group or to a class investigation.

Practical investigations

The investigation could be a **fair test** – which involves the manipulation of variables. This is the typical experiment carried out in the laboratory.

- The variable being investigated is the **independent variable** (e.g. temperature), and is altered over a range (e.g. 0 °C to 50 °C).
- The factor being measured with respect to the independent variable is called the **dependent variable** (the specific factor being measured – e.g. 'Number of bubbles produced per minute').
- Other factors (or variables) that may affect the results being measured need to be **controlled**/kept constant (e.g. light intensity, CO_2 concentration).

The investigation could also be a modelling, or a pattern-seeking activity. Pattern seeking is the typical field study of an organism and some aspect of its habitat/niche (e.g. substrate preference of mangroves reflected in density of pneumatophores of mangroves in areas of differing drainage; stoat predation).

- A pattern-seeking investigation involves some method of *sampling*.
- Manipulation of variables is not usually involved and there may not be a dependent or independent variable.

A pattern-seeking investigation carried out for Bio 2.1 may also be used as part of, or contribute evidence to Bio 2.6 – refer Chapter 17.

This chapter will emphasise the fair-test investigation, as it is the most common investigation. However, the principles of the investigation, especially the requirements of a quality report, are equally applicable to all methods of investigation.

Activity 12B: Redundancy and 'codon dictionary' (Page 123)

1. **a.** GGA ATC GTG CCC CAA
   b. CCT TAG CAC GGG GTT
   c. pro – tyr – his – gly – val
2. ACC UUA UCG AGG UAA – thr, leu, ser, arg, stop
3. AUG is the codon that indicates the start of the polypeptide chain in translation while UAG is a stop codon that indicates the end of the polypeptide chain, so the end of translation.
4. The code is redundant because many amino acids are coded for by more than one codon.
5. The advantage of redundancy is that if a mistake occurs in transcription (a mutation), there is a chance that the new codon will still code for the same amino acid, so there is no change to the protein, which will function normally.
6. Start with the codon dictionary and work out the relevant codes:
   mRNA: GGU GUU AAA; tRNA: CCA CAA UUU; DNA: CCA CAA TTT (template strand; coding strand: GGT GTT AAA)
   In the nucleus, part of a strand of a DNA molecule would carry the code CCA CAA TTT. During transcription, RNA polymerase would read the strand, and build an mRNA strand using complementary nucleotides, stopping at the terminator sequence. The mRNA codons formed would be GGU GUU AAA. The new mRNA strand would break free. After editing and splicing, the mature mRNA would travel from the nucleus to a ribosome in the cytoplasm. The ribosome would move along the mRNA and read the mRNA instructions, three bases (one codon) at a time. During this translation stage, tRNA strands, each carrying an amino acid, would line up on the mRNA strand. For the peptide chain glycine-valine-lysine, their anticodons, complementary to the mRNA, would be CCA CAA UUU. Held closely together, the amino acids would join, with peptide bonds. Finally, a release factor would bind to a stop codon, ending translation and releasing the peptide chain from the ribosome into the cytoplasm.

Activity 13A: Mutagens, mutations and phenotype (Page 127)

1. **a.** Gene mutations occur within the gene and involve changes in the base sequence of DNA by substitution, deletion, insertion of bases. Chromosomal mutations involve whole genes on chromosomes or entire chromosomes.
   b. Substitution involves the replacement of one base by another in a section of DNA, e.g. change from A to C so sequence TAG becomes TCG; deletion involves the removal of a base, e.g. removal of A from sequence TAG, which becomes TG_; insertion involves the addition of a base to a sequence, e.g. addition of A to sequence TAG so becomes TAA G_ _.
   c. A mis-sense mutation changes an amino acid in a protein, but this does not change the biological function of the protein; same-sense mutation does not result in a change in an amino acid so consequently the protein remains the same; nonsense mutation causes early termination of protein synthesis as a stop codon occurs prematurely.
   d. Haploid or n is half a set of chromosomes (one of each homologous pair; occurs in the gametes); diploid or 2n is the full set of (paired) chromosomes in the individual.

Answers

For *each* group, reasons for *differences* between the groups need to be *explained*, including the following.

- Habitat – e.g. dependency on water for fertilisation versus internal fertilisation, adaptations of conifers and angiosperms to full terrestrial existence, methods of pollination and seed/spore dispersal related to environment.
- Size – e.g. the comparative change in size of gametophyte and sporophyte, structure and size of flowers and pollen grains relative to pollination methods.
- Life cycle – e.g. the alternation of generations, the increasing dominance of the sporophyte, seed dormancy, rapid flowering and seeding of desert plants to take advantages of short periods of heavy rain, co-evolution with animal pollinators, internal versus external fertilisation.

Activity 28: Experimental design and interpretation (Page 291)

Aspects of certain answers are not definitive (e.g. the methods given are examples of those that might be used to test the hypothesis given). Other methods of testing may be equally suitable; the details of the method given (e.g. quantities/times/trials) may all be changed to suit the circumstances.

1. a. The investigation as given would not be accurate enough to allow a valid conclusion to be made or for the investigation to be repeated by another person.

- The Vaseline will trap any mosquito that lands on it by chance and cannot be taken as an indicator of temperature attraction.
- The heater and ice pack will give temperature differences, but there has been no attempt to measure the temperature in the aquarium or to relate it to temperature of any mammal host.
- The ice pack will melt and spread water along the floor, which will not only affect the temperature gradient but will also provide a safety hazard with the heater.
- The size/dimensions of the aquarium have not been given, so the set-up cannot be duplicated.
- The time allowed for one trial (one hour) is much too long to be realistic – mosquitoes find their host very quickly.
- The control does not relate to the investigation. If temperature difference is being tested, then the control would be an aquarium with uniform temperature throughout to see if the mosquitoes were attracted to any particular end/area – if they were found to prefer one area per se, this would mean the results were biased from the very start.
- To better test the hypothesis, the body temperature of the host needs to be known and this generated (by a heater) in the centre of a suitable container. As the distance from the heater increases, it will represent the temperature gradient from the host. If the mosquitoes fly towards the heater consistently, then they are probably being attracted by temperature.

b. Aim: To find out whether mosquitoes are attracted to their host by the temperature gradient from its body.

Method: This would need trialling and changing as required.

- Set up a large transparent plastic container 1 m square. Include a large, clear, labelled diagram of the final set-up used.

Answers

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