

SURFING

**UNIT
1**

QCE BIOLOGY

Unit 1 Cells and Multicellular Organisms

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Science Press

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QCE BIOLOGY

UNIT 1

UNIT 1

Cells and Multicellular Organisms

In this unit you will:

- Explore the ways biology is used to describe and explain how the structure and function of cells and their components are related to the need to exchange matter and energy with their immediate environment.
- Understand the structure and function of cells.
- Examine the structure and function of plant and animal systems at cell and tissue levels to analyse how they facilitate the efficient provision or removal of materials.
- Investigate stem cell research, animal ethics, organ and tissue transplantation, bio-artificial organs and photosynthesis productivity.
- Develop your inquiry skills and practical skills.
- Conduct real and/or virtual laboratory work and microscopic examination of cells and tissues.
- Construct models to describe and interpret data.

When **raising a number to the n th power**, multiply the percentage error by n . When taking the n th root of the number, divide the percentage error by n . For example, $(4.8 \pm 1\%)^2 = 23.04 \pm 2\% = 23.04 \pm 0.4608$ and with significant figures taken into account 23 ± 0.46 .

When **averaging a set of readings**, the greatest deviation of any reading from the average value is taken as the absolute error.

Reliability and validity

Reliability means an experiment or set of results can be repeated by other people at other times and the results will be the same.

Validity refers to how a test measures what it is meant to measure. The dependent and independent variables need to be clear, other variables need to be controlled and data collecting instruments and techniques need to be suitable for the task.

To be valid, a task or data must also be reliable. However, the task or data may be reliable (get the same result each time) but may not be valid (does not meet the aim of the task).

QUESTIONS

- What is meant by scientific notation?
- Convert each of the following into micrometres.
 - 3 millimetres
 - 1500 millimetres
 - 67 centimetres
 - 0.24 metres
- What information is given when using significant figures?
- Describe how you make an approximation with rounding off.
- Change the following numbers to 3 significant figures.
 - 0.000987521
 - 147239
 - 6.722
 - 26.983
- Distinguish between random errors and systematic errors.
- Use an example to distinguish between precision and accuracy.
- What is meant by the limit of reading of an instrument?
 - Use an example to show the limit of reading of an instrument.
- What is meant by the maximum uncertainty of a reading?
- Distinguish between relative uncertainty and percentage uncertainty.
- A measurement of 3.2 cm is made on a scale that is divided into millimetre divisions. What is the:
 - Limit of reading on this scale?
 - Absolute uncertainty in this reading?
 - Relative uncertainty in this reading?
 - Percentage error of this reading?

- Distinguish between reliability and validity.
- Copy out and complete the following table for a set of results that were measuring the size of a prokaryotic cell.

Table A.1 Measuring prokaryotic cells.

Reading (μm)	6.5	7.2	3.8	10.4	6.6	5.9	8.2
Average reading (μm)							
Difference of each reading from average (μm)							

- What is the length of this cell with its absolute error?

- The diagram shows four cells on a grid.

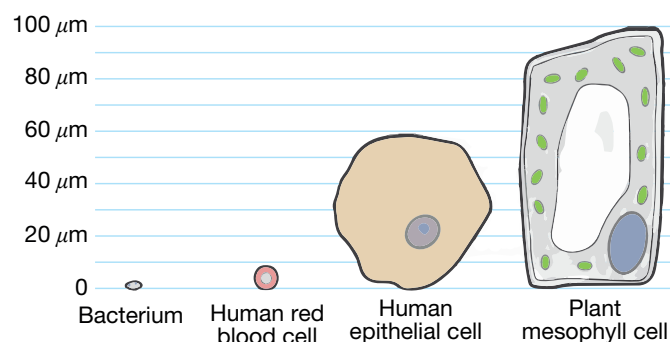


Figure A.1 Four cells.

Measure the length of the four different cells.

- The diagram shows a drawing of a mitochondrion.

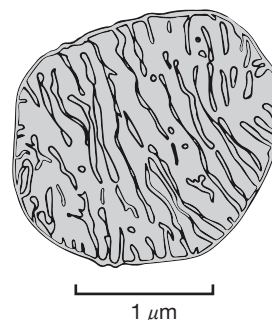


Figure A.2 Mitochondrion.

Determine the real size of this mitochondrion.

- A biologist measured the root length of some grass plants and recorded the following results.

Table A.2 Measured root length of grass plants.

	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5
Root length (mm)	5.6 $\pm$ 0.2	10.2 $\pm$ 0.2	11.4 $\pm$ 0.5	16.7 $\pm$ 0.2	8.9 $\pm$ 0.3

What is the average root length for these plants?

- 10.56 ± 0.2 mm
- 10.6 ± 0.2 mm
- 10.56 ± 0.28 mm
- 10.6 ± 0.5 mm

B School Light Microscope

Biology students need to be able to use a monocular light microscope. The light microscopes found in schools are compound microscopes with magnifying lenses used in series to provide an enlarged image of a specimen. Light is transmitted through the specimen to reach the eye of the observer. The specimen needs to be very thin to allow light to pass through. A simple light microscope like the one used by van Leeuwenhoek has one lens.

The eyepiece lens on most microscopes is $10\times$ and some microscopes have interchangeable eyepieces, e.g. $5\times$ or $10\times$. There is usually a choice of at least two objective lenses, for example $10\times$ and $40\times$. The overall magnification is calculated by multiplying the degree of magnification of the objective lens by the degree of magnification of the eyepiece lens. The $100\times$ objective is an oil immersion lens and can only be used with a special oil between the slide and the lens.

Many school light microscopes are **parfocal** which means that a specimen viewed under low power will automatically be in focus or near focus when the nosepiece is rotated from low power to high power.

Rules for using a light microscope

There are several important **rules** to follow when using a light microscope.

1. You must always use two hands when carrying a microscope. One should hold the arm and the other hand needs to be beneath the base.
2. Never touch the lenses with your fingers.
3. When you have finished using your microscope the nosepiece needs to be rotated so the low power objective is facing the stage and then lower the objective down to the stage.
4. Never leave a slide on the stage.
5. Place the dust cover over the microscope and return the microscope to its proper location.
6. If you made a wet mount slide, make sure your work area is clean and dry and all glass slides and cover slips are returned to their proper location at the end of the experiment.

Setting up a microscope

1. Place the microscope on the desk or bench with the arm *towards* you. This means that the stage is facing *away* from you.
2. Turn the coarse adjustment knob and raise the nosepiece.
3. Rotate the nosepiece so that the low power objective is facing the stage.
4. Look through the eyepiece and adjust the mirror and the diaphragm so that there is a bright circle of light visible.

5. Place the slide on the stage. Stage clips can be used.
6. Look at the stage from the side and lower the low power objective using the coarse adjustment knob. Stop before the objective touches the slide.
7. Look through the eyepiece and slowly turn the coarse adjustment knob until the image comes into focus.
8. Use the fine adjustment knob to bring the image into sharp focus.

QUESTIONS

1. Identify each part of the compound light microscope shown in the diagram.

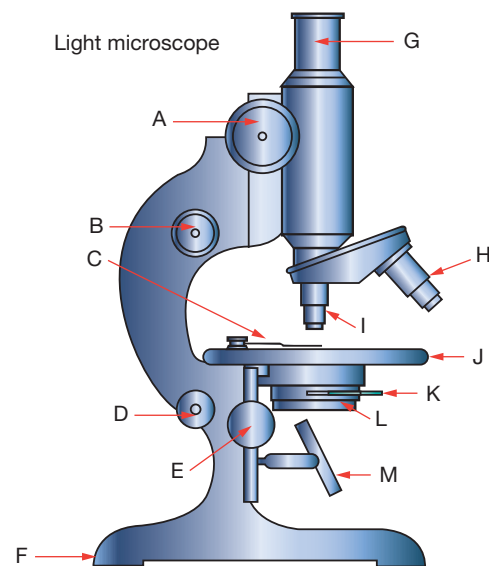


Figure B.1 Compound light microscope.

2. Explain why it is necessary to always use two hands when carrying a light microscope.
3. Explain why it is important to view the stage from the side when you lower the low power objective and then always move the objective lens away from the microscope slide.
4. If an eyepiece has a magnification of $10\times$, what is the overall magnification for each of these objective lenses?
 - (a) Low power objective $10\times$.
 - (b) High power objective $40\times$.
5. Outline the function of the iris diaphragm.
6. Explain why it is usually necessary to adjust the amount of light after changing objective lenses.
7. How does a stereo microscope vary from a light compound microscope?
8. Explain why it is important not to touch the lens with your fingers and discuss what you would do if you found a fingerprint on the lens.

C Using a Light Microscope

The use of a light microscope is determined by its magnification and resolution. **Resolution** refers to the minimum distance between two points to distinguish them as two points – it refers to the clarity of the image. **Magnification** in microscopy refers to the ratio of the object's actual size to its image. Most light microscopes cannot resolve detail finer than $0.2\ \mu\text{m}$ and can effectively magnify objects up to $1000\times$. Many light microscopes used by students in schools are only equipped with lenses that allow up to $400\times$ magnification.

Magnification is limited by the resolving power of the microscope – increasing magnification will only give a bigger blur and not more detail. The resolution is determined by the shortest wavelength of light being used to illuminate the specimen.

When using a light microscope it is important to determine the diameter of the field of view under low power. A minigrid slide that has a 1 cm square of graph paper gives you the ability to estimate the diameter of the field of view. The diagram shows a section of minigrid with a central mm square divided into 0.1 mm divisions.

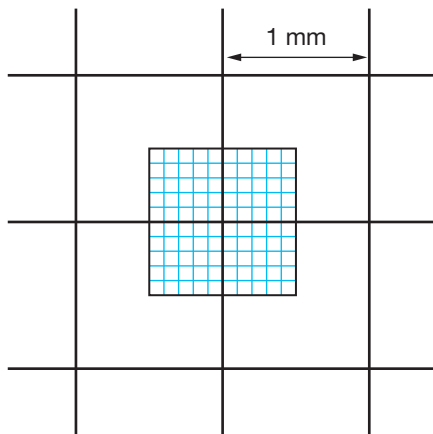


Figure C.1 Section of a minigrid with the central area subdivided into 0.1 mm divisions.

By placing the minigrid with a line crossing the diameter of your field of view and the mini-minigrid on this line, you can estimate the diameter of the field of view in millimetres (mm). The measurement can easily be converted into micrometres (μm).

Depth of field in microscopy can be shown by placing three different strands of hair over each other on a slide and making a wet mount. To determine the position of the three strands you need to focus up and down with the fine adjustment knob. This skill is used to determine positions of organelles or structures in thicker sections of tissue or in large unicellular organisms.

QUESTIONS

1. Distinguish between magnification and resolution.
2. The diagram shows a minigrid under lower power of a light microscope using an eyepiece $10\times$ and a low power objective $10\times$.

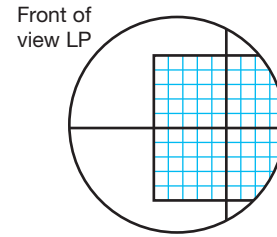


Figure C.2 Minigrid under a light microscope.

- (a) Estimate the diameter of the field of view in millimetres and micrometres.
 - (b) If the high power objective ($40\times$) was used on this microscope, what would be the diameter of the field under high power?
3. The diagram shows the appearance of the letter 'e' as seen under low power of a light microscope.



Figure C.3 Letter 'e' as seen under the microscope.

Discuss why viewing the letter 'e' under the microscope is used to show important aspects of the viewed image of an object.

4. Describe how you would determine the position of different organelles in a large unicellular organism being viewed in a wet mount under a light microscope.
5. The diagram shows a plant root hair as seen under a light microscope that has a minigrid.

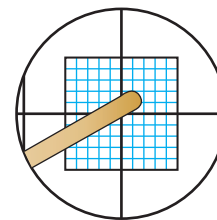


Figure C.4 Root hair and minigrid under a light microscope.

What is the diameter of the root hair in millimetres and in micrometres?

6. Describe how you would record your observations when carrying out an experiment using a light microscope.
7. If you are trying to focus a microscope and have raised the body tube more than 2 cm above the slide, what should you do next?

D Drawing Scaled Diagrams

To draw a scaled diagram you must first know the dimensions of the object you wish to draw. If you are looking down a microscope you need to know the diameter of the field of view. Note that the field of view is different for different microscopes.

Steps to follow

1. Determine the size of the object, e.g. length and width.
2. You need to determine the scale you will use and draw a scale bar.
3. To work out a scale bar you can use the formula:

$$\frac{\text{Actual scale bar}}{\text{Actual field of view}} = \frac{\text{Drawing scale bar}}{\text{Drawing field of view}}$$

Example

The diagram shows a photomicrograph of Euglena using a light microscope with 10× ocular lens and 10× objective lens. Total magnification is thus ×100.

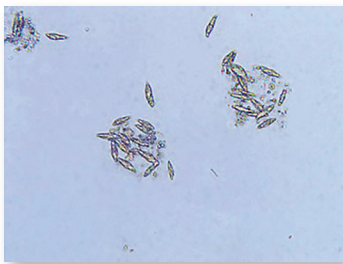


Figure D.1 Euglena viewed under light microscope ×100.

The measured width of the field of view was 1.3 millimetres which needs to be converted to micrometres. The **actual field of view** is 1300 μm. The actual scale bar can now be determined.

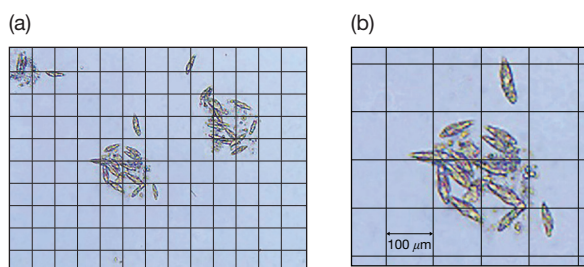


Figure D.2 (a) Actual field of view divided with a grid. (b) Actual scale bar determined for actual field of view.

A scaled diagram of Euglena can now be drawn.

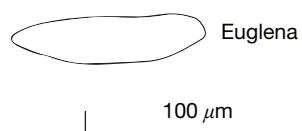


Figure D.3 Scaled diagram of Euglena.

QUESTIONS

1. What is the difference between using the terms ×10 and 10×?
2. (a) If the ocular lens is 10× and the objective lens is 10×, what is the total magnification?
(b) If the ocular lens is 10× and the objective lens is 40×, what is the total magnification?
3. A light microscope has a diameter of the field of view (FOV) under a total magnification of ×100 of 1.5 mm.
(a) What is the diameter in micrometres?
(b) If the same ocular lens was used and the objective lens was changed from 10× to 40×:
(i) What is the new magnification?
(ii) What is the new FOV?
4. If using an actual field of view of 1300 μm with ×100 magnification and an actual scale bar of 100 μm, what drawing field of view is needed for a drawing scale bar of 1 cm = 100 μm?
5. Draw a scaled diagram for each of the following.

Photomicrograph	Description
	White blood cell and red blood cell
	Amoeba
	Seven squamous epithelial cells
	Cross-section leaf

E Writing a Practical Report

Each practical investigation should be recorded in a scientific report. A standard report has the following aspects.

- Title
- Aim
- Introduction or rationale or hypothesis
- Equipment
- Variables
- Method
- Risk assessment
- Results
- Discussion
- Conclusion
- References or Bibliography

A practical report is written in the **third person, past tense**, so that making a slide of onion skin would be written as ‘a slide of onion skin was made’.

Aim

The aim is a brief statement of the purpose of the investigation. The aim usually begins with ‘To’, e.g. ‘To investigate the structure of plant cells using a light microscope’.

Introduction

An introduction is needed if there are scientific theories, laws, or relationships which are being used or tested to achieve the aim. If an hypothesis is being tested it needs to be included in the introduction. An **hypothesis** can be written ‘**As the** (independent variable), **the** (dependent variable) **will**’. For example, an hypothesis could be ‘As the amount of carbon dioxide gas increases, the rate of photosynthesis increases.’

Equipment

All required equipment and quantities of equipment should be listed. If the equipment needs to be assembled into a specific set-up, a diagram of the set-up should be drawn. The diagram should be a suitable size, drawn in pencil, with labels and follow the standard rules for scientific diagrams. The choice of equipment contributes to showing the validity of the method.

Variables

When designing an investigation it is important to identify the independent variable and the dependent variable and the factors that have been controlled to make sure the method is valid. For example, when testing if increasing the amount of carbon dioxide available to a plant increases the rate of photosynthesis in the plant, the independent variable is the amount of carbon dioxide and the dependent variable is the rate of photosynthesis.

When carrying out this experiment you would need to control the type of plant, the amount of light given to each plant, the amount of water given to each plant and the temperature.

However, not all biology investigations involve dependent/independent variables, e.g. studying the structure of plant cells using a light microscope would not need this section in the practical report.

Method

The method is usually written as a series of dot points showing the logical sequence of steps that were followed as the experiment was carried out. The degree of detail to put into the method is usually left to common sense. The way the results are measured and recorded needs to be included and the number of multiple trials needs to be stated. The method tests the aim and shows the validity of the experiment and the number of repeated trials contributes to the reliability of the experiment.

Risk assessment

All relevant risks need to be identified with a reason why it is a risk. A safety precaution for each risk then needs to be stated to show how each risk can be avoided. The treatment for each situation also needs to be stated.

Results

Collected data needs to be presented in the most suitable format. In many instances data can be summarised in a table, chart or graph. The results section can include calculations, e.g. working out an average and the manipulation of data.

Discussion

The discussion is very important and needs to have an evaluation of the investigation. There should be a statement to indicate if the results supported the hypothesis (if there was an hypothesis) and if the data shows any trend or pattern. The results need to be explained, stating any assumptions made about the system, or identifying sources of error and/or any limitations of the data. The results can be compared with known data and suggestions made about improvements and ideas for further investigations.

Conclusion

The conclusion needs to be concise and relate back to the aim. If an hypothesis was being tested there should be a statement saying the results supported/did not support the hypothesis. The results should *not* be repeated and there should *not* be another discussion.

References

Sources of information and help need to be acknowledged using correct formats. Sources can be written material, e.g. books, periodicals and journals, webpages and/or advice from help bodies. Assistance from individuals with an expertise that helped in some way with the investigation can also be acknowledged in this section.

QUESTIONS

- Some senior biology students studied a row of plants growing in the garden outside their laboratory. The plants were all the same species and had been planted at the same time. They noticed that the plants that were permanently in the shade had larger leaves than the plants that received direct sunlight for most of the day.
 - Suggest an hypothesis that could be investigated for these observations.
 - For the hypothesis you suggested in part (a), identify the independent variable and the dependent variable.
 - If the students carried out an investigation to test their hypothesis, what factors would they need to control and keep constant?
- Some senior biology students studied red blood cells and white blood cells using the high power objective of a light microscope. They used a minigrid scale to work out the diameter of these blood cells.
 - Write a suitable aim for this experiment.
 - Suggest why the students needed to use the high power objective to observe red blood cells and white blood cells.
 - List the equipment the students would need to carry out this investigation.
 - Identify a safety precaution the students would have needed to follow to carry out this investigation.
- The diagram shows a graph drawn by students in their results section of their practical report.

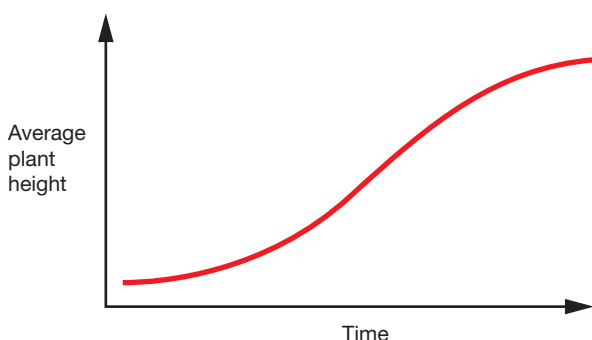


Figure E.1 Graph of student results.

For these results what is the independent variable and the dependent variable?

- Three groups of students were asked to set up their own experiment to find out if plants require light for survival. After group discussions, the following methods were used – group 1 used method 1, group 2 used method 2 and group 3 used method 3.

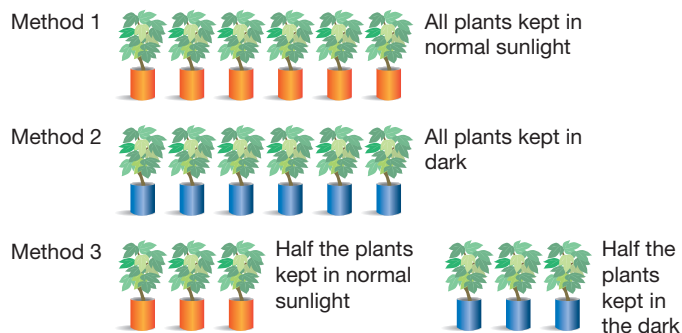


Figure E.2 Diagram of the different methods used by the three student groups.

Which method would be the most valid? Explain your reasoning.

- A group of four students observed a plant in its pot.



Student 1 - 'The plant has been too long in hot sunlight'.
 Student 2 - 'The plant has not been given enough water'.
 Student 3 - 'The pot has a drooping plant in it'.
 Student 4 - 'The plant roots have been damaged'.

Figure E.3 Plant in its pot and student comments.

- Which student has written an observation?
 - In a practical report which section has the observations?
- The diagram shows the process of scientific method.

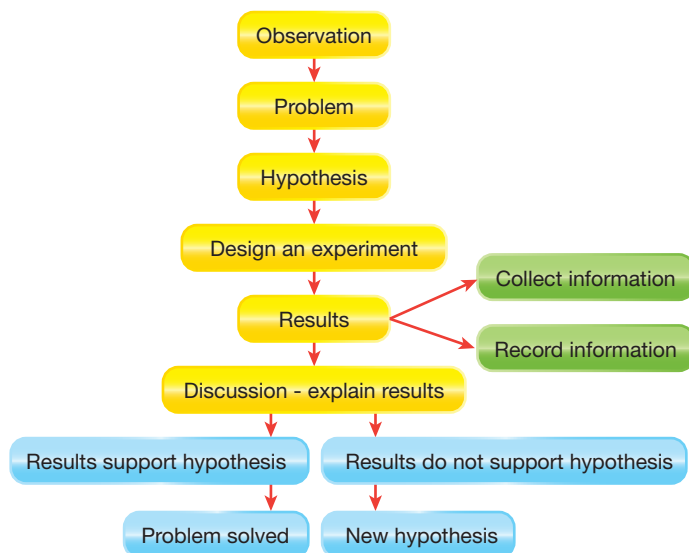


Figure E.4 Scientific method.

Explain how this process relates to writing practical reports.

F Making a Wet Mount

Many specimens are mounted in water, 50% glycerine or some other medium before they are studied under a light microscope. The refractive index of the mounting medium allows a better examination of detail than studying a dry sample. The cover slip reduces the reflecting surfaces and keeps the specimen from quickly drying out under the heat of the light.

Steps in preparing a wet mount

1. Clean a glass microscope slide and cover slip by holding the sides and making sure you do not leave fingerprints on either object.
2. Place the thin section specimen to be studied in the centre of the slide.
3. Place a drop of water (or whichever medium you are using) on the specimen.
4. Place the edge of the cover slip on the slide so that it is just touching the edge of the medium. This causes the medium to spread along the edge of the cover slip.
5. Use a needle to lower the cover slip over the specimen.

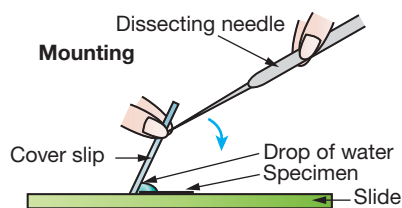


Figure F.1 Making a wet mount.

6. Dry the slide if any medium has overflowed from beneath the cover slip. A specimen should never be 'floating' beneath the cover slip in too much medium. Too little medium can lead to many air bubbles which means a new slide will have to be made.

Staining

Specimens are stained to provide contrast and to identify specific chemicals or structures. The stain may be applied directly to the specimen, e.g. a drop of iodine solution is placed on the specimen instead of a drop of water, or the stain may be applied by irrigation. The irrigation technique is used if you wish to observe the specimen before and after staining. To irrigate a slide you place a piece of paper towelling or tissue on one side of the cover slip and using a dropper place one drop of the dye on the other side of the cover slip. You can observe the movement of the dye across the slide while looking down the eyepiece. The table summarises the uses of some common dyes used in school microscopy.

Table F.1 Common dyes.

Stain	Its Use
Iodine solution	A weak solution of potassium iodide is the distinguishing test for starch (solution turns from yellow to blue/black). In plant cells lignified cell walls stain various colours of golden brown while cellulose walls remain unstained. It makes the nucleus more visible.
Toluidine blue	Is a 'double stain'. It is a blue solution that reacts with cations in plant materials to give several different staining reactions. Polyphenolic compounds, e.g. lignin and tannins stain green, greenish-blue or bright blue, e.g. xylem stain green. Pectic acids stain pinkish-purple, e.g. carbohydrate walls of parenchyma. Nuclei become visible and it does not stain cellulose or starch.
Phloroglucinol and HCl	Is a specific test for lignin staining lignified walls bright red.
Neutral red	Stains primary cell walls and is often used as a counterstain in combination with other dyes.
Methylene blue	Is used to stain animal cells and shows the nucleus and cytoplasmic granules, e.g. staining cheek cells and blood films.

QUESTIONS

1. Explain why it is important to use a needle to lower the cover slip onto the specimen.
2. If care is not taken when preparing the wet mount, there may be numerous air bubbles present. Describe the appearance of an air bubble.
3. For each of the following situations, identify the cause of the problem with the slide.
 - (a) The specimen keeps 'floating' and moving out of focus.
 - (b) Individual cells are not distinct and the image remains blurry when the fine adjustment knob is used to focus up and down.
 - (c) Thick black lines rim around the specimen and the image is unclear beyond these lines.
4. The diagram shows a section of onion epithelium stained with iodine.

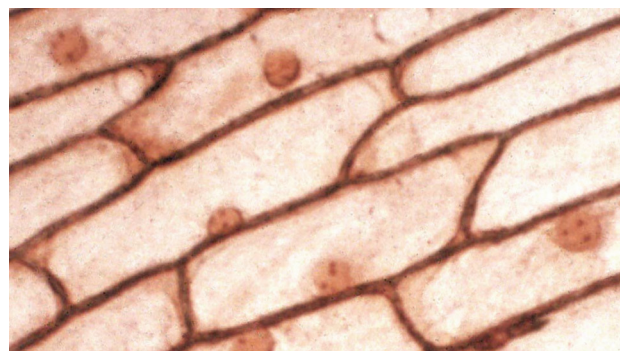


Figure F.2 Onion epithelium.

Identify the structures that are visible in this section.

G Drawing Biological Diagrams

Microscopy and other biological investigations often involve drawing a suitable biological diagram of the observed specimen. You do not have to be an artist to draw a diagram that clearly represents your observations.

Requirements for a good biological drawing

1. Your drawing must be clear and simple.
2. You must use a sharp pencil. Coloured pencils should only be used if given this particular instruction from your teacher.
3. The drawing in your report or notes should be a suitable size, e.g. the circle to indicate the field of view of a light microscope should be at least 5 cm diameter. The drawing should be large enough to allow all details to be easily drawn without squishing structures into a small space.
4. The size of each part of the drawing should be in proportion to the observed specimen, e.g. if there are 5 cells across the diameter of the field of view of the light microscope, your drawing should have 5 cells across the circle you have drawn.
5. Your drawing should accurately show each significant feature of the specimen. It should not be an idealised or artistic impression and should not be shaded in to give a three-dimensional version of the specimen. It is customary to shade in the nucleus if it has been stained.
6. The outermost boundary of the specimen should be a complete line. Each cell in a diagram should have an outer unbroken line, e.g. to show the cell membrane in animal cells or cell walls in plants.
7. Any additional drawn structures should be labelled. You need to use a ruler for the labelling line and labelling lines should never cross each other.
8. Every diagram needs to:
 - Have a title which clearly identifies the specimen.
 - Have a statement about the magnification, e.g. LP (100 $\times$) or HP (400 $\times$).
 - Identify any stain that was used if it was a wet mount.
9. If you were observing a living organism, you will need to have additional notes to describe any movement or activities you observed.

QUESTIONS

1. Explain why you should always take a pencil, sharpener, a good eraser and a ruler to each biology lesson and especially into assessment tasks and exams.

2. Study the diagram which shows two examples of student drawings of onion epithelium. Assess each diagram.

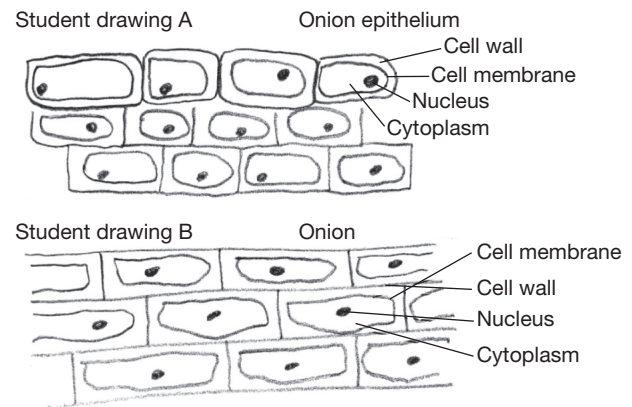


Figure G.1 Student drawings of onion epithelium.

3. The diagram shows onion epithelium stained with iodine under HP (400 $\times$).

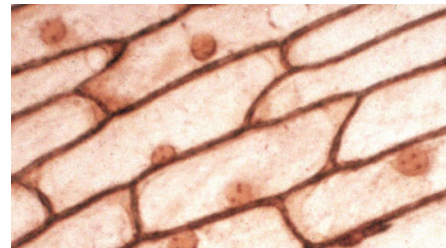


Figure G.2 Onion epithelium.

Draw a biological drawing of this specimen.

4. The diagram shows a student drawing of red and white blood cells. Assess this drawing.

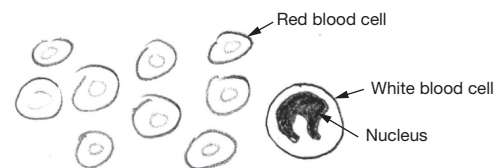


Figure G.3 Student drawing of red and white blood cells.

5. Explain why students must always use prepared slides of human blood and human cheek cells.
6. Which of the diagrams below shows the correct method for making a wet mount?

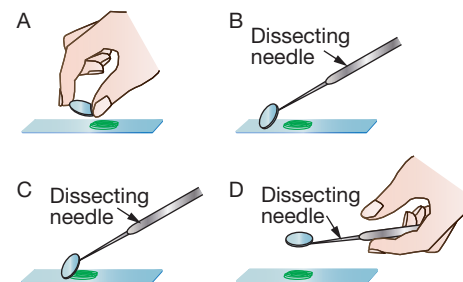


Figure G.4 Making a wet mount.

H The Electron Microscope

The electron microscope provides greater detail about cell structure. The electron microscope sends a stream of electrons through a vacuum. The electron beam is focused by electromagnets, magnified by an objective lens and projected onto a fluorescent screen or photographic film. Since the beam of electrons has a much shorter wavelength than visible light resolution is greatly improved, e.g. approximately 0.002 nm, although in practical situations it can be limited to 2 nm. Typically they provide a resolution of 0.5 nm (400 times better than a light microscope) and magnify up to 500 000 times.

Transmission electron microscopes

The transmission electron microscope (TEM) uses the same basic principles as the light microscope with a beam of electrons passing through the specimen instead of a beam of light. The TEM is used to study the internal ultrastructure of cells. The specimen is stained with heavy metal atoms which attach to particular cellular structures, preserved by a chemical fixative, embedded in plastic then cut into exceedingly thin slices (50 to 100 nm). You can see objects to the order of several nanometres (10^{-9} m) increasing the capacity for medical, biological and materials research. Many organelles were discovered using the TEM, e.g. ribosomes. One of the main disadvantages of the TEM is that the method of specimen preparation kills the cells and the specimen is viewed in a vacuum. This means living cells cannot be viewed. Specimen preparation also produces artefacts and structural features that do not exist in living cells.

Table H.1 Features of the electron microscope.

Feature	Electron microscope
Magnification	Up to 300 000 $\times$.
Resolution	Approximately 0.0005 μm .
Stains	Heavy metal stains identify substances, structures and provide contrast for easier viewing. No colour stains.
Living specimen	The electron microscope does not allow viewing of living cells.
Mounting	Metal background in a vacuum chamber.
Focusing	By electromagnetic lenses.
Energy source for viewing	A beam of electrons is passed through the specimen.

Scanning electron microscopes

The scanning electron microscope (SEM) emits an electron beam which is rapidly passed back and forth over the surface of the specimen. Surface variations alter the pattern of the scattering of the electrons and the pattern is recorded, amplified and transmitted to a TV monitor.

This gives a three-dimensional detailed view of the surface of the specimen. The image has great depth of field.

QUESTIONS

- Outline why the electron microscope has better resolution than the light microscope.
- Outline the basic principle behind the operation of an electron microscope.
- Construct a table to compare the advantages and disadvantages of a light microscope.
- Discuss the importance of the transmission electron microscope.
- Discuss the importance of the scanning electron microscope.
- Identify the type of microscope that was used to view each of the following.

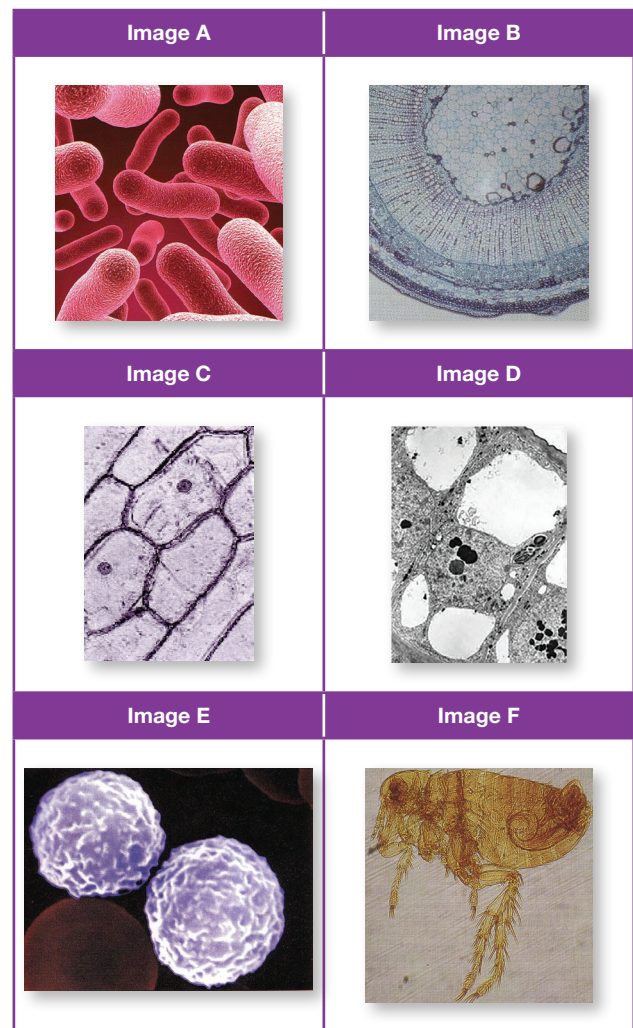


Figure H.1 Images from different types of microscopes.

- What is the limit of resolution of a transmission electron microscope?
 (A) 0.5 centimetres. (B) 0.5 millimetres.
 (C) 0.5 micrometres. (D) 0.5 nanometres.

I The Stereo Microscope

The **stereo microscope** has two ocular lens so that the left eye and the right eye each view the object from different angles. This sends two images to the brain. The brain then produces a three-dimensional image of the object. Thus the microscope gives a stereoscopic view or 'stereo' view of an object.

Some compound microscopes have double eyepieces which make viewing easier but give both eyes the same image and do not provide the three-dimensional images provided by stereo microscopes.

To use a stereo microscope the eyepieces need to be adjusted. There is variation in the distance between the pupils of the eyes of each person and this means that the position of the eyepieces of the stereo microscope need to be corrected to suit the requirements of each person.

Different parts of a specimen come into focus when focusing up and down while using a stereo microscope. Organisms are three-dimensional and the stereo microscope allows viewing of the different levels of the specimen. For larger specimens every feature cannot be seen clearly at the same time.

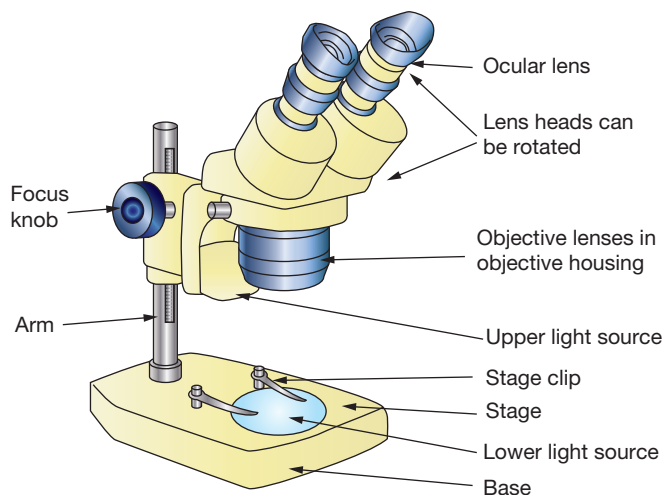


Figure I.1 Stereo microscope.

Resolution, illumination and magnification of a stereo microscope

A stereo microscope usually has poor resolution as the lenses are a distance away from the object.

Most stereo microscopes use reflected light from an upper and/or lower light source. It is important when observing live organisms, e.g. worms and insects not to leave the light source shining on the organism for too long. The heat can kill the organism.

Most stereo microscopes have magnifications from $10\times$ to $40\times$.

Uses of a stereo microscope

A stereo microscope is often used when dissecting small organisms and is very useful when you need to carefully observe the external features of a specimen.

If a camera and/or computer is attached to the stereo microscope the image can be recorded and displayed on a screen. Since the camera is only connected to one eyepiece the result will be a 2-D image.

QUESTIONS

1. What is the distinguishing feature of a stereo microscope?
2. When are you likely to use a stereo microscope?
3. The diagram shows a side view of a stereo microscope.

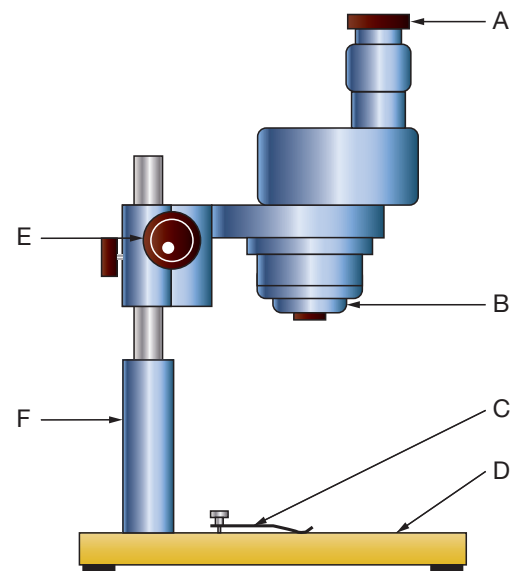


Figure I.2 Side view of a stereo microscope.

Identify the parts of the microscope labelled, A, B, C, D, E and F.

4. Explain how a compound microscope with double eyepieces may not provide a three-dimensional image to form a 'stereo microscope'.
5. Explain why many stereo microscopes have poor resolution.
6. Compare the magnification of a typical stereo microscope with a typical monocular microscope found in schools.
7. When studying crystals, e.g. salt crystals under a stereo microscope, explain why it is advisable to put a piece of black paper beneath the crystal.
8. Explain why some parts of an organism may appear out of focus while studying a specimen with a stereo microscope.
9. Which of the following would *not* be suitable to be observed using a stereo microscope?
(A) Red blood cells. (B) Honey bee.
(C) Eucalypt leaf. (D) Salt crystal.

TOPIC 1.1

Cells As the Basis Of Life

In this topic you will:

- Compare prokaryotic and eukaryotic cells.
- Identify key organelles.
- Describe stem cells and their properties.
- Describe the hierarchical organisation of cells, tissues, organs, and systems.
- Explain how the specialised structure of cells relates to their function.
- Describe the fluid mosaic model of the cell membrane.
- Explain how the cell membrane regulates movement of substances into and out of cells.
- Compare active and passive transport.
- Explain how the size of a cell is limited by surface area to volume ratio and the rate of diffusion.
- Interpret data from surface area to volume ratio and rate of diffusion experiments.
- Investigate advances in technology that allowed scientists to reprogram cells to become pluripotent.
- Appreciate the ethical treatment of animals as sentient beings.
- Use a light microscope and electron micrographs to view cells and tissues.
- Explore the safety, ethics and efficacy of stem cell technologies.

1 Assumed Knowledge Topic 1.1

QUESTIONS

1. Identify seven properties of living organisms.
2. The cell is the basic unit of life. What structural features of cells are possessed by all living things?
3. Draw a fully labelled diagram of a plant cell as seen under a light microscope.
4. Draw a fully labelled diagram of an animal cell as seen under a light microscope.
5. Identify the following parts of a light microscope and use by a person.

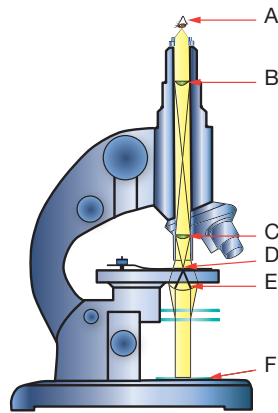


Figure 1.1 Light microscope.

6. Describe one safety precaution you should follow while using a light microscope.
7. What is the function of the nucleus of a cell?
8. What is the function of the cell membrane?
9. What is cytoplasm?
10. Define protoplasm.
11. Describe a chloroplast.
12. Define:
 - (a) Respiration.
 - (b) Diffusion.
 - (c) Osmosis.
13. The diagram shows an experiment where a bag made of dialysis tubing which acts as a selectively permeable membrane was filled with molecules and placed in a beaker containing the same type of molecules.

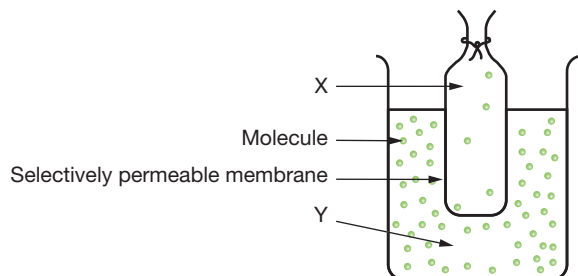


Figure 1.2 Experiment set-up.

After a few hours it was noted that there were more molecules in area X. Explain what had happened.

14. The diagram shows an amoeba, which is a eukaryotic single celled organism that can change its shape and is found in freshwater streams and ponds usually in decaying bottom vegetation.

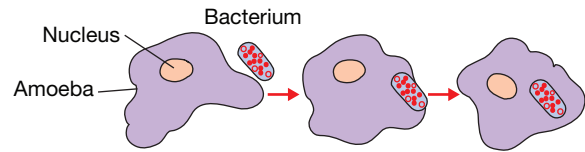


Figure 1.3 Amoeba.

What process is being shown in this diagram?

15. Define a stem cell.
16. The diagram shows the components of bone.

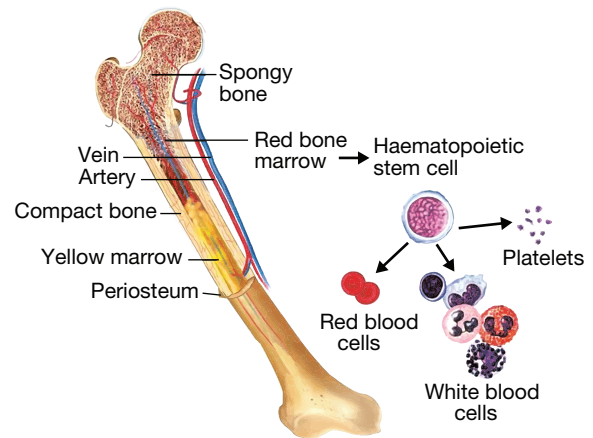


Figure 1.4 Bone and haematopoietic stem cells.

Identify some of the specialised cells that are formed in red bone marrow.

17. Distinguish between a tissue and an organ.
18. The diagram shows a physical process involving a gas in a room.

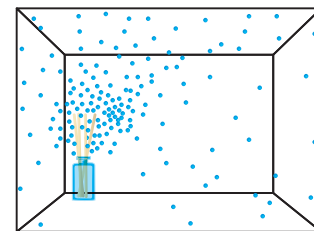


Figure 1.5 Physical process involving a gas.

- (a) Identify this process.
 - (b) Explain why this process occurs.
19. Outline the function of the following.
 - (a) Digestive system.
 - (b) Respiratory system.
 - (c) Circulatory system.
 - (d) Excretory system.
 20. In humans, what structures make up the respiratory system?
 21. (a) In humans, what is the function of the heart in the circulatory system?
(b) Identify the components of the human circulatory system.
 22. Give some examples of human connective tissue.

2 Prokaryotes

Prokaryotic organisms do not have membrane bound organelles, i.e. they do not have a nucleus, mitochondria or chloroplasts. They are the simplest of organisms on Earth, are very small, e.g. most have a diameter between 1 and 10 μm , are extremely abundant and survive in a wide variety of environments. The prokaryotic genome is in a circular DNA/protein single chromosome called the **nucleoid**. The nucleoid is in the **cytosol** (the intracellular fluid). Some prokaryote genes are found in **plasmids** which are small circular double stranded DNA molecules also in the cytosol. In prokaryotes most metabolic reactions occur in the cytosol. Many prokaryotes have **fimbriae** which are short hair-like structures on the surface that help the prokaryote stick to other cells or to a substrate. Many prokaryotes are surrounded by a **capsule** which is a sticky layer of protein or polysaccharide that can help the cell evade a host's immune system or help the cell adhere to other cells or surfaces. **Flagella** are used by motile bacteria for movement to move either towards or away from stimuli.

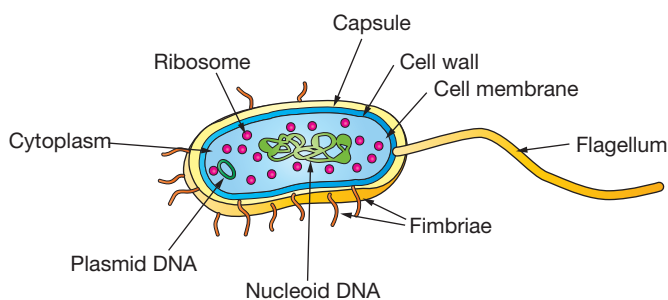


Figure 2.1 Generalised structure of a bacterial cell.

Classification of living things

Up until the 20th century people classified organisms into two groups – the **plant kingdom** and the **animal kingdom**. However, the invention of the electron microscope and new biochemical techniques has led to changes in our classification, especially with respect to the prokaryotes. The electron microscope has shown finer details of prokaryote cell structure and the analysis of DNA sequences has shown distinct differences between different types of prokaryotes.

In the 1970s a five kingdom system of classification, was introduced and the prokaryotes were placed in their own kingdom called **Monera**, which was subdivided into two groups – the bacteria (Schizophyta) and the cyanobacteria (Cyanophyta).

In 1977, Carl Woese found that the genetic make-up of the DNA sequences in bacteria separated the bacteria into two distinct groups. He named these two groups the **eubacteria** (true bacteria) later known as Bacteria and the archaeobacteria, which he later renamed the **Archaea**.

The Archaea were once thought to only live in extreme condition environments, e.g. high temperatures (higher than 100°C), deep sea trenches, alkaline or acidic waters, digestive tracts of cows and termites, or produce methane when in a group cluster. The Archaea have since been found in all types of habitats. Woese then suggested that all life should be divided into three **domains** – the Eukarya (have membrane bound organelles), the Bacteria and the Archaea.

It is believed the Bacteria and Archaea evolved from a common ancestor around 4 billion years ago.

Archaea

Some Archaea are called 'extremophiles' as they exist in extreme conditions and they can make a variety of protective molecules and enzymes to help them survive in these conditions, e.g. defensive molecules on their cell surface to prevent the action of acids, or enzymes to survive extreme hot or cold temperatures. **Methanogens** are Archaeans that produce methane gas as a waste product. They can live in an anaerobic environment (no oxygen) such as the intestinal tract of animals, or mud at the bottom of lakes and swamps. **Halophiles** live in salty environments, **thermophiles** live at extremely hot temperatures and **psychrophiles** live at unusually cold temperatures. Archaeans can use a variety of materials as a source of energy, e.g. hydrogen gas, carbon dioxide, sulfur and one group of halophiles contain bacteriorhodopsin which is a light sensitive pigment that can use light energy to provide chemical energy in a way different to photosynthetic plants.

Bacteria

Until recently the Bacteria were classified on shape (bacilli, cocci, spirilla), their reaction to the Gram stain, their ability to form spores and their method of energy production (heterotroph, autotroph, chemotroph).

The **Gram stain** was instigated by Christian Gram in 1884 and shows two different kinds of bacterial cell walls – gram negative stain red, gram positive stain purple.

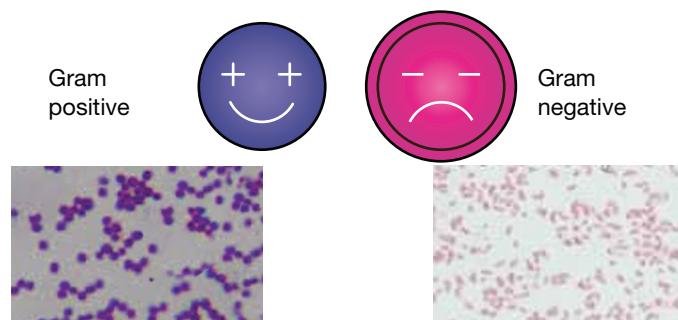


Figure 2.2 Gram stain.

3 Eukaryotes

A eukaryote has membrane organelles, e.g. nucleus, mitochondria. Eukaryotes include single celled organisms, e.g. some protista and some fungi and multicellular organisms, e.g. plants, animals, some protists and some fungi.

The oldest fossils of eukaryotes are around 2.1 billion years old. Analyses of DNA sequences suggest that the common ancestor of multicellular eukaryotes lived around 1.5 billion years ago.

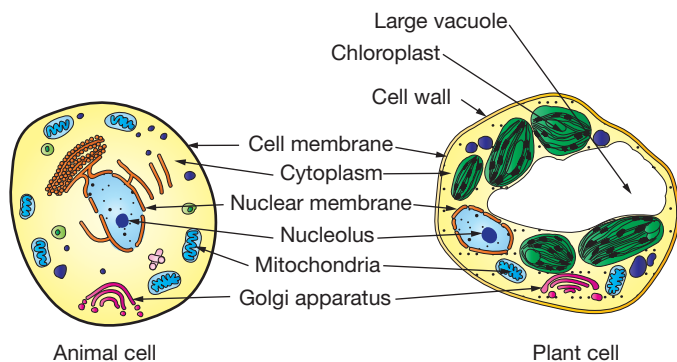


Figure 3.1 Generalised eukaryote cells.

Endosymbiont theory

Several areas of evidence support the **endosymbiont theory** which proposes that mitochondria and chloroplasts (and other plastids) were once small prokaryotes that were engulfed by larger cells and as either undigested prey or as a parasite lived in a symbiotic relationship with its host. Eventually the host and the endosymbiont became inseparable and eukaryotes evolved from this relationship.

Endomembrane system

The **endomembrane system** of eukaryotic cells includes the cell membrane, the nuclear membrane, the endoplasmic reticulum, the Golgi apparatus, lysosomes and other vesicles and vacuoles found within the cell. The arrangement of the internal membranes inside a eukaryotic cell divides the cell into compartments which have different environments suitable for different metabolic reactions. Enzymes are found on membranes, including the cell membrane, which means the membranes are directly involved in cellular reactions. The type of biochemical process that occurs depends on:

- The nature of the internal membrane.
- The arrangement of the internal membrane.
- The presence of specific enzymes.
- Environmental factors.

Eukaryotes have specialised organelles that carry out biochemical processes, e.g. chloroplasts carry out photosynthesis, mitochondria carry out cellular respiration, lysosomes contain hydrolytic enzymes that break down macromolecules and recycle the cell's own organic material. Smooth endoplasmic reticulum is involved in the synthesis of lipids, metabolism of carbohydrates and the detoxification of drugs and poisons and rough endoplasmic reticulum is involved in the production of proteins.

The **nucleus** contains most of the genes of eukaryotic cells. Chloroplasts and mitochondria also contain DNA which is like the chromosomes of bacteria.

QUESTIONS

1. What is meant by a eukaryote cell?
2. Which kingdoms have organisms that are eukaryotes?
3. What is the age of the oldest eukaryote fossils?
4. When did the common ancestor of multicellular eukaryotes most likely live on Earth?
5. Outline the endosymbiont theory.
6. Identify the parts of the endomembrane system of eukaryotes.
7. List the factors that control biochemical processes in cells.
8. Identify the organelle that is responsible for the following functions.
 - (a) Cellular respiration.
 - (b) Photosynthesis.
 - (c) The breakdown of macromolecules and recycling of organic material in the cell.
 - (d) Metabolism of carbohydrates and detoxification of drugs and poisons.
9. Where is DNA found in a eukaryotic cell?
10. The diagram shows the structure of *Euglena*, a single celled organism commonly found in pond water.

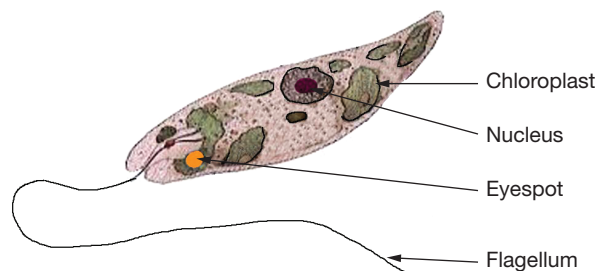


Figure 3.2 *Euglena*.

What would be the best description of *Euglena*?

- (A) A prokaryote.
- (B) A bacteria.
- (C) A plant.
- (D) A eukaryote.

8 Chloroplasts

Chloroplasts contain the green pigment chlorophyll. They are organelles with a double membrane found in leaves and other green organs of plants and in algae. In green plants a large number of chloroplasts are found in leaves in the mesophyll layer – palisade mesophyll and spongy mesophyll. Chloroplasts are oval in shape, typically $5\ \mu\text{m}$ long by $2\ \mu\text{m}$ wide and 1 to $2\ \mu\text{m}$ thick. Their size and shape can change in light and darkness and with their activities. Within a cell, chloroplasts are mobile and move around the cell along tracks of the cytoskeleton. In palisade mesophyll cells the chloroplasts will move in cytoplasmic streaming to the upper end nearest the top of the leaf to receive light and then will move away as others take its place. The diagram shows a section of a chloroplast.

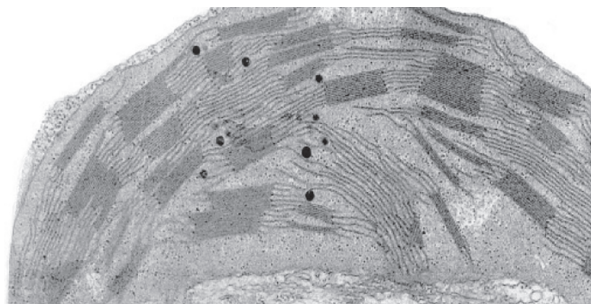


Figure 8.1 Part of a chloroplast.

Chloroplasts consist of a double membrane with a very narrow intermembrane space. Within the chloroplast there are thylakoids which are flattened membranous sacs that are stacked into grana (singular granum) and interconnected with thin tubules. The stroma is the fluid inside a chloroplast and contains enzymes, DNA and ribosomes.

Table 8.1 Parts of a chloroplast.

Feature	Structure	Function
Thylakoid membrane	Flattened disc shape with large surface area.	Photosynthesis takes place on the thylakoid membrane. The large surface area increases the ability to absorb light and allows many reactions to occur at the same time.
Space (lumen) inside thylakoids	Small space between thylakoid membranes with small volume.	Functions as a H^+ reservoir to maintain the concentration gradient. Since the space is small the movement of a few H^+ (protons) can have a significant effect on the concentration gradient and change the pH of the lumen.
Fluid stroma	Material inside the chloroplast containing ribosomes, proteins and small circular DNA.	The light-independent reaction occurs in the stroma. To maintain the pH gradient across the membrane, the stroma is kept slightly alkaline, e.g. pH = 8.

There is usually 40 to 60 grana per mature chloroplast and 20 to 100 chloroplasts in each photosynthetic leaf cell.

Photosynthesis occurs in chloroplasts. Photosynthesis is not a single step reaction. It is a series of reactions that can be grouped into the light dependent and light independent reactions. In the light dependent reactions, light energy is absorbed by chlorophyll and used to split water into hydrogen and oxygen. This stage occurs in the grana of the chloroplasts. In the light independent reactions the hydrogen is added to carbon dioxide to form sugar. This stage occurs in the stroma of the chloroplast. The diagram shows the generalised structure of a chloroplast.

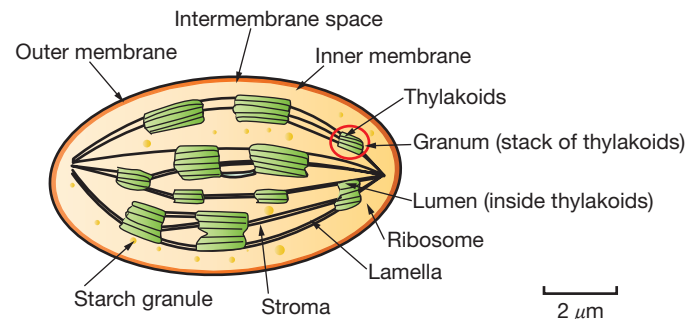


Figure 8.2 Generalised structure of a chloroplast.

QUESTIONS

- Identify the groups of organisms which possess chloroplasts.
- Describe the structure of chloroplasts.
- Explain why palisade mesophyll tissue has large numbers of chloroplasts.
- Explain how the structure of a chloroplast is related to its function.
- How many chloroplasts and grana per chloroplasts are found in a typical photosynthetic leaf cell?
 - Suggest why there is an upper limit to the number of chloroplasts that a cell will contain.
- The diagram shows a chloroplast dividing.

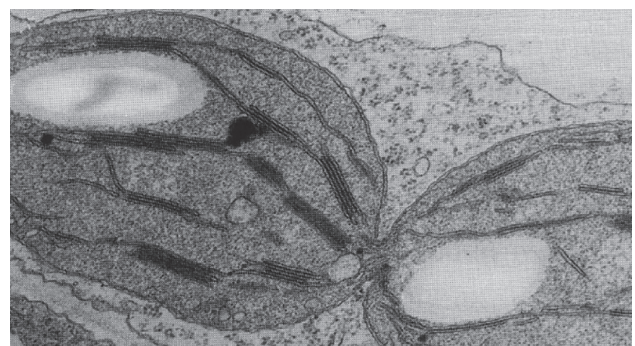


Figure 8.3 Chloroplast dividing.

Chloroplasts can divide independently of the nucleus. Explain why they are able to do this.

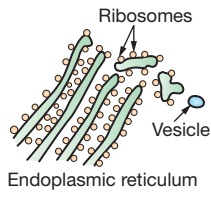
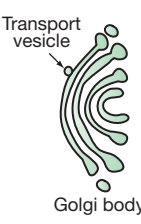
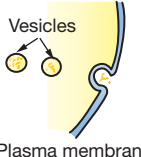
9 Golgi Bodies

A Golgi body is a stack of flattened membrane bound sacs called cisternae. The cisternae form an extensive network in the cell. The membrane of each sac surrounds a separate internal space that is not continuous with the cytosol. The membranes on the opposite sides of a Golgi body are quite different in thickness and composition with the side receiving the materials called the cis face and the side releasing the materials the trans face. The vesicles around the Golgi body are involved in transferring materials between parts of the Golgi body and other structures.



Figure 9.1 Golgi body.

Table 9.1 How Golgi bodies are involved in secretion from a cell.

Organelle	Diagram	What happens
Rough endoplasmic reticulum		Step 1 – Ribosomes on rough endoplasmic reticulum produce polypeptide chains. The new protein enters the lumen of the rER and is sectioned off to form a vesicle. The transport vesicle moves to the Golgi body.
Golgi body		Step 2 – The transport vesicle from rER joins with the Golgi body and its contents are added to the lumen. The Golgi body modifies the substance. New vesicles are formed and bud off. Domes of these transport vesicles contain secretions that leave the cell.
Plasma membrane		Step 3 – Transport vesicles from the Golgi body travel to the plasma membrane. The membrane fuses with the vesicle and the substance is secreted from the cell.

The cis face is usually found near the rough endoplasmic reticulum (rER) and is the convex side of the stack faces. Vesicles containing the proteins formed by the ribosomes on the endoplasmic reticulum fuse with the cis face fuse with the cisternae and release their contents into the lumen inside the sac. As the substance moves from the cis face to the trans face, it is modified by enzymes so that the Golgi bodies are capable of producing a large variety of carbohydrates and proteins. Vesicles are pinched off from the trans face and transport the Golgi products to specific organelles within the cell or to the plasma membrane where they are secreted from the cell.

Most Golgi bodies consist of 5 or 6 cisternae. Within the Golgi body the proteins from the ribosomes may be cut into smaller proteins or carbohydrates may be attached to make glycoproteins.

Cytoplasmic vesicles are classified as either secretory vesicles which contain proteins to be exported or storage vesicles which do not leave the cytoplasm. Lysosomes are the major storage vesicles of the cell. Endocrine cells secrete hormones. Endocrine cells contain large numbers of secretory vesicles formed by the Golgi bodies. When the cell receives a signal for secretion the secretory vesicle releases its contents by exocytosis into the extracellular space.

QUESTIONS

1. Describe the structure of Golgi bodies.
2. Outline the function of Golgi bodies.
3. Discuss the importance of the cis and trans face of Golgi bodies to the function of the organelle.
4. Draw a flow diagram to show how Golgi bodies are involved in secretion.
5. Describe cytoplasmic vesicles.
6. Identify a type of cell that is likely to have a large number of Golgi bodies and explain why they need such a large number of these organelles.
7. The diagram shows a Golgi body.

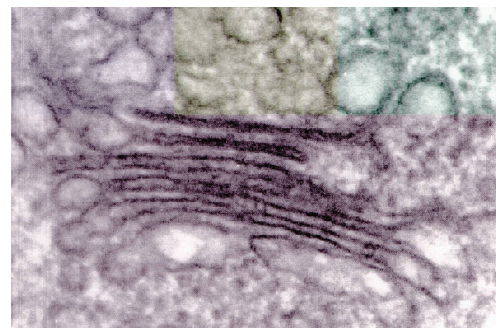


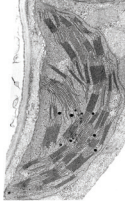
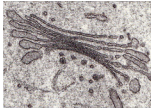
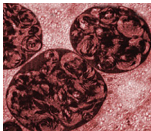
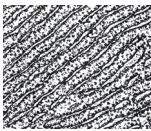
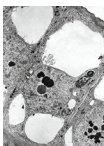
Figure 9.2 Golgi body.

Draw a line diagram of this organelle and discuss how you can distinguish the cis and trans faces.

10 Cell Organelles Summary

All cells have a **cell membrane**. The **cytoplasm** is the entire contents of the cell inside the cell excluding the nucleus. The semi-fluid part of the cytoplasm is the **cytosol**. Cell organelles are specialised structures found in the cell.

Table 10.1 Summary of cell organelles.

Organelle	Its structure	Its function
Mitochondria 	Mitochondria are oval shaped with a double membrane. The inner membrane is highly folded (folds called cristae) to increase surface area for site of chemical reactions.	It is the site of aerobic respiration and where most ATP (adenosine triphosphate) is generated.
Chloroplast 	Chloroplasts have a double membrane with stacks or grana containing chlorophyll to trap sunlight. The grana are in a proteinaceous matrix (stroma).	It is the site for photosynthesis in plant cells converting sunlight energy to chemical energy stored in sugar.
Golgi body 	Is a single membrane structure with sacs stacked like pancakes. Vesicles contain macromolecules, e.g. enzymes, hormones and pinch off from the stack.	Modification of lipids and proteins and storage and packaging of materials for export from the cell.
Lysosome 	A membrane bound organelle containing enzymes and are produced in Golgi bodies.	Pick up and break down unwanted materials or foreign invaders, e.g. old organelles, bacteria, food.
Endoplasmic reticulum 	Network of internal membranes, tubules and vesicles which increase in number as the cell becomes more active in protein synthesis.	It is involved in the transport of materials in the cell, the site of synthesis of many proteins and lipids and connects the cell membrane with the nuclear membrane.
Ribosome  Black dot on ER	Very small, spherical granules made of RNA and protein often attached to endoplasmic reticulum.	It is the site of polypeptide and protein synthesis.
Vacuole 	A fluid filled membrane bound sac. In animals they are usually small, but in plants can be large.	Variety of functions, e.g. storage, digestion or water removal. Involved in turgor pressure in plant cells.

QUESTIONS

- Define cytosol.
- List the parts of the cell that are involved in the membrane system of the cell.
- Identify the organelles involved in collecting or releasing energy.
- Explain why cells that have a high rate of protein synthesis have a very large number of ribosomes present in the cytosol.
- In plant and animal cells, the endoplasmic reticulum (ER) makes up more than half the total membrane of the cell. The tubules (cisternae) of ER have an internal space called the ER lumen (cisternal space). The ER membrane connects with the nuclear membrane so that the ER lumen is continuous with the space between the two membranes of the nuclear membrane.
Suggest why there is a need to connect the nuclear membrane to the membrane system in the cytosol.
- Name the form of energy produced by cellular respiration.
- (a) What is the function of vacuoles?
(b) Compare the vacuoles found in plant cells and in animal cells.
- Which of the following organelles is involved in the breakdown of unwanted materials?
(A) Golgi bodies. (B) Mitochondria.
(C) Ribosomes. (D) Lysosomes.
- The diagram shows a section of a cell.

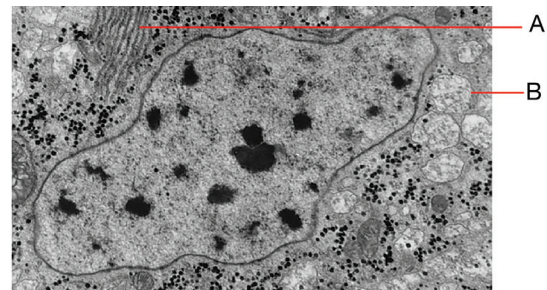


Figure 10.1 Section of a cell.

What are structures A and B?

	Structure A	Structure B
(A)	Endoplasmic reticulum	Nucleus
(B)	Golgi body	Lysosome
(C)	Endoplasmic reticulum	Lysosome
(D)	Golgi body	Mitochondria

- Which of the following organelles is involved in the packaging and export of materials from a cell?
(A) Golgi bodies. (B) Mitochondria.
(C) Ribosomes. (D) Lysosomes.

11 Stem Cells

A **stem cell** is a relatively unspecialised cell that originates through the process of mitosis and can divide by cell division to produce identical daughter cells and to differentiate to form different specialised cells.

Totipotent stem cells can give rise to any type of differentiated cells and form a foetus. The union of sperm and ovum forms a zygote and the cells formed from the first few divisions before the formation of the blastocyst are totipotent.

Pluripotent stem cells can form into any of the embryonic germ layers and give rise to all cell types of the body, e.g. embryonic stem cells from the inner cell mass of the blastocyst are pluripotent. They cannot give rise to a placenta and umbilical cord. In mammals pluripotent stem cells are found in the embryo blastocyst – the early stage of development when the cells form a hollow ball. In humans the blastocyst forms about one week after fertilisation.

Multipotent stem cells can develop into more than one cell type but not all cell types, e.g. adult stem cells found in specific tissues are multipotent such as bone marrow stem cells which give rise to the different types of blood cells and brain stem cells which give rise to nerve cells. Multipotent stem cells function to replenish cells lost from normal turnover or disease.

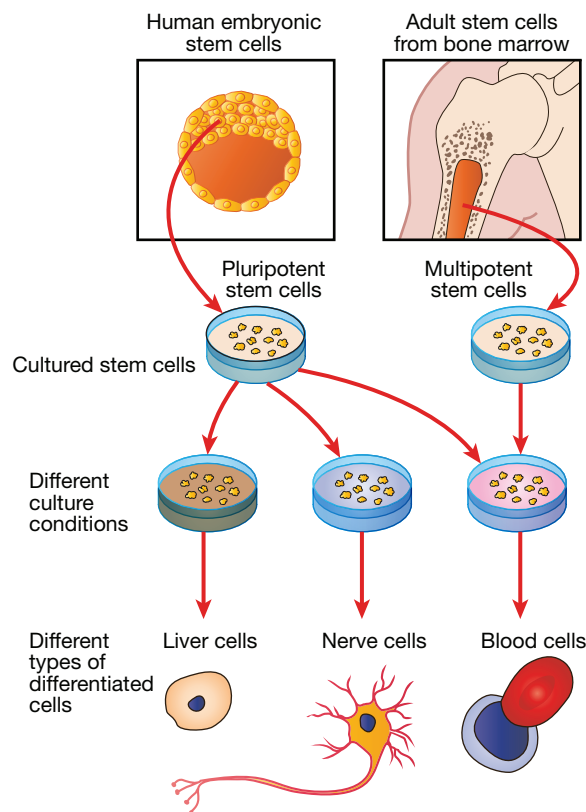


Figure 11.1 Stem cells.

Induced pluripotent stem cells (iPS) have been created in laboratories, e.g. the first iPS were formed using viruses to insert extra copies of genes into tissue specific cells. They can give rise to all cell types but there are some differences to naturally occurring pluripotent stem cells.

Embryonic stem cells

If given the correct environmental conditions, embryonic stem cells can keep dividing and propagating themselves indefinitely.

Embryonic stem cells that are pluripotent come from the inner cell mass of a blastocyst. The **blastocyst** is an embryonic stage in mammals that is a hollow ball of cells produced about one week after fertilisation in humans. The blastocyst consists of over 100 cells with a blastocoel which is a fluid filled cavity and an inner cell mass (ICM). The blastocyst implants in the endometrium, e.g. in humans implantation begins around day 7 and is usually completed by day 14.

Some of the **trophoblast**, the outer layer of cells of the blastocyst develops into the chorion which is an extraembryonic membrane that encloses the entire embryo and forms the placenta. The inner cells of the blastocyst will develop into the embryo and other extraembryonic membranes. These membranes include the amnion which secretes amniotic fluid in which the embryo floats. The inner cell mass will give rise to specialised cells, e.g. muscles, nerves, heart, lung, liver and kidneys. In humans the heart begins beating by the fourth week and can be detected with a stethoscope by the end of the first trimester.

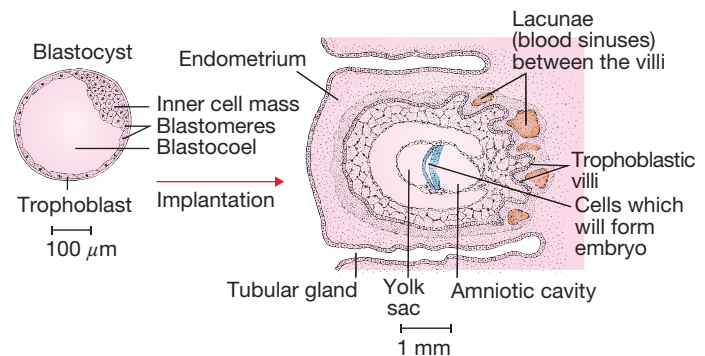


Figure 11.2 Blastocyst and implantation.

The trophoblast cells of the blastocyst cause chemical changes in the endometrium as the embryo penetrates into the endometrial tissues during implantation. As it grows out it begins to form the placenta.

At eight weeks the embryo is called a **foetus**.

Humans, like other vertebrates are triploblastic with three germ layers. The three germ layers are the ectoderm, the mesoderm and the endoderm. Each layer gives rise to particular body parts. **Organogenesis** is the development of body organs from the three germ layers.

The table shows some of the body parts associated with each germ layer.

Table 11.1 Body development from three embryonic germ layers.

Ectoderm	Mesoderm	Endoderm
Skin epidermis	Notochord	Epithelial lining of digestive tract and respiratory system
Sensory receptors in skin	Skeletal and muscular system	Liver and pancreas
Epithelial lining of mouth and rectum	Excretory system	Thyroid and parathyroid glands
Nervous system	Circulatory and lymphatic systems	Lining of urethra, urinary bladder and reproductive system
	Dermis of skin	

Adult stem cells

Adult stem cells or tissue specific stem cells are un specialised and undifferentiated and found in particular locations in the body. They divide and produce new cells for repair and maintenance of body parts. The daughter cells will differentiate and become specialised with specific structures and functions. There are several types of adult stem cells, e.g. haematopoietic stem cells in the bone marrow, mammary stem cells, intestinal stem cells, mesenchymal stem cells, endothelial stem cells, neural stem cells, testicular stem cells, olfactory adult stem cells and neural crest stem cells.

Neurospheres are free-floating clusters of neural stem cells cultured in vivo. Investigations into neurospheres aim to isolate neural stem cells which could be used in treating brain diseases.

QUESTIONS

- Define a stem cell.
- What are totipotent stem cells and where are they found in mammals?
- What are pluripotent stem cells and where are they found in mammals?
- What are multipotent stem cells and where are they found in mammals?
- What is a blastocyst?
- In humans what happens to the blastocyst?
- What is the trophoblast?
- What happens to the trophoblast?
- Which cells of the blastocyst become the embryo?
- In humans when does an embryo become a foetus?
- Define organogenesis.
- Jellyfish and corals are diploblastic with an ectoderm and an endoderm. How does this compare with humans and other vertebrates?
- What is cell differentiation?
- Describe adult stem cells.

- What is the function of adult stem cells?
- In humans identify the body parts that develop from:
 - The ectoderm.
 - The mesoderm.
 - The endoderm.
- The diagram shows the location of stem cells in an adult human.

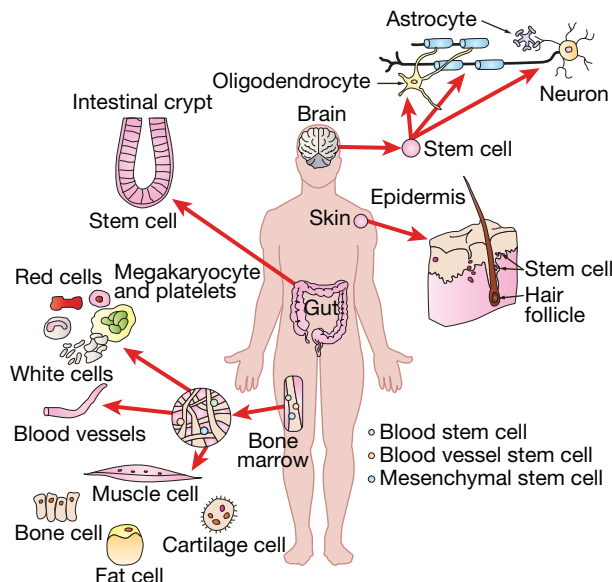


Figure 11.3 Location of stem in an adult human.

Construct a table to show the location of stem cells in the human body and the cell types that are produced at that site.

- What are induced pluripotent stem cells?
- Which cells are likely to form from haematopoietic stem cells?
 - Lining of blood vessels.
 - Mammary gland cells.
 - Lining of the lung.
 - Blood cells.
- The diagram shows a blastocyst.

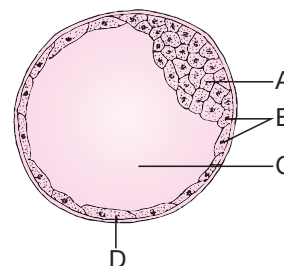


Figure 11.4 Blastocyst.

Which part of the blastocyst has the stem cells that will develop into the embryo and give rise to all cells of the body?

- Part A
- Part B
- Part C
- Part D

13 Differentiation and Specialised Cells

Differentiation is a process when a young, relatively unspecialised cell develops into a more mature state to become a more specialised cell. When cells differentiate they are no longer similar to the parent cell in structure or function. Specialised cells carry out particular functions leading to a division of labour which means particular tasks can be carried out more efficiently.

Cell specialisation occurs when there is **differential gene expression**. The nucleus of each nucleated cell (except gametes which are haploid and have half the number of chromosomes) has a full set of chromosomes. When a specific gene is 'switched on' the cell can change structure and shape so that it becomes specialised to carry out a particular function. Differentiated cells have genes that are switched on that make them specialists in making tissue-specific proteins. For example, muscle cells are specialised to produce the proteins myosin and actin which are needed for muscle contraction. In the human body there are over 200 recognisably different types of cells.

Tissues are groups of cells carrying out a particular function. A tissue may have only one kind of cell or several kinds of cells. There are four main types of mammalian tissue.

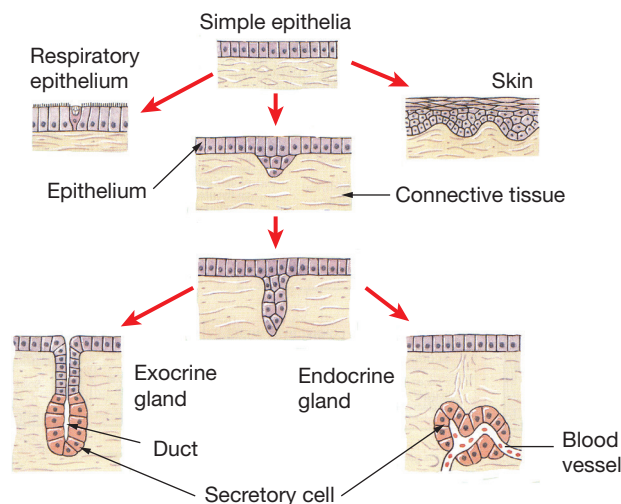


Figure 13.1 Epithelial tissue.

Epithelial tissue

Epithelial tissue (epithelia) covers many surfaces and linings of body cavities. Endothelia lines internal cavities. Epithelial tissue acts as a protective layer and as a barrier against infection by microbes or water loss. Epithelial tissue is found in the outer part of the skin and the linings of the digestive tract, the lungs, the blood vessels, the body cavity and various ducts.

Epithelial cells group together to form sheets which can be strengthened with bundles of filaments running from cell to cell. Simple epithelia can be squamous (flat), cubical or columnar with some having microvilli on one side. Microvilli increase the surface area of the cell to aid the movement of substances into and out of the cell, e.g. in the small intestine and the walls of kidney tubules. Epithelium tissue is usually separated from the underlying tissue by an extracellular fibrous **basement membrane**. The basement membrane is usually made of a network of white, wavy, non-elastic collagen fibres.

Epithelia can differentiate to form the secretory cells of glands or become sensory cells, e.g. olfactory cells in the nose. The gland cells can be unicellular gland cells or a section of the epithelial tissue can invaginate to form a multicellular gland such as an endocrine gland (ductless gland) or an exocrine gland (has duct).

Connective tissue

Connective tissue is found in many areas of the body and includes bone, cartilage, blood, tendons and ligaments. A large proportion of connective tissue is an intercellular matrix that contains a network of protein fibres in a semiliquid ground substance. The matrix is secreted by connective tissue cells and can be liquid, semi-solid or solid. Blood and lymph have liquid matrixes. Connective tissue contains **collagenous fibres** which are non-elastic and do not easily tear when pulled lengthwise. **Elastic fibres** which can stretch and return to their original length and **reticular fibres** which are thin and branched crosslink to form a fine network.

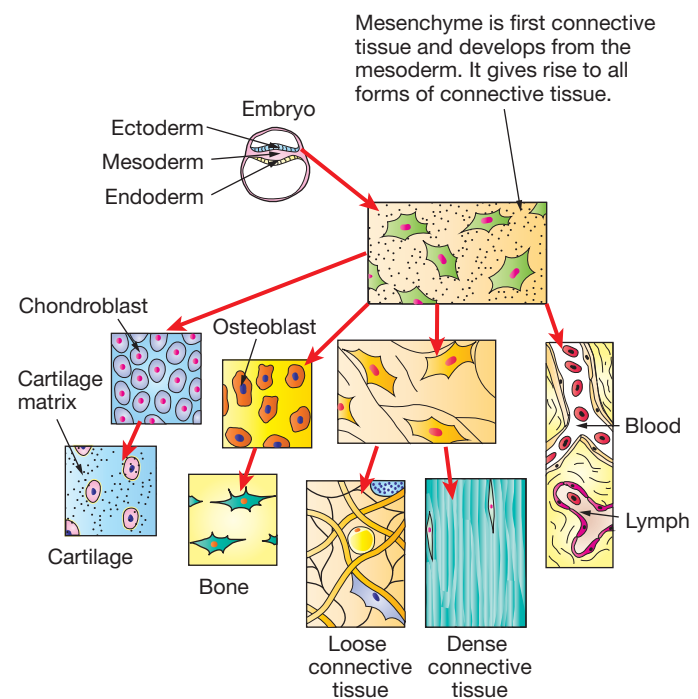


Figure 13.2 Connective tissue.

Muscle tissue

Muscle tissue is specialised to convert chemical energy in ATP into mechanical energy for movement. Smooth muscle forms the walls of many internal cavities, e.g. intestines, blood vessels and bladder. Striated muscle is connected to bones either directly or via a tendon to give voluntary motion. The heart is made of cardiac muscle.

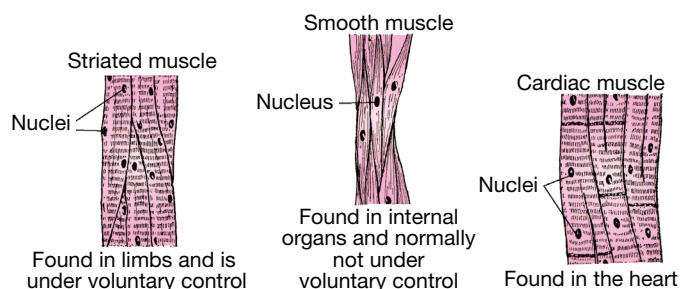


Figure 13.3 Muscle tissue.

Nervous tissue

Nervous tissue consists of specialised cells called neurons (nerve cells) and glial cells. The stem cells in the embryonic brain produce both neurons and glia. A neuron consists of dendrites which pick up the signal and transmit the impulse from their tips to the rest of the neuron. There are several types of neurons, e.g. in the retina there are bipolar cells and ganglion cells and in the brain the neurons of the cerebellum are different to the neurons of the cerebral cortex. Motor neurons take messages from the central nervous system to muscles or glands. Sensory neurons take messages from a sensory receptor to the central nervous system. Supporting glial cells help neurons function correctly.

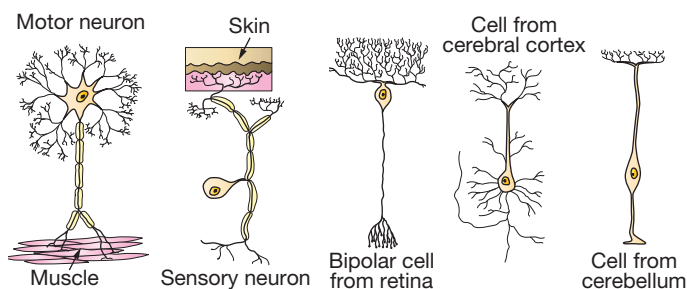


Figure 13.4 Different types of neurons.

QUESTIONS

- Define differentiation.
- Explain why multicellular organisms need specialised cells.
- What is meant by differential gene expression?
- Identify some proteins made by muscle cells that give these cells their particular ability to contract and relax and outline why this is an important substance for muscle cells.
- Are all cells in a tissue identical? Use an example to explain your answer.
- Identify the four main types of mammalian tissue.
- Describe where epithelial tissue is found.
- What are the three basic shapes of epithelial cells?
- Explain the presence of microvilli on epithelial cells.
- What is the basement membrane?
- Distinguish between an exocrine gland and an endocrine gland.
- Where is connective tissue found in the body?
- Outline the function of muscle cells.
- Identify the function of the three types of muscle cells.
- Name the types of cells found in nervous tissue.
- Use examples to show the range of different specialised nerve cells.
- The diagram shows a type of specialised cell.

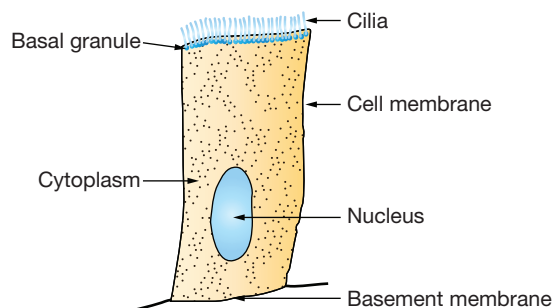


Figure 13.5 A specialised cell.

What is the name of this type of cell?

- Columnar epithelial cell.
- Muscle cell.
- Neuron.
- Squamous epithelial cell.

- The diagram shows a type of tissue.

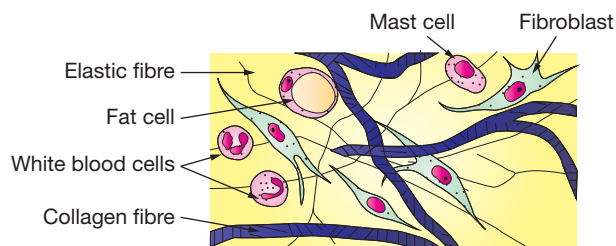


Figure 13.6 A specialised tissue.

What is the name of this type of tissue?

- Nervous tissue.
- Dense connective tissue.
- Loose connective tissue.
- Epithelial tissue.

- What type of cells can become specialised to form gland cells?
 - Neurons.
 - Epithelial cells.
 - Muscle cells.
 - Connective tissue cells.

Section B – Written Response (25 marks)

16. Study the electron micrograph of an organelle.

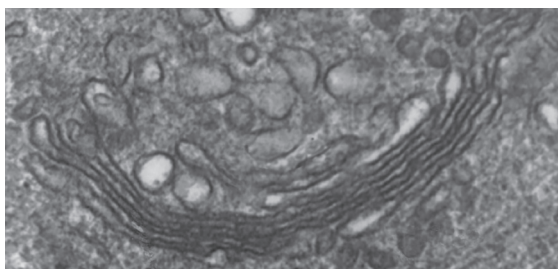


Figure TT1.1.9 An organelle.

- (a) Identify this organelle. (1 mark)
 (b) State its function. (1 mark)
17. A large raw potato is peeled and two cubes are cut from the remaining block. One cube X has sides $1\text{ cm} \times 1\text{ cm} \times 1\text{ cm}$, while the other cube Y has sides $2\text{ cm} \times 2\text{ cm} \times 2\text{ cm}$.

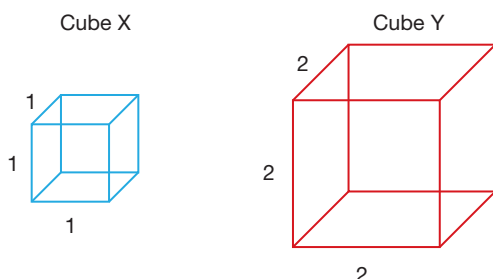
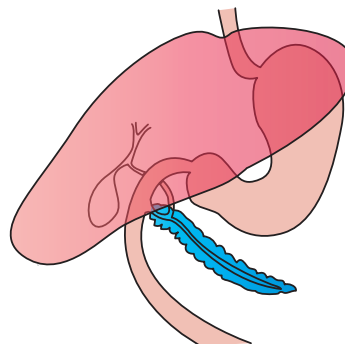


Figure TT1.1.10 Two cubes of potato.

- (a) Explain what would happen if cube Y was placed in a very strong salt solution. (3 marks)
 (b) Explain any difference that would occur if cube X was placed in a salt solution with the same concentration. (2 marks)
18. Distinguish between diffusion, osmosis and active transport noting the concentration gradient and the energy requirements for the movement of substances. (6 marks)

19. The diagram shows part of the digestive system.



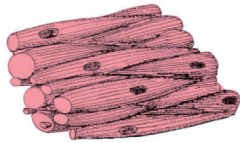
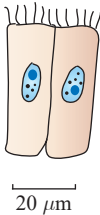
- S Stores food. Produces acid and enzymes.
 T Regulates passage of chyme into small intestine from stomach.
 U Takes secretions to the duodenum.
 V Exocrine gland produces digestive enzymes.
 W Receives chyme from the stomach and digestive secretions from the pancreas and liver.
 X Secretes bile into a network of narrow channels.
 Y Stores and modifies bile, absorbing water and concentrating bile salts and other components.
 Z Empties secretions into the duodenum.

Figure TT1.1.11 Part of the digestive system.

Copy the diagram and correctly match each part and its description by labelling the diagram. (8 marks)

20. The table shows two types of cells found in animals.

Table TT1.1.12 Different types of animal cells.

Animal cell A	Animal cell B
	

Identify each type of cell and relate its structure to its function. (4 marks)

TOPIC 1.2

Exchange Of Nutrients and Wastes

In this topic you will:

- Describe the structure and function of carbohydrates, proteins and lipids.
- Describe the role of digestive enzymes.
- Explain the structural features of exchange surfaces.
- Describe closed circulatory systems.
- Identify the parts of a nephron and their function.
- Explain glomerular filtration, selective reabsorption, and secretion across nephron membranes.
- Describe the structure and function of enzymes, and the role of the active site.
- Compare the induced fit and lock and key models.
- Explain how different factors affect enzyme activity.
- Appreciate how understanding anatomy and physiology aids prediction, diagnosis, monitoring and treatment of disease.

49 Assumed Knowledge Topic 1.2

QUESTIONS

1. Name the four basic groups of organic compounds.
2. What are inorganic compounds?
3. The diagram shows the human digestive tract. Identify each part.

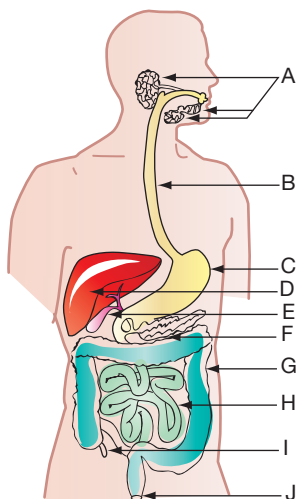


Figure 49.1 Human digestive tract.

4. For each of the following parts of the digestive system, outline its structure and its main function.
 - (a) Mouth.
 - (b) Oesophagus.
 - (c) Stomach.
 - (d) Small intestine.
 - (e) Large intestine.
 - (f) Anus.
5. The diagram shows a simple model of digestion.

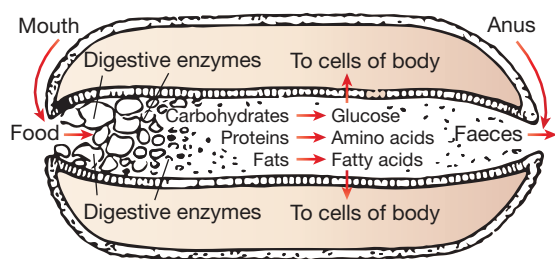


Figure 49.2 Simple model of digestion.

- (a) From this model what foods are broken down into:
 - (i) Glucose?
 - (ii) Amino acids?
 - (iii) Fatty acids?
 - (b) Explain why scientists make simple models such as this simple model of digestion.
6. Define an enzyme.
 7. Identify the group of enzymes that break down:
 - (a) Carbohydrates.
 - (b) Proteins.
 - (c) Lipids.
 8. What is meant by pH?
 9. What is meant by a 'closed' circulatory system?

10. The graph shows the action of an enzyme at different pH.

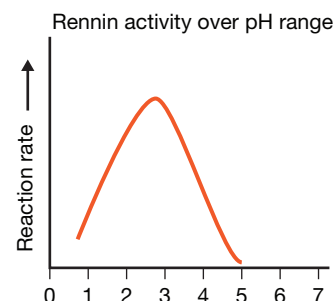


Figure 49.3 Enzyme action and pH.

What is the optimal pH for this enzyme from this graph?

11. The diagram shows a simple model to illustrate the specificity of enzymes on substrates.

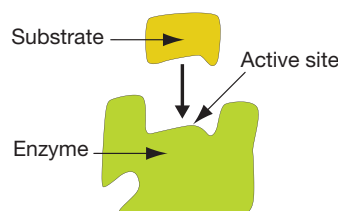


Figure 49.4 Simple model of enzyme and substrate.

What is meant by:

- (a) Substrate?
 - (b) Active site?
12. What is the basic structural and functional unit of the kidney?
 13. List three features of an efficient nutrient exchange surface.
 14. The diagram shows the cross-section of a villus.

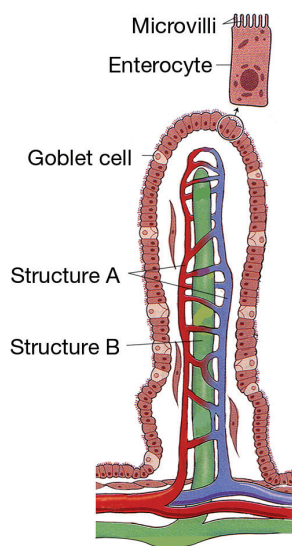


Figure 49.5 Villus cross-section.

- (a) Where are villi located in the human body?
- (b) What is the function of a villus?
- (c) Identify structures A and B.
- (d) Explain the significance of the microvilli.