CHAPTER 4

Genetics 1: DNA and Variation

NCEA Level 1 material covered in this chapter is for Achievement Standard 90948 (Science 1.9) 'Demonstrate understanding of genetic variation', by looking at:

- Structure of DNA.
- How DNA is replicated.
- Genes, alleles, and mutations.
- Chromosomes and DNA.
- How cells divide – mitosis and meiosis.
- Sex determination.

The genetic message – DNA

Just as a plan and raw materials are needed to build a house, there must be *information* to build an organism. Living things all use the same kind of information, stored in a chemical called **deoxyribonucleic acid**, or **DNA**. DNA contains the information we inherit from our parents.

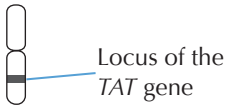
DNA is the *genetic material* and is located in threadlike bodies called **chromosomes**, which are in the nucleus of every cell.

- DNA *stores information* for building a new organism.
- DNA can be copied or *replicated*, so it can be handed down to future generations. ('Like begets like', ie offspring always resemble their parents (though not usually exactly) – the information for building a new organism must therefore have been replicated (copied) in the parents before being handed down to the next generation.)

Chromosomes are divided into smaller segments called **genes**. A gene is a defined sequence of DNA bases located at a specific place on a particular chromosome, called its **locus**.

Example

Scientists have given numbers, from 1 to 23, to each pair of human chromosomes. On each chromosome of pair 16, there is the *TAT* gene, which codes for an enzyme found in the liver that breaks down the amino acid tyrosine into substances that are excreted from the body. Too much tyrosine in the body is harmful.



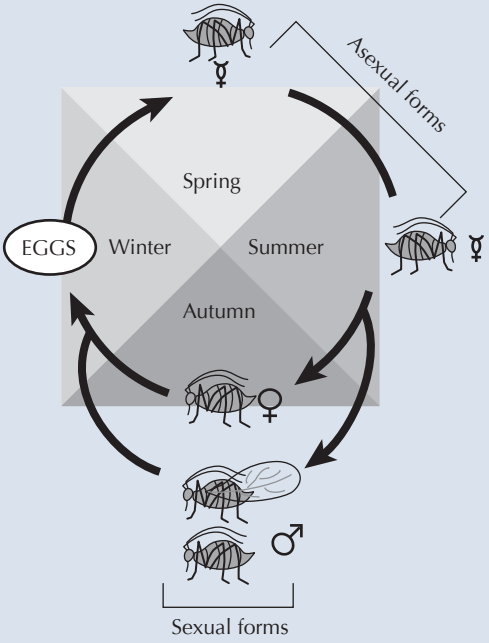
Chromosome 16

Each gene consists of thousands of smaller units called **nucleotides**. Each nucleotide consists of three parts:

- A *phosphate* group.
- A *sugar*, deoxyribose.
- A **base** – which can be of four kinds – adenine (A), guanine (G), thymine (T), cytosine (C).

Activity 6C: Sexual and asexual reproduction

1. Aphids are a small sap-sucking insect that can reproduce both sexually and asexually. The life cycle of an aphid is shown in the following diagram. Use the diagram to answer the questions that follow.



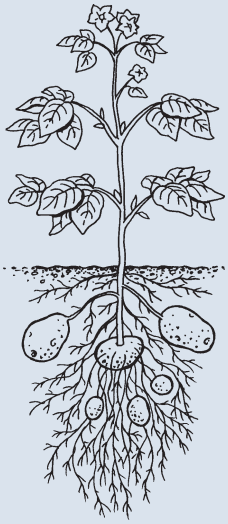
a. Describe what is meant by the terms 'sexual reproduction' and 'asexual reproduction'.

b. Explain why aphids carry out only *asexual* reproduction during spring and summer.

c. Discuss why aphids reproduce sexually during the autumn.

d. In a constantly warm environment, such as a greenhouse, an aphid population can continue to reproduce asexually for many years, never carrying out sexual reproduction. Discuss the advantages and disadvantages to aphids of reproducing asexually for a long period of time, like this.

2. Potato plants can reproduce both asexually and sexually. The potato tuber produces buds that grow into stems and leaves, and roots together with more potato tubers form under the soil. Eventually flowers form on the stems and produce fruit and seeds. Home gardeners often cut a sprouting potato into pieces and plant the 'eyes' to grow more potatoes.



a. Explain which of the two ways in which potatoes reproduce is sexual and which is asexual.

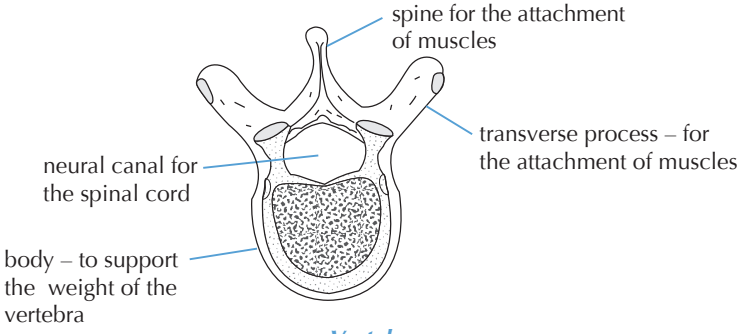
b. Explain why gardeners choose to grow potatoes from 'eyes' rather than from seeds.

c. Discuss why it is advantageous for potato breeders to continue growing new varieties of potato from seeds produced from flowers.

The vertebral column

The **vertebral column** or backbone is made of 33 bones called **vertebrae** that work together. The functions of the vertebral column are:

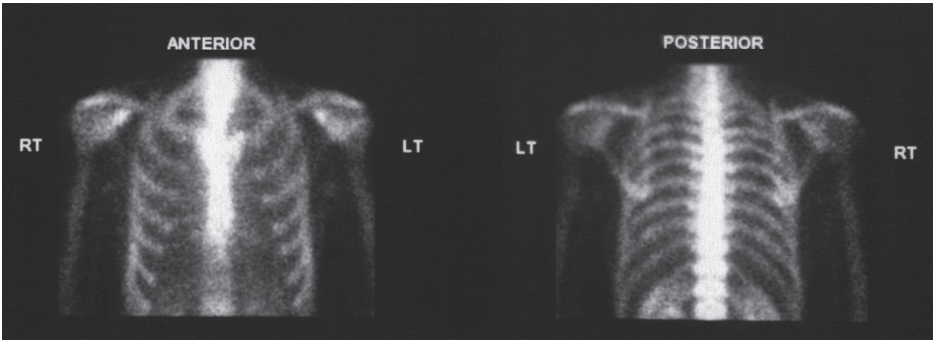
- Support of the upper body.
- Protection of the spinal cord.
- Attachment points for the ribs and back muscles.
- Head movements (nodding and turning).
- Trunk movements (bending and turning).



Vertebra

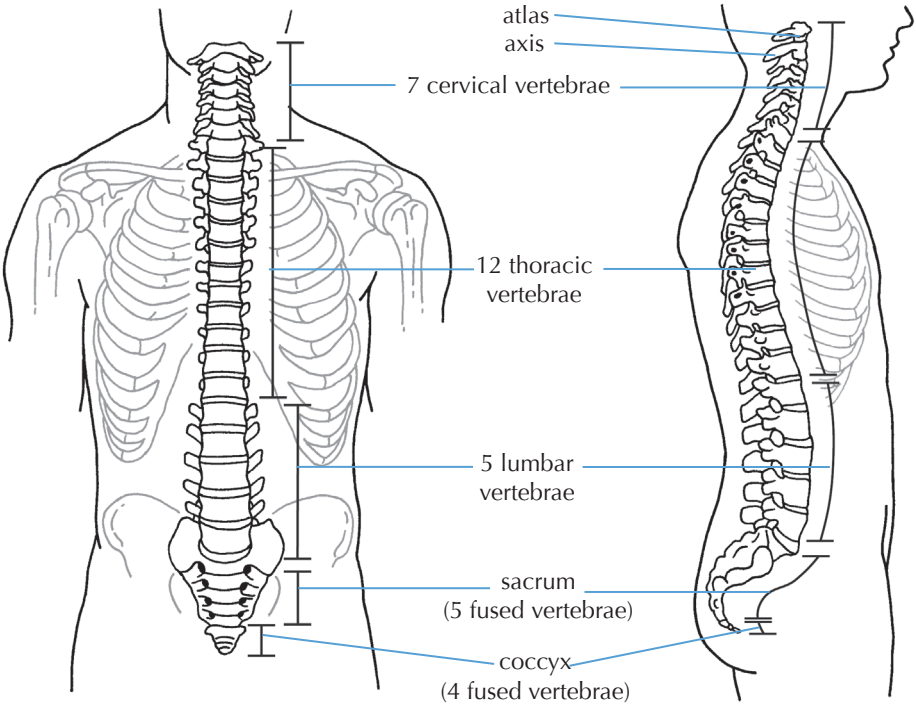
The bones of the vertebral column are grouped into five sections:

- The **cervical** vertebrae are small and give shape to the neck. The atlas and axis are shaped to balance the head and allow it to nod and turn.
- The **thoracic** vertebrae are those in the area of the chest. The ribs attach to them, forming the rib cage.
- The **lumbar** vertebrae are the largest vertebrae, which carry the most weight. Most of the bending of the back happens in this region.
- The **sacrum** is formed by the fusion of five vertebrae. They form part of the pelvic girdle.
- The **coccyx** or 'tail bone' is made by the fusion of four vertebrae.



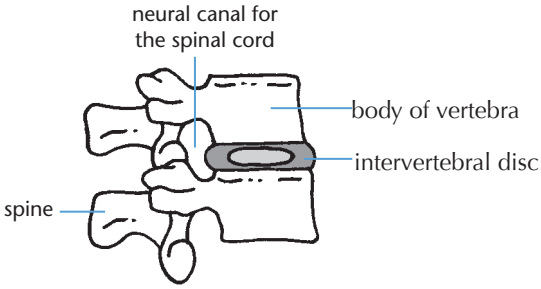
Left: Front view (anterior) **Right: Back view (posterior)**

X-rays showing the vertebral column, shoulders, ribs

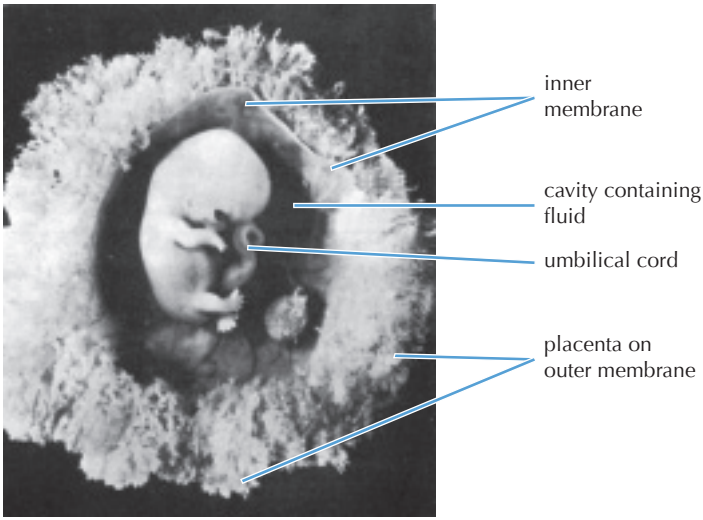


The body and the vertebral column

Intervertebral *discs* are made of cartilage with a tough outer layer and a soft jelly-like centre. They sit between each vertebra, providing cushioning and shock absorption.



Vertebrae and disc



Photograph of a baby at 8 weeks' gestation with its membranes in the uterus. The baby is in the transition period from embryo to foetus. Seven months of growth lie ahead before its birthday

Birth

During the last few weeks of pregnancy, the baby has usually come to lie with its head down against the **cervix**, or neck of the womb.

When the baby is ready to be born, a chemical signal is sent across the placenta to the mother. As a result, the muscles of her womb begin to contract strongly about once every 15 minutes. These contractions are stimulated by the hormone **oxytocin**, produced by the pituitary gland.

▼

The contractions become stronger and more frequent, pressing the baby's head against the cervix. Early in labour the amnion breaks and the amniotic fluid pours out – this is called 'breaking the waters'. During the next few hours, the cervix is slowly stretched from its normal 5 mm or so to about 10 cm, causing 'labour pains'. This is the *first stage of labour*, and by far the longest.

▼

When the cervix is fully widened or dilated, the *second stage of labour* begins. The mother begins to push with her abdominal muscles as well, forcing the baby out. The umbilical cord is cut and normally the baby takes its first breath very soon thereafter.

▼

About half an hour after the baby has been born, the placenta is passed out – this is the *third stage of labour*.

curds may then be treated with a variety of microbes (eg Danish Blue cheese owes its colour to the fungi added to the cheese as it matures).

Chymosin is traditionally obtained from calves, but with the increasing demand for vegetarian cheeses, it is also made artificially. The gene for chymosin has been transplanted from cattle into bacteria, which then make the chymosin.

Bread- and wine-making

In bread-making, yeast is used to produce thousands of tiny bubbles of CO_2 by fermenting sugar. A mixture of yeast, sugar and water is put in a warm place. The yeast feeds on (ferments) the sugar and uses the released energy to reproduce.

glucose ⟶ ethyl alcohol + carbon dioxide + energy

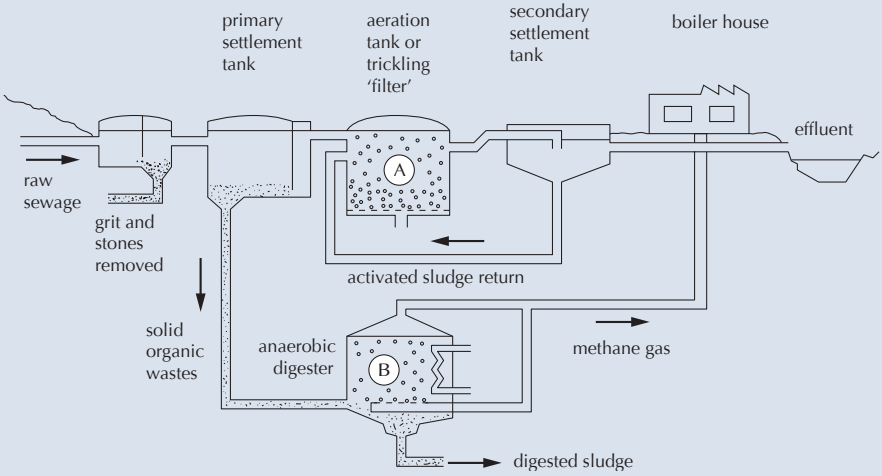
The CO_2 causes the dough to rise. The bread is then baked, during which the alcohol evaporates.

In wine-making, it is the alcohol that is the useful product, the CO_2 simply bubbling away. In brewing of beer, both alcohol and CO_2 are used.

Activity 13B: Using micro-organisms

1. Explain why fungi and bacteria are important in nutrient cycles such as the carbon and nitrogen cycles.

2. The diagram shows a typical sewage treatment station.



a. Some of the end products of the treatment are useful to humans. Describe one use for each of the following:

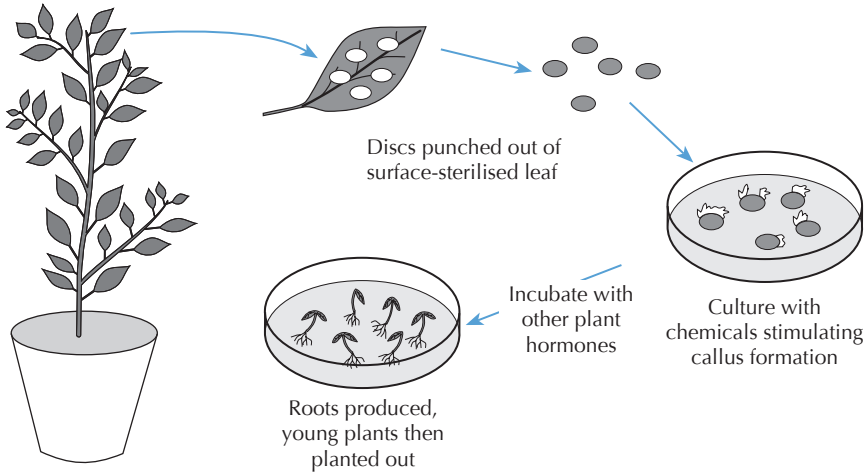
- Digested sludge.
- Methane.

b. The conditions in tank A and tank B of the sewage treatment station affect the biological processes that the micro-organisms carry out there.

i. Explain how the conditions in tank A affect the organisms.

ii. Explain how the conditions in tank B affect the organisms.

A more sophisticated way is to remove tiny fragments such as discs cut from leaves, and to use these to produce new plants. Leaf discs cannot by themselves grow into new plants – they must first be treated with the appropriate plant hormones in a sterile growth medium. These hormones stimulate the disc to produce a mass of new cells called a **callus**, from which a new plant can grow.



A method of vegetative propagation

Perennation

'Perennation' in plants means 'surviving from year to year'.

The energy reserves of bulbs, corms, tubers and rhizomes enable them to survive the winter and from year to year. Plants that survive from year to year are **perennials**.

- In herbaceous perennials, all the aerial parts die back at the end of the year and new growth is resumed from buds at or below ground level.
- In woody perennials, growth is resumed from buds well above ground, so the plant continues to increase in height each year.

Biennials live for two years, the first being devoted to storage of energy reserves, and the second to flowering.

Domesticated biennials, such as the carrot, are harvested at the end of the first year, before they get the chance to use up their energy stores on flowering.

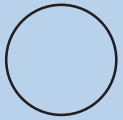
Annuals complete their entire life cycle in a year or less.

Activity 15A: Roots and shoots and vegetative reproduction

1. For each of the phrases **1**–**20**, write the letter **A**–**T** of the term to which it applies.

Phrase	Applied term
1. Angle between leaf and stem	**A.** Annual
2. Flowering plant with two cotyledons (seed leaves) in the embryo	**B.** Apical meristem
3. Flowing plant with one cotyledon in the embryo	**C.** Axil
4. Growth in length of stem or root	**D.** Axillary bud
5. Horizontally growing underground stem	**E.** Biennial
6. Layer of dividing cells that gives rise to layer of protective cork	**F.** Bulb
7. Layer of dividing cells that gives rise to new xylem and phloem	**G.** Cambium
8. Leaf stalk	**H.** Cork cambium
9. Long side shoot growing over soil surface from parent, developing into an independent plant	**I.** Corm
10. Mass of dividing cells at the tip of a shoot or root	**J.** Dicotyledon
11. Miniature shoot at the base of a leaf	**K.** Differentiation
12. Plant that completes its life cycle in one growing season	**L.** Explant
13. Plant that completes its life cycle in two growing seasons	**M.** Internode
14. Plant that survives from year to year	**N.** Monocotyledon
15. Process by which cells specialise for different functions	**O.** Perennial
16. Region of stem between two nodes	**P.** Petiole
17. Small part of a plant (eg leaf disc), removed for purpose of artificial vegetative propagation	**Q.** Primary growth
18. Tip of stem that grows down into soil and becomes swollen with energy reserve	**R.** Rhizome
19. Underground shoot storing energy in short, vertically growing stem	**S.** Runner
20. Underground shoot storing energy in swollen leaves or leaf bases	**T.** Stem tuber

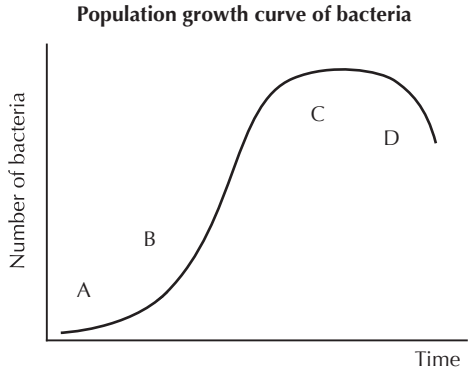
2. a.

Type	Bacillus	Vibrio	Spirillum	Coccus
Shape	Rod shape. 	Bent rod shape. 	Spiral shape. 	Spherical. 

b. *Streptococcus* – causes throat infections; *Staphylococcus* – causes pimples and skin infections; *Mycobacterium tuberculosis* – causes TB (tuberculosis); *Salmonella* – causes gastroenteritis or food poisoning (any one).

c. Decomposers feed on dead or decaying matter, whereas parasitic bacteria feed on a living host. Decomposers cause no harm, while parasitic bacteria harm the host.

d. i.

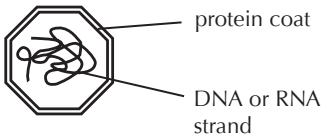


ii. Bacteria reproduce by binary fission – growing and dividing in two. With sufficient food, water, space and appropriate temperature, many bacterial species can reproduce every 20 minutes. In (A) there are no restraints on reproduction (plenty of food, no toxic wastes), so each bacterium reproduces quickly. Population growth is exponential. In phase (B), each bacterium is reproducing more slowly because food is becoming scarce and/or wastes are accumulating. Despite this, the curve continues to get steeper because decreasing reproduction is more than offset by the increasing number of 'parents'. In (C), the decreasing reproduction more than offsets the effect of the increasing number of 'parents'. In (D), numbers of living bacteria fall.

3. a. 1. Sporangium – The case that contains the spores. When the spores are ripe, the case bursts, releasing the spores. 2. Spore– the reproductive structure of a fungus. A spore can germinate and grow into a new fungus. 3. Hyphae – fine threads that grow into the food source, secreting enzymes into it to digest food so it can be absorbed by the fungus.

b. Yeast cells ferment glucose, forming ethanol (alcohol) and carbon dioxide. The carbon dioxide makes bread rise or puts bubbles in fizzy alcoholic drinks such as beer. The ethanol is the alcohol in beer and wine.

4. a.



b. The virus cannot grow on the bread because bread is not alive, and will not provide the cellular mechanisms required by the virus to reproduce and therefore survive.

5. a. The loop would have been sterilised by heating to a high temperature/using a flame for the high temperatures to kill any bacteria on the loop that might contaminate the agar/give a false result.

b. The agar plates would be stored upside down in a warm place/at around 25 °C.

Upside down because if water from respiration builds up on the agar plate, pathogenic anaerobic bacteria might reproduce in it OR warm place because the microbes need warm temperatures to reproduce.

c.

d. The agar plates would be burned so the high temperatures could kill all pathogens.

e. i. 'A' was a control plate to ensure the agar plates were not already contaminated.

ii. Plates B and C show that warm temperatures are needed for bacterial reproduction. There was no bacterial growth in plate C, which had been placed in the fridge, compared with some colonies at 25 °C. Plate D shows that the air in a crowded café contains many more microbes than the air in an uncrowded laboratory, as the bacterial colony growth from the café was greater from the start. Plate E shows bacteria either cannot reproduce, or they die in conditions of low pH, since there was no bacterial growth.

6. a. Edible mushrooms have pink or brown gills and creamy white skin that peels off easily.

b. A mushroom carries out extracellular digestion/secretes digestive enzymes onto the substrate that digest the substrate so the nutrients are small enough to be absorbed into the cells of the mushroom.

c. A spore germinates if it lands on a suitable substrate under suitable conditions. Millions of spores are produced because so many do not land on a suitable substrate/are damaged/destroyed.

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