Solutions for all
Life Sciences
Grade 11
Learner's Book

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R Simenson  CD van der Merwe  J Webb
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Welcome to Solutions for all Life Sciences Grade 11 Learner’s Book

Life Sciences is the scientific study of living things from molecular level to their interactions with one another and their environments. The study of Life Sciences includes obtaining certain knowledge (theory) about living things and skills necessary to study and investigate living things (practical work). Through the process of learning and doing we hope you develop an interest and appreciation for living things on Earth.

Solutions for all Life Sciences Grade 11 Learner’s Book has sufficient content knowledge and background information to ensure that you acquire everything (and a bit more) required by the Curriculum and Assessment Policy Statement (CAPS).

Solutions for all Life Sciences Grade 11 Learner’s Book includes sufficient practical tasks to ensure that you develop the skills necessary to become a true scientist.

In the Further Education and Training band the Life Sciences content framework is organised according to four knowledge strands. Knowledge strands are developed progressively over the three years of FET. These knowledge strands are:

- Knowledge Strand 1: Life at the molecular, cellular and tissue level
- Knowledge Strand 2: Life processes in plants and animals
- Knowledge Strand 3: Environmental studies
- Knowledge Strand 4: Diversity, change and continuity.

As you progress in your study of Life Sciences you will come to realise how interlinked these strands are. Not all of these knowledge strands are covered in each year of FET. In Grade 11 Knowledge strand 1 (Life at the molecular, cellular and tissue level) is not covered. Also note that Knowledge strand 3 (Environmental studies) is not covered in Grade 12, but you will be examined on the work covered in this strand in Grade 12.

The three specific aims in Life Sciences are:

- Specific Aim 1, which relates to knowing the subject content (theory)
- Specific Aim 2, which relates to doing science or practical work and investigations
- Specific Aim 3, which relates to understanding the applications of Life Sciences in everyday life, as well as understanding the history of scientific discoveries and the relationship between indigenous knowledge and science.

At school level one of the reasons for taking Life Sciences is to provide a sufficient background for further studies in one or more of the biological subdisciplines. There are many different careers in the field of Life Sciences. Each career requires special knowledge and skills. The following table shows a few of these careers.
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<th>Brief description of job</th>
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<td>Dentist</td>
<td>Diagnoses, prevents and treats problems related to teeth and the gums.</td>
</tr>
<tr>
<td>Doctor</td>
<td>Diagnoses, treats and prevents diseases in humans.</td>
</tr>
<tr>
<td>Dietician</td>
<td>Advises patients about suitable diets for their individual needs or conditions.</td>
</tr>
<tr>
<td>Biokineticist</td>
<td>Specialises in exercise therapy for sportsmen/-women and injured people.</td>
</tr>
<tr>
<td>Palaeontologist</td>
<td>Studies the fossilised remains of plants, animals and humans. Uses this information to provide a picture of the history of life on Earth.</td>
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<tr>
<td>Forensic scientist</td>
<td>Analyses physical evidence collected at crime scenes.</td>
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<tr>
<td>Geneticist</td>
<td>Studies the inheritance of characteristics, particularly the characteristics that lead to disorders or diseases in humans.</td>
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<tr>
<td>Animal scientist</td>
<td>Conducts research in selecting, breeding, rearing and studying diseases of domestic animals.</td>
</tr>
<tr>
<td>Aquaculturist</td>
<td>Studies fish populations and ways of breeding fish for commercial use.</td>
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<tr>
<td>Veterinarian</td>
<td>Diagnoses, prevents and treats diseases in domestic and/or wild animals.</td>
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<tr>
<td>Landscape architect</td>
<td>Designs outdoor and public spaces to achieve environmental, social and aesthetic outcomes. Includes urban design, urban or town planning, environmental restoration, parks and recreation planning and private residence planning.</td>
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<tr>
<td>Food scientist</td>
<td>Studies the chemical, physical and biological aspects of different kinds of food to ensure that it is prepared, preserved and packaged correctly. Also ensures that it is tasty and safe to eat.</td>
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<tr>
<td>Microbiologist</td>
<td>Studies the biology of microscopic organisms such as viruses, bacteria, fungi and protists. Investigates how these organisms affect living organisms and the environment.</td>
</tr>
<tr>
<td>Ecotoxicologist</td>
<td>Studies substances that are toxic to the environment and their effect on animal life.</td>
</tr>
<tr>
<td>Environmental consultant</td>
<td>Provides specialist advice on environmental impacts. Conducts environmental impact assessments.</td>
</tr>
<tr>
<td>Environmental health officer</td>
<td>Helps to ensure that public health standards are met in relation to water, sanitation air, land etc.</td>
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<tr>
<td>Conservationist</td>
<td>Works to preserve biological diversity, especially in natural environments.</td>
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How to use Solutions for all Life Sciences Grade 11 Learner’s Book

The content knowledge in Solutions for all Life Sciences Grade 11 Learner’s Book is organised according to topics. Each topic is structured in the same way:

**Topic opener page:** The topic starts with a full-colour photograph of something that is related to the content of the topic. A list, ‘What you will learn about in this topic’, shows what you should know after you have worked through the topic. There is also a section called ‘Let’s talk about …’. This introduces the topic and includes questions related to the photograph. The idea is for you to start thinking about new things you will learn about in the topic.

**What you know already:** On the second page of each topic you will find the features ‘What you know already’ and ‘Check myself’. These two features ensure that you know what you need to know before continuing with the new work. It is revision of a previous grade’s work.

**Units and lessons:** Each topic is divided into units that are further divided into lessons. A lesson consists of content and concludes with an activity (either one you can do in the classroom or a practical task). You may be required to start a classroom activity in class and then complete it at home. The mark allocation given at each question is only a guide to what type of answer is expected. The lessons break the work up in little chunks of information. This helps you to be sure you know and understand a certain section of the work before moving on to the next new section of work. For each term, one practical task serves as a suggested formal assessment task. You could be assessed on these tasks, so watch out for them.

**Enrichment activities:** The enrichment activities are additional activities. These are for you to find out more about what was covered in the lesson.

**Questions on ...:** The topic ends with a variety of additional questions. These questions may be used for extra practice and assessment.

**Summary:** Each topic ends with a summary of the work covered in the topic. You could use these summaries as study notes, just to recap on what you should know at the end of the topic.

Other features to look out for are:

**Word boxes:** Certain words are explained in the margin to help you understand the information better. Also always keep a dictionary handy. If you understand a word, your studies will be a lot easier.

**Cool fact, Something interesting and Hot topic:** This is interesting information relating to the content, just to make you think.

**Diagrams and illustrations:** The diagrams are included to help you understand the written words. Use the pictures when working through the text. When you see something, you will remember a lot better.

The publisher and authors wish you all the best in your study of Life Sciences Grade 11.

Good luck!
Biodiversity of micro-organisms

What you will learn about in this topic

- The basic structure and general characteristics of viruses, bacteria, protists and fungi
- The roles that these groups play in maintaining balance in the environment and web of life
- Symbiotic relationships between nitrogen-fixing bacteria and plants, and *Escherichia coli* in the human intestine
- The effects and management of diseases caused by micro-organisms
- Immune responses of plants and animals against infecting micro-organisms and the use of vaccinations
- The use of drugs such as antibiotics on micro-organisms
- The use of micro-organisms to produce medicines
- Traditional technology to produce products such as beer, wine, and cheese

Let’s talk about the biodiversity of micro-organisms

The photograph may look like a strange robot, but it is actually a human immunodeficiency virus, commonly known as HIV, which is a micro-organism. Which other types of micro-organisms do you know of? Some micro-organisms can cause disease, but others play an important ecological role in maintaining the balance in the environment or are useful in biotechnology applications. How do plants and animals fight disease-causing micro-organisms? In which useful ways are micro-organisms used?
In Grade 10 you learnt about the wide diversity of living organisms and their classification into related groups. Organisms are classified into five kingdoms: Monera (bacteria), Protista, Fungi, Plantae and Animalia. The organisms in each kingdom are grouped according to specific characteristics. This topic will expand on the specific structure and characteristics of the kingdoms Monera (bacteria), Protista and Fungi.

Table 1.1 lists descriptions of the five kingdoms. Read each description and then answer the questions that follow.

Table 1.1

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<td>More than 1 million species&lt;br&gt;&lt;b&gt; Multicellular &lt;/b&gt; with nuclei = eukaryotic (genetic material is enclosed by a membrane)&lt;br&gt; All heterotrophic&lt;br&gt; Motile (can move around)&lt;br&gt; Specialised sense organs</td>
</tr>
<tr>
<td>B</td>
<td>More than 100 000 species&lt;br&gt; Mostly multicellular with nuclei = eukaryotic&lt;br&gt; Heterotrophic or saprophytic</td>
</tr>
<tr>
<td>C</td>
<td>More than 10 000 known species&lt;br&gt; Unicellular with no true nucleus = prokaryotic (genetic material is not enclosed by a membrane)&lt;br&gt; Autotrophic or heterotrophic</td>
</tr>
<tr>
<td>D</td>
<td>More than 260 000 species&lt;br&gt; All autotrophic&lt;br&gt; Multicellular with nuclei = eukaryotic&lt;br&gt; Cell walls made of cellulose</td>
</tr>
<tr>
<td>E</td>
<td>More than 100 000 species&lt;br&gt; Mostly unicellular with a true nucleus = eukaryotic&lt;br&gt; Some live in colonies&lt;br&gt; Some move using cilia, flagella and/or pseudopodia&lt;br&gt; Autotrophic or heterotrophic</td>
</tr>
</tbody>
</table>

1. Identify the five kingdoms (represented by the different letters) from the descriptions in the table.
2. Give two examples of organisms that belong to each kingdom.
3. a) What do we call organisms that you cannot see with the naked eye? Name two examples.
   b) When studying these organisms, which piece of laboratory equipment would you use in order to see them?
4. Differentiate between the following terms:
   a) heterotrophic and autotrophic
   b) unicellular and multicellular.
5. Explain the main differences between prokaryotic and eukaryotic cells.
Viruses

It is difficult for biologists to classify viruses as living or non-living, or even to place them into any of the five kingdoms. Viruses do not directly use energy, cannot actively maintain their structure, and cannot eat, respire, reproduce or excrete. Viruses are said to be obligate intracellular parasites as they are unable to reproduce themselves and have to multiply inside a host’s cell using its genetic material. However, viruses do have the same nucleic acids as living organisms, hence the argument about their classification.

Basic structure of viruses

Viruses come in different shapes and sizes. Figures 1.1 and 1.2 show a bacteriophage and the tobacco mosaic virus. Note how they differ in appearance. Even though different viruses look different, they all have the same basic structure.

A virus has an inner core of either DNA or RNA (but not both). Some viruses with RNA, such as HIV, which causes acquired immune deficiency syndrome (AIDS), are called retroviruses. The nucleic acid is surrounded by an outer protein coat or capsule, which protects the viral genetic material. The capsules may have many different shapes. Some viruses have capsules that are surrounded by a covering that contains some of the host cell’s membrane. Viruses have no cytoplasm and have no membrane-bound organelles.

Viruses have the following characteristics:
- Viruses are acellular as they are not complete cells.
- Viruses are extremely small (20–300 nm) and can only be seen using an electron microscope.
- Viruses have many different shapes.
Viruses do not perform any of the metabolic reactions of living organisms. They do not produce their own energy through cellular respiration and therefore they need not exchange gases.

Viruses cannot reproduce unless they invade a host cell.

Viruses are parasitic on plants, animals, protists and bacteria.

Viruses have the ability to assemble themselves.

Most viruses are pathogens as they cause disease in their hosts.

**Cool fact**

**Where do viruses come from?**

In 1892, the Russian scientist Dmitri Ivanovsky discovered that an organism far smaller than bacteria caused tobacco leaves to become speckled and discoloured. Only later did scientists name these tiny disease-causing organisms viruses. Viruses were seen for the first time through an electron microscope in the 1940s.

Today we know what viruses are, but nobody knows how they originated. Some scientists say they evolved from parasites of bacteria, while others believe that they developed from fragments of nucleic acids that escaped from and survived outside their parent cells.

**Classroom activity 1**

1. Why might viruses be classified as non-living? (6)
2. Draw a labelled diagram showing the structure of a typical virus. Next to each label, write the function of that structure. (14)
3. Explain why viruses are described as being parasitic. (2)

**Enrichment activity**

Micro-organisms are not measured in the usual units of length such as centimetres, millimetres or metres. Viruses are measured in units called nanometres (nm). There are a billion nanometres in a metre. Bacteria are bigger than viruses and are measured in micrometres (µm). One millimetre equals a thousand micrometres.

This activity will help you to develop an understanding of the size of these micro-organisms and why it was so difficult to see them in the past.

1 000 nanometres (nm) = 1 micrometre (µm)
Bacteria

Scientists once believed that diseases and all of life appeared from nothing. This was called spontaneous generation. In 1859, the French scientist Louis Pasteur showed that boiled soup in sealed flasks did not become rotten – even if left for months – unless it was contaminated by air from the outside world. Pasteur showed that invisible organisms were causing the soup to become rotten. Pasteur now had support for the theory that tiny organisms, which were called ‘germs’, caused disease and spoiled food. Today we know that these invisible organisms were bacteria. Many types of bacteria have been discovered since then, some useful and some dangerous. Bacteria have been found deep beneath the Earth and high in the atmosphere – in fact, they are everywhere.
**Basic structure of bacteria**

Bacteria are unicellular organisms that are classified as prokaryotes. This means they do not contain membrane-bound organelles such as a nucleus, chloroplasts or mitochondria. Their DNA floats freely in the cytoplasm (nucleoid). The cell wall is lined with a cell membrane and often covered by a slime capsule to prevent it from drying out. In many pathogenic bacteria the slime capsule also serves as a barrier against phagocytes (white blood cells). Ribosomes are found in the cytoplasm. Some bacteria have long whip-like appendages called flagella that are used for locomotion. Bacteria may have one, a few or many flagella in different positions on the cell. Bacteria may also have hollow, hair-like structures called **pili** that are used to attach to other cells. Figure 1.3 shows the structure of a typical bacterium.

Bacteria have the following characteristics:

- Bacteria belong to the kingdom Monera. Bacteria are unicellular cells that are prokaryotic. These are simple cells with no true nucleus and which have no membrane-bound organelles.
- Bacteria are in every known habitat on Earth.
- Bacteria can be classified according to their shape:
  - **coccus** – spherical
  - **bacillus** – rod shaped
  - **spirillus** – spiral shaped.
- Bacteria may also be classified according to the way in which they obtain their energy:
  - Photosynthetic bacteria get their energy from the sun.
  - **Chemosynthetic** bacteria get their energy from inorganic chemicals. For example, they convert nitrates to nitrates, and sulphur to sulphates to obtain energy.
  - Heterotrophic bacteria get their energy by feeding on organic matter. Enzymes are secreted and nutrients are absorbed into the cell.
- Bacteria mainly reproduce asexually through **binary fission** in favourable conditions.

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Fig. 1.3 Structure of a typical bacterium

Fig. 1.4 The different shapes of bacteria
Classroom activity 2

1. Why are bacteria classified as prokaryotes? (4)
2. To which kingdom do bacteria belong? (1)
3. What is the function of the slime capsule in a bacterium? (2)
4. Why is the DNA-containing part of a bacterium called a nucleoid and not a nucleus? (2)
5. By what process do bacteria replicate in favourable conditions? (1)
6. Draw a labelled diagram of a bacterium. Write the function of each structure next to its label. (15)

Practical activity 1

This is a prescribed practical task.

Grow your own bacteria colonies

You will need:
- two plastic Petri dishes with a thin layer of sterile nutrient agar on the bottom
- toothpicks
- cotton buds
- sticky tape
- permanent marker pen
- self-sealing plastic bags
- microscope slide
- cover slip
- eye dropper
- water
- hand lens

Method
1. Seal one of the plastic Petri dishes with sticky tape. This will be your control.
2. Take a sample by rubbing a cotton bud over an object that you want to check for bacteria (for example, your hands or plaque off your teeth).
3. Place the sample onto the agar in the other Petri dish by lightly rubbing the earbud over it.
4. Repeat steps 2 and 3 for other objects, each time using a new cotton bud. Be careful to place each sample onto its own area on the agar.
5. Tape the Petri dish closed. By writing on the lid of the Petri dish, outline the area for each sample on the lid and note where the sample was taken from.
7. Place them in a warm, dark place for a week.
8. Once you have some visible growth, describe the appearance of the plate.
9. Examine the plate through a hand lens.
10. Draw what you see.
Protista

The kingdom Protista contains nearly 200 000 species, and so is a highly diverse and complex kingdom. Protists consist of three main groups: animal-like protists (i.e. protozoa), plant-like protists (e.g. algae) and fungus-like protists (e.g. slime mould).

Basic structure of Protista

Protists are all eukaryotes as they have a true nucleus and membrane-bound organelles. Protists are micro-organisms that are simple in structure. Most are unicellular, although some are multicellular. They range from tiny microscopic organisms to huge tree-like structures.

Protists have the following characteristics:

- Protists are eukaryotic as they have a proper nucleus.
- Protists are classified according to how they obtain nutrition and how they move.
  - Animal-like protists are called protozoa, which means ‘first animal’. They are mostly heterotrophic or parasitic. Animal-like protists are classified according to how they move. They move by using pseudopodia, cilia or flagella.
  - Plant-like protists are autotrophic as they contain chlorophyll and can produce their own food through the process of photosynthesis. Plant-like protists can be unicellular (e.g. Euglena) or multicellular (e.g. kelp), form colonies (e.g. Volvox).
  - Fungus-like protists are decomposers, which makes them heterotrophs. They digest their food by releasing digestive enzymes into the organic matter and absorbing the nutrients.

Questions

1. Is there a difference between the bacterial colonies (in size and colour) from the different samples? Explain these differences.
2. Is there any growth on the control?
3. Is there a difference between the bacterial colonies (in size and colour) of the control and the experiment?
4. Is there a difference in the number of bacterial colonies on the control and the experiment? What is the purpose of the control?

Some precautions

When you are finished with the experiment, give the Petri dishes back to your teacher so that they can be destroyed. The agar and bacteria colonies need to be disposed of in an appropriate way to prevent the spread of disease.
Protists reproduce asexually through binary fission in favourable conditions. In unfavourable conditions sexual reproduction can occur. A resistant zygospore is formed.

Unicellular algae make up the bulk of phytoplankton in the ocean. Many of the seaweeds are multicellular, but lack specialised tissues.

Classroom activity 3

1. What are the properties of a eukaryotic cell? (2)
2. What is a protist? (3)
3. What are the main differences between plant-like, animal-like and fungi-like protists? (3)
4. How do protists differ in structure from bacteria? (1)

Fungi

This group of organisms includes moulds, yeasts, mildew, rusts and mushrooms. Structurally, fungi are divided into two main groups: unicellular and multicellular. Yeasts are typical unicellular fungi. Common bread mould (Rhizopus) and mushrooms are common multicellular fungi.

Basic structure of a filamentous fungus

Fungi have a unique cell wall structure made up of chitin, which is the same substance that forms the exoskeletons of insects. Multicellular fungi are made up of branched intertwining ‘threads’ called hyphae. All the hyphae together are referred to as the mycelium of the fungus. The body of most fungi is made up of hyphae.

In most fungi, the hyphae have cross-walls called septa. Some fungi, such as common bread mould, do not have cross-walled hyphae. Each hypha contains one or more

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zygospore
a thick-walled, resistant spore formed from a zygote in fungi or algae

unique
one of a kind

chitin
makes up the cell wall of fungi

hyphae (sing.: hypha)
part of multicellular fungi

mycelium
all the hyphae of a fungus together

Fig. 1.7 Example of fungi: a) mushrooms b) yeast cells
nuclei. In some fungi, the hyphae fuse together to form a fleshy fruiting body. For example, a mushroom is a fruiting body – the rest of the mycelium of the fungus grows underground.

Fungi have the following characteristics:
- Fungi belong to the kingdom Fungi, which includes micro-organisms such as yeasts, moulds and mushrooms.
- Fungi are all eukaryotic.
- Fungi lack chlorophyll, so are heterotrophic saprophytes. Fungi feed on whatever they grow on by secreting enzymes to break down the complex nutrients into simple nutrients such as glucose. These simple nutrients are absorbed through the wall into the fungal body.
- Most fungi are filamentous. Filamentous fungi are frequently multinucleate.
- Fungi differ from plants in that the cell walls of fungi contain chitin, whereas the cell walls of plants contain cellulose.
- Fungi reproduce both sexually and asexually. Reproduction is accomplished by the release of sexual or asexual spores. Under favourable conditions millions of asexual spores are produced and dispersed over a large area.

![Mould on bread](image1.png) ![Rhizopus](image2.png) ![Microscopic view of mycelium](image3.png)

**Practical activity 2**

This is a prescribed practical task.

Study the microscopic structure of different fungi

**You will need:**
- fermenting yeast mixture
- bread
- water
- a plastic bag
- a hand lens or microscope
- microscope slides
- permanent marker pen
Method
1. Take a slice of bread and moisten it with a little water.
2. Put the bread in a plastic bag and seal it with a knot.
3. Leave the bread for a couple of days.
4. Examine the bread mould using a hand lens. If you have a microscope, complete steps 5 to 7.
5. Transfer a small amount of the fermenting yeast mixture onto a clean microscope slide. Mark the slide X with the marker pen.
6. Scrape some mould off the slice of bread and transfer it onto another microscope slide. Mark the slide Y with the marker pen.
7. Use the lowest magnification of the microscope to study both slides.
8. Draw what you see under the hand lens or microscope on slides X and Y. You should be able to see single and budding yeast cells on slide X.

Questions
1. How are fungi different from the other kingdoms? (3)
2. Give three examples of fungi. (3)
3. Name two structural differences you can see between the fungi on slides X and Y. (4)
4. Where does mould come from? How did it get onto the bread? (1)
5. Why is bread mould classified as a saprophyte? (2)
6. Does fresh bread contain spores? Give reasons for your answer. (2)
Micro-organisms and their role in maintaining a healthy environment

Micro-organisms play an important part in maintaining the balance in the environment and the web of life. They are found everywhere – even in the most extreme ecosystems. There is a continuous exchange of materials and energy between living organisms and their environment. For instance, oxygen, water and nitrogen are constantly being absorbed and used by living organisms. These substances are then recycled and re-used through the natural processes of respiration, excretion and decay. In this way, the materials used to sustain life are used again and again to rebuild and maintain balance in the environment.

Viruses

Viruses control many ecological processes, such as nutrient cycling, bacterial and algal biodiversity and algal bloom control. Scientists have recently discovered that there are many viruses found in the ocean. When sea organisms die from a viral infection, their bodies provide nutrients to bacteria in deeper parts of the ocean. Viruses are pathogens and cause many diseases in plants, animals and humans. Disease helps control the numbers of dominant host species.

Bacteria

There are many different types of bacteria that are very useful to us. Photosynthetic bacteria are producers that use energy from the sun to turn carbon dioxide and water into sugars. In some bacteria oxygen gas is released into the atmosphere as a by-product. Chemosynthetic bacteria also act as producers. They use energy from chemical reactions instead of sunlight, together with a source of carbon and water, to create sugars and various by-products.

Bacteria are involved in decomposition. They break down dead organic matter and return nutrients to the ecosystem. They create humus in soil, which improves the quality and water-holding capacity of the soil. Bacteria keep the surface of the Earth clear of dead bodies and waste matter through decomposition.

Bacteria play an important role in recycling nitrogen. Nitrogen forms an essential part of protein and nucleic acids. About 80% of nitrogen is found in the atmosphere. Atmospheric nitrogen is converted into nitrates through lightning and by nitrogen-fixing bacteria in the soil. Plants remove the nitrates from the soil and animals obtain the nitrogen by eating the plants. Animals excrete faeces and urine, which are converted into nitrates by other bacteria. Fungi and saprophytic bacteria decompose
the proteins of dead plant and animal matter and these minerals are returned to the soil to be converted into nitrates again.

**Protists**

Algae are important in *aquatic* environments because they produce food for the rest of the ecosystem. Many algae are also used as a source of food for people – particularly in eastern cultures. Algae produce more oxygen than terrestrial plants; therefore they play a crucial role in maintaining the oxygen levels in the atmosphere.

*Diatoms* play an important role in aquatic environments by providing a source of food and oxygen for heterotrophs due to the presence of photosynthetic pigments. Their remains produce powder-like deposits that accumulate on the ocean floor. These form large accumulations of sediment known as diatomaceous earth, which is used as a filtering agent.

Dinoflagellates (algae protists) live symbiotically with sea anemones. These partnerships form the trophic and structural foundation of coral reef ecosystems. Larger algae such as kelp provide shelter and habitat for fish and aquatic invertebrates. Many water moulds are saprophytic and live in fresh water. They play an important role as decomposers of dead algae and animals.

Some parasitic protists are pathogens such as *Trypanosoma gambiens*, which causes African sleeping sickness, and *Plasmodium vivax* and *Plasmodium falciparum*, which cause malaria in tropical regions across the world. Many of these pathogens have a big ecological impact when they cause the death of animals.

**Fungi**

Certain fungi have great ecological value. In nature, saprophytic fungi decompose dead organic matter and make nutrients available for new plant life.

Some single-celled fungi can convert organic matter. They use organic compounds to obtain energy and create various by-products. For example, yeast cells turn sugar into carbon dioxide and alcohol during fermentation. Mushrooms are a food source for many animals. Other fungi are used in environmental biotechnology in the clean-up of chemical pollutants such as oil or detergents.

Some fungi form symbiotic relationships with other plants. *Mycorrhiza* fungi live on the roots of some plants and act as root hairs for the plants, allowing them to get nutrients from the soil. A special group of fungi live in a *mutualistic relationship* with unicellular algae to form *lichens*. Lichens are an interesting group of organisms. They are found in many different habitats, from moist rainforests to dry and exposed mountain tops. Where they grow on rocks, they start the process of soil formation.
Other fungi are pathogenic, meaning they may cause diseases in plants, animals and humans. Certain fungi, such as *Candida albicans*, can be beneficial when present in small amounts in body tissues. However, they can overgrow in certain circumstances (e.g. low immunity in people living with AIDS) and become harmful (opportunistic fungi).

**Classroom activity 4**

1. Name and explain three different ways micro-organisms obtain energy. (7)
2. Give three examples each of micro-organisms that form (a) mutualistic and (b) parasitic relationships. (6)
3. Some of the earliest life forms on Earth appear to be bacteria. These early organisms existed before the Earth had an oxygen-rich atmosphere. From your studies on bacteria, what evidence can you find to support the theory that the earliest life forms were probably bacteria? (2)
4. Give three ways that protists are ecologically important. (3)
5. Write a paragraph to explain what would happen to the atmosphere if marine algae were overharvested or killed by water pollution. (3)

**Symbiotic relationships involving bacteria**

Bacteria form valuable relationships with humans, animals and plants. Close relationships between different species are called symbiotic relationships. You will learn more about symbiotic relationships in Topic 9 (Population ecology). Mutualism is a symbiotic relationship in which both species involved in the relationship benefit. Examples of mutualism are the relationships between legume plants and nitrogen-fixing bacteria, and humans and the bacteria found in the human intestine.

**Nitrogen-fixing bacteria in plants**

In Grade 10 you learnt about the nitrogen cycle and that nitrogen is needed by all organisms as it forms an important part of proteins. Gaseous nitrogen in the atmosphere cannot be used by most organisms. Nitrogen-fixing bacteria are an essential part of all ecosystems to ensure that nitrogen is available to support life on Earth. Plants such as peas, beans, clover and many thorn trees have developed a mutualistic symbiotic relationship with nitrogen-fixing bacteria. These bacteria are found in nodules on their roots. The bacteria inside the root nodules change this free nitrogen into ammonia and amino acids, which plants can absorb and use for growth and the synthesis of proteins and nucleic acids. In return, the bacteria are protected and obtain carbohydrates from the plants.

![Nodules full of nitrogen-fixing bacteria on a legume plant](image-url)
Escherichia coli in the human intestine

*Escherichia coli* bacteria live inside the large intestine of humans. This environment protects the bacteria, provides them with a good supply of food and allows the bacteria to grow and reproduce safely in large numbers. In return, the bacteria provide the human body with extra vitamins (biotin and vitamin K), which assist in the absorption of nutrients.

Bacteria are also found in the rumens of cows and sheep. They secrete an enzyme called cellulase, which breaks down or digests the cellulose in the plants that the animals eat. The cellulose is broken down into simpler sugars, which the cells can use for energy. Beneficial bacteria such as intestinal flora are often referred to as probiotics.

Classroom activity 5

1. Explain why the relationship between the bacteria in the root nodules of legumes and the plant is a mutualistic relationship. (5)
2. Why do plants need nitrogen? (2)
3. Nitrogen gas is unusable to most plants. Name the form of nitrogen that is usable by plants. (1)
4. Explain why the relationship between *E. coli* and humans is considered a mutualistic relationship. (4)
5. Explain how cows benefit from having bacteria living in their rumens. (3)
Diseases caused by viruses

Viruses cause a variety of infectious diseases in plants, animals and humans. The tobacco mosaic virus attacks tobacco plants, causing mosaic patterns in the leaf. Viral diseases such as rabies, distemper and foot-and-mouth disease affect animals. Examples of viral diseases that affect humans are flu, the common cold, HIV/AIDS, chickenpox, measles, polio and smallpox. The smallpox virus killed 300–500 million people in the 20th century alone. Today, smallpox is one of the few diseases that has been almost completely eliminated. Vaccinations are used to protect people from many viral diseases, including smallpox. Viruses are spread by vectors, the air and water.

Effect of rabies

Rabies is caused by an RNA virus, and can be controlled by the regular vaccination of household pets or elimination of animal carriers, as well as vaccination of humans. The word ‘rabies’ comes from the Latin word for madness because the rabies virus infects the nervous system of mammals, causing them to become mentally disturbed and aggressive. Infected animals may bite others, passing on the virus in their saliva and spreading the disease. There is no effective treatment for rabies.

Humans are at risk from the virus because their pets or farm animals may become infected with the disease and bite them. Rabies infections from dog bites are the most common. About 55 000 people die from rabies each year. Most of these cases occur in the developing world. In South Africa about 20 people die each year.

The rabies virus is a bullet-shaped virus which, like HIV, has a core of RNA at its centre. When a person is bitten by an infected animal, the rabies virus enters the body and travels up the nerves to the brain. After between 20 to 60 days the infected person may complain of headaches, a fever and a sore throat. Later they become partially paralysed, confused, agitated, terrified, and start imagining that they are seeing things. They may suffer from convulsions, produce huge amounts of saliva and eventually fall into a coma and die. One of the symptoms of rabies is that a patient who has become partially paralysed finds it difficult to swallow and drink water, with the result that they panic when given water to drink. This is called hydrophobia (hydro = water and phobia = fear of).

Managing and treating rabies

A vaccine against rabies was developed in 1885 by Louis Pasteur and Emile Roux. Anybody working with animals, for example a veterinarian, should be vaccinated against rabies. If a person is bitten by an animal with rabies there is a chance they can be cured.
Effect of HIV/AIDS

Today, HIV/AIDS is one of the most feared viral diseases. We first became aware of the disease in 1981, when doctors in the United States identified the first cases of AIDS in San Francisco and New York. A number of people started dying from diseases that are not normally fatal in a person with a healthy immune system. A little later, drug addicts who shared needles showed the same symptoms. In 1982, the disease was given the name acquired immune deficiency syndrome or AIDS. HIV weakens the immune system and the person living with AIDS has no protection against infection. AIDS is an incurable disease.

Between 1983 and 1985, it became clear that AIDS was caused by a virus called the human immunodeficiency virus (HIV). Scientists learnt that the virus was found in blood and other fluids of the human body. In Grade 10 you learnt that white blood cells defend the body from invading micro-organisms such as viruses and bacteria. Scientists understood that the HIV attacked the white blood cells (lymphocytes), especially the T-lymphocytes in the body. These white blood cells activate an important part of the immune system. Without T-lymphocytes, the immune system stops working. A blood test for the virus was licensed early in 1985. People who tested positive for antibodies against the virus are said to be HIV positive (HIV+). They could be HIV+ for up to 10 years before finally contracting AIDS. Why does it take so long for symptoms to show?
The HIV is a slow virus and has a long **incubation period** that can run into years. The incubation period is the time between exposure to HIV and the appearance of the first symptoms. During the incubation period the virus invades and destroys T-lymphocytes. At first, the body is able to make enough T-lymphocytes to keep up with the loss of T-lymphocytes due to the HIV invasion. Over time, as the virus continues to copy itself, there are fewer and fewer T-lymphocytes to fight infections. The T-lymphocyte count (the number of T-lymphocytes in the blood) of the infected person is so low that the person’s immune system does not work effectively. This is when the person becomes infected with many opportunistic infections such as thrush or yeast infections, tuberculosis, bacterial pneumonia, meningitis and certain cancers. It is then said that the person has AIDS. If untreated, the person would eventually die because of the opportunistic infections that destroy the body.

HIV is transmitted from one person to another through the body fluids from an infected person.

- HIV is spread through unprotected sex with an infected partner. This can happen when body fluids such as semen, vaginal fluids or blood from an infected person get into the body of someone who is not infected. Everyone who has unprotected sex with an infected person is at risk of contracting HIV. People who already have another sexually transmitted disease are even more at risk.

- Sharing needles used to inject drugs or other substances (including needles used for injecting steroids, tattooing, piercing and body art) can transmit HIV. If the person on whom the needle was used is infected with HIV, the blood on the needle can infect anyone else who uses the same needle.

- Children can be infected with HIV if an infected pregnant woman passes the virus to her unborn child. Treating the mother and child at around the time the baby is delivered can reduce the baby’s risk of infection. Delivery through **Caesarean section** can reduce the baby’s risk of infection.

- In the past, blood transfusion was also a method of spreading the virus. However, blood for donation is screened very carefully these days so blood transfusion is no longer considered a risk.

More than 30 years after the discovery of HIV/AIDS, scientists are still searching for a cure. By 2009, almost 65 million people were living with HIV and more than 28,9 million people had died from HIV/AIDS worldwide.

**Managing and treating HIV/AIDS**

We can take steps to stop the spread of the virus, for example by avoiding unprotected sex and having only one sexual partner. Testing is necessary because
people who are infected with HIV may not know that they have the virus and can infect other people. There have been many campaigns encouraging people to know their HIV status as a way of preventing the spread of the disease.

**Antiretroviral drugs** have also been developed. Antiretroviral drugs are medicines used to treat diseases caused by retroviruses, primarily HIV. The South African public health service provides HIV-positive people with a combination of three antiretroviral drugs. These are zidovudine, lamivudine and nevirapine. Each type of antiretroviral drug works at a different step of the HIV life cycle. For example, the antiretroviral drugs stop the enzyme reverse transcriptase, which turns the HIV RNA into HIV DNA. The HIV DNA combines with the DNA of the T-lymphocytes to make new viruses. Antiretroviral treatment must be taken strictly as prescribed and under medical supervision for the rest of the person’s life.

Antiretroviral drugs do not cure HIV, but there are many benefits of taking them. The immune system is restored and protected, the reproduction of the virus is controlled and the health of people living with HIV/AIDS improves, allowing them to live longer.

### Classroom activity 7

<table>
<thead>
<tr>
<th>Region</th>
<th>Number living with HIV (million)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sub-Saharan Africa</td>
<td>25.0</td>
</tr>
<tr>
<td>Asia</td>
<td>8.30</td>
</tr>
<tr>
<td>Eastern Europe and Central Asia</td>
<td>1.50</td>
</tr>
<tr>
<td>Latin America</td>
<td>1.60</td>
</tr>
<tr>
<td>Middle East</td>
<td>0.54</td>
</tr>
<tr>
<td>Other countries</td>
<td>1.76</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>38.70</strong></td>
</tr>
</tbody>
</table>

1. When did doctors first detect AIDS? (1)
2. What does AIDS stand for? (4)
3. How is HIV spread between people? (5)
4. How does HIV destroy the immune system of the body? (3)
5. Name three ways to avoid getting HIV/AIDS. (3)
6. What is an antiretroviral drug? (1)
7. Explain what an opportunistic infection is. Give two examples. (5)
8. How do antiretroviral drugs slow down the spread of HIV? (3)
9. According to the United Nations, 65 million people around the world have been infected with HIV since the first cases of HIV and AIDS were detected 30 years ago. About 29 million people have died. The distribution of the number of people living with HIV in various parts of the world by the end of 2009 is indicated in Table 1.3.

a) State two reasons why the figures reported in this table may not be accurate. (2)
b) Using the information in Table 1.3, calculate the relative percentage of HIV-infected people in each region. (6)
c) Use the percentages calculated in question (b) to draw a pie chart of the proportion of HIV-infected people in each region. (11)
Influenza

Influenza is caused by a number of RNA viruses which infect warm-blooded animals. It infects the nose, throat and lungs of mammals and the respiratory tract and gut of birds. Swine flu and avian flu are forms of flu that normally infect pigs and birds (especially water fowl) but may be passed on to humans, where they can cause a severe disease.

Effect of influenza

Influenza is a potentially fatal viral disease. It is different to the common cold. The common cold is caused by a group of viruses called rhinoviruses and coronaviruses. Influenza is caused by influenza viruses, type A, B or C. Type A is the most virulent. Only type A can infect both humans and animals. Different strains of the influenza A virus are named by a combination of letters and numbers for example H1N1. The H (haemagglutinin) and the N (neuraminidase) stand for the main types of proteins found in the protein coat of the virus. The RNA mutates regularly, giving rise to new strains of the virus. Therefore the immune system has to constantly adapt to fight the new strain. This constant mutation often allows the virus to escape the immune system of the host. The host is therefore at risk of developing influenza virus infections throughout life.

The H1N1 virus commonly known as Spanish flu had devastating effects towards the end of World War I (1918); more than 20 million people died. Because of the movement of troops the flu virus spread rapidly throughout the world until it became a pandemic. Many young people who would not normally have been affected by the flu died. The same strain of virus reappeared several times in later years. In 2009 the H1N1 virus commonly known as swine flu appeared. Many people did not have antibodies that

Fig. 1.12 Structure of the influenza virus

Fig. 1.13 Special thermal imaging cameras that detect people with high temperatures are used at airports to detect people with swine flu.
could recognise the virus. This is why it spread so quickly and killed 18 000 people worldwide.

When diseases spread quickly like this epidemics can occur. Worldwide flu kills between 250 000 and 500 000 people per year. Influenza is on the top ten lists of killer diseases in many countries.

The flu virus is transmitted through the air in tiny droplets of saliva when flu sufferers cough, sneeze and talk. Flu may also be spread when a person (or some other host) touches a surface that has the flu virus on it and then touches their mouth or nose. Once a person has been infected by the flu virus it enters the epithelial cells of the nose, throat and lungs (or gut in the case of birds) where it multiplies, causing various symptoms. In humans the symptoms include fevers (high temperatures) and chills, headaches, coughing, a sore throat, a runny and blocked nose, aching muscles, fatigue, vomiting or diarrhoea. In vulnerable groups such as children, pregnant women and the elderly, it can cause death. Side effects of infection with the influenza virus may include bacterial infections, ear and sinus infections and pneumonia. People tend to get flu more readily in winter because they stay indoors with the windows closed.

Flu is also linked to heart disease as it can infect the heart muscles and weaken the heart. Treatment of flu includes plenty of rest and lots of fluids. Vaccines are available but these cannot keep pace with a virus that is constantly mutating.

Managing and treating influenza

In South Africa May/June and September/October are the flu months and it is recommended that all people, especially those in the vulnerable groups, be vaccinated. The vaccines contain inactivated forms of the flu virus and teach the body to recognise and destroy the certain viral strains. Besides vaccination the disease can be treated or at least managed in various ways:

- Use antiviral drugs that are available to treat flu.
- Cover the nose and mouth with a tissue when coughing; dispose of tissues hygienically.
- Wash hands often with soap and water and avoid touching the eyes, nose and mouth.
- Avoid sick people.
- Encourage sick people to stay in a separate area.
- Keep surfaces clean, washing them with soap and disinfectant.

Antibiotics are not effective when treating viruses, because they have no proper cellular structure. Antibiotics only work on bacteria. Doctors prescribe antibiotics to reduce the chance of any secondary bacterial infections. These infections occur when the immune system is weak. The best way to prevent getting flu is to eat properly so as to keep your immune system strong. Traditional healers use many plants to ease the symptoms of flu. These include Cape honeysuckle, wild camphor, wild dagga, wild olive and lemon bush.
Diseases caused by bacteria

Bacteria cause diseases in plants and animals. Some human diseases caused by bacteria are tuberculosis (TB), leprosy, cholera, dysentery, typhoid, food poisoning, syphilis, tooth decay and anthrax.

Effects of bacterial blight

Blight is a disease caused by several species of bacteria and some fungi too. Plants become infected when wet or moist conditions carry on for too long. The first symptoms of infection are small, green watery spots on leaves and other plant tissues. As the bacteria multiply the plant tissue dies, turning the spots brown and forming irregular blotches. Sometimes these blotches are surrounded by yellow rings. Eventually the leaves or other parts of the plant turn brown, causing the plant to wilt and die. On grapes the stems become infected, forming reddish-brown streaks. In Afrikaans blight in grapes is called vlamsiekte, because the streaks look like flames. Other types of plant that may be infected are barley, rice and beans. Blight can cause serious losses of these economically important crops.

Managing and treating bacterial blight

- Avoid keeping plants in wet or moist conditions, which promote bacterial growth. Overhead or sprinkler irrigation can contribute to the spread of blight.
- Plant plants apart to allow air to circulate between them and for them to dry properly after rain or irrigation.
- Destroy or deep plough infected plants and their seeds.
- Rotate crops (alternating one crop type with another) to help control the spread of bacterial blight between different parts of the same field and from season to season.
- Planting two crops in between one another, commonly known as intercropping, also helps to control the spread of bacterial blight.
- Use strains of crop plants that are genetically resistant to blight.
Effects of cholera

Cholera is a disease caused by comma-shaped bacteria called *Vibrio cholera*. The cholera bacteria are spread from person to person in water and food contaminated with faeces. The bacteria can survive in streams, rivers, lakes and estuaries for days. Cholera bacteria secrete toxins in the human digestive system which cause severe watery diarrhoea, stomach cramps, vomiting and nausea. These symptoms result in severe dehydration, a dry skin and mouth, thirst, sunken eyes, and tiredness. Left untreated, cholera may result in a severe drop in body temperature and blood pressure, and eventually death.

Cholera is found in overcrowded areas where there is lack of a treated water supply and adequate sanitation. For example, people might be obtaining their drinking water from rivers and using the nearby bushes for toilets. Cholera is common during floods and earthquakes where water and sanitation works have been destroyed. Cholera may also be found in densely populated rural areas and informal settlements.

Cholera was first recorded in India in 1563, and then spread around the world in 1817. In 1961 a cholera outbreak in Indonesia became a pandemic when it spread around the world, killing 120 000 people. Cholera outbreaks in 2001 and 2008 in South Africa affected almost 120 000 people, with 289 dying from the disease. On 12 January 2010, Haiti was struck by a powerful earthquake, causing a disruption of water and sanitation facilities that resulted in a cholera outbreak. As many as 252 640 were infected and 4 672 people died from the disease.

Managing and treating cholera

Cholera can be treated with antibiotics. When drugs are not available it is treated with the replacement of large amounts of fluids and electrolytes as soon as possible. If treatment is effective the person will get better within a few days. When a person is too dehydrated and too weak to drink fluids they can be put on an intravenous drip to rehydrate. A homemade sugar and salt solution can be made to prevent the person from dehydrating further. However, it is essential that the person be taken to hospital as quickly as possible for treatment. Figure 1.14 shows how to make up a rehydration solution.

![Fig. 1.14 Make your own oral rehydration mixture to treat cholera.](image)
There are many simple things you can do to avoid the disease even if you have no proper toilet facilities or treated drinking water supply:
- Wash your hands with soap and water after going to the toilet.
- Wash your hands before preparing food or eating a meal.
- Wash and cook food thoroughly to kill any bacteria present.
- Clean containers used to store drinking water thoroughly and regularly.
- Disinfect drinking water by filtering and boiling for three minutes or treating with \( \frac{1}{4} \) teaspoon of household bleach (0.5% and unscented) per ten litres for half an hour.
- Bury faeces and place toilet facilities far away from drinking water.

Classroom activity 9

1. Write three short paragraphs explaining:
   - the signs and symptoms of bacterial blight
   - the causes of bacterial blight
   - the treatment and management of bacterial blight. (8)
2. Explain why an oral rehydration mixture is so successful in treating cholera. (6)
3. Discuss the following statement: Cholera is a disease that is mainly found in the developing world. (5)

Effect of tuberculosis

TB is a serious infectious disease that occurs frequently in South Africa. It is caused by the bacterium *Mycobacterium tuberculosis*. This disease kills almost three million people each year. The bacteria can attack any part of the body, but usually attack the lungs.

TB affects humans and some animals. It spreads from one person to another through the air. People who are infected become sick and infectious. When they cough or sneeze, the TB bacteria pass into the air in tiny droplets of saliva. A person who breathes in these bacteria will catch the disease. A person with active TB disease will, on average, infect between 10 and 15 people each year.

People who are infected with TB do not always experience the symptoms of the disease immediately; they do not feel sick and cannot spread TB. TB can lie dormant within the body for many years. A person with dormant TB will get TB symptoms only if their immune system becomes weak. A person who has been infected with TB and is not yet sick is said to have latent TB infection (LTBI). People with LTBI could take medicine so that they will never develop the TB disease.
Symptoms of TB depend on where in the body the TB bacteria are growing. TB in the lungs causes a bad cough that lasts longer than two weeks, pains in the chest and coughing up blood or sputum (phlegm from deep inside the lungs). People with active TB are always tired and suffer from headaches. They may lose a lot of weight and get chills and fevers. Unless they are treated for TB, they may infect other people and even die.

A TB infection is diagnosed using a simple skin test. A needle is used to introduce fluid called tuberculin under the skin. After a few days, the amount of reaction to this fluid is assessed. If there is a large amount of swelling, the person probably has a TB infection. A TB infection is identified using X-rays or sputum samples.

According to the World Health Organization:
- One person is newly infected with TB every second.
- One third of the world’s population is currently infected with TB bacteria.
- Approximately 5–10% of the people who are infected with TB (but who do not have HIV) will show symptoms of TB during their lifetime.

**TB and HIV**

HIV weakens the immune system. An HIV-positive person is many times more likely to get TB than someone who does not have HIV/AIDS. If a person with dormant TB gets HIV/AIDS, their immune system is weakened. The TB bacteria then become active and the person may die of TB. All HIV-infected people should be given a TB test to find out if they have LTBI. If they have LTBI they should start treatment to prevent them from developing TB. TB can be prevented or cured in people with HIV infection.

**TB in South Africa**

In 2008, South Africa had almost 400 000 people living with TB and 26 000 deaths as a result of the disease. This incidence is much higher than the average incidence of the rest of the world.

Figure 1.15 shows the number of cases of TB reported each year in South Africa between 1990 and 2009.
Managing and treating TB

About 50 years ago, four very powerful drugs were developed to cure TB. Doctors estimated that we would eradicate TB by 2010. Since 1985, however, there has been an increase in the number of cases of TB. This is partly because of the rise in the number of HIV/AIDS cases and partly because TB bacteria have become resistant to the TB drugs. Some strains of bacteria are even resistant to more than one of the drugs.

Bacteria are becoming resistant to TB drugs because TB bacteria die very slowly. It takes at least six months for the medicine to kill all the TB bacteria. Some sick people take the drugs for only a few weeks and then they start to feel better. If they stop taking the drugs at this point, the more resistant bacteria are left alive in their bodies. These drug-resistant bacteria may spread to other people and infect them with TB.

If the newly infected person does not take the medicine for the full period, the bacteria become even more resistant to the TB drugs. Eventually, the drugs may have no effect at all on the bacteria.

In South Africa, TB agencies are using directly observed therapy (DOT) treatment. A trained health care worker provides the prescribed TB drugs and watches the patient swallow every dose. To prevent TB bacteria from developing drug resistance, people with TB have to take the drugs for six to eight months. For the first two months, they have to take the drugs with a nurse or doctor watching them to make sure that they are doing it properly. If any of these people have a form of TB that is already resistant to the drugs, it will take almost two years to treat them. Luckily, though, we only have to treat people with TB for three weeks before they stop spreading TB to other people. This DOT campaign has led to improved efforts to prevent and control TB.

You have learnt that South Africa faces one of the highest incidences of TB in the world. We also have to deal with multidrug-resistant (MDR) TB. This is a strain of TB that has acquired resistance to various TB drugs. It usually develops because of poor management and ineffective treatment of ordinary TB. MDR TB is more difficult to treat than ordinary TB.

Another strain of MDR TB, called XDR TB, has also appeared in South Africa. In November 2007, the Department of Health reported 481 cases of XDR TB, of which 216 patients had died. At least 30 new cases were being reported each month. This strain of TB is even more infectious and more difficult and expensive to treat than MDR. It poses a serious global health threat and could have a serious impact on the world HIV/AIDS problem.
Effect of anthrax

Anthrax is a serious disease of wild and domestic animals such as antelope, goats, sheep and cattle. It is caused by rod-shaped bacteria *Bacillus anthracis* which may spread to humans and cause death. This type of bacteria spreads easily because it forms thick-walled spores that may last up to fifty years in the soil. When spores are inhaled or swallowed or come into contact with a tear in the skin, they become active bacteria and multiply rapidly.

The first signs of an anthrax skin infection in a human are small sores that develop into blisters and then become pus-filled ulcers with black centres. Anthrax of the skin is seldom fatal. An anthrax infection of the digestive system results in nausea and loss of appetite, which develop into bloody diarrhoea, fever, stomach pains and possibly death. The most dangerous type of anthrax is respiratory system anthrax. Symptoms are a sore throat, mild fevers and muscle pains (as in a cold or flu) which then lead to coughs, painful chest, shortness of breath, tiredness and possibly death.

Animals pick up anthrax from the soil where the spores lie dormant. People most often contract anthrax from handling infected animal products such as hides and wool, or eating undercooked contaminated meat. Anthrax has also been used as a weapon. In 2010 terrorists in the United States posted anthrax spores in envelopes to various workers in government, including some US senators. Twenty-two people opening the envelopes contracted the disease and five of those people died.

Managing and treating anthrax

Anthrax was the first disease proved to be caused by a bacterium. The German scientist Robert Koch in 1875 proved that bacteria from a farm animal that had died from anthrax would cause the disease in mice. Six years later Louis Pasteur demonstrated a vaccine against anthrax in sheep, goats and cattle. Many years later a vaccine was developed for humans.
Farm animals such as sheep and cattle should be vaccinated against anthrax. People working in high-risk situations, for example those working with animal hides and wool, or soldiers who might be exposed to anthrax as a weapon of biological warfare, should also be vaccinated. Once a person has been exposed to anthrax they should be given antibiotics. All infected clothes, animal hides, wool and animal carcasses should be destroyed by burning.

### Classroom activity 11

1. Explain how anthrax is normally passed from domestic and wild animals to humans. (3)
2. How do wild and domestic animals become infected? (1)
3. What are the three main forms of anthrax in humans? (3)
4. Explain why anthrax has been used in biological warfare. (5)
5. Who should be vaccinated against anthrax? (2)

### Diseases caused by protists

Many protozoa cause diseases, such as sleeping sickness, amoebic dysentery and malaria, in people and animals. Dinoflagellates produce toxins that are some of the most deadly poisons known to humans. They produce a red tint to seawater known as a red tide. Mussels and oysters feed on dinoflagellates. These toxins accumulate in their digestive tracts. If humans eat these infected shellfish, they become poisoned and suffer from paralytic shellfish poisoning and often die.

### Effect of malaria

Malaria kills millions of people throughout the world every year – mostly in Africa. The disease is common in the tropical and subtropical parts of Africa, Central and South America, and Asia. Malaria is an increasing problem around the world. In part this is caused by changing global temperatures and drug resistance.

Malaria is a disease caused by four different protist species called plasmodia. A plasmodium is a single-celled protist that occurs in parasitic forms only. Plasmodia cause disease by destroying the red blood cells of the host (the infected person). The plasmodium parasite completes its life cycle in two different organisms: humans and female *Anopheles* mosquitoes. The plasmodium parasite reproduces both sexually and asexually by producing spores.

Female *Anopheles* mosquitoes acquire plasmodia parasites when feeding on the blood of an infected host. The infected female mosquitoes are called vectors, because they carry and transmit the plasmodia to the other people that they feed on.
Fig. 1.16 The distribution of malaria throughout the world

Fig. 1.17 The life cycle of malaria

Plasmodia reproduce sexually in the female mosquito

Female mosquito bites a human and transfers the plasmodia parasite into the blood

Female mosquito bites human and sucks up blood containing plasmodia parasites

Plasmodia travel to the liver and enter the liver cells. Plasmodia start to reproduce asexually in the cells.

Plasmodia burst out of the liver cells and enter the bloodstream

Once in the blood, plasmodia enter the red blood cells and reproduce asexually again.
**Symptoms of the disease**

After a person has been bitten by an infected mosquito, it takes up to two weeks for flu-like symptoms to show. The patient experiences chills, high fever, shivering and sweating, headaches and vomiting. The shivering is caused when the parasites burst out of the red blood cells. The fevers and sweats come and go depending on the stage of the life cycle of the parasite. In severe cases convulsions occur, which eventually lead to a coma and finally death. The liver and spleen become infected and swollen, which leads to jaundice as a result of liver damage. Once the red blood cells become infected, they rupture and the patient develops anaemia. The infected red blood cells can cause blockages in the blood vessels of major organs such as the kidneys, the liver and the brain, and this often leads to the death of the patient.

**Treatment of malaria using traditional and modern medicines**

People use both traditional and modern medicines to treat diseases. Modern treatment involves the use of anti-malarial drugs such as quinine, chloroquine and mepacrine. These drugs interrupt the parasite’s life cycle. However, they sometimes fail to eliminate the disease completely because some resistant parasites can remain hidden in the liver. In severe cases of the disease, a blood transfusion may be necessary.

The herb sweet wormwood (*Artemisia annua*) is a traditional malaria remedy that has been used in China for many years. Today, scientists are researching the use of *Artemisia annua* as a source for artemisinin drugs to be used in Africa. Artemisinin interrupts the life cycle of the malaria parasite by stopping its multiplication in the liver and blood cells. Sweet wormwood grows mainly in the mountains of South East Asia. Artemisinin is too complex to be synthesised chemically. The cost of extracting artemisinin from sweet wormwood plants is very high, especially for poor countries such as those in Africa and South America.

**Prevention and control**

Understanding how malaria is transmitted has helped the South African Department of Health develop appropriate control and management strategies. Malaria prevention includes measures taken against mosquito vectors and against the malaria
parasite *Plasmodium*. These include vector control programmes managed by health authorities, personal protection measures to avoid mosquito bites and the use of preventative medicines.

Prevention at a personal level includes using insect repellents and insecticides and sleeping under mosquito nets that have been soaked in an insecticide. Environmental control can be done by draining stagnant water in which mosquitoes breed and spraying insecticides in homes to kill adult mosquitoes. Another method is to introduce certain kinds of fish into ponds where mosquitoes breed (these fish eat mosquito eggs, larvae and pupae).

In areas where malaria is a problem, various other methods are used to prevent the disease from spreading. Insecticides have been used to spray areas where mosquitoes live and breed. One insecticide that is used is the chemical called DDT. This is a poisonous chemical that has been banned in most countries because of its negative impact on the environment. However, it is still being used in malarial areas in southern Africa as there is currently no effective alternative.

Through effective malaria control measures, the transmission of malaria has been limited to the north-eastern part of South Africa, mainly in the low-altitude areas of Limpopo, Mpumalanga and northern KwaZulu-Natal. Malaria is seasonal in South Africa, with the highest risk being during the wet summer months (September to May). Visitors to these areas should consult a doctor or clinic about taking malaria tablets.

**Classroom activity 12**

1. To which group of organisms does the malaria parasite belong?  
2. How many hosts are needed to complete the life cycle of a mosquito? Name them.  
3. Explain why a person suffering from malaria becomes jaundiced and anaemic.  
4. What precautions should a person visiting a malaria area take to avoid contracting the disease?  
5. Explain how the malaria parasite is transmitted from host to host.  
6. Figure 1.20 shows a temperature chart of a person suffering from malaria. The first fever attack usually takes place 10 days after infection. Such an attack is characterised by three stages: cold, hot and sweating stages. Assume that day 1 on the chart was 22 March 2011. From the chart, determine:
   a) the normal body temperature (in °C) of a healthy person  
   b) the number of fever attacks recorded.
Diseases caused by fungi

There are more than 100,000 fungal species. Only a small percentage is responsible for causing diseases in humans and animals. However, many fungi are plant pathogens, attacking and killing plants such as wheat and maize. Athlete’s foot, thrush, and ringworm are common fungal diseases in humans.

Effect of rusts

Rusts are plant diseases caused mainly by microscopic parasitic fungi that belong to the genus *Puccinia*. Rusts infect many different types of plants and can have devastating effects on important economic crops such as wheat, barley, oats, and rye. Spores of the rust fungi may infect the leaves, stems, flowers, and seeds of a host. The spores form germ tubes that grow into the plant cells to take out water and nutrients. As the fungus grows, it forms reddish-brown marks that eventually become full of rust-coloured spores. These spores are dispersed by the wind to infect new plants. *Puccinia* species tend to be very specific to their hosts.
Some rust species infect more than one plant species to complete their life cycle, while others will only have one plant species as a host. Rusts can seriously damage plants, causing huge financial losses if they are economically important crops such as wheat.

Managing and treating rusts

Like bacterial blight, rusts spread when plants are exposed to moist or wet conditions for long periods of time. Rusts can be treated with fungicides, but they can also be prevented or managed by:
- not exposing crops to moist, humid conditions for long periods (e.g. as may be caused by sprinkler irrigation)
- planting plants far enough apart to allow for air circulation and drying of the plants after they have been wet
- rotating crops to stop the spread of the disease
- using rust-resistant varieties of crops.

Effect of thrush

Thrush is the common name for candidiasis, which is caused by a yeast fungus called Candida albicans. Candida yeasts are common in humans but are usually controlled by the body’s immune system. When a person has a weakened immune system candida infections can occur. Infections are common in people who are undernourished, stressed or suffer from AIDS or have cancer.

Candida thrives in warm, moist places. Infections usually occur in the vagina, on male genitals and in the mouth. Oral thrush infections are common among young children, especially when being breast or bottle fed. Vaginal thrush infections are common in women who are pregnant or using oral contraceptives. Symptoms are a burning, itching irritation with a thick, whitish discharge. Males do not get infected as often as females. Those infected may have low immunity, be taking a course of antibiotics or have had sexual intercourse with an infected partner.

Symptoms of thrush infections
- The mouth becomes red and swollen, with white or bluish-white patches.
- Nappy rash has many causes, but nappy rash caused by candida is a red pimply rash with sharp outlines.
- Candida causes painful burning and itching in the vagina and a white discharge.
- The tip of the penis may become red and swollen from a candida infection, usually from having sexual intercourse with an infected person.
Causes of thrush

Thrush may appear for no apparent reason. Some causes of thrush include the following:
- When the immune system is weak, for example when one has HIV/AIDS or the body is run down.
- When the skin is kept moist for too long, e.g. when a baby wears a wet nappy for too long.
- When people wear tight clothes and underwear that do not allow air to circulate, moist conditions develop that are ideal for the development of thrush.
- Antibiotics may kill useful bacteria that normally keep the candida fungus under control within the body.
- Sexual intercourse which may irritate the skin.
- High blood sugar levels such as in diabetics.
- Use of perfumes or soaps that change the pH of the skin.

Managing and treating thrush

Visit the doctor to confirm your diagnosis. Your doctor will prescribe medicine to treat the thrush. A thrush infection can be treated using topical creams or oral medication. Rinsing the vagina using a douche is also recommended. An old traditional remedy for thrush is to make a douche out of sour fig (Carpobrotus edulis) leaves and vinegar. If you are sexually active, your partner should be treated as well, to avoid reinfecting you. Have your blood sugar levels checked if you keep getting fungal infections or skin ulcers. Avoid harsh perfumed soap, especially in sensitive body areas.

Diet can also play a role in preventing candida infections. Yeasts thrive on sugars, so avoid eating foods containing refined white sugar and processed carbohydrates such as bread. Eat lots of fresh vegetables and fruit and eat yoghurts with probiotic cultures to help reduce the infection.

Classroom activity 13

1. What is the correct name for thrush? (1)
2. Why is this fungus mostly found in the throat and vagina? (2)
3. Suggest why males are not infected as commonly as females. (3)
4. What sort of foods would:
   a) encourage thrush infections (1)
   b) discourage thrush infections? (1)
Effect of ringworm

The same fungus that causes athlete’s foot also causes ringworm, which causes red itchy patches on the face (*Tinea barbae* or *faciei*), scalp (*Tinea capitus*), and hands (*Tinea manus*). *Tinea* is the Latin name meaning growing worm. People used to think that they were caused by worms, hence the name ringworm. Ringworm is infectious and can be passed along on combs, brushes and clothing. Ringworm can also infect dogs and cats, which may then transmit the infection to humans.

Managing and treating ringworm

Ringworm can be treated by antifungal creams or powders. Infections of the toenails and scalp are tougher to treat and may require taking anti-fungal medicine by mouth (consult your doctor about this). Avoid sharing brushes, combs, hair accessories, towels or clothing with infected people. You should avoid touching pets that have signs of ringworm (typically bald spots).

Effect of athlete’s foot

Many people, at one time or another, have suffered from an itchy red rash between their toes. This is called athlete’s foot or *tinea pedis* (*tinea* means fungus and *pedis* means feet). Athlete’s foot is caused by tiny filamentous fungi that invade our skin if they are given a moist, warm place to live – for example, between the toes. The same fungus also causes ringworm. If the fungal infection is not treated, the skin between the toes may crack and bleed, and start to smell. The fungal infection may also spread to the soles of the feet and the palms of the hands. Sometimes, athlete’s foot is accompanied by a fungal infection under the toenails, which makes them thicken and go green or yellow.
Managing and treating athlete’s foot

The fungus that causes athlete’s foot needs warm, moist conditions to thrive. Here are some tips to avoid athlete’s foot:

- Wear shoes that allow your skin to breathe, for example leather shoes.
- Try not to wear running shoes too much, as they tend to make the feet sweat.
- Wear thick woollen or cotton socks that will absorb sweat from the feet.
- Try to change your socks twice a day.
- Wash your feet every day and dry them with a clean towel.
- Powder your feet and socks with an anti-fungal powder to absorb moisture and kill fungi.
- Wear slops in public places such as school gyms, swimming pool change rooms and showers (instead of going barefoot).

If you think you have athlete’s foot, visit your doctor to confirm the diagnosis. You can buy anti-fungal creams or powder from your pharmacist. Make sure that you use the powder or cream every day for at least a week or two. Follow the pharmacist’s instructions carefully. Visit your doctor if the treatment does not work. Remember to follow the tips suggested above to keep your feet as dry as possible during treatment.

Classroom activity 14

1. Why do you think that the fungi that cause disease in humans and animals are described as parasitic? (2)
2. Why do you think that keeping your feet dry is a good way of avoiding athlete’s foot? (2)
3. Give a few basic principles or rules to help people to avoid and treat fungal diseases. (5)

Practical activity 3

This is a prescribed practical task.

Look for signs of plant diseases in the garden

You will need:

- notebook
- pencil
- hand lens
- camera (optional)
- book of plant diseases
Method
1. Carefully study the leaves of plants and look for the following signs:
   - wilting leaves and shoots
   - rust-coloured patches
   - black or brown spots
   - mould patches
   - white or light green spots
   - lumps and curling leaves.
2. Jot down your findings and describe how these diseased leaves differ.
3. Keep a record of the different types of diseases that you found by drawing the damaged plants, taking photographs or even pressing the leaves by covering them in tissue paper and putting them inside a thick book.

Questions
1. What plant diseases did you find?
2. Look at the diseased plants. Could you find anything that might be causing the spread of the disease? (For example, overwatering might result in the spread of a fungus or bacteria.)
3. Were there any diseases not caused by fungi or bacteria? Explain your answer.
4. Do some research and describe how to prevent or treat fungal or bacterial plant diseases.
Immune response of plants and animals

Living organisms have evolved many defence mechanisms against diseases. Immunity is the ability of an organism to resist disease. The process is brought about by complex reactions within the bodies of living organisms. Plants and animals are continually under threat of infection by viruses, bacteria and fungi. The micro-organisms that could cause disease are called pathogens. It is the task of the immune system to keep these microbes out of the body or, if they do enter the body, to find them and destroy them. Through a series of steps called the immune response, the immune system attacks organisms and substances that invade body systems and cause disease.

Immunity in plants

Plants do not have an immune system, but use passive mechanisms of protection. For example, mechanical barriers against infection, such as waxy cuticles, bark, lignin and suberin in cell walls keep out pathogens and hold moisture. Plants also secrete irritating juices that prevent insects and animals from eating their tissues. In these ways plants can improve their chances of survival, but are not able to attack and fight an infection by a pathogen.

Any wounds in vascular plants can be plugged with parenchyma cells forming callus tissue. Chemicals such as resin and gums act as antiseptics and prevent the entry of micro-organisms, as well as providing a natural resistance to fungal infections.

Organisms can, however, invade plants through splits in the bark and insect mouthparts can pierce cuticles. When plants detect an invading pathogen, they release high levels of salicylic acid in the affected tissue. This induces programmed cell death in the affected tissues, which restricts the spread of the pathogen and also activates responses elsewhere in the plant. The result is that the plant can resist further attacks on other tissues.

Immunity in animals

Animals, unlike plants, have an internal immune system to defend themselves against micro-organisms. This is known as a natural immunity. In Grade 10 you learnt that the immune system consists of the skin, lymph system, spleen and bone marrow. The immune system manufactures white blood cells (leucocytes) that destroy pathogens. There are two types of leucocytes: lymphocytes (B and T) and phagocytes.

When pathogens invade the body, their proteins are foreign to the body. These foreign proteins are called antigens. B-lymphocytes detect the antigens and produce their own proteins to destroy the invaders. These proteins are called antibodies. The antibodies attach themselves to the antigens, causing them to clump together. T-lymphocytes destroy them and the phagocytes engulf them through a process called phagocytosis. This is called active immunity, as the body has made antibodies through direct contact
with a pathogen. These antibodies continue to exist in the body after it has recovered from a disease. If the body is exposed to the pathogen at a later date, these antibodies are already available, allowing the immune system to react more quickly to the invading pathogen and destroy it before it can multiply.

**Vaccinations**

Vaccination is an effective means of stimulating active immunity. A vaccine is a substance that is injected into the body or given orally to prevent a specific disease. The immune system protects the body by fighting disease-causing organisms such as viruses and bacteria. We can speed up the body’s immune response to a specific disease-causing organism by giving it a vaccination for this disease.

A vaccine is made from a weakened form of a disease-causing organism. For example, the tetanus vaccine contains the inactive form of the bacteria that causes tetanus. When you are vaccinated against tetanus, your immune system responds to the inactive tetanus bacteria by making antibodies that will destroy any tetanus bacteria. If you happen to be exposed to tetanus bacteria later, the antibodies already exist. The lymphocytes recognise the bacteria quickly, so they multiply and destroy the bacteria before they have a chance to make you sick.

![Image of how a vaccine works]

*Fig. 1.27 How a vaccine works*

The use of vaccines has completely eradicated (destroyed) the disease smallpox and almost completely eradicated polio.

All South African children should be vaccinated against the following diseases:
- hepatitis (viral)
- diphtheria, tetanus and whooping cough (bacterial)
- *Haemophilus influenza* (viral)
- polio (viral)
- measles, mumps and **rubella** (viral)
- chickenpox (viral).
These vaccinations are given at separate intervals such as six weeks, three months, 12 months and 18 months of age. Each time the vaccination is given it has a higher dose so that the body can build up a good supply of antibodies.

**Cool fact**

Salicylic acid, which is used in the painkiller aspirin, is one of the chemicals released by a plant when it is damaged. The salicylic acid spreads through the plant and triggers the release of toxic substances.

**Classroom activity 15**

1. What is meant by immunisation? (5)
2. Explain how a vaccine protects a person against disease. (3)
3. Explain the difference between an antigen and an antibody. (4)
4. Explain the difference between the terms active and passive immunisation. (7)
5. a) What childhood diseases did you suffer from? (1)
    b) Could you suffer from these again? Explain your answer. (2)
    c) Which diseases were you vaccinated against? (2)
6. Discuss if there is value in being vaccinated against diseases such as flu. (5)
Use of drugs to control micro-organisms

Humans have struggled against death, diseases and infections caused by bacteria for thousands of years. Not long after World War I, during which thousands of soldiers died from infected wounds, medicines were invented that could cure many bacterial diseases and infections. These antibiotics were discovered quite by accident.

In 1928 Alexander Fleming, a Scottish doctor and researcher, returned to his laboratory after a family holiday. In one corner was a stack of dishes containing bacteria that he had grown before he went away. He noticed that one of the dishes was contaminated with mould and that the bacteria around the mould had been destroyed. Fleming cultured the fungus and found that it belonged to the genus Penicillium and that it was able to destroy many types of bacteria. It took 17 years to learn how to mass-produce the penicillin. Today there are more than 100 types of antibiotics developed using the tools of biotechnology.

Antibiotics work in several different ways to destroy bacteria. They stop the bacteria from forming cell walls or making proteins and nucleic acids while developing. Some antibiotics alter the permeability of the cell membrane, causing the bacteria to lose vital substances. Other antibiotics interfere with the enzyme action during metabolic processes. These antibiotics are called antimetabolites.

Antibiotics are used against bacteria, fungi and parasites. If antibiotics are overused or used incorrectly the bacteria may become resistant. You learnt how the tuberculosis bacteria have become resistant to antibiotics, making it very difficult to control the disease. Over time, the DNA in bacteria mutates, which helps them to withstand the attack of antibiotics. When bacteria become resistant to antibiotics they are able to block the access point of the antibiotic or alter the target site of the antibiotic. Some bacteria can inactivate the antibiotic or even actively transport the antibiotic out of the cell. Figure 1.28 shows how bacteria can become resistant to antibiotics.

One way of ensuring that bacteria do not become resistant to antibiotics is to complete the course. This minimises the risk of a few resistant bacteria surviving the medicine. Superbugs are bacteria that are resistant to all known antibiotics.
Classroom activity 16

1. In an investigation, two sterile agar plates were inoculated with bacteria from the same culture. Then, using a syringe, 2 cm³ of an antibiotic solution was added to plate 1 and 2 cm³ of sterile water was added to plate 2. Figure 1.29 shows the plates after 24 hours.
   a) Explain why the agar was sterilised at the start of the investigation. (1)
   b) The water was added to plate 2 as a control. Explain why this control was necessary. (2)
   c) Give two ways in which antibiotics kill bacteria or prevent them from multiplying. (2)
   d) Explain why some bacteria were able to grow on plate 1. (2)
   e) Describe how an antimetabolite works to destroy harmful bacteria. (2)

2. Read the article below and answer the questions that follow:

Fourth superbug victim dies in SA
Sapa, 01 November 2011

A fourth person died in a Benoni hospital after contracting the superbug New Delhi metallo-beta-lactamase (NDM-1), according to a report yesterday.

The patient, who had been in the Life Glynwood Hospital for several weeks, died on Saturday, The Star newspaper reported. NDM-1 is an enzyme that makes bacteria resistant to antibiotics. Ten patients at the hospital had been diagnosed with the enzyme and four had been released from hospital after treatment. Two remained in isolation wards. Life Glynwood Hospital spokeswoman Marietjie Shelly said: ‘One of these patients has been treated in ICU since admission.’

"The other patient was in ICU earlier, but the patient’s condition has improved to the extent that intensive care is no longer required." The last confirmed case of the superbug was on 21 October. She said strict precautions were being followed to prevent the spread of NDM-1.

In September, one confirmed case was reported at Charlotte Maxeke Johannesburg Academic Hospital. Professor Adrian Duse, head of the outbreak response unit of the National Institute for Communicable Diseases, said it could not be determined to what extent NDM-1 had
Micro-organisms to produce medicine

Many micro-organisms are useful. They have been used in biotechnology to develop drugs, vaccines and better ways to diagnose and treat diseases. Bacteria and viruses are often used in biotechnology.

Production of insulin through genetic engineering

Insulin is a hormone that is secreted by the pancreas to control the sugar levels in your blood after eating. Without insulin, glucose levels in the blood would become very high and could lead to death. Type 1 diabetes is a disease where the pancreas does not secrete sufficient insulin. Diabetes patients inject insulin into their blood to make sure that their blood sugar levels do not become too high.

Producing this insulin has always been a problem. In the past, insulin was taken from the pancreases of pigs or cows when they were slaughtered. This had several problems as the insulin was chemically different from human insulin, causing allergic reactions in some diabetics. It was expensive to produce and there was always a limited supply.

Today, bacterial DNA plasmids are used in bioengineering to produce insulin. This is done by isolating the human insulin gene from a human chromosome and then inserting it into the bacterial plasmid. Bacteria divide very quickly, so large numbers of insulin-producing bacteria can be cultivated. This insulin is easily extracted. Insulin is therefore now much cheaper to produce, more readily available and chemically identical to human insulin. Figure 1.30 shows how the process of insulin production occurs. Read each step carefully so you can learn how insulin is produced.
The technique of recombining genes in micro-organisms also has now been used to produce hormones such as human growth hormone, which controls the absorption of calcium into bones. Recombinant gene technology has been used to produce safer vaccines such as the hepatitis B vaccine.

Interferon is a protein used in the treatment of AIDS. Interferon helps cells to break down viruses and stop them from dividing. The bacterium *Escherichia coli* has been used to produce interferon. Interferon was originally extracted from white blood cells but thousands of litres of blood were needed to produce a small amount of interferon, making it extremely expensive. Today genetically engineered interferon is available, making it more affordable.

**Penicillin: The first miracle drug**

Earlier you learnt that penicillin is an antibiotic that is produced using the fungus *Penicillium*. Antibiotics are chemicals that can kill or stop the growth of disease-causing bacteria. The ability of penicillin to cure people of many once-fatal bacterial infections has saved so many lives that it has been called a ‘miracle drug’. Penicillin kills bacteria by preventing the bacteria from forming new cell walls. The bacteria die because they cannot complete the process of cell division that produces new bacteria.
1. The steps for making insulin using genetic engineering are written below. However, they are not in the correct order. Create a flow chart to describe the process that is used to get bacteria to produce human insulin. \(8\)
   - The bacteria are cultured and as they multiply, the plasmids multiply and more insulin is made.
   - The gene for human insulin production is cut out of a human chromosome.
   - The plasmid is put back into a bacterium where the gene for insulin starts making tiny amounts of insulin.
   - The insulin gene is inserted into a plasmid, which is a circle of bacterial DNA that can divide and multiply inside a bacterium.

2. Why it is better to inject insulin from a human than from pigs or cows into diabetes patients? \(2\)
Micro-organisms and traditional biotechnology

All over the world people drink *fermented beverages* during many types of celebrations. Beer brewing and wine making are among the oldest biotechnologies in the world. In South Africa, various alcoholic drinks are produced using yeast. For example, the Western Cape is well known for its wine production. Traditional African beers are mostly made from sorghum and maize. In some communities, marula fruit and honey are also used to make traditional alcoholic beverages.

The traditional beer-making process

Either sorghum or maize is used as the main source of sugars to make alcohol. The first stage is the preparation of the sorghum seeds. The seeds are left covered with water in a clay pot for a day. They absorb water and swell. The soaked sorghum seeds are drained and placed in a tightly sealed clay pot to germinate into sprouts. The sprouts are allowed to dry in the sun. The drying process stops germination. The dried sprouts are crushed and ground with traditional grinding stones to produce malted, coarse sorghum meal.

In the next stage, the maize and malted sorghum meal are soaked in warm water for about a day. On the second day, the fermented soaked mixture is cooked in big pots to form soft porridge. This process is called mashing. The soft porridge is cooled in large clay pots.

The next stage is the fermentation process. A small amount of the milled and dried sorghum seeds – which carry the natural yeast – are introduced into the cool, soft porridge. The mixture is mixed with large amounts of water and poured into big clay fermentation pots. The surface of these pots contain yeast cells left from the beer that was previously stored in the pots. These yeast cells, together with those from the sorghum seeds, are used to ‘kick start’ the process of fermentation. The yeast converts the sugars in the sorghum and the maize into alcohol.

Fermentation is temperature dependent, so the mixture ferments much faster in summer than in winter. The quality of the froth that is produced during fermentation acts as a guide for the beer makers to determine if the beer is ready for straining.
In the next stage, traditional straining equipment – such as woven grass bags and sieves made from metal and wood – is used to strain the beer. The matured beer is stored in clay pots in a cool place, ready for drinking. Traditional beer has a thick consistency with a refreshing acidic flavour.

**Traditional sources of yeast for brewing**

Indigenous tribes in South Africa used various plant roots as a source of yeast to start fermentation in beer production. The roots of plants such as *Khadia acutipetala* (common name khadi) and *Mestoklema tuberosum* (common name *donkievygie*) contain yeasts and moulds that were commonly used in South Africa for fermenting traditional beers. Today, commercial yeasts are used to start fermentation, standardise flavour and improve the quality of beer. Local supermarkets keep a variety of commercial brewing and baking yeasts.

**Wine making**

Wine is fermented fruit juice. The most common fruit used is grapes, but it can be made from many other fruits. In Japan and China, rice is used to make wine. Grape berries are crushed to form a juice called must. The must is left to ferment and after a couple of weeks it turns into wine. The colour of the wine depends on the type of grape used and the time the skins are left in the must. The longer the skins are left in, the redder the wine becomes.

**Making cheese**

Cheese has been made for thousands of years. It was a way of extending the shelf life of milk in the days before fridges were invented. The different flavours of cheeses depend on the type of milk and which micro-organisms are used. Milk contains a sugar called lactose, a protein called casein, water, fat and minerals. A bacterium called *Lactobacillus* ferments the lactose sugar, changing it into lactic acid. Lactic acid causes the casein to curdle and separate from the liquid whey. The solid curds are washed, salted and moulded into cheeses.

Soft cheeses contain more water than hard cheeses. Some cheeses have a fungal growth on them, which gives them a strong flavour. An example of this type of cheese is blue vein cheese, where the fungus *Penicillium roqueforti* grows through the cheese. Other fungi, such as *Penicillium camemberti*, grow on the surface of the cheese, maturing into a more runny cheese. Examples of this type of cheese are Camembert and Brie.

Yoghurt is made in a very similar way. The lactic acid produced during the fermentation process is what causes yoghurt to have a sour taste. When you see the phrase ‘live cultures’ on yoghurt tubs it refers to the presence of bacteria such as *Lactobacillus acidophilus*. These bacteria are good for your digestive system.
Classroom activity 18

1. Discuss the importance of yeast in beer brewing and bread making.  
2. Explain how bacteria are used in the production of yoghurt, cheese and sour milk.

Questions on the biodiversity of micro-organisms

1. Give the correct term for each of the following:
   a) Viruses that contain an enzyme that copies information from RNA genes to DNA
   b) True cells with membrane-bound organelles and a nucleus
   c) In-built immune system found in animals to protect themselves
   d) White blood cells of the immune system that fight disease
   e) Organisms that do not contain membrane-bound organelles

2. Each of the following questions consists of a statement or description in the first column and two items numbered (i) and (ii) in the second column. Consider which item(s) relate(s) to the statement or description. Write your choice next to the relevant question number by using the following codes:
   A – if only item (i) refers to the statement or description
   B – if only item (ii) refers to the statement or description
   C – if both item (i) and (ii) refer to the statement or description
   D – if neither of the items refers to the statement or description

<table>
<thead>
<tr>
<th>Statement or description</th>
<th>Item</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Symptoms of athlete’s foot</td>
<td>(i) Fever</td>
</tr>
<tr>
<td></td>
<td>(ii) Vomiting</td>
</tr>
<tr>
<td>b) Diseases caused by viral infections</td>
<td>(i) Chickenpox</td>
</tr>
<tr>
<td></td>
<td>(ii) Oral thrush</td>
</tr>
<tr>
<td>c) Vaccination</td>
<td>(i) Passive immunity</td>
</tr>
<tr>
<td></td>
<td>(ii) Acquired immunity</td>
</tr>
<tr>
<td>d) Products produced during the fermentation process of making beer</td>
<td>(i) Alcohol</td>
</tr>
<tr>
<td></td>
<td>(ii) Carbon dioxide</td>
</tr>
<tr>
<td>e) Uses of bacteria</td>
<td>(i) Making antibiotics</td>
</tr>
<tr>
<td></td>
<td>(ii) Nitrogen cycling</td>
</tr>
</tbody>
</table>

(5)
3. A South African Department of Health study estimated that 28% of pregnant women were living with HIV/AIDS in 2007.
   a) What does the acronym HIV stand for? (1)
   b) HIV/AIDS has reached pandemic proportions. Explain what pandemic means. (2)
   c) Why are the HIV statistics related to pregnant women readily available to the South African Department of Health? (2)
   d) Explain why it is difficult to get an accurate statistic regarding the total number of people living with HIV/AIDS in South Africa. (2)
   e) Name one way to prevent HIV transmission during sexual intercourse. (1)
   f) Mention two negative impacts that AIDS will have on the South African economy. (2)
   g) Study Figure 1.33 representing an HIV and answer the questions that follow.
      i) From the label list below, match the structural part to the correct label (A, B, C or D).
         viral RNA, viral envelope, glycoproteins, capsid (4)
      ii) What is the function of the structure labelled C? (1)

4. Every day 5 000–6 000 people die of tuberculosis. About 75% of these people are in the age group between 15 and 54 years, the most productive age in any nation. TB has a destructive effect on social and family life. It is estimated that TB patients lose 3–4 working hours per day (productive time).

Write an essay on tuberculosis. Discuss the following:
   a) symptoms
   b) treatment and prevention
   c) possible effect of TB on the South African economy
   d) the role of businesses in the management and control of TB. (15)
Viruses are acellular. They are obligate parasites, as they are unable to reproduce themselves and so multiply inside a host’s cell using its genetic material.

Bacteria were the first organisms to have a cellular structure and are classified as prokaryotes.

Some bacteria are harmful, while many are very useful.

Protista was the first kingdom to have eukaryotic cells.

Protists consist of three main groups: animal-like protists (i.e. protozoa), plant-like protists (e.g. algae) and fungus-like protists (e.g. slime mould). Protists are classified according to how they obtain nutrition and how they move.

The kingdom Fungi are mostly saprophytic decomposers. Fungi have a unique cell wall structure made up of chitin.

Micro-organisms play an important part in maintaining the balance in the environment and the web of life.

Bacteria form symbiotic relationships with humans, animals and plants.

Some micro-organisms can cause diseases.

Diseases caused by viruses:
- Rabies: It is caused by an RNA virus that is transmitted through animal saliva. Affected animals can become mentally disturbed and aggressive. Infections can be controlled through vaccination of household pets.
- HIV/AIDS: It is caused an RNA virus known as HIV. The virus is transmitted through body fluids from an infected person to another and weakens the immune system. The effects of infection can be managed through the use of antiretroviral drugs.
- Influenza: The disease is caused by an RNA virus that is transmitted in droplets through the air. It affects the nose, throat and lungs. Infection can be controlled through annual vaccination.

Diseases caused by bacteria:
- Bacterial blight (plant disease): Plants become infected in long periods of moist conditions. The disease causes loss of crops. It can be prevented through crop rotation and intercropping.
- Cholera: Bacteria are transmitted by contaminated food and water. Infection causes severe diarrhoea, but can be treated with antibiotics. The spread of cholera can be avoided by practising proper hygiene.
- Tuberculosis: Bacteria are transmitted through the air in droplets. TB bacteria can be dormant in the body for a long time. Because of a weakened immune system, an HIV-positive person is more likely to contract TB than an HIV-negative person. Because TB bacteria can become resistant to drugs, TB patients must complete the full antibiotic treatment regime.
Anthrax (animal disease): Although this is an animal disease, it can also be spread to humans. The disease can be managed and treated through vaccination and antibiotics.

- Diseases caused by protists:
  - Malaria: The disease is caused by *Plasmodium* parasites, which completes its life cycle in the female *Anopheles* mosquito (vector) and humans. Humans become infected when bitten by a female *Anopheles* mosquito. The disease causes flu-like symptoms. Treatment includes the use of antimalarial drugs; prevention includes vector control measures by health authorities.

- Diseases caused by fungi:
  - Rust (plant diseases): As with bacterial blight, plants become infected in long periods of moist conditions. The disease causes loss of crops. Crop rotation and intercropping can prevent fungal rust.
  - Thrush: The infection is caused by a yeast fungus, which thrives in warm, moist conditions. A thrush infection can be treated by using a topical cream or oral medication.
  - Ringworm and athlete’s foot: The infections are caused by the same fungus. Ringworm causes red itchy patches on the face, scalp and hands, while athlete’s foot causes an itchy rash between the toes. Both infections can be treated using antifungal creams.

- Immunity is the ability of an organism to resist disease. There are two kinds of immunity, namely active and passive immunity.

- Plants do not have an immune system. Plants have passive mechanisms of protection. Animals have an internal immune system with which to defend themselves against micro-organisms. This is known as a natural immunity.

- Some fungi are used to make antibiotics. The discovery of antibiotics and vaccinations has greatly reduced the incidence of death from many diseases. If antibiotics are overused or used incorrectly there is a chance that the bacteria will become resistant.

- Some bacteria are involved in mutualistic relationships with plants and animals.

- Vaccinations provide some form of immunity against disease.

- Many micro-organisms are useful as they have been used in biotechnology to develop drugs and vaccines, as well as better ways to diagnose and treat diseases. Bacteria and viruses are often used in biotechnology.

- Several bacterial and fungal organisms are used to make cheese, wine, yoghurt and beer.
Let’s talk about the biodiversity of plants

In Grade 10 you learnt about the Five Kingdom classification system. Plants belong to the kingdom Plantae. What criteria must an organism meet in order to belong to the kingdom Plantae? It must contain the green pigment chlorophyll. However, algae also have chlorophyll yet they are not placed in this kingdom. Which other criteria do you think there are for classifying an organism as a plant? Plants need to be able to produce oxygen. They are multicellular and their cells are surrounded by a cell wall made of cellulose. Finally, they all show alternation of generations in their life cycles.
In Grade 10 you learnt about plant tissues and organs. What you learnt applies to the group known as the flowering plants. These are currently the dominant plant form on Earth.

Flowering plants are autotrophic and photosynthesise using chlorophyll. They have four plant organs – roots, stems, leaves and flowers. They have vascular tissue. Their cells have differentiated into several types of tissues – meristem, epidermal, parenchyma, collenchyma, sclerenchyma, xylem and phloem. They produce spores, seeds and fruits.

You will learn in this topic that there are many groups of plants that do not have all of these features.

See how much you remember from Grade 10 by completing the following exercise.

1. Give a definition of tissue.
2. Name the two types of cells that make up xylem tissue.
3. What are the functions of xylem tissue?
4. List the main function of each of the organs in a flowering plant.
5. The mesophyll of a leaf contains chlorenchyma. How does this tissue differ from parenchyma?
6. What are the specialised cells in a lower leaf epidermis called? Make a simple labelled drawing to show the structure of these cells.
7. a) A section through a tree trunk is shown in Figure 2.1. Suggest reasons for:
   i) the broad ring shown at A
   ii) the narrow rings shown at B
   iii) the scar shown at C.
   b) Estimate the age of this tree when it was cut down.
The fossil record, which you learnt about in Grade 10, shows that the first land plants appeared in the Ordovician period of the Palaeozoic era, about 480 million years ago. Flowering plants only made their first appearance in the late Cretaceous period of the Mesozoic era. This was towards the end of the reign of the dinosaurs, some 68 million years ago. Since then, the adaptation of plants to life on land has enabled them to survive in a wide variety of habitats.
The plant kingdom is divided into plants that have vascular tissue and those that do not, as shown in Figure 2.2. There is only one group of plants that lacks vascular tissue and that is the bryophytes. The rest of the plant groups, that is the ferns and the seed-bearing plants, have vascular tissue, which includes tracheids and xylem vessels. These plants are grouped together and called tracheophytes because of the presence of tracheids in the vascular tissue.

A unique feature of plants is that they undergo an alternation of generations during their life cycle. This means that an asexual generation is followed by a sexual generation. The asexual generation is called a **sporophyte** and it is **diploid** (2n). It produces **haploid** (n) structures called spores by the process of meiosis. Meiosis is a special type of cell division. It differs from mitosis in that the number of chromosomes in the cell is halved. Meiosis is important in sexual reproduction and you will learn about this process in Grade 12. The spores grow into a **gametophyte**.

The gametophyte is the sexual generation as it produces gametes or sex cells (n), which fuse together during fertilisation. This returns the plant to a diploid (2n) state. The result of fertilisation is a diploid (2n) **zygote**. The zygote grows into another asexual sporophyte generation and so the process is repeated.

**Classroom activity 1**

1. What feature separated the terrestrial plants from the ancestral aquatic algae? (2)
2. Which feature is common to conifers and flowering plants but not ferns? (1)
3. How long after the emergence of the first terrestrial plants did it take for flowering plants to develop? (2)
4. If the sporophyte generation of a plant has 36 chromosomes, how many chromosomes would there be in:
   a) the gametophyte plant  
   b) the spore  
   c) the zygote  
   d) the gametes?  
5. Do you think any of the dinosaurs regularly ate fruit? Explain your answer.  
6. What important characteristics have plants developed as they have become more advanced?  

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**Bryophytes – the mosses**

Bryophytes, for example mosses, are the most primitive land (terrestrial) plants. They are non-vascular so they need to absorb water directly from the soil and the air. The water moves from cell to cell by osmosis. They were the first plants to emerge from water and attempt to live on land. They retain many features that make them dependent on water. For example, they can only grow in moist environments as they are dependent on water to complete the life cycle. Bryophytes are the only division or group of plants that have a dominant gametophyte (n) generation. The green carpet of moss plants you see is the sexual, gamete-producing generation of the life cycle. A carpet of moss has separate male and female shoots all mixed together. During fertilisation, the male sperm cells have to swim to the eggs of the female shoots. This means that without water they cannot reproduce. The gametophyte is green and is able to photosynthesise.

**Characteristics of bryophytes**

- **Vascular tissue:** Bryophytes do not have vascular tissue. These plants resemble algae in that the plant body (gametophyte) is a **thallus**. This is because the plant body does not have vascular tissue (xylem and phloem) and, like the algae, cells are haploid. Not having vascular tissue means these plants stay short in height. Vascular tissue is what gives support to plants and enables them to grow tall. Mosses would not be able to remain upright on land without any xylem. Most mosses are no more than about 2 cm tall and grow to form a green carpet of cover in moist areas.

- **Leaves and roots:** Bryophytes do not have true roots, stems or leaves. Root-like structures called **rhizoids** anchor the plant to a **substrate** such as a rock. This is why mosses are able to grow on rocks in damp areas. They do not need deep roots in soils to be able to absorb water. The leaf-like structures are only one cell thick. They do not have a waxy, waterproofing cuticle covering them as is the case in true leaves (refer to

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4. If the sporophyte generation of a plant has 36 chromosomes, how many chromosomes would there be in:
   a) the gametophyte plant  
   b) the spore  
   c) the zygote  
   d) the gametes?  
5. Do you think any of the dinosaurs regularly ate fruit? Explain your answer.  
6. What important characteristics have plants developed as they have become more advanced?

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**Fig. 2.4 A moss gametophyte generation with sporophyte generation attached**
Grade 10 work on leaf structure). Without this cuticle, mosses lose water easily. The absence of a cuticle, however, enables them to absorb water directly through any part of the plant body (thallus) and not only through the rhizoids. Most mosses are able to withstand long periods of drying out and then seemingly spring back to life when water is available.

- **Spores**: Spores are the asexual reproductive structures formed by the sporophyte generation of the life cycle. Spores are formed by meiosis, a specialised cell division that halves the number of chromosomes. The spores are formed in a sporangium called the capsule. Mosses produce only one kind of spore and are therefore homosporous. The sporophyte is attached to the female gametophyte with a seta. The sporophyte is dependent on the gametophyte for water and some food. Large numbers of haploid (n) spores are produced. These are spread by wind.
- **Fruit**: No fruit or seed is produced. Fertilisation of gametes produces a zygote (2n), which grows into an embryo. The embryo grows into the sporophyte.

### Cool fact

Sphagnum moss plants contain empty cells that help retain water in drier conditions. Sphagnum can hold up to 20 times its dry weight in water. This is why this moss, when dried, is very popular among florists for lining hanging baskets and keeping the plants in the basket moist.

### Practical activity 1

This is a prescribed practical task.

**Study fresh moss**

**You will need:**
- dissecting microscope or hand lens
- drawing paper and pencil

**Method**

Collect fresh moss from your area. Look near an outside tap or a damp area. Study the moss using a dissecting microscope or a hand lens.

1. Make a drawing of one plant. Label rhizoids and leaf-like structures.
2. Find some moss that has the sporophyte generation attached to it. Examine the sporophyte and draw the capsule.
3. Collect some spores from the capsule and spread them on damp cotton wool in a Petri dish. Close the lid of the dish to keep it moist inside. Observe the dish daily until the spores begin to grow.
4. Find the mass of some fresh moss. Dry the moss out for one week and then find the mass of the dry moss. Calculate the percentage of water that was lost by the moss.
Pteridophytes – the ferns

Pteridophytes (the ferns) are an intermediate group of plants between bryophytes (mosses) and seed plants. They are advanced in that the sporophyte generation is now dominant. In other words, the fern plant you see is the sporophyte generation. They still show a few primitive features: they have swimming sperms for which water is required and the structure of the gametophyte generation is very similar to that of mosses in a number of ways. The gametophyte is a green thallus with no cuticle or vascular tissue. Ferns are more advanced in other respects in that they have vascular tissue and they are better adapted to living on land. Ferns can inhabit a wider range of habitats than mosses, but the water-dependent sexual generation of the life cycle is still a restriction on their distribution. The fern group ranges from small, floating aquatic species to tall tree ferns reaching many metres in height. Ferns reproduce using spores. They have neither seeds nor flowers.

Characteristics of pteridophytes

- **Vascular tissue**: Ferns have vascular tissue. Phloem and xylem (with tracheids and vessels) are present. The vascular tissue provides some support and this has enabled ferns to grow taller on land than mosses. The xylem offers the plant body support due to the presence of **lignin** in the cell walls.

- **Leaves and roots**: Ferns have true leaves called fronds. The leaves are compound and supported by a stiff, tough shaft called a rachis. True leaves have a cuticle that prevents water loss and vascular tissue in veins in the leaf. A cuticle does, however, prevent water from being absorbed through the leaves as in mosses. Instead, ferns use their tough, wiry **adventitious roots** to absorb water, as well as to anchor the plant in the soil. These roots grow off an underground stem called a rhizome (see Figure 2.5).

- **Spores**: Underneath the leaves small structures called **sori** (singular: sorus) develop. The sori contain a number of sporangia. Division by meiosis gives rise to a great many haploid spores (n). Ferns are homosporous as they produce only one kind of spore. These spores are flung out when ripe. If they land in a suitable place, they will germinate. They develop into the tiny, moisture-dependent gametophyte generation. The gametophyte generation is a heart-shaped thallus. Reproductive organs develop on the undersurface of the thallus. Water is needed for the male sperms to swim to the female egg. The gametophyte generation is a primitive stage. It is the one water-dependent feature in an otherwise well-adapted terrestrial plant.

- **Fruit**: No fruit is produced. Ferns do not have seeds. A fertilised egg develops into a diploid embryo. The embryo immediately grows into a new sporophyte plant. The new sporophyte is temporarily dependent on the gametophyte for food until it can develop its own first leaves and take over photosynthesising.
As the first group of plants with conducting tissue, the pteridophytes were also the first plants to successfully colonise the terrestrial environment. Some, such as tree ferns, can get quite large thanks to their vascular conducting tissue, and groups of tree ferns grow close together to form forests. They are also an important source of food for terrestrial animals.

![Fig. 2.6 A tree fern forest](image)

**Practical activity 2**

This is a prescribed practical task.

**Study fern plants**

**You will need:**
- hand lens
- slides or micrographs of fern gametophytes
- dissecting microscope
- pencil and paper

**Method**

Collect fresh ferns from your area. Look in forest areas and gardens.

1. Use a hand lens to observe the fronds, rhizome and roots of a fern.
2. Locate a sorus on the frond and view it under a dissecting microscope. Describe what you see. (2)
3. New fronds have a particular way of growing. Find some new growth on your fern and describe the growth form. (2)
4. How is the new growth of a fern protected? (2)
5. Observe prepared slides or micrographs of fern gametophytes. In which ways does the structure of the gametophyte differ from that of the sporophyte? (4)
6. Draw up a table in which you compare the gametophyte and sporophyte of a moss with that of a fern. (13)
7. What do mosses and ferns both require for reproduction? (1)

**Gymnosperms – the conifers**

Gymnosperms were the first group of plants to produce seeds. All plants that produce seeds are grouped together as Spermatophyta, a name which literally means ‘seed plants’. The seeds that gymnosperms produce are not surrounded by a fruit and so are called naked seeds. It is from this feature that the group gets its name (**gymnos**
Another feature of the plants in this group is the presence of cones. The seeds develop on the surface of scale-like appendages on the cones. This group of plants was also the first to become truly terrestrial. They do not require water for fertilisation to occur. Like the ferns, the gymnosperms have a dominant sporophyte generation. The gametophyte generation is now greatly reduced and barely visible.

**Cool fact**

Some species of conifers can live for a very long time. The oldest tree on Earth is thought to be a 4 800-year-old bristle-cone pine in America called ‘Methuselah’. A redwood tree named ‘Hyperion’ has been declared the tallest tree in the world. It is 115 m tall!

**Characteristics of gymnosperms**

- **Vascular tissue**: Consists of phloem and mainly tracheids (refer to plant tissues in Grade 10). The presence of large numbers of tracheids makes the wood of gymnosperms soft. They are referred to as softwood trees, for example pines. The tallest trees in the world are the giant redwoods, which are conifers. They can only grow this big because of the large number of tracheids in the stems.
- **Leaves**: Leaves are in the form of needles. These are extremely tough and narrow. This is another adaptation to living on land. The narrow, thin shape, as well as the cuticle covering the needles, minimise water loss from the leaves. The leaves photosynthesise.
- **Roots**: Roots anchor the plant and absorb water from the soil. The root network is large and goes deep into the soil. The roots need to be like this as many of the coniferous trees are very tall, so need to be well anchored in the soil. Many of the gymnosperms require a fungus in the soil to be associated with the roots. The fungus, called mycorrhiza, forms a fine mass of thin threads that function like root hairs to absorb water for the trees.
- **Seeds/spores**: Produced in cones. These plants are **heterosporous**, which means they produce two different types of spores, a small microspore which becomes the male gametophyte and a larger megaspore in which the female gametophyte develops.

**Fig. 2.7 Needles and cones of a pine tree**
The gametophyte generation is now entirely contained within the sporophyte generation. Ovules develop into seeds after fertilisation and the zygote inside them becomes an embryo.

- **Fruit**: Gymnosperms do not have fruit. Their seeds are ‘naked’. The seeds develop on the surface of the scales of female cones. When the seeds mature, part of the scale lifts off and forms a wing to assist with the dispersal of the seeds (see Figure 2.8). The seeds are dispersed by wind.

**Something interesting**

The gymnosperm group of plants is economically important in South Africa. We use pine trees for inexpensive furniture and to make paper. Yellowwoods and Oregon pine are prized for making furniture, as are many other species of trees within this group.

**Practical activity 3**

This is a prescribed practical task.

Study fresh pine tree material

**You will need:**
- pine branch with leaves
- pine cones (female and, if available, male)
- drawing paper and pencil
- microscope and slides

**Method**

1. Feel the texture of the leaves on the pine branch and observe their arrangement. Describe what you see.  
2. Examine some female cones and, if available, some male cones. Check to see if you can find any seeds still in the female cone. Draw up a table in which you compare the structure of these two types of cones.  
3. Why are the female cones harder, tough and spiky?  
4. Make a slide of some pollen, if available, and view it under a microscope. Draw a pollen grain to show any visible features.  
5. Look at the needle of a pine tree under a microscope. Where are the stomata located?
Angiosperms – flowering plants

Flowering plants began to emerge towards the end of the Mesozoic era. In Grade 10 you learnt that this was just before the age of the dinosaurs came to an end. Flowering plants soon became the dominant form of plants on Earth. Angiosperms have a dominant sporophyte generation, which is diploid, and they have the most reduced gametophyte generation of all plants. Angiosperms provide food for humans in the form of cereals, fruit and vegetables. The angiosperms are divided into monocotyledons and dicotyledons. These names are based on the seed structure of the plants. Seeds have either one or two cotyledons present. The presence of flowers as reproductive structures is unique to this division of plants.

Characteristics of angiosperms

- **Vascular tissue:** This group of plants has well-developed vascular tissue with phloem and xylem that contain both tracheids and vessels. Phloem conducts food in solution from the leaves to other parts of the plants. Xylem conducts water and dissolved minerals from the roots to the leaves. Vascular tissue is arranged in vascular bundles (Figure 2.9). Monocotyledons have less well-developed vascular tissue than dicotyledons. This is why most monocotyledons are small and **herbaceous**.Dicotyledons are capable of growing into large trees because of the arrangement of their vascular bundles (Figure 2.9).

- **Leaves and roots:** Dicotyledonous plants have broad leaves with a network of veins. The leaves are attached to the stems by short stalks. Roots are usually **tap roots**. Monocotyledons have narrow, strap-shaped leaves with parallel veins (see Figure 2.10). There are no leaf stalks – the leaves attach directly to the stem. This is called being **sessile**. All leaves have a cuticle to restrict water loss. The leaves also have pores, called stomata, for gaseous exchange on their undersurface. Roots in monocotyledons are small and close to the surface. These are called adventitious roots.
• **Seeds/spores**: Angiosperms are heterosporous. Spores are produced by flowers and give rise to an extremely reduced gametophyte generation. Microspores in anthers give rise to pollen grains. Inside the pollen is the male gametophyte generation. It consists of only two cells. Megaspores develop in the ovules inside the ovary of the flower. One megaspore grows into an eight-celled female gametophyte. One of these eight cells forms an ovum. The female gametophyte never leaves the protection of the ovule in the ovary.

Pollen develops a tube that grows towards the egg cell, carrying two sperm nuclei that are formed with it. This tube has done away with the need for water for successful fertilisation to occur since the sperm nuclei are delivered right to the egg cell. Both sperm nuclei are used. This is called double fertilisation. One sperm nucleus fuses with the ovum to form a zygote. The second sperm nucleus fuses with two polar nuclei in the female gametophyte and forms **triploid (3n)** endosperm tissue. Endosperm tissue is what makes up **cotyledons**.

Fertilised ovules become seeds whilst the zygote becomes the embryo. The formation of the seed ends the reproduction process that started with the forming of the flower. Seeds are surrounded by a tough seed coat called a **testa**. Inside the seed, the cotyledons provide a food store for the embryo once it starts to grow. If the plant has two cotyledons it is classified as a dicotyledon, for example a peanut. If the seed has only one cotyledon it is a monocotyledon, for example a maize plant.

• **Fruit**: Seeds are housed and protected inside a fruit, which forms from the swollen and enlarged ovary of the flower. Angiosperms are the only group of plants to produce fruits. At first the fruits are hard and bitter, and not nice to eat. This is a way of protecting the seeds as they mature. Later the fruit ripens and becomes soft and more appetising. This entices animals to eat the fruit and so help disperse the seeds.

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**Fig. 2.11 Fertilisation in angiosperms**

**Fig. 2.12 The seeds of an apple are formed from ovules. The fruit is from the swollen ovary.**
Decreasing dependence on water for reproduction

In ferns, which are lower vascular plants, the development of conducting tissues in the sporophyte was an important evolutionary step. The next important development in the plant kingdom was pollen and pollen tubes to ‘carry’ sperm to the egg rather...