The science of biology

Unit 1

Contents

1.1 The methods of science

By the end of this section you should be able to:

- Define science as a way of knowledge and explain it as a way of looking at and thinking about natural events.
- Describe and explain the main steps that scientists follow when they are investigating something.
- Demonstrate scientific methods by narrating how Louis Pasteur and Alexander Fleming used the scientific method to solve problems.
- Plan and conduct an experiment to investigate a particular observation.
- Write a report for a scientific experiment.

Scientists investigate natural events to try to find out exactly why and how they happen. To arrive at an answer, they need conclusive evidence that a certain factor causes the event. Very often, this kind of evidence can only be obtained by carrying out experiments. You will learn how to proceed from identifying the problem to planning and carrying out an investigation in such a way that the results will enable you to conclude that the factor you are investigating does (or does not) cause the event to happen. Along the way, you will see how some of the greatest biologists have used this scientific method in their investigations. You will also learn how to write a report on a scientific investigation in such a way that scientists all over the world would be able to instantly recognise the stages in your investigation and carry it out for themselves if they wanted to check your results.

What is the science of biology?

Biology is the science of life and living organisms. You know from earlier studies that an organism is a living being made from one cell (for example bacteria, unicellular algae) or many cells (for example, animals, plants and most fungi).

The word biology is derived from two Greek words:
bios *– meaning 'life' and*
logos *– meaning 'study'*

When we think of biologists, we often have quite a narrow view of what they do. But, just as all chemists don't wear white coats, all biologists don't look down microscopes in laboratories. Here are just a few of the areas of biological study.

Some biologists become astrobiologists. These biologists engage in all kinds of research to try to find evidence of life on other planets in our Solar System and in galaxies elsewhere in the Universe.

Other biologists take part in biomedical research. These biologists help in many areas, including the development of new drugs and vaccines. They also study the ways in which diseases develop to gain a better understanding of them so that cures can be found.

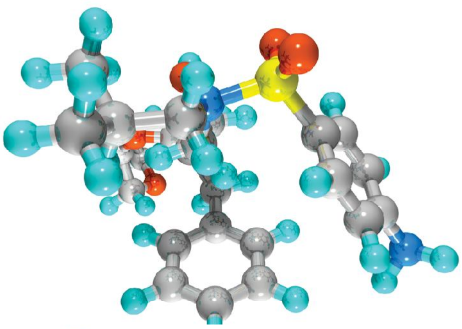
Others still become microbiologists. These biologists study how micro-organisms of all kinds function. Some micro-organisms cause disease, and understanding how they work makes a treatment more likely. Many microbiologists are studying the human immuno-deficiency virus (HIV) to get a better understanding of how AIDS develops and how it can be treated.

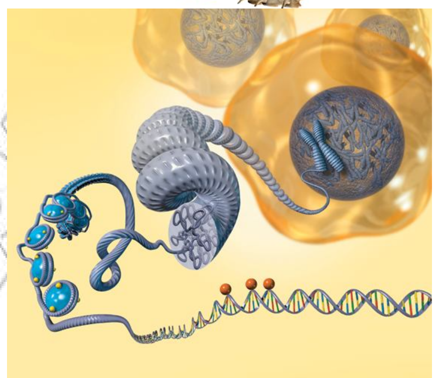
Paleobiology is a fascinating area of study to many people. Paleobiologists try to find out more about the way in which life began on Earth and how it has evolved from simple life forms into more complex ones. They use evidence from fossils and from studies of the chemistry of ancient rocks to make estimates of when and how new life forms appeared on the planet.

Many different biologists are involved in the Human Genome Project. This enormous project has produced the first ever map of the 46 chromosomes found in human cells. It has located the tens of thousands of genes and has determined the exact structure of each chromosome. Although the 'map' is finished, there is still much to be found out. Analysis will continue for many years to come.

Besides these biologists, there are others who are, perhaps, more recognisable. These include: doctors, dentists, veterinary surgeons, nurses, physiotherapists, botanists, zoologists, physiologists, biochemists, agricultural biologists, ecologists, ethologists, entomologists, geneticists, oncologists, neurobiologists, parasitologists . . .

. . . and many, many others besides.





Genetics, paleobiology, biomedics... Even trying to find signs of life on other planets: it's all Biology!

What is science?

The word science comes from the Latin word *scientia*, which means 'knowledge'. But science isn't just about having knowledge: science is a unique system of acquiring knowledge based on the **scientific method**. This science is sometimes called **experimental science**, because it depends very heavily on experimentation to obtain the information. This is different from **applied science**, in which scientific research is used to meet certain human needs. However, it is often difficult to separate the two.

Activity 1.1: What do *you* think science is?

Gregor Mendel was a monk and so not obviously 'a scientist'. He was puzzled by the patterns of certain features in the offspring of mice and pea plants. He carried out many carefully controlled breeding experiments with pea plants and, by analysing his results thoroughly, he was able to form the basic laws of how genes are inherited.

Isaac Newton is famous the world over because an apple falling on his head gave him an idea. Why did the apple fall towards the earth and not travel away from the earth into space? After some considerable thought and work, Newton worked out the basic laws of gravitation that apply to all particles and bodies anywhere in the Universe. Naturally, he couldn't test this easily by experiment!

KEY WORDS

scientific method *the process by which scientists approach their work*

experimental science *the use of experiments to obtain information*

applied science *the use of scientific research to meet certain human needs*

'Recipe' for bees: Kill a young bull and bury it in an upright position so that its horns protrude from the ground. After a month, a swarm of bees will fly out of the corpse.

'Recipe' for mice: Place a dirty shirt or some rags in an open pot or barrel containing a few grains of wheat or some wheat bran. In 21 days, mice will appear. There will be adult males and females present and they will be capable of mating and reproducing more mice.

People had seen swarms of bees flying from a bull's carcass and mice emerging from containers containing dirty shirts and cereal. They assumed that, because the two events were linked, that one caused the other. **How could you repeat the 'mice from shirts' investigation to show conclusively that the mice did (or did not) come from the shirts?**

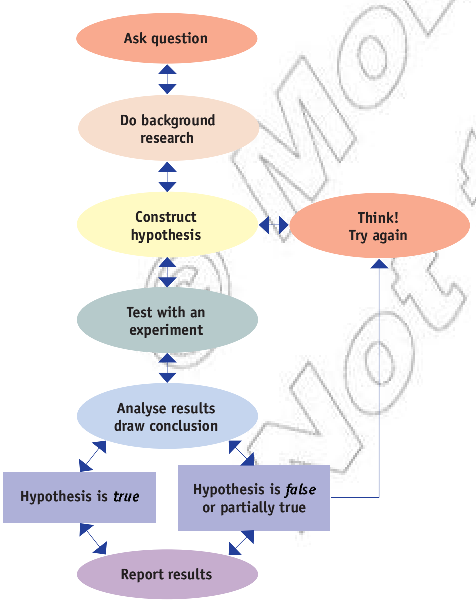


***Figure 1.1** The scientific method*

Both of these men are ranked as great scientists, yet the work they did seems to be very different. So what is it that allows us to call them scientists? What is science?

Write a short paragraph to explain why we would consider Mendel and Newton to be scientists.

Science is an ongoing effort to find new information and principles which can increase human knowledge and understanding. In their research, scientists collect evidence that supports or disproves a particular suggested explanation of a natural phenomenon. One important idea in science is that any suggested explanation of a phenomenon should be capable of being proved wrong. If there is no way of proving it wrong, how can other people accept that it is correct? This is what distinguishes science from religious beliefs.

What is the scientific method?

This is the process by which biologists and all other scientists approach their work. For centuries, people based their explanations of what they saw going on in the world around them on observations, without testing their ideas to see if they were true. One ancient belief was that simple living organisms could come into being by **spontaneous generation**. This idea suggests that non-living *objects* can give rise to living *organisms*.

As an example:

- **Observation**: Every year in the spring, the river Nile flooded areas of Egypt leaving behind mud containing many nutrients that enabled the people to grow that year's crop. However, along with the muddy soil, large numbers of frogs appeared that weren't around in drier times.
- **Conclusion**: Muddy soil gives rise to frogs!

Also, before the invention of the refrigerator, animal carcasses were hung by the heels in butcher's shops and people would ask the butcher to cut off the part they wanted. The shop was always full of flies. So people believed that the meat had turned into flies!

Because of these and other observations, many people, including quite eminent 'scientists' of the day, produced recipes for 'creating' life from non-living objects. It took the work of Louis Pasteur using the proper scientific method to finally disprove this myth.

Read the information and question in the box on the left and think about how you would test whether an explanation is true or false.

What are the main steps of the scientific method?

The scientific method consists of a number of stages. These are summarised in the flowchart.

So what is happening at each of these stages? What is the biologist doing and what do we mean by **hypothesis**?

To help you understand what is happening at each stage of the scientific method, an example using the growth of a tomato seed is detailed below.

Table 1.1 *How a biologist would follow the scientific method*

Step of the method	What happens at this step
Ask a question	Something catches our imagination. We know that tomato seeds germinate when they are planted. But, why don't tomato seeds grow inside tomatoes?
Do background research	Before we start trying to do the whole investigation ourselves, we will first check scientific magazines and the internet to see if anyone else has looked into the problem, or into a similar problem. We find out that there are substances in plants that control growth, called growth regulators.
Construct hypothesis	'There are chemicals in tomatoes that stop the seeds from growing whilst they are still in the tomatoes themselves.' This hypothesis is testable by an experiment. We think that it is a chemical that is responsible. So how do we prove that? We could try covering some seeds with tomato juice and others with water and see if any germinate. Based on our hypothesis, we can make a **prediction**: 'Seeds covered in tomato juice will not germinate as well as seeds covered in water'.
Design and carry out an experiment to test the hypothesis	1. Put several tomatoes in a blender. 2. Filter (strain) the blended material through some muslin. 3. Collect the tomato seeds and wash them in distilled water. 4. Place 20 in a Petri dish on filter paper and cover them with the tomato juice obtained from filtering the tomatoes. 5. Place 20 in a Petri dish on filter paper and cover them with the same volume of distilled water. 6. Place them in a growth cabinet that will keep the temperature and lighting conditions constant.

Continued

KEY WORDS

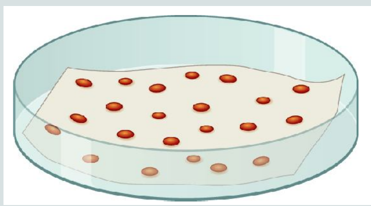
spontaneous generation *the appearance of living organisms from non-living matter*

hypothesis *an educated guess about what a biologist thinks the explanation of an observation will be. But it has to be stated in such a way that it can be tested by an experiment*

prediction *an educated guess as to how the biologist thinks his/her experiment will turn out*

Figure 1.2 *Tomato seeds don't germinate inside tomatoes. What's stopping them?*

A hypothesis that said 'There is *something* in tomatoes that stops seeds germinating' would be too vague and we couldn't test it by experiment.



Filtering removes all the cells. Washing in distilled water means that there are no chemicals on the seeds at the start of the experiment. A Petri dish is a convenient container. Filter paper inside can hold water for the seeds. Placing equal numbers of seeds in each and keeping them in the same conditions makes it a 'fair test'. The only difference between them is the chemicals in the tomato juice.

Any difference in the results must be due to this difference in the two conditions. The seeds that were covered only in distilled water form the **control** group. This is a standard against which we can compare. If we had just used the **experimental** group (the ones covered in tomato juice), we would have had nothing to compare them with. We wouldn't have known whether or not germination was the same, better or worse than normal.

Control group and experimental group

A control group acts as a 'standard' for comparison. It is used to 'isolate' the factor we are investigating and show that changes are due to this factor. For example, in drug trials, one group of people with the condition the drug is used to treat is given a tablet containing the drug (the experimental group). Another group is given a placebo – a tablet containing no drug (the control group). If both groups get better, then it seems that the drug is having little effect. If only the experimental group get better, this must be due to the drug. Without the control group we wouldn't have been sure.

KEY WORDS

control group *the standard group in an experiment in which the experimental groups are compared with*

experimental group *the group in an experiment which is being experimented on in order to compare with the control group*

	7. Leave them for four days. 8. Check the number that have germinated in each condition. 9. Repeat the experiment 50 times to confirm your results.
Analyse results and draw conclusions	Out of 1000 seeds sown in each condition, 668 germinated in the distilled water (13.36 per dish) and 265 germinated in the tomato juice (5.3 per dish). It seems like something in the tomato juice is affecting the germination of the seeds. It can't be the cells themselves, because they were filtered off. It must be a chemical in the juice.
Accept or reject the hypothesis	It seems as though the hypothesis is along the right lines; the tomato juice will only contain chemicals, not cells, and it does reduce the amount of germination. So we accept the hypothesis. But inside the tomatoes themselves, none of the seeds germinate. There is a bit more work to do yet!
Report results	We must now decide whether or not to report the results to other biologists. Someone else might decide to take the work further and try to isolate a particular chemical from the many in the juice to find exactly what is stopping them from growing inside the tomato itself.

The next section of this unit gives some case studies taken from the experiences of some scientists.

How did the scientific method disprove the idea of spontaneous generation?

What about the belief that rotting meat produces flies? How could you disprove that by using the scientific method? Well, in 1668 an Italian biologist, Francesco Redi, did just that. Many scientists consider this to be the first true 'experiment'. He used wide-mouth jars containing meat. Some jars were left open to the air. Others were covered with a piece of gauze.

After several days, maggots and then flies could be seen in the open jars, but none appeared in the closed jars.

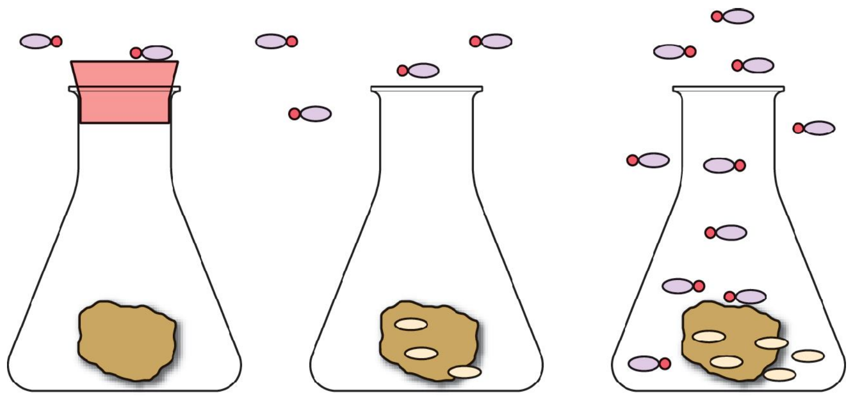


***Figure 1.3** Francesco Redi's 1668 experiment*

Redi hypothesised that only flies could produce more flies and predicted that, in his experiment, flies would be found in the open jars, but not in the covered jars. He maintained all the jars under the same conditions and so he controlled many variables. By choosing to cover some jars with gauze rather than an impermeable seal, he allowed air to enter all the jars – again he controlled a variable that could have affected the outcome of the experiment. His results matched his prediction and when other people tried the experiment, they too got the same results. Redi was able to conclude that flies cannot be produced from rotting meat. He also went on to say that it was unlikely that any form of spontaneous generation was possible.

Most people accepted this for larger organisms, but, at round about this time, the microscope had been invented and the whole world of microbiology was opened up. Many people still believed that micro-organisms could arise by spontaneous generation. It took the work of Louis Pasteur to disprove this. In 1859, Pasteur carried out experiments to show that the micro-organisms that caused wine and broth to go cloudy came from the air and were not made from the broth itself. He used special 'swan-necked flasks' like that shown in Figure 1.4.

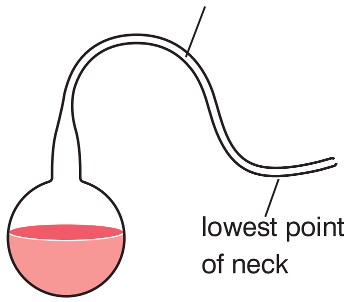


***Figure 1.4** A swan-necked flask like the ones used by Louis Pasteur*

Pasteur boiled broths in swan-necked flasks to kill any micro-organisms that might be in them. The boiling forced steam and air out of the flasks. When the boiling stopped and the broth cooled, air was sucked back into the flasks. Some contained a filter to prevent all solid particles from getting into the growth medium from the air. Others had no filter but, in these, the dust (and the micro-organisms) in the air settled in the lowest part of the neck of the flask. All the flasks were kept under the same conditions in Pasteur's laboratory.

Pasteur found that the broths stayed clear for months. At the end of this time, he treated the flasks in one of three ways:

- He left some of them as they were.
- He broke the necks on some.
- He tilted others to allow the dust in the low part of the neck to mix with the broths.

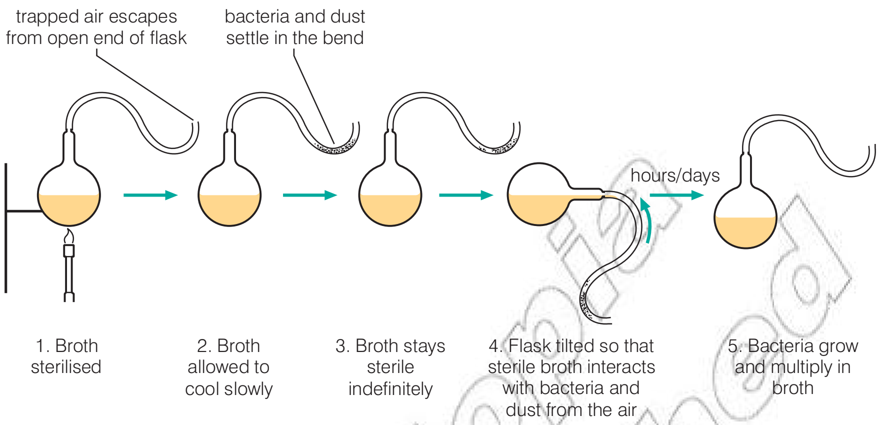


Figure 1.5 *A summary of Pasteur's procedure*

The broths in the second two groups of flasks turned cloudy (due to the presence of micro-organisms) within days. The broths in the first group remained clear. After this, people were forced to admit that spontaneous generation, even of micro-organisms, could not happen.

KEY WORDS

independent variable *the variable that the experimenter changes to see if this affects the performance of the dependent variable. Does the presence or absence of a drug in a tablet (independent variable) affect the recovery of the patient?*

dependent variable *the factor in an experiment that the scientist measures to see if it changes when the independent variable is changed*

Activity 1.2 Pasteur's work

Pasteur's work is another good example of the scientific method at work. See if you can identify the various stages.

1. What do you think might have been Pasteur's hypothesis?
2. Outline the plan of his experiment. Did he have any controls?
3. What do you think he might have predicted?
4. Did his results support his prediction?
5. What conclusion was he able to draw?

One stage in the scientific method is to 'do background research'. Pasteur certainly did that. He knew that other scientists had tried to disprove spontaneous generation before him and he was able to draw on the results of their experiments and improve their technique.

Activity 1.3 Library search

Do a library search to find out about the work of Lazzaro Spallanzani. How do you think his work influenced Pasteur?

What do we mean by cause and effect?

Scientific experiments try to establish cause and effect. This means that they try to prove that a change in one factor brings about a change in another factor. The factor that the scientist changes, or manipulates, is called the **independent variable** (or **IV** for short). The factor that the scientist measures to see if it changes when the IV is changed is called the **dependent variable** (or **DV** for short). The scientist will want to find out if changes in the independent variable produce changes in the dependent variable. In the example on pages 5 and 6, the independent variable was the presence or absence of tomato juice. The dependent variable was the number of tomato seeds germinating.

To prove cause and effect – to prove that it is changes in the IV (and nothing else) that are causing changes in the DV – we must take all the steps we can to ensure that the experiment is a **fair test**. We must make sure that any other factors which could affect the results are the same for the different conditions we set up. In the tomato seed example, if one group of seeds had been at a higher temperature than the other group, this could have made them germinate faster. We wouldn't have known whether it was the tomato juice affecting the results or the temperature. Our experiment would not be valid. So we must keep constant anything other than the IV that might influence the results. These are **controlled variables**. In the tomato seed experiment, the controlled variables were:

- temperature
- lighting conditions
- number of seeds per dish, and
- volume of liquid added (water or tomato juice).

Occasionally, there is a variable that might influence the results that you can't control. Such a variable is a **confounding variable**. This is because it 'confounds' the interpretation of the results. You couldn't be certain that it was the IV producing the changes in the DV because of the presence of the confounding variable.

For example, if you measure the carbon dioxide uptake by wheat plants as the light intensity changes over the day, you cannot control the effect of change in temperature. It could be a confounding variable.

KEY WORDS

fair test *an experiment in which the only difference between different repeats of the experiment is the different values of the independent variable, all other factors that could affect the outcome have been kept constant (they have been controlled)*

controlled variables *factors other than the independent variable that are kept constant in order to avoid influencing results*

confounding variable *a factor that can't be controlled which may influence the result of the experiment*

accuracy *how precisely something has been measured or counted*

Accuracy, reliability and validity in scientific experiments

People often confuse these ideas, but they are really quite separate notions and all are important to how well an experiment is received by other scientists.

Accuracy

Accuracy refers to how precisely you measure or count something. For example, you could measure time with a clock, a wristwatch or a stop-clock accurate to 0.01 seconds. The level of accuracy you choose must reflect the magnitude of what you are measuring. You don't always need the most accurate measuring instrument. For example, if you were timing a reaction that was likely to last a few minutes at most, the stop-clock would be the best choice. But if you were timing something that lasts several hours, you just don't need that level of precision and it might even be a hindrance – by measuring the seconds accurately, you might lose track of the hours!

To measure volume, you could use:

- a syringe
- a measuring cylinder
- a pipette
- a burette

All of these come in various sizes. Look at the ones shown in the diagrams.

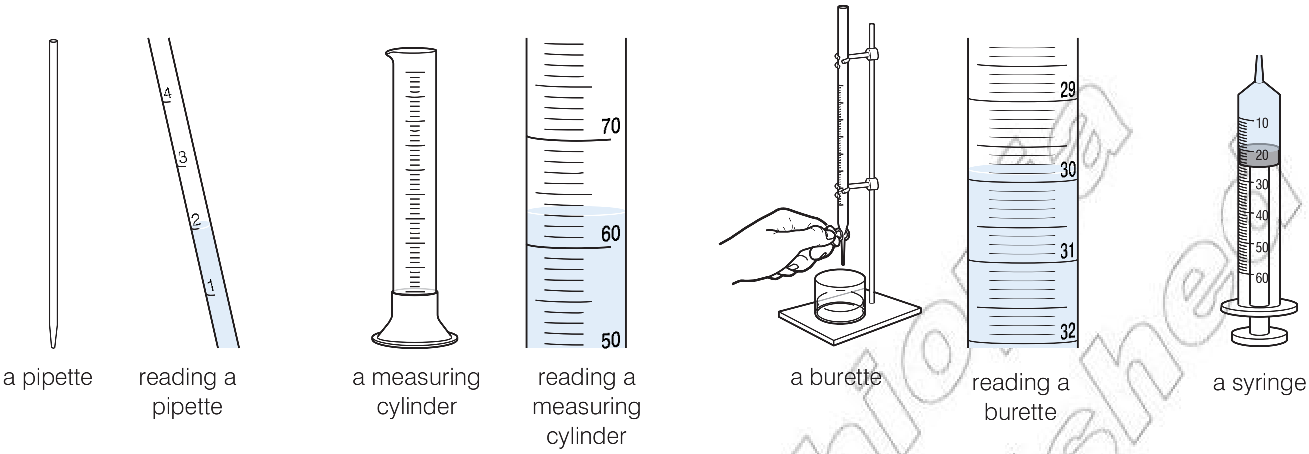


Figure 1.6 *Different measuring apparatus*

To measure 3.5 cm^3 accurately, the pipette would be best.

To measure 200 cm^3 you would use the measuring cylinder. This one holds 100 cm^3 and so you would have to fill it twice. The burette would be more precise, but less convenient and would you need the extra precision on quite a large volume?

KEY WORDS

reliability *a measure of how dependable and consistent the results of an experiment are*

anomalous results *are really odd results that do not fit the general pattern*

colorimeter *measures how much light passes through a liquid*

Activity 1.4

Which apparatus would you use to measure out 36 cm^3 of water?

Reliability

Reliability is a measure of how dependable our results are. If we were to repeat the investigation, would we get more or less the same results? There are several things we can do to increase the reliability of our experiments.

- We can standardise all our procedures, so that we always do exactly the same thing. This makes it much more likely that we will be able to repeat our results.
- We can repeat it many times ourselves. This allows us to see, hopefully, a general pattern. It also allows us to:
  - spot any **anomalous results** and, if it is justified, to exclude these
  - calculate an average result, which is likely to be more representative than any individual result
- We can try not to use personal judgement. For example, if in a given experiment we have to wait until a solution turns a certain shade of red, one person's judgement will almost certainly differ from the next person's. There are ways around this:
  - We can have a 'standard' to compare our experiment to. In other words, something containing the chemical that is the exact colour we need it to be. This helps, but we must still make a judgement.
  - We can use a special apparatus called a **colorimeter**. This measures how much light passes through a liquid. It is nearly always better to *measure* than to *judge*.

Validity

This is about whether or not our experiment measures what it says it is measuring. In the tomato seed experiment, we said that our results were due to the presence or absence of tomato juice. For our experiment to be valid, we must be certain that our results were only due to the changes in the independent variable and nothing else. So had we not controlled all the other variables, our experiment would not have been valid.

Activity 1.5: Planning investigations

Now it's your turn! Plan experiments to investigate the following observations:

1. When a winemaker used lactose (milk sugar) instead of sucrose (ordinary table sugar) the wine he made tasted like fruit juice. (*Hint: you need to know how well the yeast is fermenting the two sugars.*)
2. In the area near an old copper mine, no plants grow. Go further away and more and more plants are growing. An analysis of the soil near the mine found that there was an unusually high concentration of copper dissolved in the water in the soil. (*Hint: remember plants grow from seeds!*)
3. The leaves of plants wilt more quickly on a hot day than on a cooler day. (*Hint: think what you lose more of on a hot day than a cool day.*)

Don't forget, you will need to have:

- a hypothesis (from which you can make a prediction)
- a plan, containing:
  - a clear method of changing the independent variable
  - a clear method of measuring the dependent variable
  - methods of controlling other potentially confounding variables
  - methods of ensuring appropriate levels of accuracy, reliability and validity

How do we write reports on scientific experiments?

When biologists write a report on an investigation they have just done, they write it with a view to having it published in a scientific journal, such as *Nature* or *Science*. These journals are read by many other biologists who will want to understand their work and, perhaps, repeat it to check on the results. It is important, then, that the layout of the report is recognisable to everyone and understandable by everyone. So, there is a set way to lay out such a report. It is not always identical in every case, but there are certain 'rules' to follow.

Example

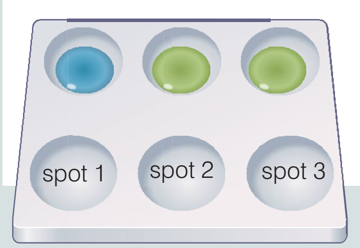


Figure 1.7 *Using a standard to compare colour changes*

In the investigation demonstrated above we are waiting for the chemical to change colour from being blue (as in the first spot) to the same yellow as that in spot 3. Clearly, spot 2 hasn't quite got there. The experiment isn't quite over yet. But without the 'standard' to compare against, we might have thought that it was. However, it would be even more reliable if we measured it in a colorimeter.

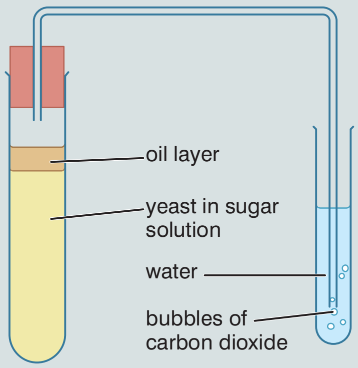
Activity 1.6 Spotting anomalous results

Which is most likely to be an anomalous result in the following table? Explain your reasoning.

Temperature (°C)	Enzyme activity (%)
5	3
10	17
15	36
20	55
25	42
30	85
35	97

Experiments can be reliable without being necessarily valid. If you consistently omit the same important step (for example, consistently forget to control the same variable), you may well keep getting the same results. But they will be the wrong results and your experiment will not be valid.

You can measure the rate of fermentation of yeast using simple equipment as shown in the diagram below. You can count the number of bubbles of carbon dioxide produced in five minutes and work out a rate per minute.



There must be:

- a title, which states clearly what is being investigated
- a hypothesis, stated clearly in terms of how the independent variable is expected to influence the dependent variable, often extended to a prediction for the particular experiment
- a clear description of the experimental procedure; this must be in such detail that anyone of the same level of understanding could easily replicate the procedure and it must include:
  - the apparatus used (a diagram of the assembled apparatus is useful)
  - details of any chemicals used; what volumes or concentrations or masses were used
  - details of any organisms used (for example, yeast, mice) – what strain and how many
  - details of any control experiments
- a full account of the results obtained; it is often helpful to summarise these (where appropriate) in graphs, charts and tables
- the conclusions that have been drawn from the results
- an evaluation of the procedure; this is an honest assessment of the limitations of the procedure that has been used, pointing out any unavoidable limitations and inaccuracies that arose
- an acknowledgement of the use of any other person's work; this is usually done by identifying by a number the place in the report where other work has been used, and then listing the sources at the end of the work

So, for the tomato seed experiment, the report could look something like this:

Section	How it would be written
Title	An investigation into the effect of tomato juice on the germination of tomato seeds.
Hypothesis	A chemical in tomato juice inhibits the germination of seeds.
Prediction	Seeds covered in tomato juice will germinate less well than seeds covered in distilled water.
Procedure	30 tomatoes were blended for five minutes. The blended material was then filtered through some muslin and the liquid (juice) was collected. The seeds were extracted from the cellular material, which was then discarded. The juice was diluted with distilled water to give a total volume of 550 cm^3. The tomato seeds were washed in distilled water for 30 seconds, to remove any chemicals from their surface. They were dried briefly on filter paper. 100 Petri dishes were prepared by placing a piece of filter paper in each. Each piece of filter paper had a 0.5 cm grid drawn on it.

	20 seeds were placed in each Petri dish on the intersections of the lines of the grid (to ensure even spacing in all dishes). 10 cm^3 tomato juice was added to half of the Petri dishes and 10 cm^3 distilled water was added to the other half. All the dishes were placed in an incubator at a temperature of 20 °C for four days. At the end of this time the number of successful germinations in each dish was recorded and means for each condition were calculated. If a radicle (root) of 0.5 cm or more was present, the seed was said to have germinated.
Results	Out of 1000 seeds sown in each condition, 668 germinated in the distilled water (13.36 per dish) and 265 germinated in the tomato juice (5.3 per dish).
Conclusion	The hypothesis is accepted. The germination of the seeds in the tomato juice is much less successful than in distilled water. Some chemical in the tomato juice must therefore be inhibiting the germination. In tomato fruits, no seeds germinate, but it must be remembered that in our investigation, the juice had been diluted to give sufficient volume for 50 replicates of the investigation.
Evaluation	There were no anomalous results. The germination of seeds in all of the dishes in the experimental condition (the tomato juice) was less successful than in the dishes in the control condition (distilled water). The experiment was not without limitations. • It was only carried out for four days (to limit the development of fungal growth that might have interfered with germination). Had it been carried out for longer, the pattern may have been different. • It was only carried out at one temperature; this may have influenced the experimental and control conditions differently. Repeating the investigation at a range of temperatures would help to clarify this. • The judgement of germination (a radicle of 0.5 cm length) was somewhat arbitrary, but it did overcome the problem of including in the count seeds that had merely swollen with water but not produced any growth. We are of the opinion that these limitations had only a minor effect on the validity and reliability of this experiment.
Acknowledgements	*Biology* – Martin Rowlands – information on plant growth regulators.

The above report has been tabulated for your ease of understanding. An actual report in a scientific journal would not be tabulated, although it would have many of the headings shown here.

Activity 1.7: Writing a report on an experiment

Write a report in this format as though you were Louis Pasteur and had just carried out the investigation that was to finally disprove the idea of spontaneous generation. Try to incorporate as much detail as possible so that anyone could follow your description of the procedure and repeat the investigation. Think of a way of presenting the results so that it is immediately obvious what happened. Don't forget to explain your conclusions and to write an evaluation.

Activity 1.8

A scientist observes that crocodiles often fight and bite each other. Their teeth are covered in bacteria yet crocodiles rarely get infected bites. Brainstorm how a scientist would develop and test a hypothesis to explain this observation. Turn your observations into a flowchart of the process.

Review questions

Choose the correct answer from A to D.

1. Which of these *best* describes what science is?
   A a body of knowledge
   B a way of doing experiments
   C a way of looking at and thinking about the natural world
   D a series of ideas
2. The scientific method involves:
   A putting forward hypotheses in a form that can be tested
   B carrying out experiments
   C analysing results and drawing conclusions
   D all of these
3. Which of the following is NOT a type of biologist?
   A geneticist
   B entomologist
   C astrophysicist
   D doctor
4. Scientists often use statistics when drawing conclusions because:
   A statistics are more accurate than human opinion
   B statistics are more reliable than human opinion
   C statistics are infallible
   D none of these
5. The independent variable in an experiment is the variable that:
   A is measured by the experimenter
   B is controlled by the experimenter
   C is changed (manipulated) by the experimenter
   D upsets the reliability of the results
6. The dependent variable in an experiment is the variable that:
   A is measured by the experimenter
   B is controlled by the experimenter
   C is changed (manipulated) by the experimenter
   D upsets the reliability of the results
7. Having a control condition in an investigation:
   A gives a 'standard' to compare against
   B increases the validity of the experiment
   C increases the reliability of the experiment
   D both A and B

8. Publishing reports of biological investigations in scientific journals is important because:
   - A it allows biologists all over the world to understand your reports
   - B it allows biologists all over the world to repeat your investigations
   - C it allows biologists all over the world to challenge your results
   - D all of the above
9. The scientific method is more reliable than opinion based on personal observation because:
   - A scientists are more reliable than other people
   - B the scientific method involves gathering information from controlled experiments to prove or disprove a hypothesis
   - C observation is not a valid scientific technique
   - D scientific method always gives the correct answer
10. The reliability of an experiment is increased by:
   - A carrying out repeat experiments
   - B minimising personal judgement
   - C working as quickly as possible
   - D using the most appropriate apparatus

1.2 The tools of a biologist

By the end of this section you should be able to:

- Name and describe the function of the main pieces of apparatus that are used by biologists the world over.
- Describe how these pieces of apparatus work.
- Explain how, and under what circumstances, these pieces of apparatus would be used and demonstrate the use of some of them.
- Classify the apparatus as laboratory tools, field tools or both.
- Be aware of possible health and safety implications of using these tools.

In this section you will be reviewing the nature and function of some basic 'tools' or pieces of apparatus of a biologist. Some of these you will have met before, others may be new to you. You will learn about the sort of tools that are needed in the laboratory and those that are needed when working in the field. Some pieces of apparatus are used in both situations.

Activity 1.9

Look at the list of basic tools which biologists use in the laboratory. Copy the list and write down what you would expect each piece of equipment to be used for.

What apparatus do biologists use?

How much time do you have? You only need consult the catalogue of a supplier of biological apparatus to see that the list is a pretty long one! However, we shall not be considering all the various sizes of test tubes or the different kinds of Bunsen burner or the different kinds of electronic equipment now available for biologists. We shall confine ourselves to the main items of field and laboratory equipment that biologists everywhere would recognise and be able to use.

What do biologists use in the laboratory?

This is still a large list. But there are some basic tools. These include:

- microscopes
- dissecting equipment
- Petri dishes
- pipettes and syringes
- centrifuges
- measuring cylinders
- balances

We have already considered measuring cylinders, pipettes and syringes when looking at the idea of 'accuracy' in scientific experiments. All these are used for measuring volumes, usually of liquids, but in some investigations they can be used to measure the volume of a gas. In this example, an upturned measuring cylinder is being used to collect oxygen gas produced when yeast converts hydrogen peroxide into water and oxygen.

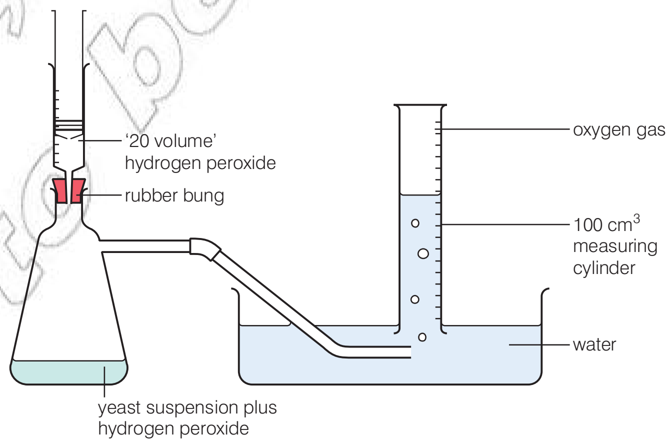


***Figure 1.8** Using a measuring cylinder to measure the volume of oxygen produced when yeast decomposes hydrogen peroxide*

Some syringes are designed specifically as 'gas syringes' and could be used as an alternative way of collecting the oxygen in the above experiment.

Balances are used for measuring mass. They come in a range of sizes and properties. Some can measure the mass of very heavy

KEY WORDS

balances *apparatus used for measuring mass*

dissect *to cut apart or separate tissue for anatomical study* objects, but not with any great degree of precision. Others measure smaller masses to the nearest 0.0001 g (one ten-thousandth of a gram).

Sometimes biologists need to **dissect** specimens to find out what they are like inside. This need not always mean dissecting a whole organism. Quite often, students dissect organs, such as the heart or the kidney, to find out about their structure. Biologists may dissect owl pellets – these are pellets containing the parts of food that the owl has eaten and that cannot be digested and have been regurgitated. Dissecting these can give information about what the bird has been eating.

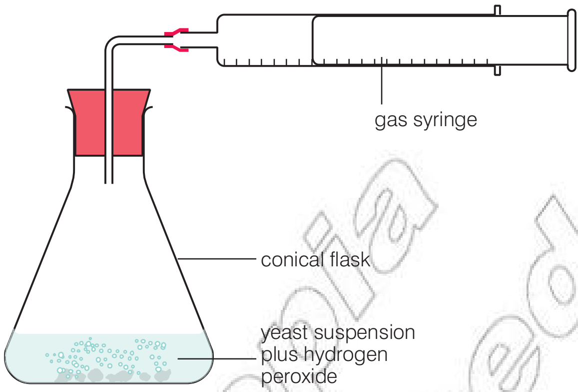
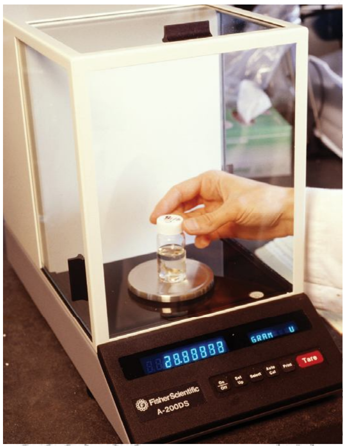


Figure 1.9 *Using a gas syringe to measure the volume of oxygen produced when yeast decomposes hydrogen peroxide*

A



B

Figure 1.10A *This balance is accurate to 0.01 g*
B *This balance is accurate to 0.0001 g.*

Figure 1.11 shows a standard dissecting kit containing a magnifying glass, scalpels, scissors, forceps (tweezers) and mounted needles. Figure 1.12 shows a student dissecting a frog. The student is using a scalpel to cut away the skin and reveal the abdominal organs. These can then be removed and studied individually.

DID YOU KNOW?

Sometimes small specimens are dissected under a microscope. This biologist is dissecting insects using a dissecting **microscope**. The magnification is not as great as other microscopes, but the image is very clear and allows delicate dissection to be carried out. Such work is necessary to help to classify new species of insects.

Figure 1.11 *A standard dissecting kit*

Figure 1.12 *Dissecting a frog*

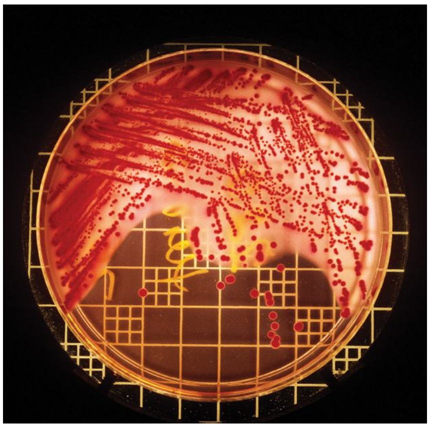


Figure 1.13 *Bacteria growing on agar in a Petri dish. The grid allows biologists to work out what proportion of the Petri dish is covered with each type of bacterium.*

KEY WORDS

agar *jelly-like substance obtained from seaweed, used for culturing micro-organisms in a Petri dish*

to ***culture*** *organisms means to grow them under special conditions that are likely to help their growth*

Figure 1.14 *Plantlets or 'explants'*

This technique of growing plants from just a few cells on special agars in Petri dishes is called **micropropagation**. It allows thousands of plants to be produced from just one 'parent' plant. All the plants produced are genetically identical.

Petri dishes are round dishes made from glass or from plastic. They are used in many different ways, but usually to culture some organisms.

They are often filled with a 'jelly' called **agar** and used to **culture** bacteria. There are many different agars containing different balances of nutrients. Each type of agar can encourage the growth of different bacteria. By marking a grid on the surface of the Petri dish, biologists can estimate how much of the dish is covered by bacteria and then use this to estimate how fast the bacteria are growing.

Petri dishes are also used to propagate or culture plants. The small 'plantlets' or 'explants' in figure 1.14 have been grown on a special agar from just a few plant cells. They will grow roots and then shoots and leaves. When they are big enough, they will be transplanted into pots of soil or compost and grown into mature plants.

Petri dishes can also be used to:

- show how effective different antibiotics are against certain types of bacteria
- show how well different concentrations of enzymes digest a substance

This Petri dish has one type of bacterium growing all over it – except in some of the areas near the white discs. These discs contain different antibiotics. The clear zones around the discs are areas where no bacteria are growing. Clearly some antibiotics are more effective against this bacterium than others.

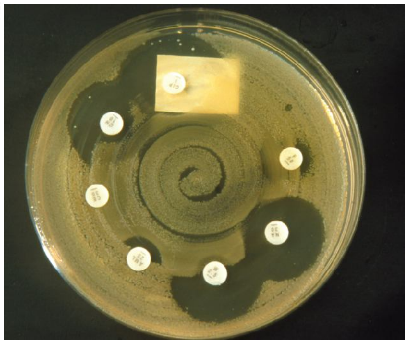


Figure 1.15 *Bacteria being cultured on agar in a Petri dish with several different antibiotic discs*

This Petri dish contains agar mixed with starch. There are several 'wells' in the agar which contain a starch-digesting enzyme. The whole area has been stained with iodine, which turns blue-black when it reacts with starch. The clear areas around the wells show that the enzyme has diffused out of the wells and digested the starch.

Figure 1.16 *'Starch-agar' with four 'wells' cut in the agar; each well contains a different strength of enzyme solution*

As you know already from your study in grade 9, microscopes are one of the most vital tools in a biology laboratory. There are two main types:

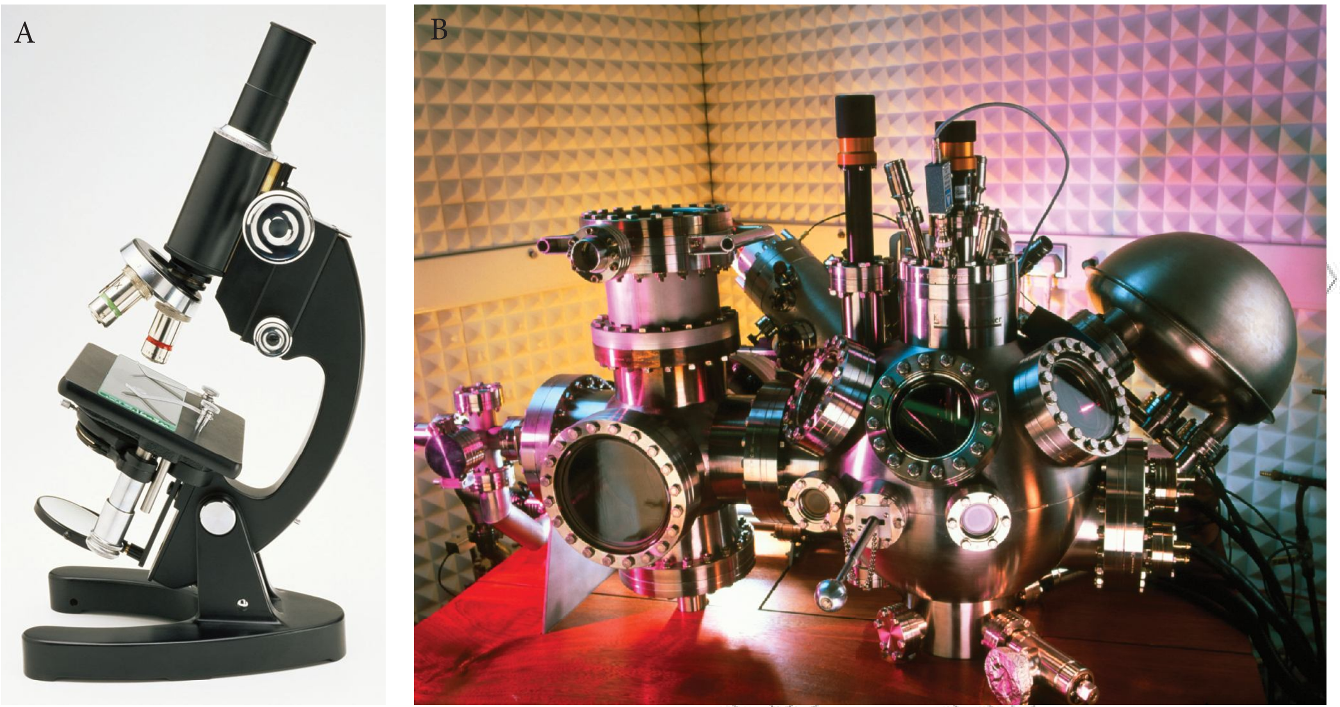


***Figure 1.17 A** A light microscope;*
***B** An electron microscope*

- **optical microscopes** that use beams of light to produce magnified images
- **electron microscopes** that use beams of electrons to produce magnified images

You are unlikely ever to use an electron microscope, simply because of cost. Light microscopes vary from basic microscopes that can be used in the laboratory and even taken out and used in the field to very sophisticated microscopes that are linked to image-enhancing computer programs to produce all kinds of images that help to make the image clearer.

Of course, biologists also use electron microscopes that give much higher magnifications and, importantly, much higher resolution, so that more detail can be seen.

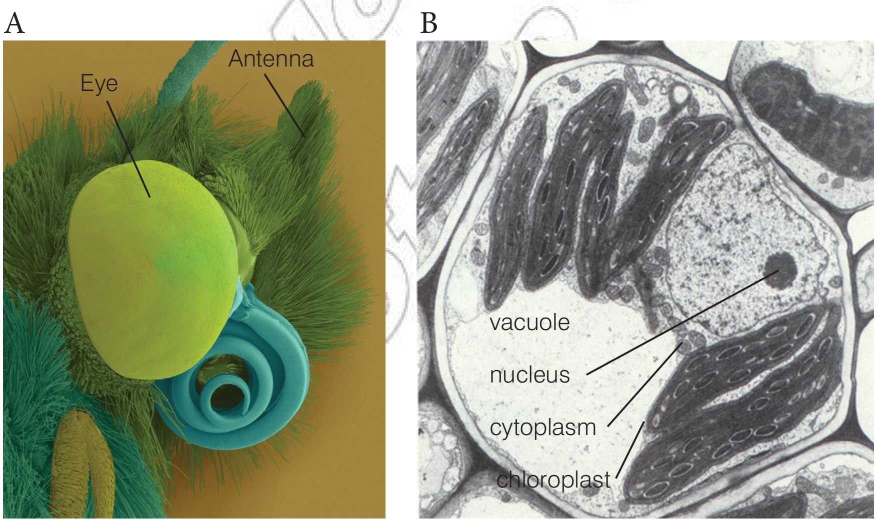


***Figure 1.18A** SEM of the head of a monarch butterfly;*
***B** TEM of a cell from the leaf of a tobacco plant*

Activity 1.10

In the photograph in figure 1.16, which well do you think contains the most concentrated enzyme?

DID YOU KNOW?

Resolution is the ability to distinguish between two points that are close together. If resolution is poor, they will merge into one point and the detail of the image will be limited. Electron microscopes have a much higher resolution than optical microscopes.

KEY WORDS

optical microscope *uses beams of light to produce magnified images*

electron microscope *uses beams of electrons to produce magnified images*

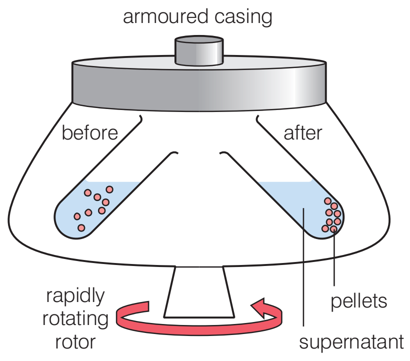


Figure 1.19 *A centrifuge*

KEY WORDS

centrifuge *machine that spins to separate solids from liquids*

quadrat *a small frame used for ecological or population studies*

Transmission electron microscopes allow researchers to view the structure of cells in great detail. The transmission electron micrograph (TEM) of the cell from the leaf of a tobacco plant in figure 1.18B shows six large chloroplasts, the vacuole of the cell and the nucleus and cytoplasm. Scanning electron microscopes do not see 'into' cells in the same way, but create images of the surface of a specimen by scanning it with a high-energy beam of electrons. Computer programming allows the different parts to be 'false coloured' for clearer interpretation. This is shown in the scanning electron micrograph (SEM) of the head of a monarch butterfly, figure 1.18A.

Centrifuges are used to separate solids from liquids where simple filtration is not adequate for the task. Some solid particles are very tiny and float around in a liquid, although they are not properly dissolved in the liquid.

Centrifugation can separate these solid particles from the liquid without the need to filter. The mixture is placed in a 'centrifuge tube' and placed in the centrifuge. The centrifuge then spins the tubes at high speed. As the tubes spin, the gravitational forces on the solid particles force them to the bottom of the tube. Some centrifuges, called 'ultracentrifuges', can spin really fast and cause extremely light particles to fall to the bottom of the tube. These ultracentrifuges are used to separate the various components of animal and plant cells. Centrifugation is commonly used in hospitals for stool tests where the ability to separate particles quickly and clearly is very useful.

Figure 1.20 *Students recording the contents of a quadrat*

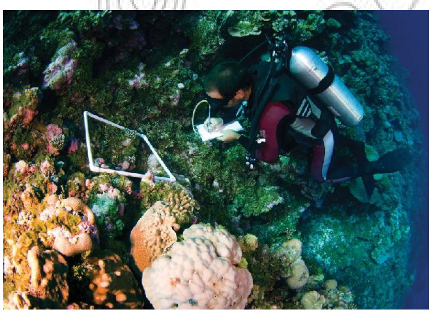


Figure 1.21 *Using a quadrat underwater*

What do biologists use in the field?

Biologists do a lot of work outside the laboratory. They study different areas to find out how the animals, plants and micro-organisms interact with each other and with the environment. They find out how an area changes over time and how it is influenced by human activity. All this involves:

- taking measurements of the abundance of organisms in the field
- taking samples of the environment (for example, soil, rocks, water) for analysis in the laboratory
- collecting specimens for identification and analysis in the laboratory

To gain an estimate of the abundance of organisms in an area, biologists often use **quadrats**. There are many different types, but the simplest is just a metal square. It is placed randomly on the ground and the organisms found inside it are counted and the numbers and types recorded. This data can be used to make an estimate of the abundance of the organisms in the area. Figure 1.20 shows students recording the contents of a quadrat.

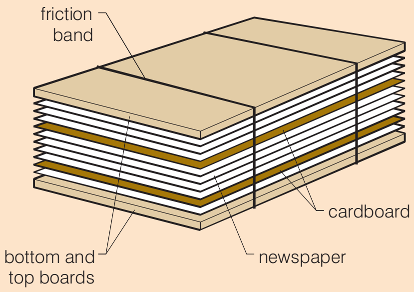
The use of quadrats is not confined to sites on land. They can be used underwater also!

Biologists also use quadrats to show how the numbers of a particular species changes across an area. To do this, they lay down a tape measure (or a long rope marked off every metre) across the area. This is called a **transect line**. They then place the quadrat by the side of the transect line and record the abundance of the organisms in the quadrat. They repeat this every metre, or every 5 or 10 metres, depending on the length of the transect. This gives a picture of how the abundance of each species changes across the area.

To collect specimens for identification in the laboratory, biologists use a range of equipment. Collecting plants is relatively easy, if they are not too large. Small parts (for example, leaves and flowers) can be collected and kept in reasonable condition for a short period in plastic jars or plastic bags. Parts of plants can also be preserved using a plant press. This preserves the shape and form of the plant parts for some time and specimens can be analysed later. Whole plants can be dug up and replanted for study in the laboratory.

Activity 1.11: Making a plant press

A plant press does not need to be an expensive item of equipment. You can make a plant press using corrugated cardboard, newspaper and some thin rope or string. The newspaper separates individual specimens and the cardboard provides support and allows the press to be tied tight to keep the specimens flat.



However, animals pose a different problem. Because they move, they must be caught. Biologists do this in many different ways. Some insects can be caught using nets like the ones shown in frrigure 1.22. Others are caught using **pitfall traps** – see page 22.

Figure 1.22 *Students using nets to collect and study insects*

Using a quadrat

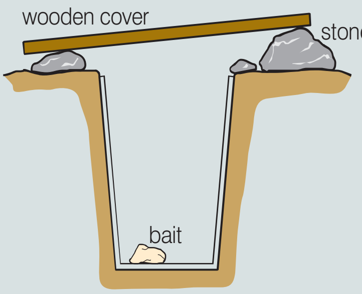
If your quadrat measures 1 m × 1 m, it has an area of 1 m^2. Suppose you place the quadrat 20 times, and find that species A occurs, on average, 3.5 times per quadrat. You can now make an estimate of how many individuals of species A are in the location you are investigating. Suppose the area of this location is 500 m^2. Your records say there are 3.5 per m^2 so the total number must be 500 × 3.5 = 1750 in the location you are investigating. The quadrats should be laid at **random** so there is no **bias**. This means you not *choosing* where you will place them, but using some other method to place them. Biologists usually use a system of random numbers from a calculator to specify at which points to place the quadrats within an area.

KEY WORDS

transect line *a straight line through an area*
random *having no specific pattern, purpose or objective*
bias *tending towards a specific result*

Pitfall traps

Pitfall traps come in a range of shapes and sizes. This simple one is just a plastic carton sunk into the soil. It would be covered with wood to keep it dark and dry and also keep any animals that fall into it out of sight of predators.



Many night-flying insects are attracted to light. A strong light bulb hung in front of a vertical white sheet will attract a great range of insects which can be picked directly from the sheet when they settle. An ultraviolet light bulb will increase the catch markedly.

Some other instruments that biologists use in the field are illustrated below.

Figure 1.23 *A data logger – this is used to record information*

Figure 1.24 *A pH kit – this is used to measure the pH of soil or water*

Figure 1.25 *A flow meter – this is used to measure the rate of flow of water*

Figure 1.26 *A field microscope – this is used to investigate the structure of specimens in the field, whilst still fresh*

Figure 1.27 *A theodolite – this is used to measure the height of trees or of slopes in the area*

One recent addition to the tool list of field biologists is the GPS (Global Positioning System) receiver. This equipment makes it possible to record positions quickly and extremely accurately. By taking several readings at different points on the perimeter of the area, an accurate map of the area can be drawn.

Figure 1.28 *A GPS (Global Positioning System) receiver*

Activity 1.12: Types of apparatus

Make a table that contains three columns. Put a heading for each column as below:

- Apparatus mainly used in the laboratory
- Apparatus mainly used in the field
- Apparatus that can be used in both field and laboratory

Try to list at least five pieces of apparatus in each column

Review questions

Choose the correct answer from A to D.

1. It is not true that:
   A electron microscopes can only be used in the laboratory
   B some light microscopes can be used in the field
   C light microscopes give better magnification than electron microscopes
   D light microscopes were invented before electron microscopes
2. A theodolite is:
   A an item of laboratory equipment that measures height
   B an item of field equipment that measures height
   C an item of field equipment that measures slope
   D an item of laboratory equipment that measures slope
3. When a biologist centrifuges a suspension, the solids are separated from the liquid in the following way:
   A The solids float to the top because they are lighter.
   B The solids are pulled to the bottom because they are heavier.
   C The solids are pulled to the bottom because they spin faster than the liquids.
   D The solids float to the top because they spin slower than the liquids.
4. Fieldwork is important in biology because biologists can gather information about:
   A individual organisms in their natural surroundings
   B how organisms are distributed in a particular area
   C how the organisms in an area change over time
   D all of the above

Activity 1.13

It is important to use equipment properly to make sure that your results are reliable and valid. Here are two very useful and very different pieces of equipment for studying biology: a microscope and a quadrat. For each one produce a set of instructions that would help a student using the equipment for the first time to use it correctly. Let a friend look at what you have done – can they follow your instructions correctly?

5. Bacteria are usually cultured in:
   A test tubes
   B beakers
   C Petri dishes
   D none of these
6. Pitfall traps are used to catch:
   A flying insects
   B small ground-dwelling animals
   C damaged plants
   D all of these
7. When estimating the numbers of a species in an area, biologists use quadrats that are:
   A placed at regular intervals along a transect
   B placed deliberately all over the area
   C placed at random
   D placed one after the other along a transect
8. When choosing an item of equipment to measure volume you should mainly consider:
   A only the total volume to be measured
   B only the precision to which the instrument can measure
   C the ease with which you can use it
   D both A and B
9. The 'white sheet and bright bulb' technique used to trap flying insects at night gives:
   A a good indication of numbers but a poor indication of types found in the area
   B a good indication of the types found in the area but a poor indication of numbers
   C a good indication of both types and numbers
   D a poor indication of both types and numbers
10. Which of the following statements is not true about transect studies of an area?
    A they give a good indication of how the abundance of different organisms changes across an area
    B they give a good indication of the overall numbers of an organism in an area
    C they show the strength of the current flow in a stream
    D they involve laying out a tape to take direct observations or lay quadrats on

1.3 The relevance and promise of biological science

By the end of this section you should be able to:

- Explain how biological science is relevant to food production, health and disease, conservation, and control of the population.
- Explain the promise of biology in relation to genetic engineering and biotechnology.

At the start of this unit we defined biology as 'the science of life'. This makes it a pretty big subject! Biology seeks to understand how all life functions – including life on other planets, should it exist. Biology attempts to give scientific answers to many questions that most people think are important. Some of these are listed below:

- Where did humans come from?
- Where did I come from?
- How do I work?
- How did all life begin?
- How is disease caused?
- How is AIDS caused?
- How can vaccines be developed against diseases like malaria and AIDS?
- What makes cancer cells different from ordinary cells?
- Will it ever be possible to grow a new kidney just for me?
- Will people one day live forever?
- What causes global warming?
- How can we solve problems of food shortage?

Activity 1.14: Library search

Select five questions that biology attempts to answer. You may choose from the above list, but there are many others. Do some research in a library and, for each, write a few lines (no more) about what biologists say about the topic and whether you accept the biological 'answer' or not. Explain why you agree or disagree.

Because biology is the science of life, biologists undertake all kinds of research. Some try to find possible biological explanations for other, non-scientific, aspects of life. Some try to find biological explanations for why some people:

- have a strong religious belief whilst others don't
- are record-breaking athletes, like Haile Gebrselassie and Meseret Defar, and others aren't
- have amazing musical talent, whilst others don't, or
- can write poetry, whilst others can't.

Biologists also try to find out why organisms behave in the way that they do. When this is applied to humans, it is often called 'behavioural psychology', but many consider it to be a branch of biology. Some of these biologists believe that it will one day be possible to understand how all the nerve cells that make up the brain interact with each other to store memories, carry out problem-solving activities and learn as well as modify behaviour patterns.

The study of biology has relevance in almost every aspect of life. It would take far too long to analyse all aspects of the relevance of biology. However, there are some which are undoubtedly of great importance.

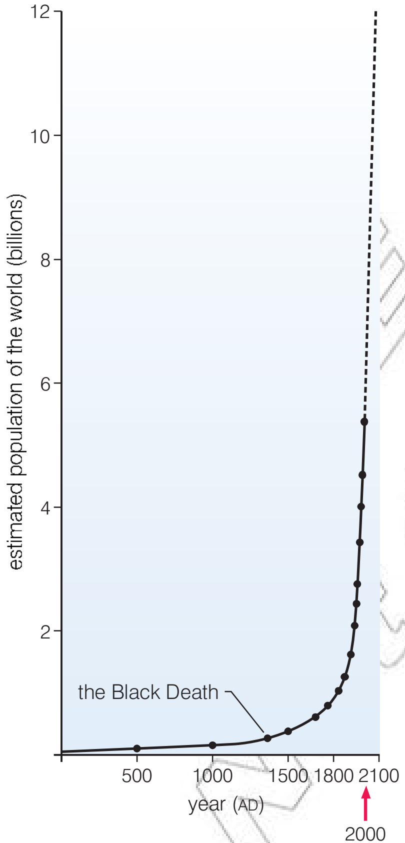


Figure 1.29 *How the world population has changed over the past 2000 years*

Biology and agriculture

The world's population is growing at an alarming rate and this poses challenges to governments all over the world. The extra people all need homes, food and all the other services that are provided.

Many biologists are addressing the problem of how to produce the extra food. However, they have another problem to consider, which is that global warming may alter the way in which crops grow. Many crops that now produce high yields in some countries will not do so if the current trends continue. Some countries will benefit, as they will find that their agricultural output will increase with global warming. There are many different estimates as to which countries will 'win' and which will 'lose'.

So how can biologists help? They are carrying out research into how to produce crop plants that:

- will be adapted to the new conditions
- are capable of producing their crop quickly so that more than one crop can be obtained per year from a field
- are disease resistant
- are drought resistant

This work involves the genetic modification of existing crop plants to give them the new characteristics that will enable them to be productive in the changed environment.

Biology and medicine

Biologists are also able to give advice on ways of reducing the rate of population growth. They can advise individuals and governments on effective methods of contraception and ways of educating people about the need to limit population growth.

Biologists, as we found earlier, are closely involved in medical work. Doctors and nurses have specialised biological knowledge and expertise to help sick people and to advise people on ways of staying healthy. Their work is supported by a whole range of other biologists, such as:

- medical laboratory technicians who test blood samples and other samples and provide reports for doctors
- medical researchers who are constantly finding out more about the ways in which disease-causing organisms function and are spread
- radiographers, who produce X-rays and other images to help in the diagnosis of disease
- specialised researchers who look into why and how cancer is caused
- drug development researchers, who usually work for a commercial company and develop new drugs to treat diseases

These are just a few of the biologists involved in medical work – there are many others.

Biology and the environment

Biologists are actively involved in monitoring the impact of global warming on the environment. Many of the fieldwork techniques we discussed earlier are used to find out how the abundance and distribution of species in areas are changing. These biologists give advice to governments on how best to conserve environments and to, where necessary, introduce new species that will maintain the best balance of species within the area.

Biotechnology is an exciting area of biological research that is expanding rapidly. It involves many different aspects of biology. Some of these can be seen in figure 1.30 on the next page.

Activity 1.15

Work in groups and brainstorm all the different ways in which biology is important. Produce a spider diagram with the word biology in the middle and show as many links to different areas as possible. Then bring all your ideas together with the rest of the class to produce one big spider diagram which could go on the wall of your classroom.

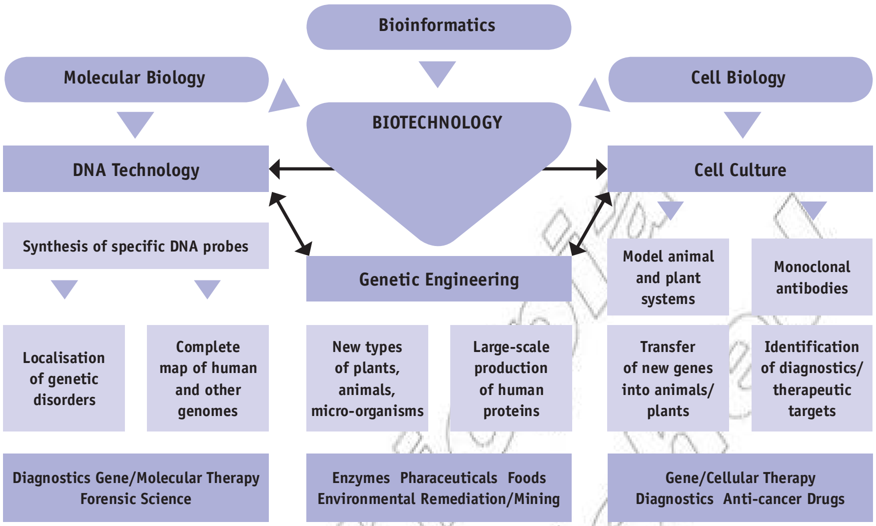


***Figure 1.30:** A flowchart showing different branches of biotechnology*

KEY WORD

biotechnology *use of micro-organisms and enzymes that will benefit mankind*

The promise of research in these fields is huge. Among the goals are:

- cures for genetic diseases
- treatments for degenerative diseases, such as Parkinson's disease and Alzheimer's disease
- establishing biologically controlled industrial processes to manufacture more biological products in the same way as insulin is now manufactured
- producing drugs that are 'tailor-made' to suit an individual's needs
- genetically modifying plants to meet a specific need; for example:
  - plants that can produce a good yield of a crop in dry conditions
  - plants that produce their own insecticide will not need to be sprayed with chemical insecticides
- cloning of productive animals and plants
- production of monoclonal antibodies that can deliver a drug to only those cells that need treatment (for example, cancer cells)
- using stem cells to repair damaged organs and, ultimately, to grow whole new organs from just a few of a person's stem cells

Biotechnology

Biotechnology isn't just new technology. Some biotechnological applications have been around for thousands of years. Using yeast to ferment sugars has been used for centuries in the manufacture of both bread and alcoholic drinks.

***Figure 1.31** Yeast is a unicellular fungus that can ferment sugar to produce alcohol and carbon dioxide.*

The relevance of biology in Ethiopia

Biology is very relevant in Ethiopia considering the issues of overpopulation, food security, environmental well-being, health care, natural resource conservation, biodiversity and others, which the country needs to address. Practical biological knowledge is of special relevance for Ethiopia and education in biology needs special attention.

- As citizens of Ethiopia we must have the biological literacy to understand and assist in the preservation, development and proper use of the abundant biological resources which are our heritage.
- We need to systematically combine the wealth of indigenous knowledge with modern science by training an army of able biologists.
- We need to control land degradation, biodiversity loss, diseases and other problems, as well as to develop the biological and agricultural potential that will contribute positively to transforming our country's economy.

Activity 1.16: Biotechnology and its relevance in Ethiopia

The list shows just some of the ways in which biotechnology is advancing and will influence our lives. Carry out a library search to investigate the potential of biotechnology. You could expand on some of the suggestions given, but try to include new ideas also. Write a report on your findings and include in your report ways in which biotechnology could help the development of Ethiopia.

Review questions

Choose the correct answer from A to D.

1. It is true to say that biotechnology is:
   - A a new and rapidly expanding area of biological research
   - B a new but relatively ineffective area of research
   - C an old but rapidly expanding area of biological research
   - D none of the above
2. Biological science is relevant to our lives because it attempts to explain:
   - A the way in which humans function
   - B the place of humans on this planet
   - C the origin of life on this planet
   - D all of the above
3. Biologists are trying to help deal with the problem of a growing population by:
   - A developing crop plants with an increased yield
   - B giving advice on the most effective programmes of contraception
   - C developing crop plants that are resistant to disease
   - D all of the above
4. Fieldwork is important for biologists engaged in environmental protection and conservation because it allows them to:
   - A gather information about how the organisms in an area are changing

B gather information about how the conditions in the environment are changing

C make predictions about future trends in the area

D all of the above

5. Which of the following is a current rather than a possible future use of biotechnology?

A producing tailor-made drugs to suit individual needs

B using stem cells to grow a new heart for someone who needs a transplant

C monoclonal antibodies used in pregnancy tests and to diagnose diseases

D producing cures for genetic diseases

1.4 Biology and HIV/AIDS

KEY WORDS

AIDS *a disease that severely reduces the body's immune functioning*

HIV *the virus that causes AIDS*

By the end of this section you should be able to:

- Explain how biologists are actively involved in the fight against AIDS.
- Describe how you can help community efforts to control AIDS.
- Describe the decisions you will need to take to help control AIDS.

AIDS is short for acquired immune deficiency syndrome and is caused by the human immuno deficiency virus (**HIV**). You will learn more about the structure of HIV and how it causes AIDS later. However, you should be aware that HIV infects cells in our immune systems called T-helper cells that enable us to fight off other diseases. For a time, our body keeps replacing the HIV-infected cells, and this can last for many years. However, the body eventually cannot keep pace and AIDS develops. People suffer from 'opportunistic' infections that they would normally have been able to fight off. They also start to develop some forms of cancer that they would not normally develop. AIDS is usually fatal.

Figure 1.32 *Opportunistic infections such as pneumocystosis or cancers such as Kaposi's sarcoma can signal the final stage of HIV infection, AIDS.*

The AIDS epidemic is affecting more people than ever before.

There are:

- 33 million people living with AIDS (2.2 million in Ethiopia)
- 2 million children living with AIDS
- 11.6 million AIDS orphans in Africa alone (650 000 in Ethiopia)
- over 17 million women living with AIDS worldwide

If the map of the world was redrawn to show the numbers of people infected by HIV, it would look something like this:

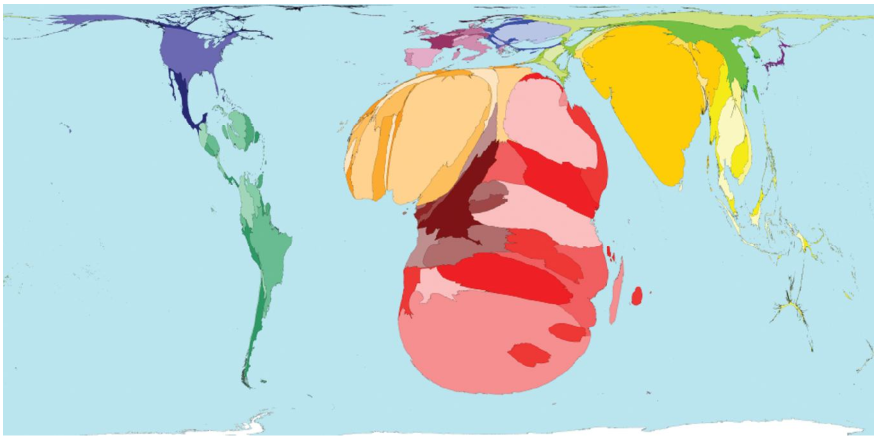


Figure 1.33 The world would look very different if it was redrawn to show global levels of HIV infection.

AIDS is largely a sexually transmitted disease (STD), although there are four main ways in which HIV can be transmitted. These are:

- homosexual or heterosexual intercourse with an infected person
- transfusion of infected blood or blood products
- sharing infected needles
- from mother to child during pregnancy

In all these cases HIV must cross a barrier and find its way into the blood so that it can infect the T-helper cells and multiply.

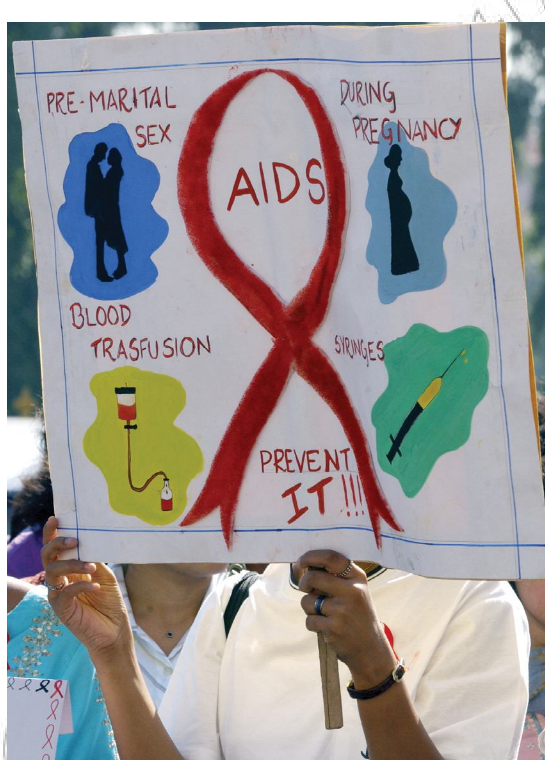


Figure 1.34 The ways in which HIV is transmitted from person to person

Activity 1.17

The poster in fig 1.34 is not completely accurate. Decide what the main mistake in this message is. Then design and make your own poster to help educate everyone in your community about the ways in which HIV/AIDS is transmitted. This helps people change their behaviour so they can avoid becoming infected.

How can biology help in the fight against AIDS?

There are several methods of combating the spread of a disease. These are described below.

- Break the transmission pathway – if the disease cannot spread from one person to another, it will eventually disappear.
- Produce drugs that kill the virus or at least stop it from reproducing. Antibiotics act in this way on bacteria, but cannot act on viruses.
- Produce a vaccine against the virus. When vaccines are used, one of the aims is to build up a 'herd immunity' to break the transmission pathway. If enough people in an area are immune, the micro-organism causing the disease cannot easily spread to an uninfected person and so the disease is eliminated.

Activity 1.18 Breaking the transmission pathway – 'brainstorming'

AIDS is a sexually transmitted disease and so breaking the transmission pathway must focus on transmission through sexual intercourse. If promiscuous sexual intercourse can be reduced, the rate of transmission of AIDS will reduce with it.

Your teacher will divide the class into groups. Each group will 'brainstorm' one of the topics in the list (although there is no reason why you should not think of others as well).

- Reasons why young women (and/or young men) should say 'no' to sexual intercourse before marriage
- Things young women (and/or young men) can do to avoid the temptation to have sexual intercourse
- Things boyfriends and girlfriends can do together without encouraging each other to have sexual intercourse
- Things young people in your community can do to occupy their free time
- Excuses given for not using condoms and responses to them

At the end of the brainstorming session, each group should produce a poster showing how their contribution would help to break the transmission pathway.

HIV and similar viruses are called **retroviruses** and they all have a similar life cycle, shown in the diagram:

1 – the entry phase

2 – viral genetic material is converted to DNA

3 – the new DNA enters the host cell DNA

4 – the new DNA 'instructs' the cell to make more HIV

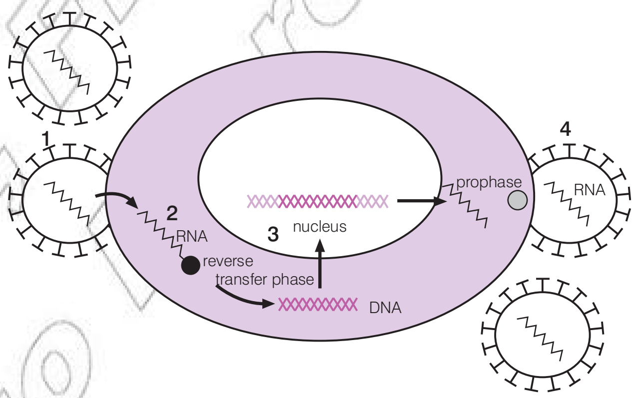


Figure 1.35 *Life cycle of a typical retrovirus*

KEY WORDS

retrovirus *a virus that inserts its RNA into the host cell where it is 'reverse transcribed' to DNA*

anti-retroviral drugs *drugs that target retroviruses and prevent them replicating*

highly active anti-retroviral therapy (HAART) *treatment using a combination of anti-retroviral drugs*

Biologists have developed drugs that target and aim to break this life cycle. They are called **anti-retroviral drugs**. There are different anti-retroviral drugs that target different stages in the life cycle. They are more effective when taken in combination than when taken singly, although there can be side effects. The combination treatment is called **highly active anti-retroviral therapy**, or **HAART**. However, it is important to remember that these drugs only treat the HIV that is currently present in the body. They do not provide any lasting immunity and a person could be reinfected.

Other biologists have been working for years to try to produce a vaccine against HIV. A vaccine *would* provide lasting immunity against reinfection by HIV. One of the problems has been that HIV mutates (changes) rapidly and that any one infected person can have several different types of HIV in them. However, researchers have found a part of the virus that is found in all strains of HIV and is crucial to the virus infecting the cells. They have constructed a vaccine based on this. Their research is also unusual because they have attached this part of HIV to a common cold virus. Previously most experimental AIDS vaccines had been based on a weakened form of HIV itself and were potentially dangerous because the virus could always revert to its infective form.

Also, other biologists are studying a group of people in Kenya who have been repeatedly exposed to HIV but never developed AIDS. Their immune responses to HIV may hold the key to a vaccine. It has been shown that human antibodies produced against HIV completely protect some monkeys against a very similar disease caused by a very similar virus. A vaccine could well be possible.

What can we do in the fight against AIDS?

There are a number of things that all of us can do. The first is to recognise that people with AIDS are quite simply sick people who need medical care as well as the support and love of their families and friends. AIDS victims have been stigmatised for years in all countries all over the world. This makes the problem worse in a number of ways:

- It makes it harder for victims to come to terms with their illness.
- It may prevent them from seeking early advice for fear of stigmatisation; this in turn may lead to further infection before the condition is diagnosed.
- It can make governments reluctant to take decisive action for fear of offending powerful pressure groups.

We must show tolerance and support. You may one day be in the unenviable position of having to watch someone you love die from a condition that gradually robs them of all ability to look after themselves and turns their body into a shadow of what it was. It could be someone much younger than you, which always seems even worse. People in this position need great strength of character to continue to support the dying person and probably support the rest of the family as well. We need friends to help us through this and we should not forget to help our friends also. The community must pull together: we cannot fight AIDS alone.

You will probably have to make some difficult choices about your personal behaviour. Communities are made up of individuals and although communities can agree a course of action, individuals must then support this course of action.

Although, as individuals, we can do little about the transmission of AIDS through infected blood products or from mother to child, there are things we can do to help control the spread of AIDS by breaking the transmission pathway. These include:

- Restricting the number of sexual partners. In terms of AIDS, this is simple mathematics. If we have sex with many people, we increase our risk of contracting HIV and then passing it on. Sex within a

Beware fake cures

Unproven AIDS cures have been around since the syndrome emerged in the early 1980s. These cures are a swindle. Someone who invests their savings in a worthless potion or an electrical zapper has less money to spend on real medicines and healthy food.

Here in Ethiopia there are a number of fake cures prescribed by different groups. Beware of such cures. They are often presented as 'the natural way to cure AIDS'. These fake cures often make things worse and at the very least they exploit a vulnerable group of people. If the cure is presented as 'the miracle cure for AIDS' or 100% effective, it is a fake. Also, be wary of someone who won't tell you what's in the cure.

Activity 1.19 Poet

Choose one of the following situations and write a poem to show how it might have happened or have been avoided:

- a girl who contracts AIDS from her only sexual encounter – a casual encounter which she did not intend; it happened when she was feeling low as a result of an argument with her best friend
- a boy who finds he has AIDS as a result of sharing needles to inject drugs
- a girl/boy who has to give up his/her dream of further education to support the family because the father is dying from AIDS

– or you could think of your own AIDS-related situations.

loving, monogamous relationship limits the spread of AIDS. This will require strength of character as friends may not be prepared to restrict the number of their sexual partners. You should not be swayed and you should try to educate them that their choice is a threat to the health and well-being of the whole community.

- Men can elect to be circumcised. This significantly reduces the risk of men acquiring HIV, although it has little effect on them passing on the virus if they do become infected.
- Not sharing infected needles. Drug users who do this are, again, threatening the well-being of the community, as they may spread the virus from one to another and then into other members of the community through intercourse. You should be aware of all the dangers of the drug habit and make an informed choice that considers not just yourself, but others as well.

Remember, community action is always better than individual action. Across Ethiopia, community initiatives and local government are coming together to make a difference in the AIDS response.

During a visit to the country, a United Nations AIDS Executive Director visited some of the programmes and projects putting into action the goals of universal access to HIV prevention, treatment, care and support services.

The government-run local health centres deliver primary health services such as family health, communicable disease prevention and control, including HIV and health education. Being aware of the advice these centres can offer is crucial in the fight against AIDS.

Activity 1.20 Good friend / bad friend

In this activity, you will be divided into groups of three to devise a short role-play. In each group:

- one person will be the 'uncertain teenager' who is tempted to try a new experience
- one person will be the 'bad friend' who will try to persuade him/her that the experience will be fun with no problems
- one person will be the 'good friend' who will try to persuade him/her that there are always consequences and he/she needs to think carefully

Temptations could include:

- a girl wanting to have sex with a popular boy who is a good athlete
- boy who has not had sex because he wants to remain AIDS-free being tempted by his girlfriend
- boy/girl being tempted to use drugs
- boy planning to have unprotected sex with his girlfriend
- boy/girl being approached to have sex with someone who has another lover

– but you could think up other topics of your own.

Each group should spend a few minutes discussing the outline of their role-play before presenting it to the class.

Review questions

Choose the correct answer from A to D.

1. The main way that AIDS is transmitted is:
   - A from an infected mother to her unborn child
   - B by using infected blood products
   - C through drug users sharing infected needles
   - D through sexual intercourse
2. Ways of reducing the transmission of AIDS include:
   - A restricting the number of sexual partners a person has
   - B male circumcision
   - C not sharing infected needles
   - D all of the above
3. Which of the following is not a reason for developing a vaccine against HIV/AIDS?
   - A it would make individual people immune to AIDS
   - B it would help to create a 'herd immunity', protecting people who were not immunised for some reason
   - C to produce a cure for people already infected with AIDS
   - D it would reduce the spread of HIV/AIDS within communities and across the world
4. Anti-retroviral drugs are drugs that:
   - A give someone immunity against AIDS
   - B break the life cycle of HIV within a cell
   - C stop the transmission of AIDS from person to person
   - D prevent other illnesses from developing in someone with AIDS
5. Community action against AIDS is essential because:
   - A it can help break the transmission pathway in that community
   - B members of the community can support each other
   - C it can help reduce the stigma of AIDS
   - D all of the above

Activity 1.21

Work in small groups. Discuss ways in which you can help prevent the spread of HIV/AIDS in your community – and how you can support those people who are already affected by this disease. Make two lists, one headed **'Preventing the spread of HIV/AIDS'** and the other headed **'Supporting people affected by HIV/AIDS'.**

Then have a session as a whole class. Put the same two titles on the board and each group adds something to the lists in turn until every idea has been used.

Summary

In this unit you have learnt that:

- Biology is the study of life and living organisms; the term biology is derived from the words *bios* (= life) and *logos* (= study).

There are many fields of biology including:

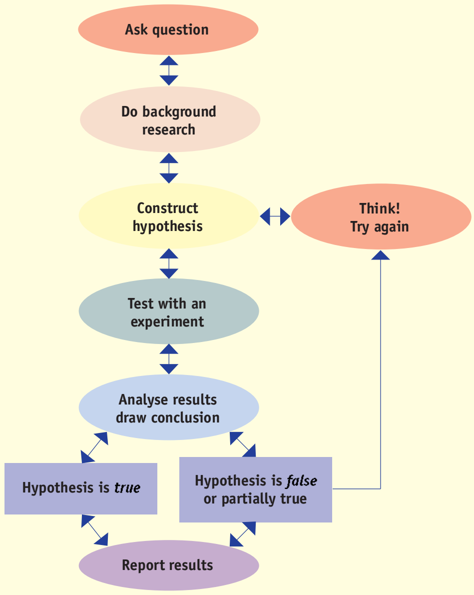
– paleobiology, the study of the origin and evolution of life

– biomedical biology, research into the development of new drugs and vaccines

– astrobiology, the investigation of the possibility of life on other planets

– and many more

- Science is a unique, experimental system of acquiring a scientific knowledge of the scientific method.
- The main steps of the scientific method are:



- Redi and Pasteur carried out controlled experiments that disproved the theory of generation.
- Scientific experiments seek to establish cause and effect.
- Experiments can only establish cause and effect if changes in the IV (independent variable) are shown to cause changes in the DV (dependent variable).
- To show cause and effect a fair test must be carried out in which other factor results are controlled so that their influence can be eliminated.
- Accuracy refers to how precisely a measurement is made.
- Reliability concerns how repeatable the results of an experiment are and how dependable they are.
- Validity concerns whether an experiment really measures what it says it is measuring.
- Scientists report the results of their research in scientific journals such as *Nature* and *Science*. These are read by other scientists working in the same field who can repeat the research and comment on any conclusions that have been drawn.
- Any report must contain:
  - a title, which states clearly what is being investigated
  - a hypothesis, often extended to a prediction for the particular experiment

  - a clear description of the experimental procedure
  - a full account of the results obtained; it is often helpful to summarise these (where appropriate) in graphs, charts and tables
  - the conclusions that have been drawn from the results
  - an evaluation of the procedure
  - an acknowledgement of the use of any other person's work
- Biologists use specialised equipment; some apparatus is used mainly in the laboratory, such as:
  - microscopes
  - centrifuges
  - Petri dishes
  - measuring cylinders
  - balances
- Other apparatus is used mainly in the field, such as:
  - quadrats
  - plant presses
  - theodolites
  - GPS receivers
  - flow meters
- Biological research is highly relevant to us all because it includes research into:
  - producing new crops that will help to feed an increasing world population
  - producing new vaccines including, one day, a vaccine against AIDS
  - producing new drugs that are more effective in treating diseases
  - the environment which will help us to maintain key habitats to prevent species from becoming extinct
  - genetic engineering which will offer ways of treating genetic diseases as well as helping to produce genetically engineered crops with a higher yield
- Acquired Immune Deficiency Syndrome (AIDS) is caused by the Human Immunodeficiency Virus (HIV).
- Africa has the highest incidence of AIDS anywhere in the world.
- HIV can be transmitted by:
  - sexual intercourse

Activity 1.22

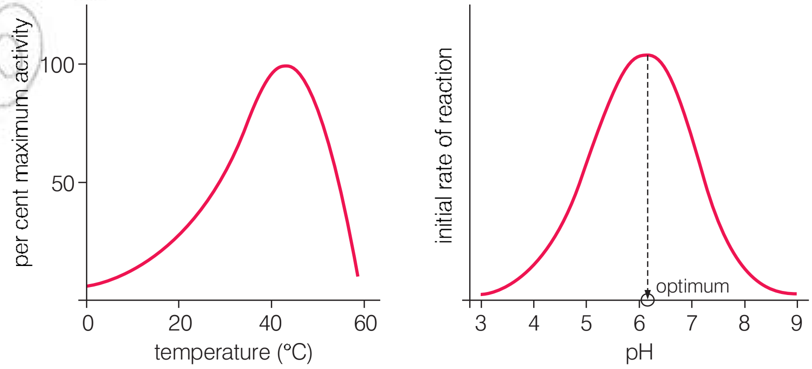
Using the ideas you developed as a class in activity 1.21, divide into groups again and produce a classroom display based on **'Preventing the spread of HIV/AIDS'** and **'Supporting people affected by HIV/AIDS'**. This display can then be used in your classroom or in the school entrance to inform and support anyone who visits, works or studies in your school.

- transfusion of infected blood
- drug users sharing infected needles
- from mother to child during pregnancy

- HIV is a retrovirus and is treated by anti-retroviral drugs.
- HAART (Highly Active Anti-Retroviral Therapy) is a combination of anti-retroviral drugs each targeted at a different phase of the HIV life cycle.
- To reduce the spread of AIDS, we should:
  - restrict the number of sexual partners
  - not share infected needles
  - encourage men to be circumcised

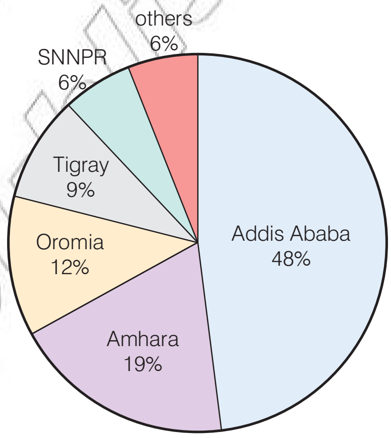
End of unit questions

1. List the main steps of the 'scientific method'. For each step, explain what is involved.
2. a) In a scientific experiment, what is:
   (i) the independent variable (IV)?
   (ii) the dependent variable (DV)?
   b) Why is it important to control all other variables?
   c) What is a control experiment?
3. Explain what is meant by the following terms in a scientific experiment:
   accuracy reliability validity
4. The graphs show the results from two experiments into how fast an enzyme works at different temperatures and at different pHs.



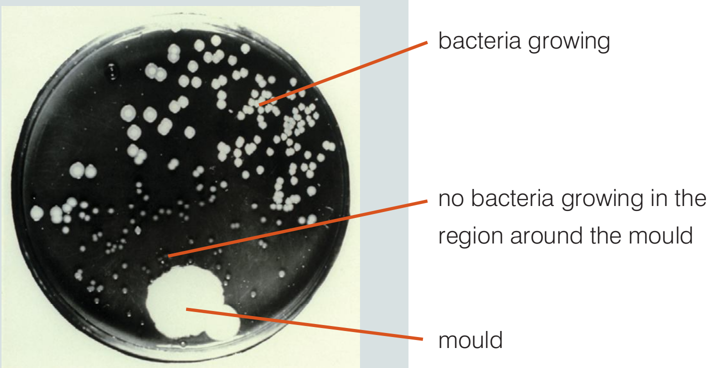
   a) Describe the results obtained for:
   (i) temperature
   (ii) pH
   b) What would be the ideal conditions for this reaction? Explain your answer.

5. For each of the following pieces of equipment:
   a) say whether you would use it mainly in the field or mainly in the laboratory
   b) say how you would use the equipment
      - optical microscope
      - quadrat
      - theodolite
      - electronic balance
      - pipette
      - Petri dish
      - plant press
6. Describe *three* decisions that individuals can take about their lifestyle to help to limit the spread of AIDS.
7. Anti-retroviral treatment (ART) involves the use of anti-retroviral drugs to treat AIDS. The pie chart shows the proportion of all people receiving ART in different regions of Ethiopia (data collected in 2005).
   a) Briefly explain how anti-retroviral drugs work.
   b) Use the chart to:
      (i) describe the distribution of ART in Ethiopia
      (ii) suggest reasons for that distribution.



8. Read the case study below of Alexander Fleming's discovery of penicillin.

In 1928, Alexander Fleming was culturing some bacteria. He left a culture plate smeared with bacteria on his lab bench while he went on a 2-week holiday. When he returned, he noticed a clear region surrounding the growth of a mould that had accidentally contaminated the plate.



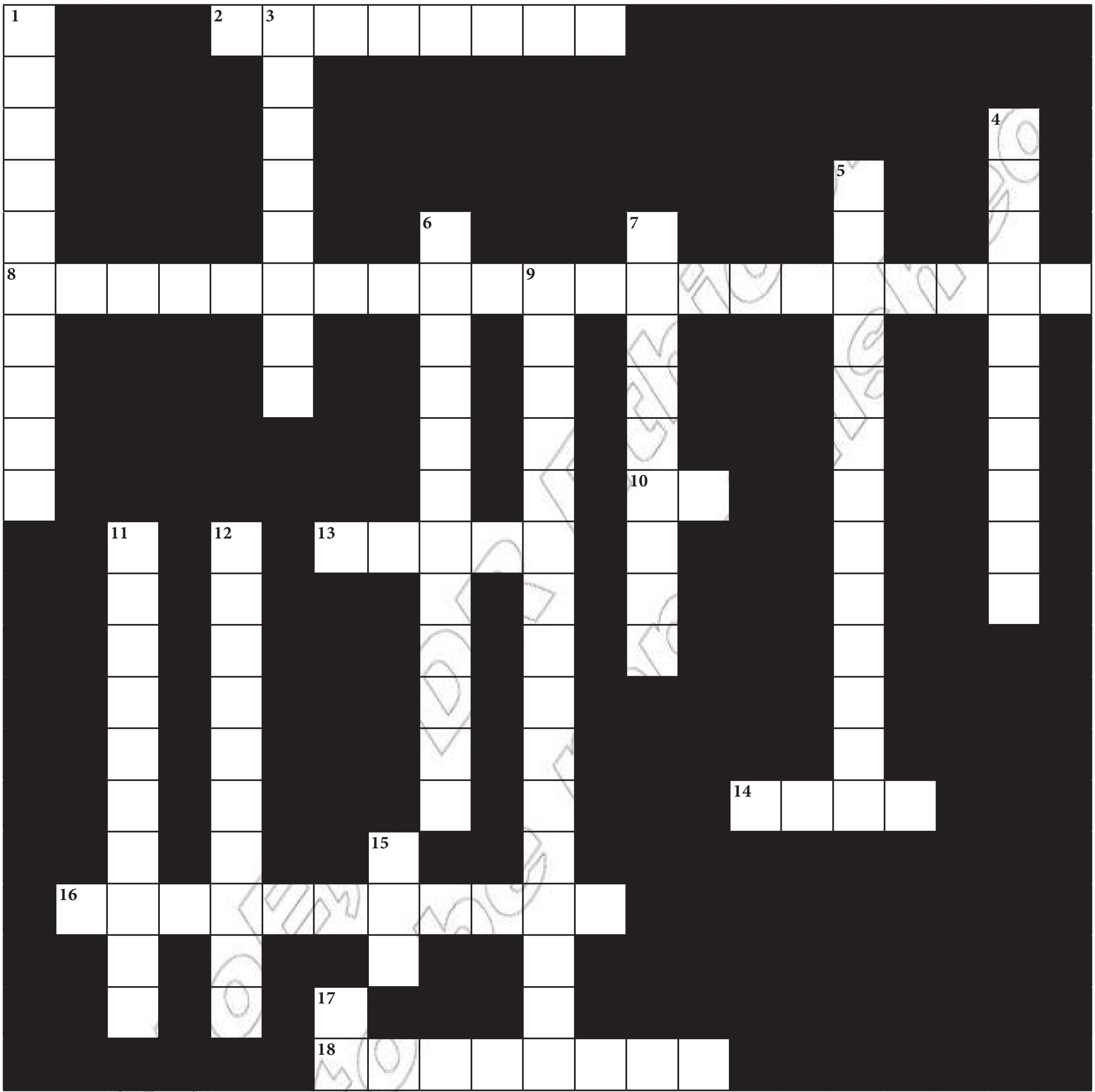
Unknown to him, a spore of a rare fungus called *Penicillium notatum* had drifted in from another lab one floor below.

Seeing that clear region led Fleming to correctly deduce that the mould must have released a chemical that inhibited the growth of the bacteria.

Fleming's deduction became his hypothesis for future experiments. He hypothesised that '*Penicillium notatum* (the mould) releases a chemical that inhibits the growth of bacteria.'

How do you suppose he tested this hypothesis using the scientific method? (*Hint: look back at the way in which Pasteur used the scientific method.*)

Copy the crossword puzzle below into your exercise book (or your teacher may give you a photocopy) and solve the numbered clues to complete it.



Across

2. An experiment in which extraneous variables have been controlled (4, 4)
8. The idea that living things can arise from non-living matter (11, 10)
10. An experimenter measures changes in this variable as the IV changes (2)
13. Highly active anti-retroviral therapy (acronym) (5)
14. The condition resulting from infection by HIV (4)

16. How consistent the results are from repeats of an experiment (11)
18. The extent to which an experiment measures what it says it is measuring (8)

Down

1. A piece of equipment for viewing small objects (10)
3. The precision with which we measure something (8)
4. A statement of the predicted effect of the IV on the DV in an experiment (10)
5. He performed an experiment to show that the spontaneous generation of flies from rotten meat could not happen (9, 4)
6. The French scientist who finally proved that spontaneous generation is not possible (5, 7)
7. A dish often used for culturing bacteria (5, 4)
9. The process scientists use in their investigations (10, 6)
11. A type of investigation that tries to establish cause and effect (10)
12. An 'educated guess' about the likely outcome of an experiment (10)
15. The virus that causes AIDS (3)
17. The variable in an experiment that the experimenter changes (2)