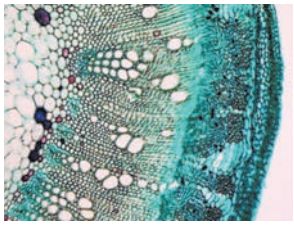
CELL BIOLOGY

IDEAS YOU HAVE MET BEFORE:

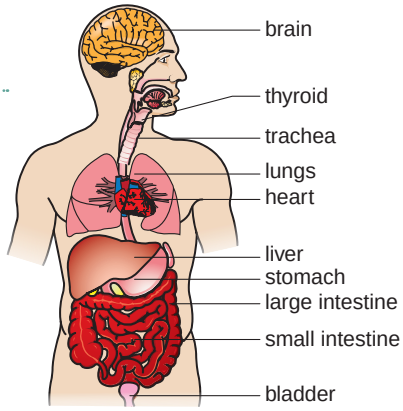
ALL LIVING ORGANISMS ARE MADE OF CELLS.

- Cells are the building blocks of life.
- Cells contain specialised structures.
- Organisms such as bacteria are unicellular.
- Most plants and animals are multicellular.



IN MULTICELLULAR ORGANISMS CELLS BECOME SPECIALISED.

- Specialised cells have a particular job to do.
- Specialised cells are organised into tissues, tissues into organs, and organs into body systems.

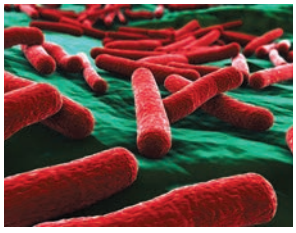


ORGANISMS OBTAIN ENERGY BY THE PROCESS OF RESPIRATION.

- The energy that is released drives all the processes necessary for life.
- Most organisms respire by aerobic respiration, using oxygen.
- Some cells or organisms can survive without oxygen. They respire anaerobically.

MICROORGANISMS CAN HELP TO KEEP US HEALTHY AND PROVIDE US WITH FOOD.

- Microorganisms produce important food products by fermentation.
- Bacteria in the gut are important in keeping us healthy.



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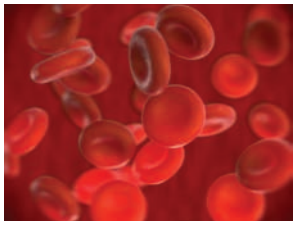
IN THIS CHAPTER YOU WILL FIND OUT ABOUT:

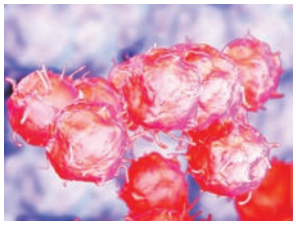
HOW HAVE SCIENTISTS DEVELOPED THEIR UNDERSTANDING OF CELL STRUCTURE AND FUNCTION?

- The structures inside cells do different jobs within the cell.
- Cells can be studied using different types of microscopes.
- The cells of bacteria are different from the cells of plants and animals.



HOW DO WE DEVELOP INTO A COMPLEX ORGANISM FROM JUST A FERTILISED EGG CELL?

- The body's cells divide and the newly formed cells are identical to the existing cells.
- Cells differentiate to become specialised, and specialised cells are organised.
- When cell division accelerates out of control, cancer develops.
- Cells that are unspecialised in the embryo, and cells that remain unspecialised in us as adults, are called stem cells.
- Stem cells could be used to treat certain conditions and diseases that are currently untreatable.

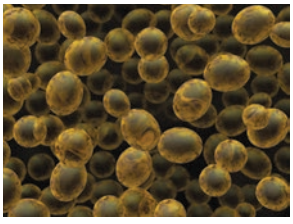


HOW DO ORGANISMS OBTAIN THEIR ENERGY FROM FOOD?

- Anaerobic respiration: when some organisms run out of oxygen, they can respire without it.
- Many microorganisms can respire anaerobically, as can the muscles of mammals for short periods.

WHY IS IT IMPORTANT TO STUDY MICROORGANISMS, AND HOW DO WE GROW THEM IN THE LAB AND COMMERCIALLY?

- The biochemistry of fermentation is involved in the production of alcoholic drinks and bread.
- Lab techniques are used to grow, or culture, microorganisms.
- Microorganisms reproduce, and the number of bacteria produced can be estimated.
- Tests can show how effective antibiotics, antiseptics and disinfectants are at inhibiting the growth of bacteria.



Looking at cells

KEY WORDS

DNA
chloroplast
chlorophyll
chromosome
eukaryotic
order of magnitude

Learning objectives:

- describe the structure of eukaryotic cells
- explain how the main sub-cellular structures are related to their functions.

Cell biology helps us to understand how parts of the cell function and interact with each other. It also helps us to learn how we develop, and about our relationships with other organisms.

Biomedical scientists use cells to look for signs of disease and in new drug development.

Plant and animal cells

Almost all organisms are made up of cells. Plant and animal cells have a basic structure.

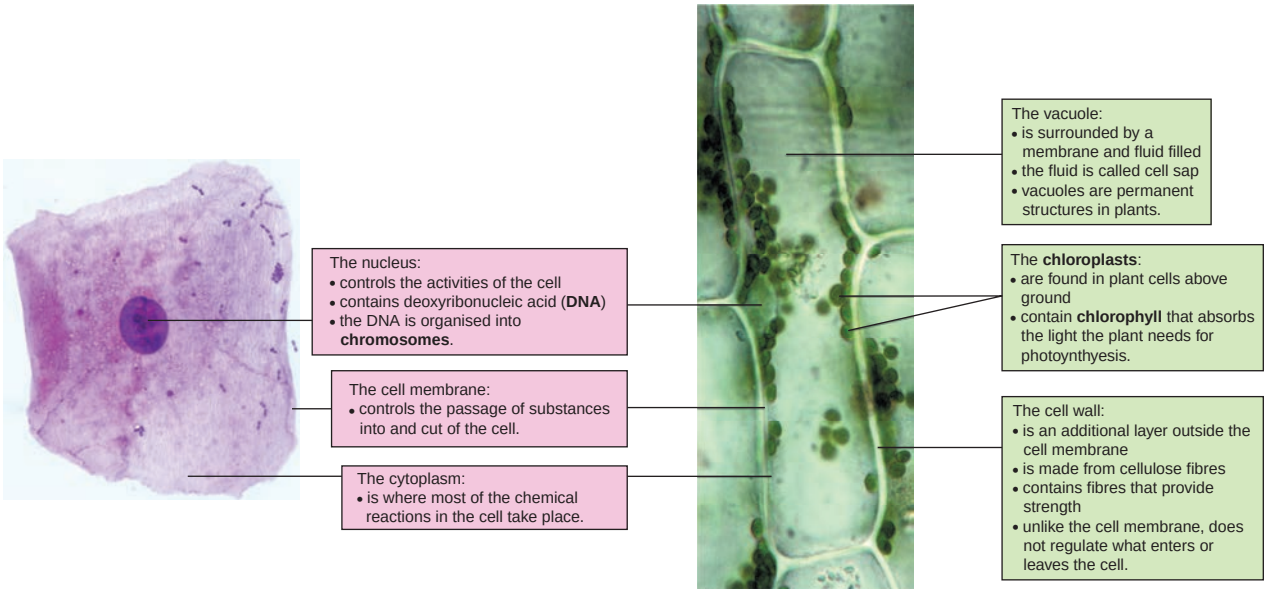


Figure 1.1 (a) A simple animal cell and (b) a plant leaf cell

This type of cell, containing a true nucleus in the cytoplasm, is called a **eukaryotic** cell.

1. **List the sub-cellular structures found in both plant and animal cells.**
2. **Which sub-cellular structures are found only in plant cells?**

What is the function of:

- **the nucleus**
- **the cell membrane?**

Figure 1.2 Growing cells in a laboratory

3 **What structure gives strength to a plant cell?**

Cell size

The smallest thing we can see is about 0.04 mm, so you can see some of the largest cells with the naked eye. For all cells, however, we need a microscope to see them in any detail.

Most animal and plant cells are 0.01–0.10 mm in size. The unit we use to measure most cells is the micrometre, symbol μm. For some sub-cellular structures, or organisms such as viruses, it is best to use a smaller unit: the nanometre, symbol nm.

1 millimetre (mm) = $\frac{1}{1000}$ m or 10^{-3} m

1 micrometre (μm) = $\frac{1}{1000}$ mm or 10^{-3} mm or 10^{-6} m

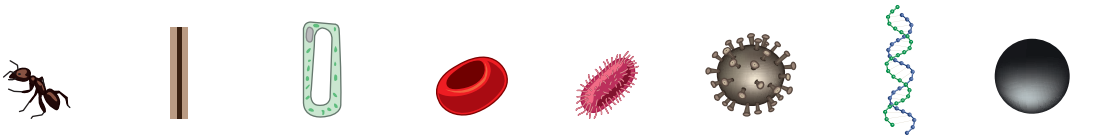
1 nanometre (nm) = $\frac{1}{1000}$ μm or 10^{-3} μm or 10^{-9} m

4 **What size is the smallest thing our eye can see, in m?**

5 **What is the range in size of most animal and plant cells, in μm?**

Order of magnitude

Figure 1.3 shows the size of plant and animal cells compared with some other structures.



ant length 3 mm | hair diameter 100 μm | leaf cell length 70 μm | red blood cell diameter 7 μm | bacterium length 1 μm | virus 100 nm | DNA diameter 2.5 nm | carbon atom 0.34 nm

Figure 1.3 Size and scale

When comparing the sizes of cells, scientists often refer to differences in **order of magnitude**. That's the difference calculated in factors of 10.

So, the difference in order of magnitude for the HIV and the plant cell:

The plant cell in Figure 1.1b is 100 μm = 10^{-4} m.

The human immunodeficiency virus (HIV) is 100 nm = 10^{-7} m.

The difference in order of magnitude is 10^3, expressed as 3.

6 **A cell membrane measures 7 nm across. Convert this to micrometres.**

7 **A white blood cell measures 1.2×10^{-5} m. An egg cell measures 1.2×10^{-4} m. Calculate the difference in order of magnitude.**

8 **Suggest what substances might pass in or out of a muscle cell and explain why.**

REMEMBER!

You'll notice that this system of units uses, and gives names to, multiples and sub-multiples of units at intervals of thousands (10^3) or thousandths (10^{-3}). A common exception is the centimetre, $\frac{1}{100}$ or 10^{-2} of a metre. But it is often convenient to use centimetres, particularly in everyday life.

The light microscope

Learning objectives:

- observe plant and animal cells with a light microscope
- understand the limitations of light microscopy.

KEY WORDS

magnification
resolving power
micrographs

The type of light microscope you have used in the school laboratory is called a compound microscope. Microscopes magnify the specimen you are looking at, making them look bigger than they are.

Figure 1.4 A light microscope

Some early microscopes had just a single lens. The compound microscope has two.

As lens-making techniques improved, microscopes were developed with higher magnifications and resolutions.

Magnification

The magnified image is produced by two lenses, an eyepiece and an objective lens. There is usually a choice of objective lenses.

Total magnification = magnification of eyepiece × magnification of objective lens

For instance, if the eyepiece has a **magnification** of ten, which is written × 10, and the objective lens has a magnification of × 40, the total magnification is × 400.

1. **Calculate the total magnification with an eyepiece magnification of × 15 and an objective lens magnification of × 40.**
2. **What magnification would the objective lens need to be to give a total magnification of × 300 with an eyepiece of × 15?**

DID YOU KNOW?

British scientist Robert Hooke first used the term 'cell'. He recorded the first drawings of cells using a compound microscope in his book *Micrographia*, which was 350 years old in 2015.

You may also have heard of Hooke for his law of elasticity, Hooke's law, in physics.

Magnification of images

The magnification described on the previous page is the magnification used to *view* an image. Microscope images, or **micrographs**, in books, scientific papers or exam papers must show the magnification in order to be meaningful.

$$\text{magnification of the image} = \frac{\text{size of the image}}{\text{size of real object}}$$

The cell in Figure 1.5 is 50 mm across on the page. In real life, it measures 40 µm.

To calculate the magnification, first convert the 50 mm into micrometres (or convert 40 µm to millimetres).

50 mm = 50 000 µm

The cell measures 40 µm

Therefore, the magnification of the image = $\frac{50\,000}{40}$ = × 1250.

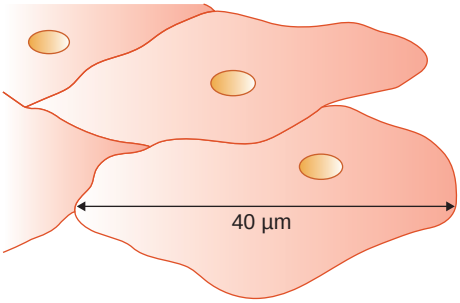


Figure 1.5 A drawing of a micrograph of a cell

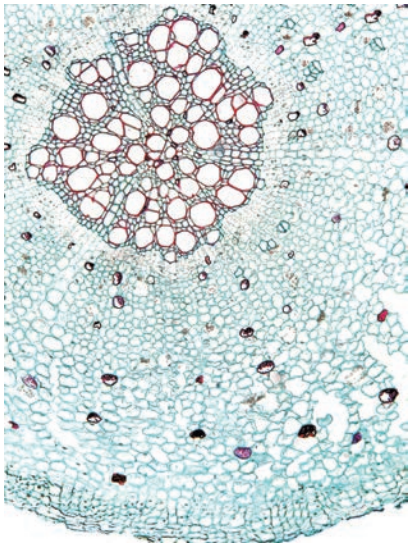


Figure 1.6 A micrograph of the cross section of a root. Magnification x100

3 **A micrograph of a plant cell in a book is 150 mm long. The plant cell measures 120 µm long. Calculate the magnification.**

4 **Why is it essential to state the magnification of an image of a cell in a book but of little value on a website?**

The limits of the light microscope

Very high magnifications are not possible with the light microscope. This is because of the light-gathering ability of the microscope and the short working distances of high-power lenses. The highest magnification possible is around × 1500.

Using higher magnification does not always mean that you can see greater detail in an image. This depends on the **resolving power**, or resolution. This is the ability to distinguish between two points. In other words, whether you see them as two points, or one.

The resolving power of a light microscope is around 0.2 µm, or 200 nm. This means that you could not separately pick out two points closer than 200 nm apart.

5 **What is the maximum resolving power of the light microscope?**

6 **What is the maximum magnification possible with a light microscope?**

7 **Make a table to show the pros and cons of using a light microscope.**

COMMON MISCONCEPTIONS

Do not confuse magnification, which is how much bigger we can make something appear, with resolving power, which is the level of detail we can see.

Think about a digital photo. You can make it as big as you like, but at a certain point you will not be able to see any more detail.

Looking at cells in more detail

KEY WORDS

scanning electron microscope (SEM)
transmission electron microscope (TEM)

Learning objectives:

- identify the differences in the magnification and resolving power of light and electron microscopes
- explain how electron microscopy has increased our understanding of sub-cellular structures.

The *transmission electron microscope (TEM)* uses an electron beam instead of light rays.

Some of the electrons are scattered as they pass through the specimen. Those able to pass through it are focused TEMs using electromagnetic coils instead of lenses.

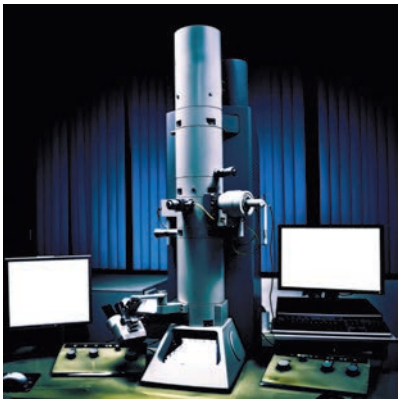


Figure 1.7 A transmission electron microscope. The electrons are displayed as an image on a fluorescent screen

Electron microscopes

TEMs are used for looking at extremely thin sections of cells. The highest magnification that can be obtained from a transmission electron microscope is around × 1 000 000, but images can also be enlarged photographically.

The limit of resolution of the transmission electron microscope is now less than 1 nm.

The **scanning electron microscope (SEM)** works by bouncing electrons off the surface of a specimen that has had an ultra-thin coating of a heavy metal, usually gold, applied. A narrow electron beam scans the specimen. Images are formed by these scattered electrons.

SEMs are used to reveal the surface shape of structures such as small organisms and cells. Because of this, resolution is lower and magnifications used are often lower than for TEM.

Electrons do not have a colour spectrum like the visible light used to illuminate a light microscope. They can only be 'viewed' in black and white. Here, false colours have been added.

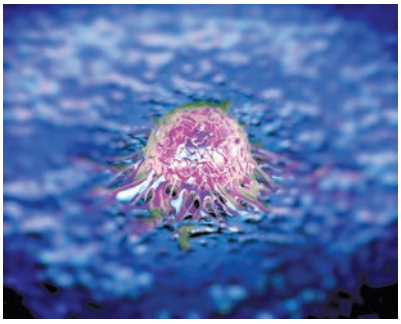


Figure 1.8 A scanning electron micrograph of a cancer cell

1. **What is the maximum resolution of an electron microscope?**
2. **What types of samples would a TEM and an SEM be used to view?**
3. **How has electron microscopy improved our understanding of cells?**

Cell ultrastructure

The TEM reveals tiny sub-cellular structures that are not visible with the light microscope. It also shows fine detail in those structures.

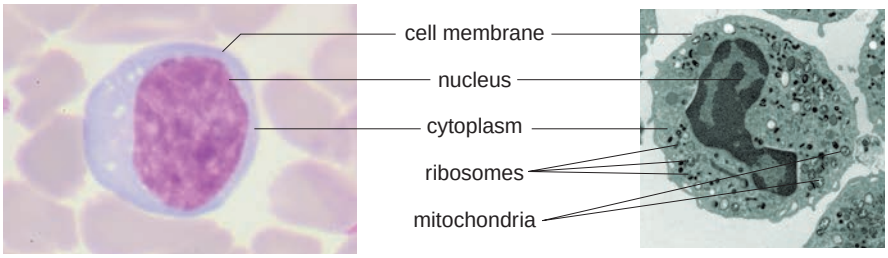
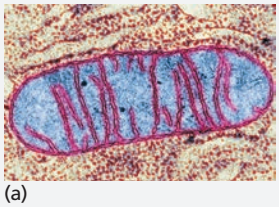


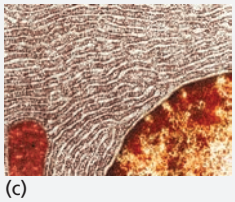
Figure 1.9 A white blood cell, as seen with a light microscope and a transmission electron microscope

We can see mitochondria and chloroplasts with the light microscope, but the electron microscope reveals their internal structure.



(a)
Mitochondria are where aerobic respiration takes place in the cell. A mitochondrion has a double membrane. The internal membrane is folded.

(b)
Chloroplasts are the structures in the plant cell where photosynthesis takes place. Like mitochondria, they also have a complex internal membrane structure.



(c)
Ribosomes are tiny structures where protein synthesis takes place. You can see them as dots in the micrograph. They can either lie free in the cytoplasm or may be attached to an internal network of channels within the cytoplasm.

Figure 1.10 Viewing (a) mitochondria, (b) chloroplasts and (c) ribosomes by transmission electron microscopy

The size of sub-cellular structures is important. Mitochondria and chloroplasts vary in size and shape. The complexity of a mitochondrion indicates how active a cell is. Chloroplast size varies from one species to another. Scientists sometimes investigate the ratio of the area of the cytoplasm to that of the nucleus in micrographs. A high ratio of cytoplasmic:nuclear volume can indicate that the cell is about to divide. A low one can be characteristic of a cancer cell.

4 **Name one structure visible to the electron microscope, but not the light microscope.**

5 **What process happens in ribosomes?**

6 **Which type of microscope would be best suited to viewing the 3D structure of a cell? Explain why.**

COMMON MISCONCEPTIONS

Don't assume that we always use electron microscopes in preference to light microscopes, or that electron microscopes are always used at high magnifications. Confocal microscopy is used in a lot of biomedical research. It can give high resolution images of live cells. And SEM is often used at low magnifications.

DID YOU KNOW?

Three scientists won the Nobel Prize in 2014 for the development of super-resolved fluorescence microscopy. It allows a much higher resolution than normal light microscopy. And, unlike electron microscopy, it has the advantage of allowing scientists to look at living cells.

REQUIRED PRACTICAL

Using a light microscope to observe and record animal and plant cells

KEY WORDS

field of view
scale bar

Learning objectives:

- apply knowledge to select techniques, instruments, apparatus and materials to observe cells
- make and record observations and measurements
- present observations and other data using appropriate methods.

These pages are designed to help you think about aspects of the investigation rather than to guide you through it step by step.

Many scientists use electron microscopes to observe fine detail in cells. But much of the microscope work carried out – including in hospital and forensic science labs – is done with the light microscope.

Preparing cells for microscopy

Live cells can be mounted in a drop of water or saline on a microscope slide.

Most cells are colourless. We must stain them to add colour and contrast. In the school laboratory, you may have used methylene blue to stain animal cells or iodine solution to stain plant cells.

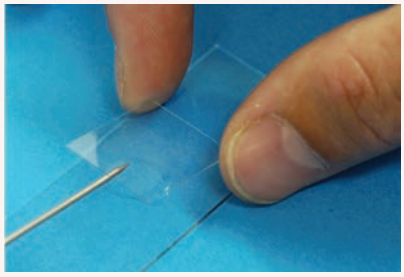


Figure 1.11 A glass coverslip is carefully lowered onto the cells or tissue, taking care to avoid trapping air bubbles. The coverslip keeps the specimen flat, and retains the liquid under it

1. **Write an equipment list for looking at cheek cells with a microscope. State why each piece of equipment is used.**
2. **Suggest why it's better to mount the cells in saline than in water.**
3. **The micrograph of the frog's blood (Figure 1.12) shows red blood cells (the lower micrograph) and two types of white blood cell.**
   - a **Label the different types of cell and the cell structures that are visible. Hint: use a photocopy or printout of the page.**
   - b **How is the structure of the frog's red blood cells different from that of human red blood cells?**

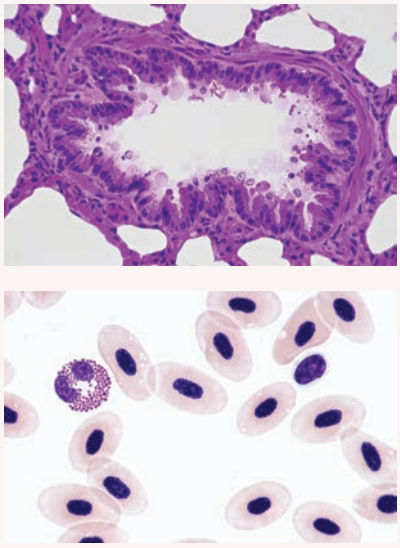


Figure 1.12 Cell biologists use other chemical stains. These are used to reveal or identify specific cell structures.

High and low power

The slide is first viewed with low power. This is because:

- the field of view with high power is small. It would be difficult to locate cells if starting with the high power objective.
- it enables you to see the layout of cells within the tissue.
- it's useful when estimating the numbers of different types

of cell on the slide or in a tissue (though here, high power may be needed).

A low power digital image (or drawing) can be used to show the arrangement of cells in a tissue. This includes regions of the tissue but not individual cells.

If required, the cells or tissue can then viewed with high power to produce a detailed image of a part of the slide.

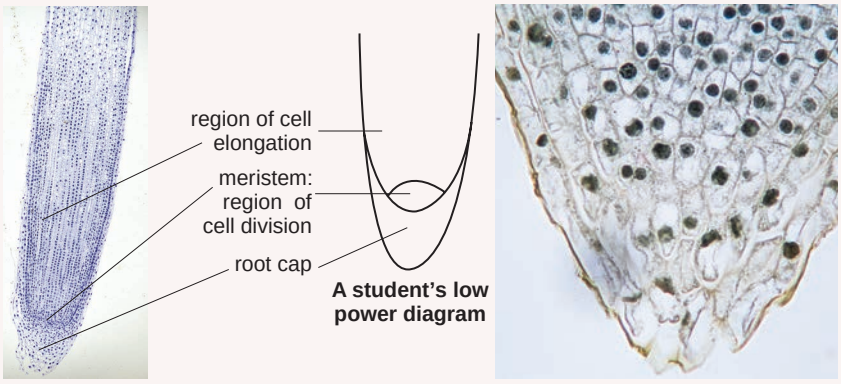


Figure 1.13 Low and high power micrographs, and a student diagram, of a plant root.

DID YOU KNOW?

These slides are temporary. If a permanent slide of cells is required, the cells or tissue must be dehydrated, embedded in wax and cut into thin slices called sections before staining.

4 **Why is a slide viewed with low power first?**

5 **On a printout of a low power plan of the root (Figure 1.13), label the root cap, meristem (the region of cell division) and the region of cell elongation.**

6 **How many cells were undergoing mitosis when the micrograph of the meristem was taken?**

Recording images

As you have seen in section 1.4, a microscope drawing or micrograph is of little value if it gives no indication of size.

It's usual to add a magnification to the image. We can then envisage, or work out, the true size of a specimen.

Alternatively, we can use a **scale bar**. Any scale bar must be:

- drawn for an appropriate dimension
- a sensible size in relation to the image.

Look at Figure 1.14. For the top micrograph, the magnification of × 1000, means that a 10 *millimetre* scale bar can be drawn to represent 10 *micrometres*.

You will find out how scientists measure, or sometimes estimate, the size of cells in section 1.17.

7 **Complete the scale bar for the bottom micrograph.**

8 **Calculate the length of the *Paramecium* in Figure 1.14.**

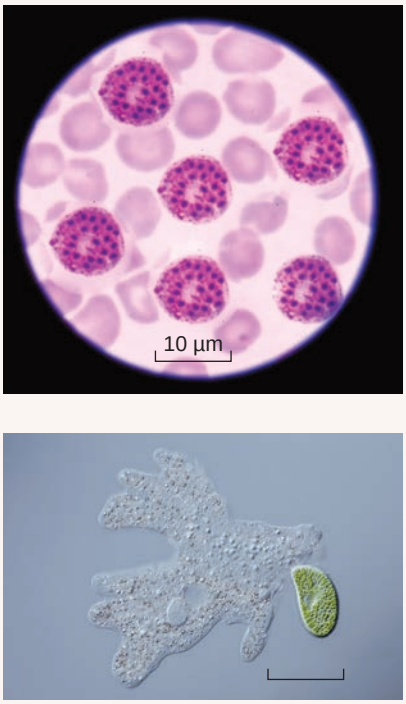


Figure 1.14 Light microscopy is also used to examine small organisms such as protists.

Primitive cells

Learning objectives:

- describe the differences between prokaryotic cells and eukaryotic cells
- explain how the main sub-cellular structures of prokaryotic and eukaryotic cells are related to their functions.

KEY WORDS

domain
kingdom
genome
nucleic acid
plasmid
prokaryotic cell
Prokaryota
eukaryotic

The oldest fossil evidence of life on Earth comes from Australia. It confirms that there were bacteria living around 3.5 billion years ago.

The bacteria probably formed thin purple and green mats on shorelines. The bacteria would have photosynthesised, but produced sulfur as waste instead of oxygen.

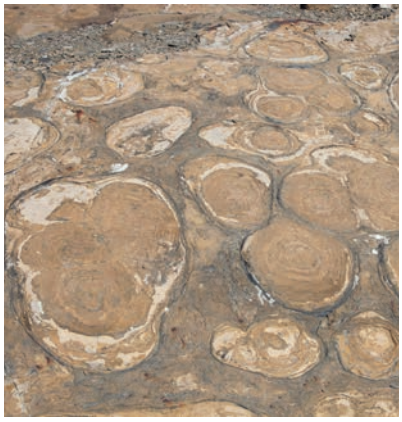


Figure 1.15 The organisms in this fossil are similar to purple bacteria that are living today

Prokaryotic cells

Bacteria are among the simplest of organisms. Along with bacteria-like organisms called archaeans, they belong to a group of organisms called the **Prokaryota**. These are single cells with a **prokaryotic cell** structure.

The cells of most types of organisms – such as all animals and plants – are **eukaryotic**. These have a cell membrane, cytoplasm containing sub-cellular structures called organelles and a nucleus containing DNA.

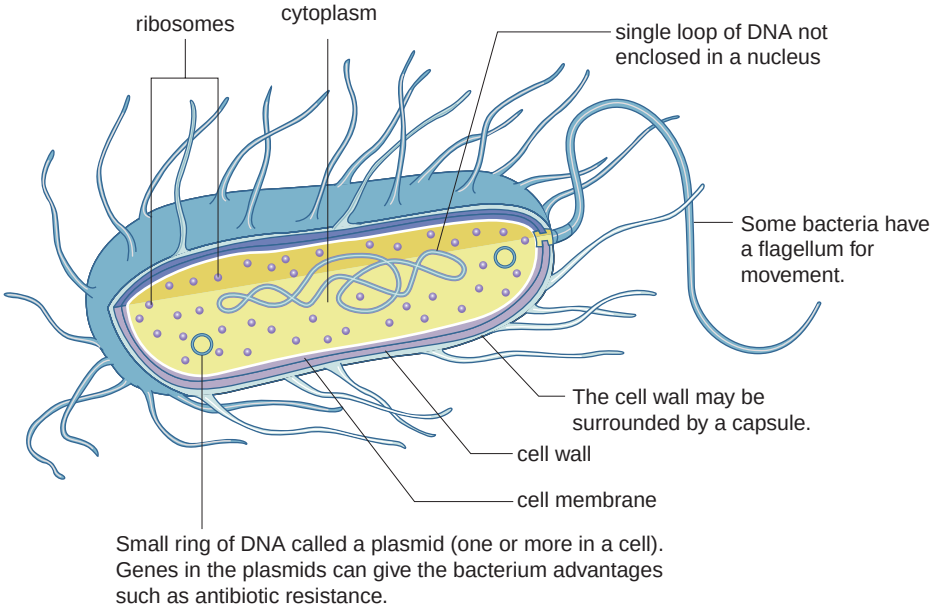


Figure 1.16 The structure of a prokaryotic cell

Prokaryotic cells are much smaller than eukaryotic cells, around 1 μm across. Their DNA is not enclosed in a nucleus. It is found as a single molecule in a loop. They may also have one or more small rings of DNA called **plasmids**.

1. **List the differences between prokaryotic and eukaryotic cells.**
2. **Where is DNA found in prokaryotic cells?**

A new classification system

By the 1970s, biologists had classified living organisms into five **kingdoms**.

Very small, microscopic organisms called archaeans were originally grouped in a kingdom with bacteria. But in 1977, American microbiologist Carl Woese suggested that certain types of organisms that lived in extreme environments or produced methane gas should be placed in a separate group.

Woese suggested that living things should be divided into three groups called **domains**: Bacteria, Archaea and Eukaryota.

3. **What are the three domains of living things?**
4. **In which domain are plants and animals?**

Chemical characteristics of archaeans

Acceptance of Woese's theory was a slow process. Even today, not everyone agrees with it, but chemical analyses have supported the idea that archaeans should be in a separate domain.

The ribosomes of archaeans are similar in size and structure to those of bacteria, but the **nucleic acid** in these structures is closer to that of eukaryotes.

When American biochemist Craig Ventner, one of the first scientists involved in the sequencing of the human **genome**, looked at the DNA of Archaea he was astounded to find that 'two-thirds of the genes [in Archaea] do not look like anything we've ever seen in biology before'.

5. **Suggest 3 different environments where you might find Archaea.**
6. **What evidence suggests that archaeans should be placed in a separate domain to bacteria?**
7. **Suggest why scientists have only discovered Archaea quite recently.**

DID YOU KNOW?

A 'superfood' called Spirulina is the dried cells of a blue-green bacterium. The cells contain high concentrations of protein, and are rich in essential fatty acids, vitamins and minerals.

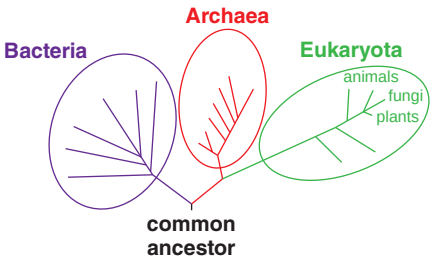


Figure 1.17 The three-domain classification system

Figure 1.18 Archaeans live in extreme environments, such as hot springs and salt lakes. Some produce methane and are important in the carbon cycle

REMEMBER!

You should aim to be able to discuss how information on Archaea, Bacteria and Eukaryota allows them to be placed in separate domains.

Cell division

KEY WORDS

mitosis
stem cells
daughter cell

Learning objectives:

- describe the process of mitosis in growth, and mitosis as part of the cell cycle
- describe how the process of mitosis produces cells that are genetically identical to the parent cell.

As an adult, we are made up of 37 trillion (3.7×10^{13}) cells. To produce these cells, the fertilised egg needs to undergo many cell divisions.

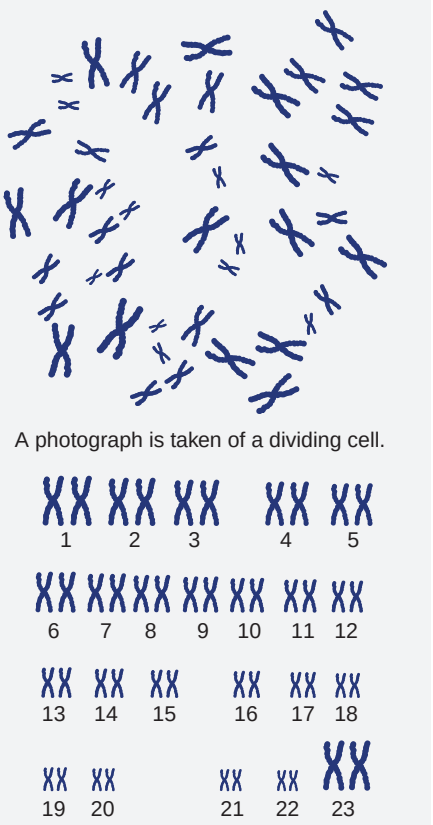
Chromosomes

As we grow, the cells produced by cell division must all contain the same genetic information.

The genetic information of all organisms is contained in chromosomes, made of DNA. The DNA in resting cells is found in the nucleus as long, thin strands. For cell division, these strands form condensed chromosomes.

Human body cells have 46 chromosomes, or 23 pairs. Each chromosome in a pair has the same type of genes along its length.

1. **How many chromosomes are found in human body cells?**
2. **How are the chromosomes arranged in a karyotype?**



A photograph is taken of a dividing cell.

The chromosomes in the photograph are cut out and arranged into pairs.
The pairs are arranged so that Pair 1 has the longest chromosomes; Pair 22 the shortest
Pair 23 is the sex chromosomes.

Figure 1.19 A profile of a set of chromosomes, called a karyotype

Mitosis

New cells have to be produced for growth and development, and to replace worn out and damaged body cells.

When new cells are produced they must be identical to the parent cell. Cells divide to produce two new ones. This type of cell division is called **mitosis**. Two **daughter cells** are produced from the parent cell.

For some cell types, new cells are produced by the division of **stem cells** (discussed later in the chapter).

3. **When are new cells produced?**
4. **In this type of cell division:**
   - **how many chromosomes do daughter cells have?**
   - **how many daughter cells are produced?**

MAKING CONNECTIONS

To come up with a figure for how many cells there are in the human body, scientists must *estimate* the number by adding up cell counts from different organs.

So that the daughter cells produced are identical to the parent cell, the DNA must first copy itself. Each of the 46 chromosomes then consists of two molecules of DNA.

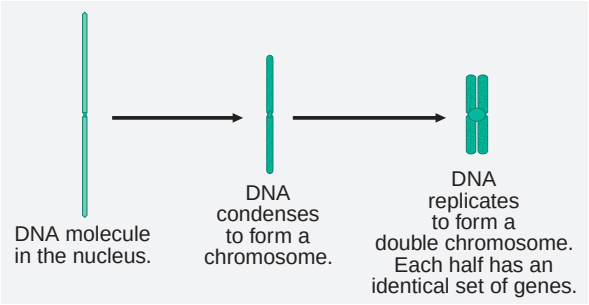


Figure 1.20 It is these 'double' chromosomes that we always see in micrographs or illustrations of chromosomes

DID YOU KNOW?

Using radioactive carbon (^{14}C) dating of a cell's DNA, researchers in Sweden have been able to estimate the lifespan of different types of cells.

During mitosis, the double chromosomes are pulled apart as each new set of 46 chromosomes moves to opposite ends of the cell (Figure 1.21). Two nuclei then form. The cytoplasm and cell membrane then divides and two cells are produced.

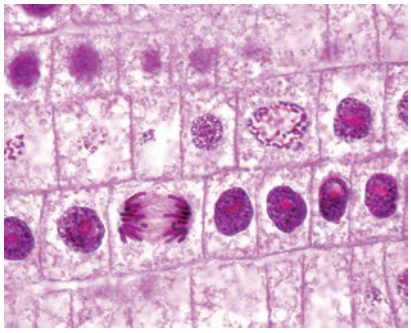


Figure 1.21 Mitosis in an onion cell

5 Why do chromosomes appear double, or X-shaped, in micrographs?

The cell cycle

A cell that is actively dividing goes through a series of stages called the cell cycle. The cycle involves the growth of the cell and the production of new cell components and division.

1. The cell grows. The number of sub-cellular structures, e.g. mitochondria and ribosomes, increases.
2. The DNA replicates.
3. Further growth occurs and the DNA is checked for errors and any repairs made.
4. Mitosis – the chromosomes move apart and two nuclei form.
5. The cytoplasm divides into two and the new cell membrane separates off two new cells.
6. Temporary cell resting period, or the cell no longer divides, e.g. a nerve cell.

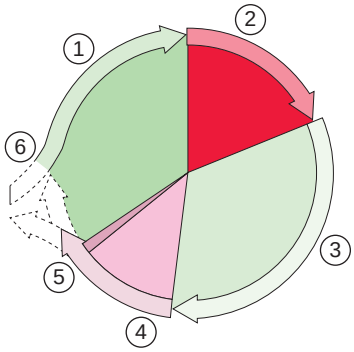


Figure 1.22 The cell cycle
In actively dividing human cells, the whole cell cycle lasts 1 hour

6 Using Figure 1.22, calculate the proportion of the cell cycle spent in mitosis. You will need a protractor.

7 If the cell cycle lasts 2 hours, estimate the time spent in mitosis.

8 Mitosis occurs rapidly in a newly formed fertilised egg. Suggest another situation in the body where you might expect cells to be actively dividing by mitosis.

Cell differentiation

Learning objectives:

- explain the importance of cell differentiation
- describe how cells, tissues, organs and organ systems are organised to make up an organism
- understand size and scale in relation to cells, tissues, organs and organ systems.

KEY WORDS

differentiation
organ
organ system
specialised
tissue

Cell division makes up only part of our growth and development.

For the first four or five days of our lives, the cells produced as the fertilised egg divides are identical. Then, some of our cells start to become specialised to do a particular job.

Figure 1.23 By this stage in its development, this human embryo has developed many of the 200 different cell types in the human body

Cell adaptations

In a multicellular organism, many different types of cell take on different roles to ensure that the organism functions properly and as a whole.

As cells divide, new cells acquire certain features required for their specific function. This is **differentiation**. A cell's size, shape and internal structure are adapted for its role. Most animal cells differentiate at an early stage.

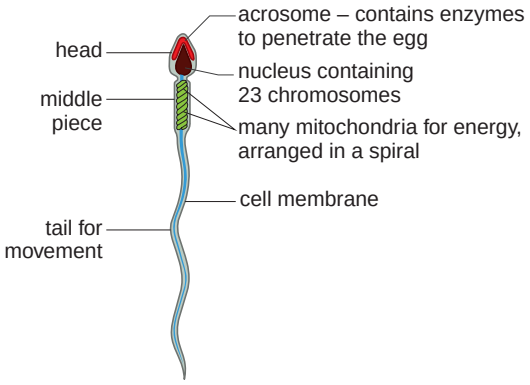


Figure 1.24 The function of a sperm cell is to swim in the female reproductive system with the aim of fertilising an egg. (Cell length 55 µm; width at widest point 3 µm)

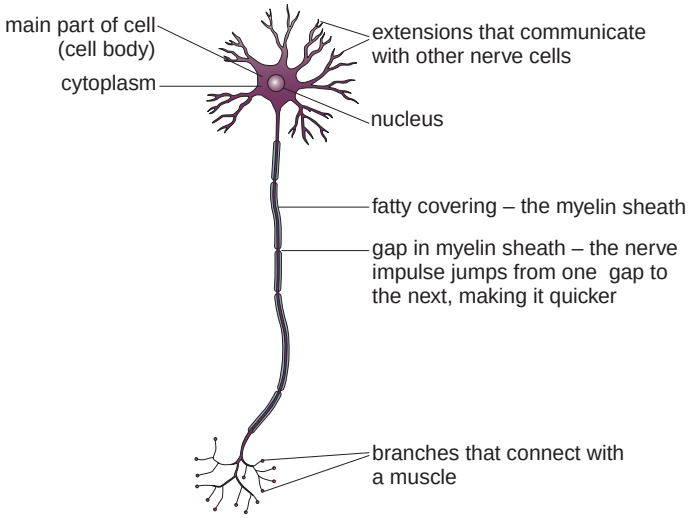


Figure 1.25 Nerve cells carry messages, or electrical impulses, from one part of the body to another. This type of cell brings about movement of the skeleton. (Motor nerve cell length: up to 1 m or more; diameter 1–20 µm)

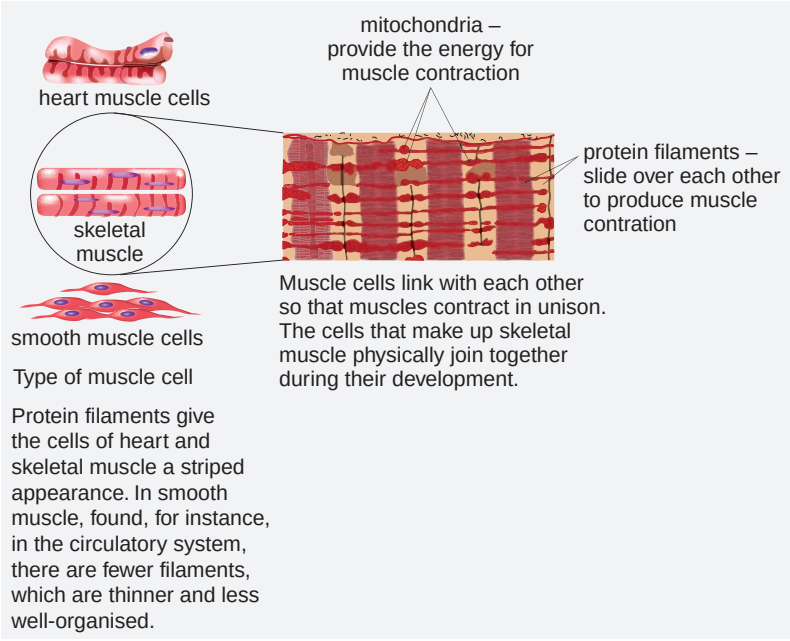


Figure 1.26 Muscle cells contain protein filaments which move as the muscle contracts. (Skeletal muscle length: average 3 cm; maximum 30 cm)

KEY INFORMATION

You can work out how the structure of a cell is related to its function, even if you are not familiar with the type of cell in the question. Look at the size, shape and surface area of the cell, and what it contains, for example mitochondria, ribosomes or a food store.

1. **How are the following cells adapted to their functions:**
   - **a sperm cell**
   - **a muscle cell**
   - **a nerve cell?**
2. **Cells of the pancreas produce the hormone insulin. Insulin is a protein. Suggest how pancreatic cells are adapted for their function.**

Cells, tissues and organs

Some cells work in isolation, like sperm cells. Others are grouped as **tissues** and work together.

A tissue is a group of cells with a particular function. Many tissues have a number of similar types of cell to enable the tissue to function.

Tissues are grouped into **organs**. Organs carry out a specific function.

Different organs are arranged into **organ systems**, for example the circulatory system, digestive system, respiratory system, and reproductive system.

3. **Arrange the following in ascending order of size:**

   system cell human body organ tissue

4. **Name two other types of cell and one other type of tissue in the circulatory system.**
5. **Red blood cells have a biconcave shape which gives them a large surface area. How is this shape related to its function?**

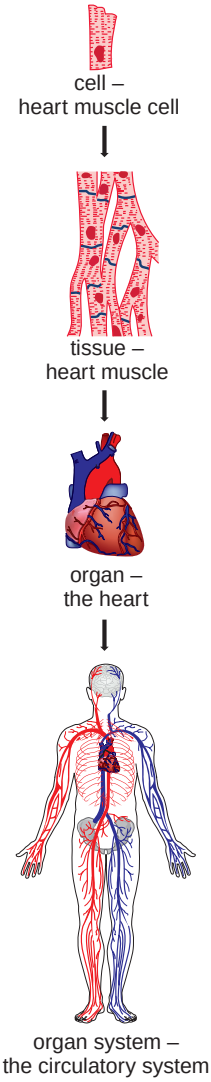


Figure 1.27 The organisation of the human circulatory system

Cancer

KEY WORDS

benign
carcinogen
malignant
mutation
secondary tumour

Learning objectives:

- describe cancer as a condition resulting from changes in cells that lead to their uncontrolled growth, division and spread
- understand some of the risk factors that trigger cells to become cancerous.

Every year, over 300 000 people in the UK are diagnosed with cancer. It is estimated, however, that four in ten cases of cancer could be prevented by lifestyle changes.

Figure 1.28 A CT scanner, used to detect cancer

What is cancer?

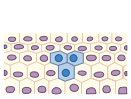
Normally, cells grow and divide by mitosis when the body needs new cells to replace old or damaged cells. When a cell becomes cancerous, it begins to divide uncontrollably. New cells are produced even though the body does not need them.

The extra cells produced form growths called tumours. Most tumours are solid, but cancers of the blood, for instance leukaemia, are an exception.

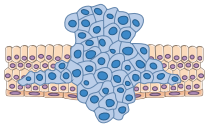
1. **What is cancer?**
2. **Name one type of cancer that does not form a solid tumour.**

Types of tumour

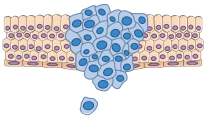
Type of tumour	Characteristics
Benign	• slow growing • often have a capsule around them, so can be removed easily • not cancerous and rarely spread to other parts of the body • they can press on other body organs and look unsightly.
Malignant	• grow faster • can spread throughout other body tissues • as the tumour grows, cancer cells detach and can form **secondary tumours** in other parts of the body.



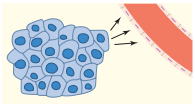
Malignant cells develop.



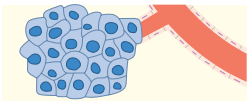
The malignant cells divide and can invade normal tissues.



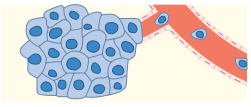
Malignant cells can detach from the tumour and spread to other parts of the body.



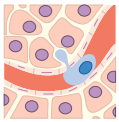
The tumour secretes hormone-like chemicals.



Blood vessels are stimulated to grow around the tumour; the blood vessels supply the tumour with food and oxygen.



Malignant cells detach from the tumour and are transported away in the blood.



The malignant cell squeezes through the capillary wall.

The cell divides to produce a secondary tumour.

Figure 1.29 The growth and spread of a tumour

3. **Name two types of tumour.**
4. **Explain why a tumour needs a blood supply.**
5. **What is the name of the type of tumour formed when a cancer spreads?**

What triggers cancer?

Chemicals and other agents that cause cancer are called **carcinogens**.

Carcinogens cause cancer by damaging DNA. A change in the DNA of a cell is called a **mutation**. Mutations can also occur by chance as a cell is dividing.

There are natural checks for such errors during the cell cycle. Some of our genes suppress developing tumours.

Several mutations, not just one, are necessary to trigger cancer. This is why we are more likely to develop cancer as we get older.

Mutations that lead to cancer can be caused by several agents:

- viruses (see Figure 1.30).
- chemicals in the home, industry or environment
- ionising radiation
- ultraviolet radiation
- lifestyle choices, such as alcohol intake or diet (see Figure 1.31).

DID YOU KNOW?

Many treatments for cancer come from plants, such as the Pacific yew and the Madagascan periwinkle. These drugs work by interfering with mitosis.

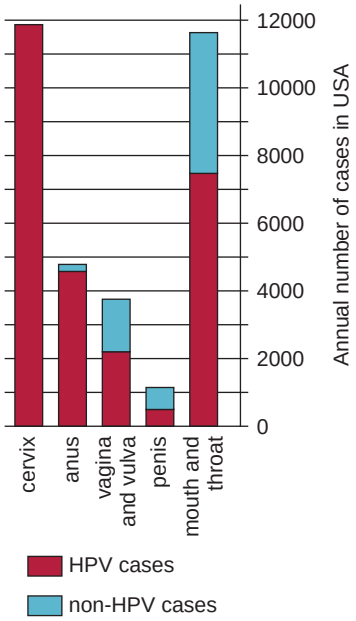


Figure 1.30 Cancers caused by the human papilloma virus (HPV)

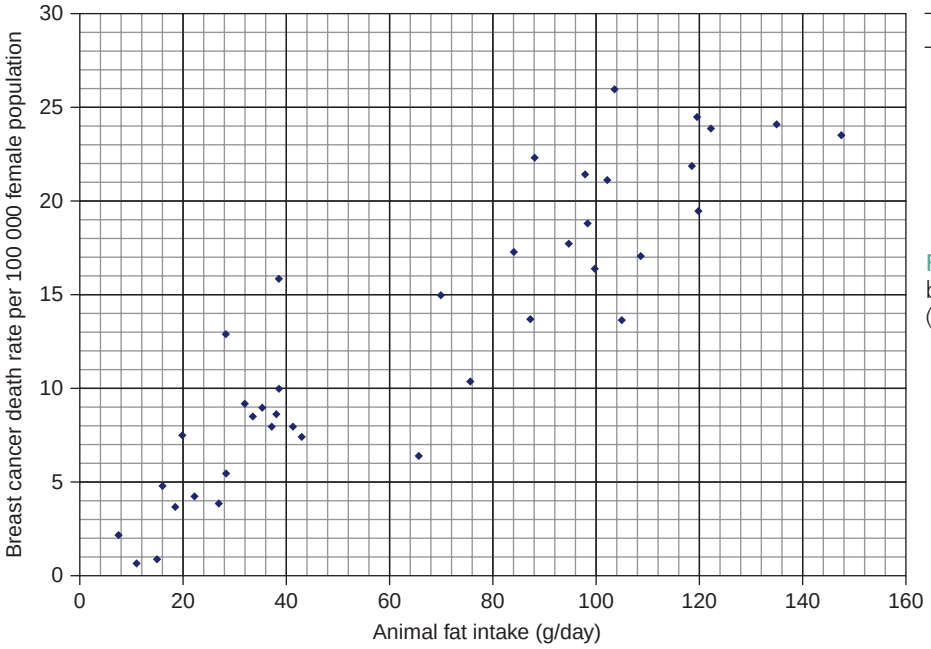


Figure 1.31 Scattergraph showing the correlation between breast cancer deaths and animal fat intake. Each data point represents a different country

6. **Which type of cancer is caused *only* by HPV?**
7. **Describe the pattern shown by the scattergraph and draw a conclusion.**

Stem cells

KEY WORDS

adult stem cell
culture
cell lines
embryonic stem cell
ethical
in-vitro fertilisation

Learning objectives:

- describe the function of stem cells in embryonic and adult animals
- discuss potential benefits and risks associated with the use of stem cells in medicine.

The UK has a shortage of blood donors.

In the summer of 2015 the NHS announced that it planned to start giving people blood transfusions using artificial blood by 2017.

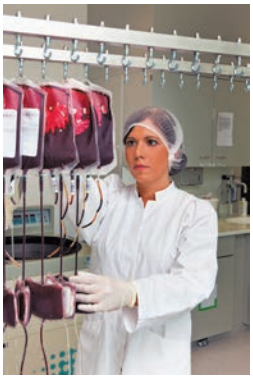


Figure 1.32 The red blood cells in the artificial blood will be produced using stem cells

What are stem cells?

Stem cells are unspecialised cells that can produce many different types of cells.

Stem cells are found in the developing embryo and some remain, at certain locations in our bodies, as adults.

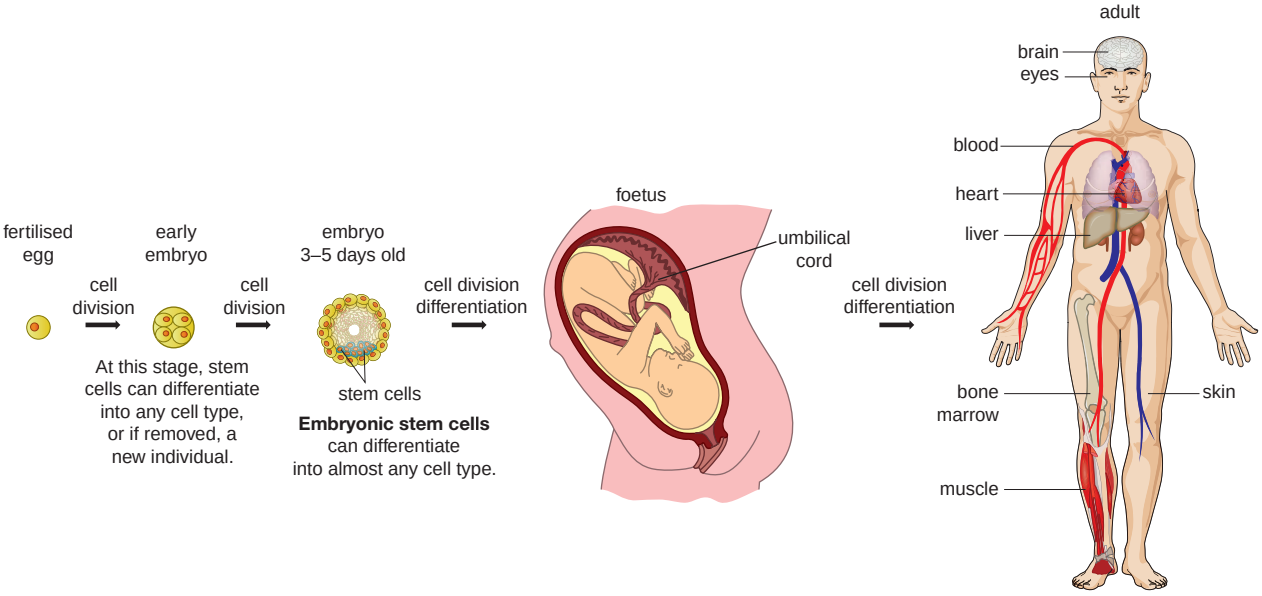


Figure 1.33 Stem cells in the human body

Adult stem cells are rare and found at certain locations only Their role is to replace body cells that die through injury and disease. They can differentiate only into cells from the type of tissue where they are found, e.g. blood, muscle.

1. **What is the function of adult stem cells?**
2. **Which type of stem cell can differentiate into more cell types?**

Stem cell transplants

Transplanting stem cells, or transplants of specialised cells grown from stem cells, could help people with:

- injuries, e.g. spinal injuries leading to paralysis
- conditions in which certain body cells degenerate, e.g. Alzheimer's disease, diabetes and multiple sclerosis
- cancers, or following treatments for cancer such as chemotherapy or radiation, e.g. people with leukaemia.

Stem cell transplants also enable chemotherapy patients, who have had their bone marrow destroyed, to produce red blood cells.

The hope is that we will be able to **culture** stem cells in limitless numbers. Stem **cell lines** produced from patients with rare and complex diseases could transform the health service.

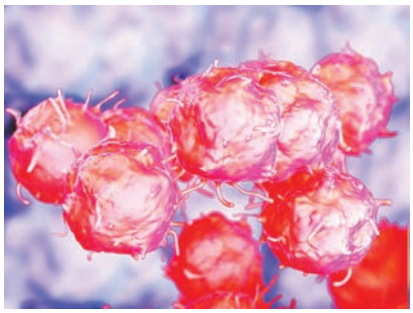


Figure 1.34 Embryonic stem cells

3 **Name two conditions that could be treated with stem cell transplants.**

4 **Why are stem cell transplants important for people who have had chemotherapy?**

Stem cell research and therapy is controversial

Stem cell research is necessary to find out more about stem cell development, and the best types to use in treatments.

The use of **embryonic stem cells**, which are removed from a living human embryo, is especially controversial.

Until recently, the embryos providing the stem cells were usually those left over from fertility treatments involving ***in-vitro*** **fertilisation** (IVF). Spare embryos would be destroyed if they had not been donated by the IVF couples for research.

British law now allows embryos to be created purely for scientific research. Some people object to this. Some religious beliefs argue that new life begins at the point of conception, so an embryo has rights. And who should decide when a human life ends?

These are moral and **ethical** questions. A moral question looks at whether something is right or wrong. An ethical question discusses the reasons why something might be right or wrong.

5 **Why do some people object to stem cell transplants?**

6 **Write down one ethical objection to stem cell research.**

7 **What are the potential benefits and drawbacks of using stem cells in medicine?**

DID YOU KNOW?

Stem cell transplants are not new. Transplants of bone marrow, which contain stem cells, have been carried out since 1968. But there are very few stem cells in bone marrow (only 1 in 10 000 bone marrow cells). We currently isolate these from blood, rather than bone marrow.

KEY INFORMATION

Current potential for adult stem cell use in therapies is restricted to certain cell lines, but it may be greater than once thought. Scientists are trying to induce them to differentiate into a wider range of tissues, a process called transdifferentiation.

Stem cell banks

Learning objectives:

- discuss potential benefits and risks associated with the use of stem cells in medicine.

KEY WORDS

donor
gene
mutation
therapeutic cloning
umbilical cord

Scientists predict that, in the future, vast banks of stored stem cells will be available to treat many medical conditions.

Figure 1.35 Stem cells can be stored in liquid nitrogen

Rejection of stem cell transplants

The stem cells from a bank originate from many different people. Rejection of stem cell transplants by a patient's immune system is, therefore, a problem.

One current solution is to find as close a match as possible between **donor** and patient cells. Another is to give the patient drugs to suppress their immune system. Scientists are looking for other ways to avoid transplant rejection.

One possible source of stem cells is blood left in the **umbilical cord** and placenta after a baby is born. Cord blood is easy to collect and store.

1. **Suggest sources of stem cells that would give the best match between donor and patient.**
2. **Suggest some possible advantages and disadvantages of having a baby's blood stored to treat possible disease or injury in later life.**

Therapeutic cloning

The idea of **therapeutic cloning** is to produce stem cells with the same **genes** as the patient. They would not be rejected by the patient's immune system.

The process involves nuclear transfer. The nucleus of a body cell from the patient is transferred to an egg cell that has had its nucleus removed.

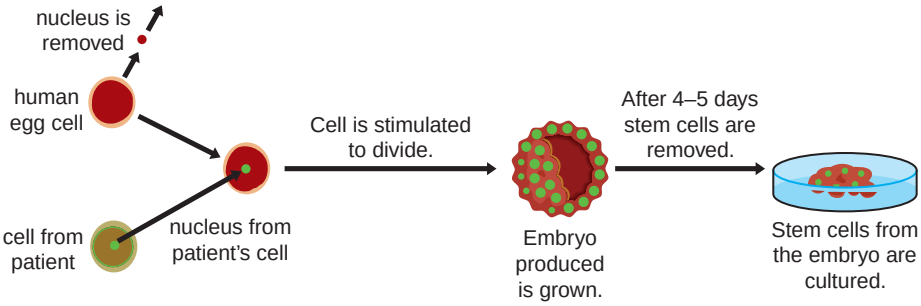


Figure 1.36 Therapeutic cloning

The stem cells are used to treat the patient. The embryo is discarded.

3 **What is therapeutic cloning?**

4 **When are stem cells removed from the embryo?**

Scientific, ethical and social questions

Many questions arise from therapeutic cloning and stem cell therapy.

The first scientific question is how successful might these therapies be? Others consider safety: stem cells kept in culture can show similarities to cancer cells. After about 60 cell divisions, **mutations** have been observed. It is also possible for viruses to be transferred with stem cells, leading to infection.

There are also ethical questions:

- Is it morally right to create an embryo with the intent of destroying it?
- Could an embryo simply become a resource for researchers?

There are also important social questions. What are the potential benefits from successful stem cell treatment and do these outweigh the objections? Public education on this issue is important.

There is no evidence that human embryos have, so far, been produced for therapeutic cloning.

5 **Give two questions scientists might have about therapeutic cloning.**

6 **Evaluate the risks and benefits as well as the ethical concerns associated with therapeutic cloning.**

DID YOU KNOW?

Scientists have succeeded in removing human skin cells and reprogramming them to become cells similar to embryonic stem cells. This removes some of the ethical concerns over stem cell transplants.

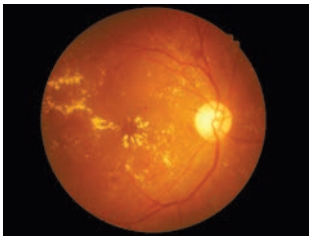


Figure 1.37 Blind patients have had their sight restored by stem cells. It has been possible to safely treat the part of the eye responsible for central vision

MAKING CONNECTIONS

You should be able to evaluate information from a variety of sources regarding practical, social and ethical issues relating to stem cell research and treatment.

Cell development

Learning objectives:

- give examples of where mitosis is necessary to produce identical daughter cells
- understand the need for the reduction decision, meiosis
- describe the use and potential of cloned cells in biological research.

KEY WORDS

asexual reproduction
differentiation
gamete
meiosis
mitosis
placenta
zygote

Cell development involves the processes of cell growth, division and differentiation. These processes are closely linked, and are a key focus for current biological research.

Cells

The cell is the basic unit of life. You will have looked at cells with a microscope in school, probably cheek cells and onion skin cells. These illustrate the basic cell pattern, but most cells in all but the simplest of organisms are much more varied in their structure.

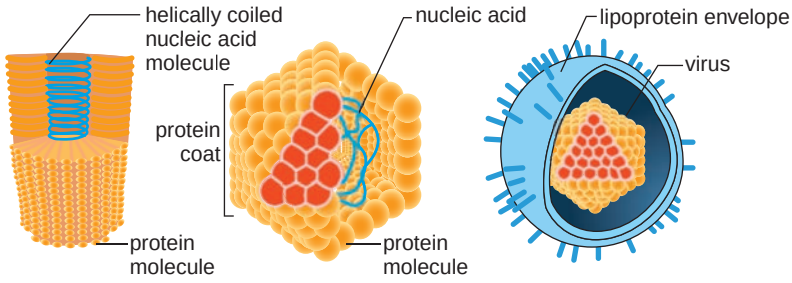


Figure 1.38 Viruses are not made up of cells. They consist simply of nucleic acid surrounded by a protein coat. Some have an outer envelope.

1. **Name one example of a human tissue where cells have merged.**
2. **Suggest why viruses can only live in other cells.**

Cell division

Human life begins as a fertilised egg cell, or **zygote.** This cell develops into an adult with trillions of cells. As new cell components are added, and the cell reaches a certain size, it divides by **mitosis**. Mitosis occurs in several other situations:

- to replace cells when they die or become damaged

- when single-celled, eukaryotic organisms reproduce by **asexual reproduction**, for example yeast
- when cancer cells divide
- when eukaryotic cells are cloned.

When an organism reproduces sexually, the sex cells, or **gametes**, cannot be produced by mitosis. If they were, the number of chromosomes in our cells would double every generation! We need another type of cell division, called **meiosis**.

3 **Give three examples of situations in which mitosis occurs.**

4 **Name one type of cell that does *not* divide by mitosis.**

Cell differentiation

Cells must become specialised for the development of complex, multicellular organisms.

Cells that can differentiate into other cell types are called stem cells. Embryonic stem cells, found after four to five days, can develop into *almost* any cell type. We can't say *'all'*, as they can't develop into cells of the **placenta**.

Stem cells have the potential to produce an unlimited amount of tissue for transplants. They are also important in medical research such as on how cells differentiate, and in the testing of drugs.

Stem cell research and treatments will require the cloning of cells. Some people object to the idea of these techniques for moral and ethical reasons.

Cancer cells divide uncontrollably by mitosis and do not differentiate into mature, specialised cells. Cancer cells early in the development of the disease can look almost normal, but in advanced cancers, differentiation in most cells is very limited.

5 **Why are some news articles that suggest that embryonic stem cells can differentiate into all cell types, strictly speaking, incorrect?**

6 **Stem cells are being used to test new drugs. What are the advantages of using human stem cells over using rats to test drugs?**

KEY SKILLS

For each chapter in the book, map out how different concepts you have learnt link with each other. Use a large sheet of paper or computer software.

Cells at work

Learning objectives:

- explain the need for energy
- describe aerobic respiration as an exothermic reaction.

KEY WORDS

active transport
aerobic respiration
exothermic respiration

This runner is using energy to run a marathon. But we all need a continuous supply of energy – 24 hours a day – just to stay alive.

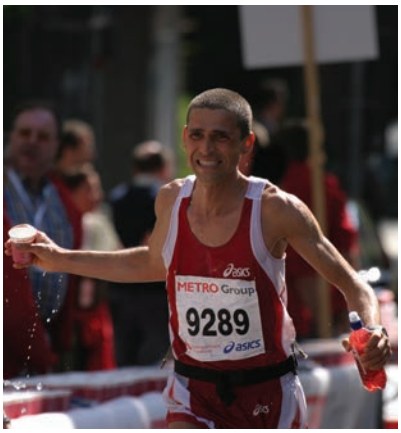


Figure 1.39 An average runner uses around 13 000 kJ of energy for a marathon

We need energy to live

Organisms need energy:

- to drive the chemical reactions needed to keep them alive, including building large molecules
- for movement.

Energy is needed to make our muscles contract and to keep our bodies warm. It's also needed to transport substances around the bodies of animals and plants.

In other sections of the book, you will also find out that energy is needed:

- for cell division
- to maintain a constant environment within our bodies
- for **active transport**. Plants use active transport to take up mineral ions from the soil, and to open and close their stomata
- to transmit nerve impulses.

1. **List four uses of energy in animals.**
2. **List four uses of energy in plants.**

Aerobic respiration

Respiration is the process used by all organisms to release the energy they need from food.

Respiration using oxygen is called **aerobic respiration**. This type of respiration takes place in animal and plant cells, and in many microorganisms.

Glucose is a simple sugar. It is the starting point of respiration in most organisms. The food that organisms take in is, therefore, converted into glucose.

This chemical reaction is **exothermic**. A reaction is described as exothermic when it releases energy. Some of the energy transferred is released as heat.

Figure 1.40 Birds and mammals use heat energy to maintain a constant body temperature

3 **What is the purpose of respiration?**

4 **How do birds and mammals make use of the waste heat energy?**

Bioenergetics

This is the equation for aerobic respiration:

glucose + oxygen → carbon dioxide + water (energy released)

$C_6H_{12}O_6$ O_2 CO_2 H_2O

This equation describes the overall change brought about through each of a series of chemical reactions. A small amount of energy is actually released at each stage in the series.

The first group of steps occurs in the cytoplasm of cells, but most of the energy is transferred by chemical reactions in mitochondria.

5 **When and where does respiration occur?**

6 **Give one characteristic feature of actively respiring cells.**

7 **Why do we often get hot when we exercise?**

Figure 1.41 Insect flight muscles have huge numbers of well-developed mitochondria

DID YOU KNOW?

The muscle an insect uses to fly is the most active tissue found in nature.

COMMON MISCONCEPTIONS

Don't forget that *all* organisms respire. The equation is the reverse of photosynthesis, but don't confuse the two. Photosynthesis is the way in which plants make their food.

Living without oxygen

KEY WORDS

anaerobic
respiration
fermentation

Learning objectives:

- describe the process of anaerobic respiration
- compare the processes of aerobic and anaerobic respiration.

Stewart is a brewer. He adds yeast to a mixture of malted barley and hops in water.

Figure 1.42 Yeast converts sugar into alcohol, or ethanol. The process is completed in around 3 days

Anaerobic respiration

The yeast respires using the sugary liquid. The yeast cells divide rapidly. After a few hours there are so many yeast cells that the oxygen runs out. The yeast is able to switch its respiration so that it can obtain energy *without* oxygen. Many microbes such as yeast can respire successfully without oxygen.

This is **anaerobic respiration** – respiration without oxygen.

Anaerobic respiration in yeast cells and certain other microorganisms is called **fermentation**.

Anaerobic respiration occurs in the cytoplasm of cells.

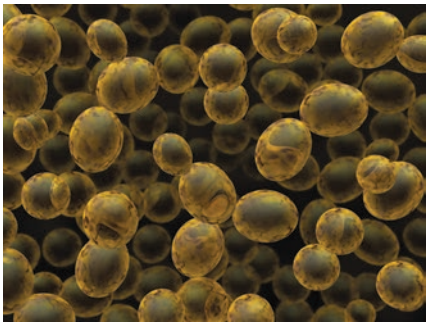


Figure 1.43 Yeast cells divide rapidly by mitosis. Many of the cells do not separate from each other

1. **What is meant by anaerobic respiration?**
2. **Why do yeast cells switch from aerobic to anaerobic respiration in the process of making ethanol?**

Baking

Yeast is also used in baking bread. Yeast is mixed with flour and some sugar. The ingredients are mixed together thoroughly and the dough is left to rise before baking it.

Figure 1.44 Dough is kneaded to mix the ingredients

3. **Explain why sugar is added to dough.**
4. **Why does the dough rise?**
5. **What happens to the alcohol made during bread production?**

The biochemistry of fermentation

The equation for fermentation is:

glucose → ethanol + carbon dioxide (energy released)

Anaerobic respiration is much less efficient than aerobic respiration. It produces only around a nineteenth as much energy. But in situations where there's little oxygen, it means that cells can stay alive, and the amount of energy produced is still enough to keep single cells running.

Certain plant cells can also use alcoholic fermentation to obtain their energy. These include plants that grow in marshes, where oxygen is in short supply. Pollen grains can also respire anaerobically.

Without oxygen, we would die. But when actively contracting, our muscles run short of oxygen. They are able to respire anaerobically for short periods of time. Lactic acid, and not ethanol, is produced.

glucose → lactic acid (energy released)

6. **Explain why it is helpful for pollen grains to respire anaerobically.**
7. **Write down the equation for fermentation.**
8. **For anaerobic respiration in muscle:**
   - **write down the word equation**
   - **work out the symbol equation.**
9. **Compare the reactants, products and the amount of energy produced for anaerobic respiration with those for aerobic respiration.**

DID YOU KNOW?

Yeast is unable to use the starch in barley for respiration. Maltsters germinate the barley grains first to break down the starch into sugar.

KEY SKILLS

You must be able to compare aerobic and anaerobic respiration: the need for oxygen, the products and the amount of energy transferred.

Growing microorganisms

Learning objectives:

- describe the techniques used to produce uncontaminated cultures of microorganisms
- describe how bacteria reproduce by binary fission
- calculate the number of bacteria in a population.

KEY WORDS

agar plate
autoclave
bacteria
bacterial growth curve
binary fission
colony
culture
culture medium
inoculating loop
nutrient broth
sterilise

We're most familiar with bacteria through the tiny minority of species that cause disease.

But harmless bacteria help us to live healthily. In our digestive system, they prevent harmful bacteria from gaining a foothold in our bodies and also produce essential nutrients.

Culturing bacteria

Owing to their size, it's best to grow bacteria in large numbers to study them. **Bacteria** are grown in **culture**, in or on a **culture medium**.

The culture medium is a liquid, such as **nutrient broth**, or a gel called agar. Different nutrients can be added to the agar. Because it's a gel, the agar contains the water required for the bacteria to grow.

All the equipment used must be **sterilised**. To make sure cultures and samples are *kept* uncontaminated by other microorganisms, and do not contaminate the environment:

- The inoculating loop must be sterilised by passing it through a Bunsen flame before and after use.
- The lid of the **agar plate** must be secured, but *not* sealed using adhesive tape.

After an investigation, agar plates are sterilised in an **autoclave** before disposal.

1. **Explain why scientists need to work with uncontaminated cultures.**
2. **What piece of equipment is used to transfer bacteria from a culture to an agar plate?**

Figure 1.45 Bacteria, or a sample under test, are transferred to an agar plate using a sterilised **inoculating loop**. After setting up the culture, the agar plates are incubated at a temperature appropriate for the bacteria to grow. Plates are incubated upside down

REMEMBER!

Cultures used for research must be kept pure. It's usual to work with one bacterium at a time. Samples must not be exposed to microorganisms in the environment, or valid conclusions cannot be drawn.

Quantitative studies with microorganisms

When supplied with nutrients and a suitable temperature, bacteria will multiply. They do this by dividing into two. The process is called **binary fission**. This is not the same as mitosis in eukaryotic cells. Binary fission involves prokaryotes with a single chromosome.

A live bacterium landing on the surface of agar will divide repeatedly to form a **colony**. A colony contains millions of bacteria.

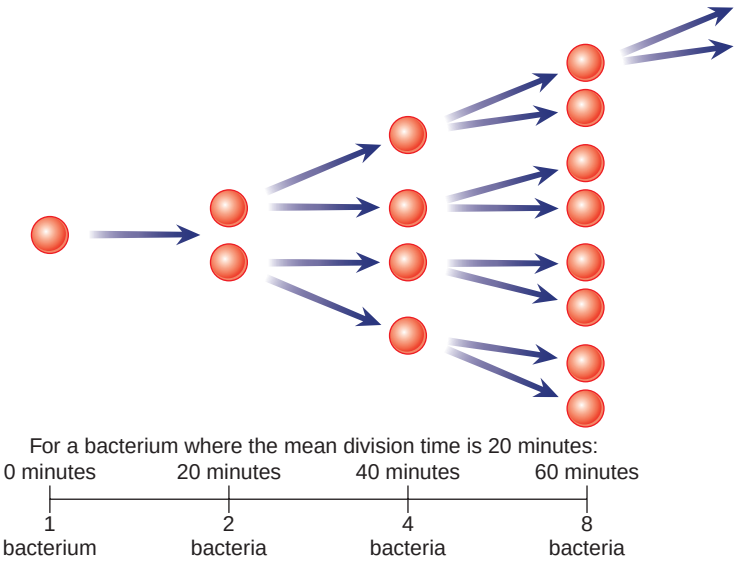


Figure 1.46 Binary fission of a bacterium

DID YOU KNOW?

The Human Microbiome Project is cataloguing the genes of the microorganism population in our intestines. There are 100 times the number of species originally thought to be present.

3. **A bacterium has a mean division time of 20 minutes. Starting with one bacterium, how long would it take to produce a million bacteria?**

4. **If the mean mass of a bacterium is 1×10^{-12} g, estimate the mass of bacteria produced in Question 3. Suggest why the true mass is likely to be lower.**

Bacterial growth curves

With the optimum conditions, some bacteria can divide into two as often as every 20 minutes. Estimates of cells in culture are plotted to produce a **bacterial growth curve**.

Values on the *y*-axis are the *logarithms* of the numbers in the population. Otherwise, the range of numbers would be too large to fit appropriately onto the scale.

After a certain time, the culture may reach its stationary phase. Binary fission slows as food begins to run out and waste products build up.

5. **What is meant by exponential growth? Name a process which causes exponential growth.**

6. **Some cultures enter a *death phase*. Suggest the possible causes.**

7. **Predict what would happen if you introduced more food during the stationary phase.**

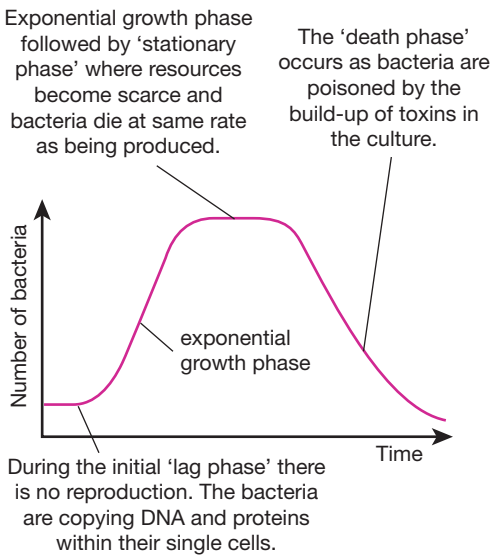


Figure 1.47 The growth curve of a bacterium

Testing new antibiotics

KEY WORDS

antibiotic
pathogen
sampling techniques

Learning objectives:

- use appropriate apparatus to investigate the effect of antibiotics on bacterial growth
- use microorganisms safely
- apply sampling techniques to ensure that samples are representative.

Bacteria are becoming resistant to antibiotics. A 2015 government report suggested that by 2050, 10 million people worldwide may die every year from diseases we can no longer cure.

Scientists are looking for new antibiotics to treat antibiotic-resistant bacteria.

Antibiotic sensitivity testing

The method used to test the effectiveness of an **antibiotic** is the disc-diffusion technique.

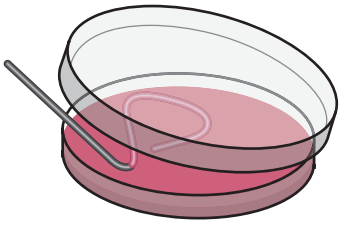


Figure 1.48 An agar plate is inoculated with the bacterium being tested and spread evenly across the plate. It is not incubated at this stage

A disc of filter paper is impregnated with the antibiotic. Several concentrations of the antibiotic are tested.

You can do this in the school lab by immersing the filter paper disc in a solution of the antibiotic, and allowing the antibiotic to drain off.

The disc is placed on the surface of an agar plate containing the bacterium being tested.

1. **The metal spreader is heated in a Bunsen flame before use and allowed to cool before spreading the bacteria. Suggest why.**
2. **When setting up the agar plate, explain why it is inoculated but not incubated.**

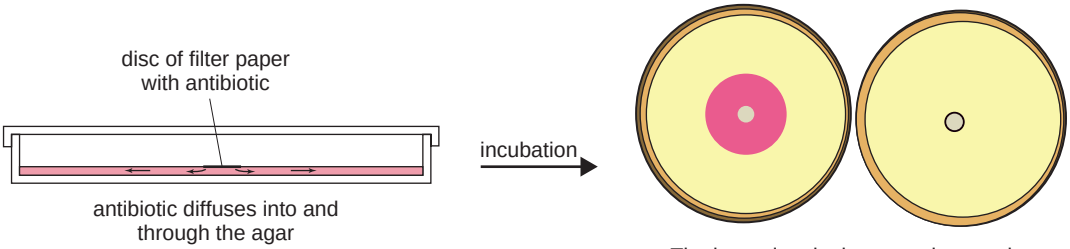


Figure 1.49 The larger the clear area, the more effective the antibiotic

Selecting the most appropriate apparatus and techniques

The apparatus and **sampling techniques** a professional scientist would use to carry out this investigation are almost identical to those you would use. However, there are two important differences:

- The standard medium for testing antibiotics is Mueller–Hinton agar, often with added blood. It contains beef and milk protein and is ideal for culturing human **pathogens**.
- Agar plates are incubated at 37°C – human body temperature. Samples in school must never be incubated above 25°C because of the risk of growing pathogens.

Figure 1.50 The sample of *Staphylococcus aureus* transferred for testing must be from a colony that looks identical to others on the plate

3 **Name three ingredients of Mueller–Hinton agar.**

4 **Suggest why scientists use no more than 12 discs per plate.**

Ensuring the investigation is valid

One of the most dangerous bacteria showing antibiotic resistance is methicillin-resistant *Staphylococcus aureus* (MRSA). A sample of bacteria for testing must be *representative* of the population of bacteria.

If the bacteria are spread appropriately, the clear zones will be uniformly circular and there will be continuous growth of bacteria across the remainder of the plate. Measurements are made with a ruler or callipers. Any plates where zones are not circular, or where there is poor growth of the bacterium, should be discarded.

5 **What is meant by a representative sample? Why is it important that the sample is representative?**

6 **How is a representative sample of the bacterial culture taken?**

7 **Why is MRSA considered such a dangerous bacteria?**

REMEMBER!

You should be able to describe the apparatus and techniques used when testing the effects of antibiotics, antiseptics and disinfectants.

DID YOU KNOW?

Two main strains of MRSA have caused problems in British hospitals since the 1990s. EMRSA16 is the most common form.

REQUIRED PRACTICAL

Investigating disinfectants

KEY WORDS

antiseptic
diffusion
incubation

Learning objectives:

- carry out experiments with due regard to health and safety
- present and process data, identifying anomalous results
- evaluate methods and suggest further investigations.

For use in a hospital, choosing the right disinfectant or antiseptic to achieve the appropriate hygiene levels is essential. The correct dilution is also important: a concentration high enough to work, but not so high as to be wasteful.

These pages are designed to help you think about aspects of the investigation rather than to guide you through it step by step.

Setting up a disc-diffusion investigation

Scientists need a number of different skills to carry out this investigation. This section looks at some of those skills.

The method used to test the effectiveness of a disinfectant (or an **antiseptic** or antibiotic) is the disc-**diffusion** technique.

In this experiment, different concentrations of the disinfectant sodium hypochlorite are investigated.

1. **In the investigation, which is the independent variable and which is the dependent variable?**
2. **Suggest the other possible variables that need to be controlled.**

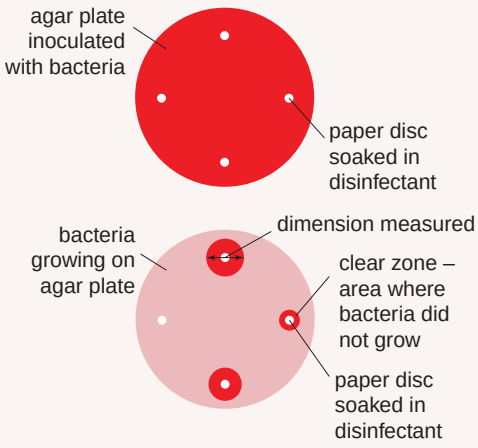


Figure 1.51 Disc-diffusion technique

Health and safety

Before scientists can begin a disc-diffusion investigation, they must carry out a risk assessment.

Hazard	Type of hazard	Risk	Safety precautions
Ethanol			
Sodium hypochlorite			
Bacteria			
Agar plate			
Add more rows to include the activities involved, e.g. flaming an inoculating loop.			

3. **Complete the risk assessment table.**
4. **Suggest why:**
   - **scientists would use Mueller–Hinton blood agar; in the school lab, you would use nutrient agar**
   - **you would incubate the plate at 25°C; the scientists at 37°C.**

Presenting and processing data

The agar plates are **incubated**, and the clear zones measured. Scientists need to analyse the data they have collected:

Concentration of sodium hypochlorite (g/dm³)	Area of clear zone around disc (mm²)			Mean area of clear zone around disc (mm²)
	Test 1	Test 2	Test 3	
0.0	0	0	0	0
0.5	0	0	0	0
1.0	32	31	34	32
1.5	91	89	91	90
2.0	470	381	379	380
2.5	499	505	497	
3.0	546	552	551	
3.5	575	568	567	
4.0	578	582	580	
4.5	580	580	580	
5.0	579	578	583	

5. **How is the area of a clear zone calculated? Hint: you need to recall a formula.**
6. **Complete the table by calculating the mean area of the clear zones.**
7. **Identify the anomalous result. How did you recognise it?**
8. **Which set of results has the highest degree of repeatability?**
9. **Plot a graph of area of clear zone against concentration.**

REMEMBER!

The area of a circle can be calculated using the formula:
area = πr^2
where *r* is the radius, the distance from the centre to the edge of the circle.

Evaluating the investigation

The experiment's aim was to find out the concentration of disinfectant that would be best for a hospital to use against the bacterium *Staphylococcus aureus*.

10. **Do you have all the information needed to draw a full conclusion, or should the scientists collect more information? Use your graph to help you make your recommendation.**
11. **We know that in the clear zone, bacteria do not grow. But we do not know if they have been killed, or just prevented from growing. Suggest a follow-up investigation.**

KEY SKILLS

In a risk assessment, you should group hazards into categories: organisms, chemicals, physical hazards and practical activities. Use the correct terminology for the type of hazard (for example, biohazard, irritant, oxidising). Think about the concentration of chemicals used. Don't forget the hazards and risks before and after the experiment, for example, the agar plate after incubation.

MATHS SKILLS

Size and number

Learning objectives:

- make estimates for simple calculations, without using a calculator
- be able to to use ratio and proportion to calibrate a microscope
- recognise and use numbers in decimal and standard form.

KEY WORDS

calibrate
graticule
haemocytometer
standard form

The size of structures is important in biology, from whole organisms to molecules.

Estimating cell size

Accurate measurements are often essential. But estimating cell size or number is sometimes sufficient and may be quicker.

To estimate cell size, we can count the number of cells that fit across a microscope's field of view.

$$\text{Size of one cell} = \frac{\text{diameter of field of view}}{\text{number of cells that cross this diameter}}$$

If the field of view of this microscope, at this magnification, is 0.3 mm, or 300 µm, we can do a quick calculation without a calculator.

Each cell must be roughly (300 ÷ 5) µm, or 60 µm across. This is an approximation, but could be important.

1. **Suggest how to estimate the field of view of a microscope.**
2. **State one advantage of estimating cell size over exact measurement.**

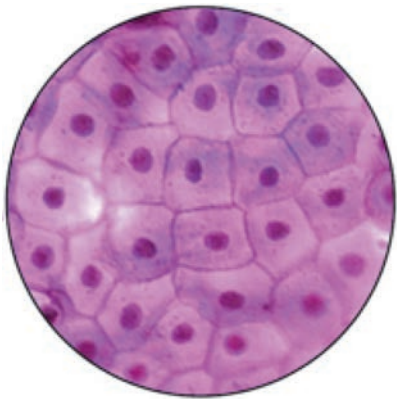


Figure 1.52: In this image, *approximately* five cells fit across the field of view. We round numbers up or down to make calculations straightforward.

DID YOU KNOW?

Scientists *estimate* cell or organism numbers when it is impossible or unnecessary to count them all.

Measuring cell size

To make accurate measurements of cell size a scientist **calibrates** their microscope. A **graticule** – piece of glass or plastic onto which a scale has been drawn – is placed into the eyepiece of the microscope.

A stage micrometer is placed on the microscope stage. This is simply a microscope slide onto which an accurate scale has been etched.

In Figure 1.53, 36 divisions on the eyepiece graticule are equivalent to 100 µm on the stage micrometer:
1 division is equivalent to $\frac{1}{36} \times 100\ \mu m = 2.8\ \mu m$

The cell highlighted in the right-hand diagram is 20 eyepiece divisions across: the width of the cell = (20 x 2.8) µm = 56 µm.

REMEMBER!

The digital point remains fixed. It is the digits that move as a number is multiplied or divided by powers of 10. So, as a number gets larger, the digits move to the left (and vice versa).

3. **What would be the diameter of a cell that was 65 divisions on this graticule?**

4. **How many graticule divisions would a cell that was 35 µm across take up?**

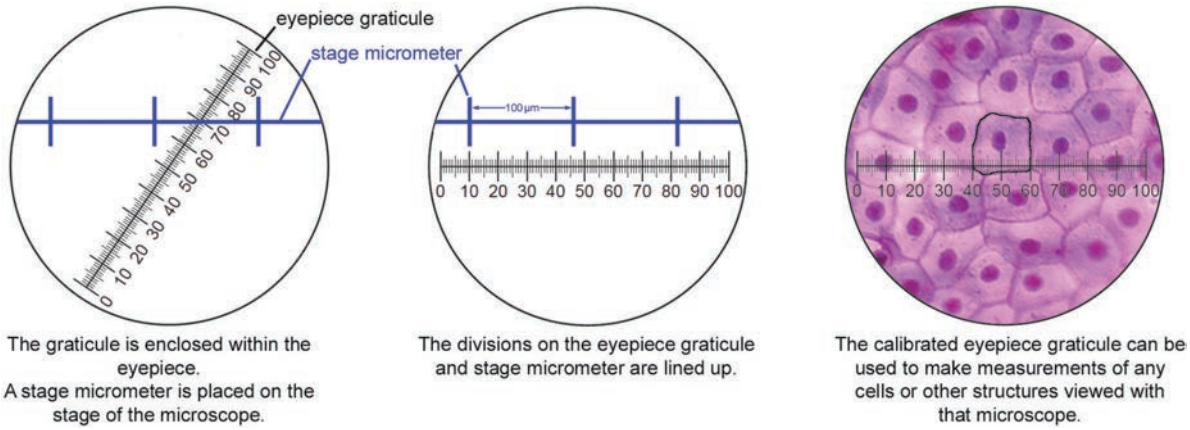


Figure 1.53: Calibrating, then using an eyepiece graticule.

Numbers written in standard form

When writing and working with very large or very small numbers, it is convenient to use **standard form**. Standard form shows the magnitude of numbers as powers of ten.

Standard form numbers are written as: $A \times 10^n$

where: A is a number greater than 1 but less than 10. This could be decimal number such as A = 3.75, as well as an integer number such as A = 7.
n is the index or power.

We use standard form with large numbers, small numbers and calculations. In standard form:

- when multiplying: multiply numbers and add powers (see example in Figure 1.54).
- when dividing: divide numbers and subtract powers.

Blood cell type	Width of an average cell (m)
Lymphocyte (small)	7.5×10^{-6}
Macrophage	5.0×10^{-5}
Megakaryocyte	1.5×10^{-4}
Neutrophil	1.2×10^{-5}

The sizes of different types of blood cell, written in standard form.

5. **Look at the table of cell sizes. Arrange the cell types in descending order of size.**

6. **How many times larger is a megakaryocyte than a lymphocyte?**

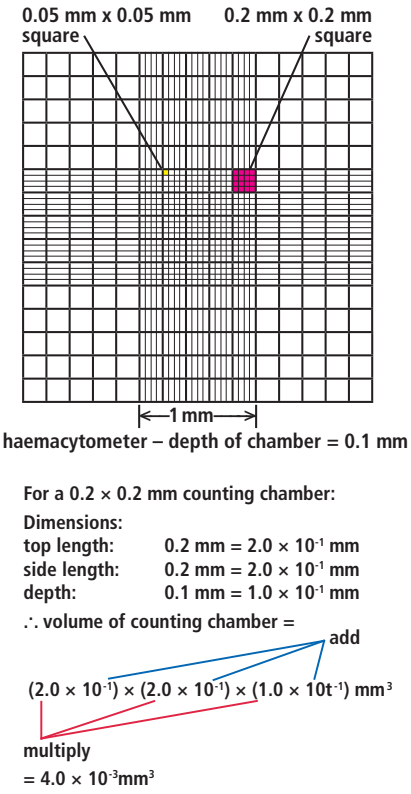


Figure 1.54: Calculating the volume of a counting chamber. The counting chamber is a hollow on a microscope slide which holds a set volume of a fluid. It has a grid ruled onto it, and a depth of 0.1 mm. The number of cells in a given volume can be calculated.

Check your progress

You should be able to:

☐ describe the functions of the sub-cellular structures found in eukaryotic cells →	☐ understand the size and scale of cells and be able to use and convert units →	☐ carry out order of magnitude calculations when comparing cell size; calculate with numbers in standard form
☐ calculate magnification used by a light microscope using eyepiece and objective lens magnifications →	☐ calculate the magnification of a light or electron micrograph →	☐ explain limitations of light microscopy and advantages of electron microscopy
☐ describe the structure of a prokaryotic cell →	☐ describe the differences between eukaryotic and prokaryotic cells →	☐ explain why scientists have now separated organisms into three domains using evidence from chemical analysis
☐ recall that cells must divide for growth and replacement of cells →	☐ describe how chromosomes double their DNA and are pulled to opposite ends of the cell, before the cytoplasm divides, during mitosis →	☐ describe the events of the cell cycle and explain the synthesis of new sub-cellular components and DNA
☐ recall that organism development is based on cell division and cell specialisation →	☐ explain the importance of differentiation and explain how cells are specialised for their functions →	☐ understand size and scale in the components of organ systems
☐ recall where stem cells are found →	☐ understand the potential of stem cell therapies →	☐ evaluate scientific and ethical issues involved with stem cell therapies
☐ recall that organisms can respire with oxygen (aerobic respiration) or without oxygen (anaerobic respiration) →	☐ use word equations to describe the processes of aerobic and anaerobic respiration →	☐ use symbol equations for aerobic and anaerobic respiration and be able to compare the two processes
☐ describe equipment, materials and procedures required to work with microorganisms →	☐ describe the process of binary fission →	☐ be able to calculate numbers of microorganisms produced given the mean generation time

Worked example

Some students see a newspaper article on a European stem cell clinic. The clinic uses stem cell therapy to treat diabetes and other conditions.

1 **What is a stem cell?**

An unspecialised cell that can differentiate, or can be made to differentiate, into many different cell types.

The part about differentiation is important.

2 **The article contains some information on the clinic's treatment of diabetes.**

It includes data on the 55 patients the clinic has treated so far, which it claims is a success.

Type of diabetes	One month after treatment, number of patients who…		
	showed an improvement	showed no change	became worse
Type 1	8	13	2
Type 2	20	9	3
Total	28	22	5

a **Calculate the overall percentage of patients who:**

- showed an improvement *50.9%*
- showed no change *40%*
- became worse *9.1%*

The calculations are correct.

The answers have not been recorded consistently, however. Think about significant figures. All the numbers in the table have a maximum of two figures, so you cannot have more in the answer.

b **Does the data support the newspaper article's claims? Explain your answer.**

My percentages show there is no difference between the overall percentage of patients who showed an improvement and those who did not.

The article is certainly untrue for Type 1 diabetes, where only 34.8% improved.

It might be true for Type 2, because 62.5% improved.

The answer draws correct conclusions from the table and uses data to support these.

With the small number of patients (23 for Type 1; 32 for Type 2), we cannot draw any firm conclusions from the small differences in numbers. Sample size is important in any scientific study.

The heading of the table says 'one month after treatment…'. This may be too early to draw any conclusions. Also, the patients may believe they feel better because they've had treatment. Importantly, we do not know how the 'improvement' was judged, another point to make in your answer.

You will notice that this question draws on your knowledge of scientific methods as well as stem cells.

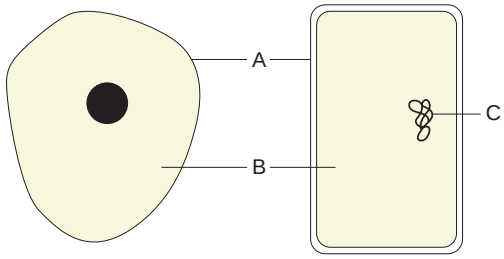
You may also have to use relevant knowledge from another topic.

When you've learnt about diabetes, you will be aware that Type 2 diabetes can usually be controlled by diet and exercise, so the 'improvements' suggested by the data may be the result of this.

End of chapter questions

Getting started

1 **The diagrams below show an animal cell and a bacterial cell.**



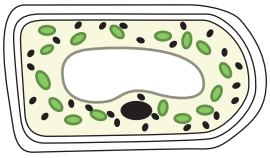
a **Name the cell part shown by:**
- **i) A** — 1 Mark
- **ii) B** — 1 Mark

b **What is the name of chemical C?** — 1 Mark

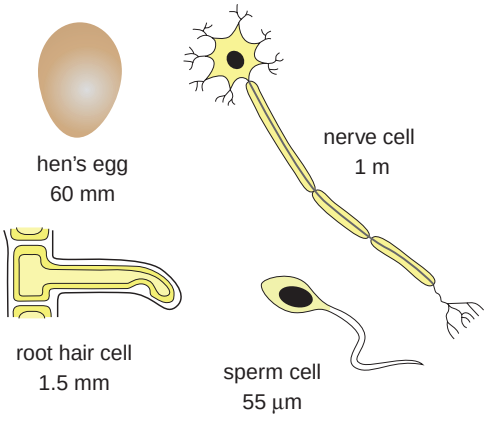
- **i) cellulose**
- **ii) chlorophyll**
- **iii) DNA**
- **iv) protein**

c **What is the function of the nucleus?** — 1 Mark

2 **Explain how you know that the cell shown is a plant cell.** — 2 Marks



3 **The diagrams below show some different objects. The length of each is included on the diagram. List them in order of size.** — 1 Mark



4 **A bacterium divides into two every 30 minutes.**

Starting with one bacterium, how many cells will there be after $1\frac{1}{2}$ hours? — 1 Mark

5 **Gemma is using Feulgen stain to stain some dividing cells.**

a **The label on the bottle of stain is shown.** 2 Marks

IRRITATING TO EYES,
RESPIRATORY SYSTEM
AND SKIN

Explain two safety precautions she should take when using the stain.

Going further

6 **Draw lines to match the two cell structures with their function.** 1 Mark

Cell structure	Function
Mitochondrion	Controls what enters and leaves cells
Ribosome	Respiration
	Protein synthesis

7 **Use words from the box to complete the word equation for aerobic respiration.** 1 Mark

alcohol	carbon dioxide	glucose	lactic acid

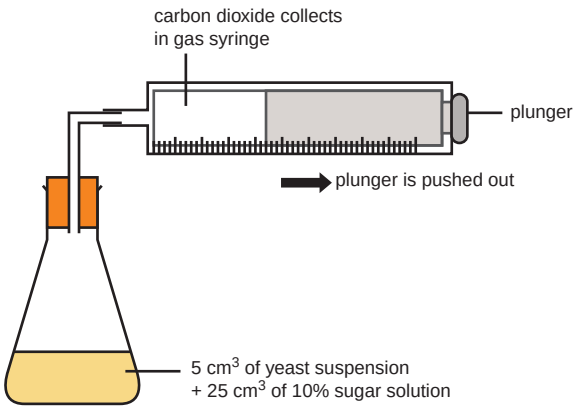
…….. + oxygen → …….. + water (+ energy)

8 **Explain how the features of a sperm cell help it to fertilise an egg cell.** 2 Marks

9 **A scientist is investigating the effect of different sugars on the anaerobic respiration of yeast.**

She measures the volume of carbon dioxide produced over a two hour period.

She investigates two types of sugar, sucrose and lactose.



a Suggest ways in which she can be sure that the readings she takes are the result of using the two different types of sugar and not from other factors. 4 Marks

b Her results are shown below. 2 Marks

Type of sugar	Volume of carbon dioxide produced (cm^3)						
	Time (min.)						
	0	20	40	60	80	100	120
sucrose	0	0.2	1.8	5.6	7.6	7.9	7.9
lactose	0	0	0	0	0	0	0

Suggest reasons for the scientist's results.

More challenging

10 Give the *two* forms of tumour. 1 Mark

11 Write down the name of the technique used to produce embryonic stem cells from a person's body cells. 1 Mark

12 Explain why mitosis is important in plants and animals. 2 Marks

13 Below are some data on the link between viruses and neck cancer over a number of years.

Year	Percentage of neck cancer cases where virus DNA was detected in tumours
1965	20
1975	23
1985	28
1995	57
2005	68

Plot a graph of the data. Connect the points with a smooth curve. 4 Marks

14 One of the images she sees is shown in the micrograph. 2 Marks

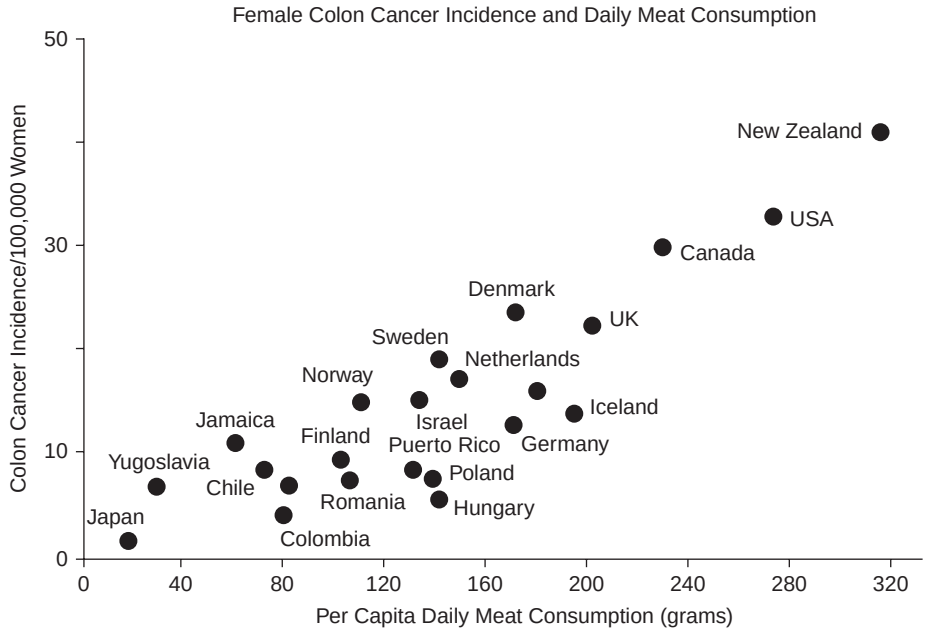
Describe what is happening in the micrograph.

Most demanding

15 **Explain how anaerobic respiration differs from aerobic respiration.** 2 Marks

16 **Some companies offer to store the stem cells found in the umbilical cord of a new born baby. These stem cells can be used for transplants or therapy for blood diseases. Suggest two possible advantages of using stem cells from an umbilical cord over using stem cells from bone marrow.** 2 Marks

17 **The graph below shows the correlation between colon cancer incidence and daily meat consumption. What conclusions can you draw from the graph? Evaluate the evidence for meat consumption affecting the incidence of colon cancer in females.**



6 Marks

Total: 40 Marks