Surfing

WACE HUMAN BIOLOGY

Unit 1 The Functioning Human Body

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Science Press

First published 2017

Science Press
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Introduction

Each book in the *Surfing* series contains a summary, with occasional more detailed sections, of all the mandatory parts of the syllabus, along with questions and answers.

All types of questions – multiple choice, short response, structured response and free response – are provided. Questions are written in exam style so that you will become familiar with the concepts of the topic and answering questions in the required way.

Answers to all questions are included.

A topic test at the end of the book contains an extensive set of summary questions. These cover every aspect of the topic, and are useful for revision and exam practice.

Words To Watch

account, account for State reasons for, report on, give an account of, narrate a series of events or transactions.

analyse Interpret data to reach conclusions.

annotate Add brief notes to a diagram or graph.

apply Put to use in a particular situation.

assess Make a judgement about the value of something.

calculate Find a numerical answer.

clarify Make clear or plain.

classify Arrange into classes, groups or categories.

comment Give a judgement based on a given statement or result of a calculation.

compare Estimate, measure or note how things are similar or different.

construct Represent or develop in graphical form.

contrast Show how things are different or opposite.

create Originate or bring into existence.

deduce Reach a conclusion from given information.

define Give the precise meaning of a word, phrase or physical quantity.

demonstrate Show by example.

derive Manipulate a mathematical relationship(s) to give a new equation or relationship.

describe Give a detailed account.

design Produce a plan, simulation or model.

determine Find the only possible answer.

discuss Talk or write about a topic, taking into account different issues or ideas.

distinguish Give differences between two or more different items.

draw Represent by means of pencil lines.

estimate Find an approximate value for an unknown quantity.

evaluate Assess the implications and limitations.

examine Inquire into.

explain Make something clear or easy to understand.

extract Choose relevant and/or appropriate details.

extrapolate Infer from what is known.

hypothesise Suggest an explanation for a group of facts or phenomena.

identify Recognise and name.

interpret Draw meaning from.

investigate Plan, inquire into and draw conclusions about.

justify Support an argument or conclusion.

label Add labels to a diagram.

list Give a sequence of names or other brief answers.

measure Find a value for a quantity.

outline Give a brief account or summary.

plan Use strategies to develop a series of steps or processes.

predict Give an expected result.

propose Put forward a plan or suggestion for consideration or action.

recall Present remembered ideas, facts or experiences.

relate Tell or report about happenings, events or circumstances.

represent Use words, images or symbols to convey meaning.

select Choose in preference to another or others.

sequence Arrange in order.

show Give the steps in a calculation or derivation.

sketch Make a quick, rough drawing of something.

solve Work out the answer to a problem.

state Give a specific name, value or other brief answer.

suggest Put forward an idea for consideration.

summarise Give a brief statement of the main points.

synthesise Combine various elements to make a whole.

1 Assumed Knowledge

1. The cell is the basic unit of life. What structural features of cells are possessed by all living things?
2. Draw a fully labelled diagram of a human epithelial cheek cell as seen under a light microscope.
3. Identify the following parts of a light microscope and use by a person.

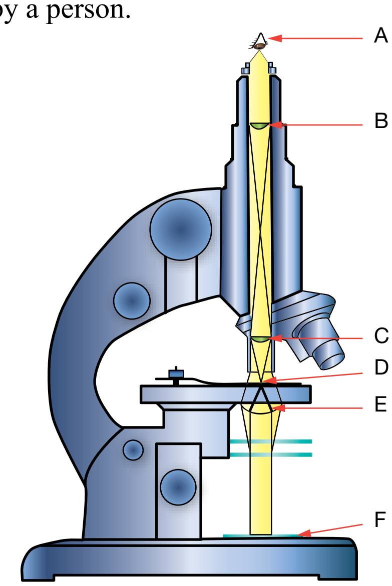


Figure 1.1 Light microscope.

4. Describe one safety precaution you should follow while using a light microscope.
5. What is the function of the nucleus of a cell?
6. What is the function of the cell membrane?
7. What is cytoplasm?
8. Define protoplasm.
9. Define cytosol.
10. Outline the function of the circulatory system.
11. A common prefix used in human biology is 'vas' or 'vaso'. What does this mean and give an example.
12. Outline the function of blood.
13. Name the three types of blood vessels.
14. Outline the function of the heart.
15. Identify the components of the human circulatory system.
16. Define respiration.
17. In humans, what structures make up the respiratory system?
18. Outline the function of the respiratory system.
19. What are lymph vessels?
20. Define metabolism.
21. Name the four basic groups of organic compounds.
22. What are inorganic compounds?
23. What is the function of the digestive system?
24. What are the two main uses of food?
25. Define an enzyme.
26. To what does the prefix 'hepat-' refer?
27. Distinguish between anabolism and catabolism.
28. Figure 1.2 shows the human digestive tract. Identify each part.

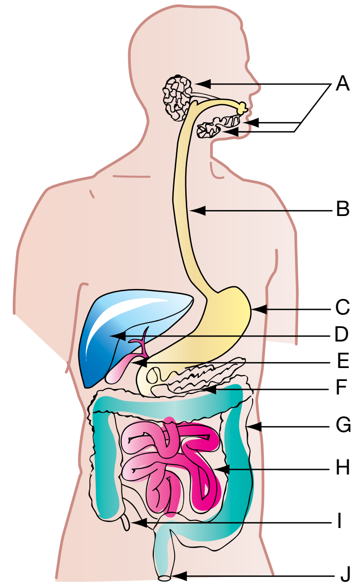


Figure 1.2 Human digestive tract.

29. Construct a table to show each of the following parts of the digestive system, to outline its structure and its main function.
    (a) Mouth.
    (b) Oesophagus.
    (c) Stomach.
    (d) Small intestine.
    (e) Large intestine.
    (f) Anus.
30. The diagram shows a simple model of digestion.

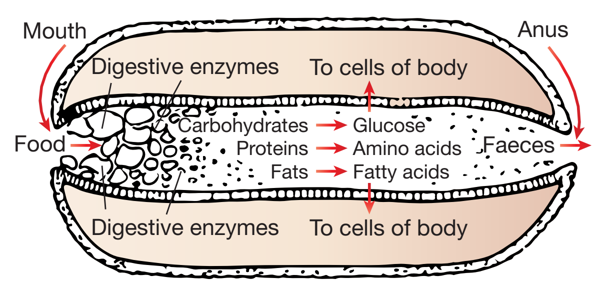


Figure 1.3 Simple model of digestion.

(a) From this model identify 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.

31. What is the function of the excretory system?
32. Outline the function of the excretory system.
33. What is the function of the muscular system?
34. Why is movement of the whole body or parts of the body needed?
35. Describe muscle tissue.

2 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 how activities affect the heart and breathing rate in humans.'

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 level of physical exercise increases, the breathing rate 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 physical exercise causes an increase in the breathing rate, the independent variable is the amount of physical exercise and the dependent variable is the breathing rate.

When carrying out this experiment you would need to control the age of the people, the type of physical exercise, the physical conditions of the person exercising, e.g. temperature, humidity, terrain/floor on which they are exercising, when the person had last eaten, physical fitness level of people involved.

However, not all biology investigations involve dependent/independent variables, e.g. studying the structure of red blood 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, web pages 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

1. A Human Biology student measured the heart rate of a test person by putting a finger on the neck of the test person and counting the number of beats in 60 seconds. The test person jumped on the spot for 2 minutes and the heartbeat of the test person was measured again in the same way.
   (a) Suggest an hypothesis that could be investigated for these observations.
   (b) For the hypothesis you suggested in part (a), identify the dependent variable and the independent variable.
   (c) If the students carried out an investigation to test their hypothesis, what factors would they need to control and keep constant?
2. Some Human 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.
   (a) Write a suitable aim for this experiment.
   (b) Suggest why the students needed to use the high power objective to observe red blood cells and white blood cells.
   (c) List the equipment the students would need to carry out this investigation.
   (d) Identify a safety precaution the students would have needed to follow to carry out this investigation.
3. The diagram shows a graph drawn by students in their results section of their practical report.

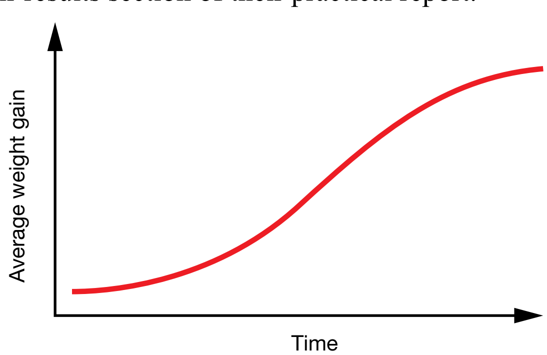


Figure 2.1 Graph of student results.

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

4. A spirometer is used to measure human lung capacity measuring the volume of air inspired and expired by the lungs.

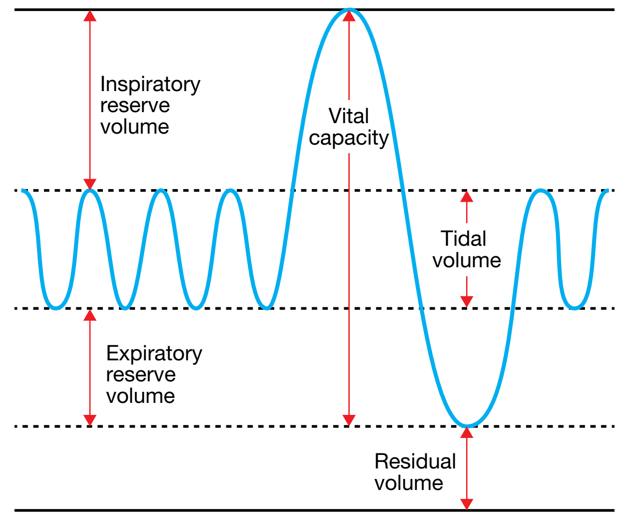


Figure 2.2 Spirometer data.

Some students used a spirometer when rested and sitting down recording the result as normal breathing rate per minute. Other students used the spirometer by breathing in as deeply as possible and then resuming normal breathing. Other students breathed out as far as possible and then resumed normal breathing. The results were tabulated and average vital lung capacity was deduced from the data. Determine the validity of this experiment.

5. The diagram shows the process of scientific method.

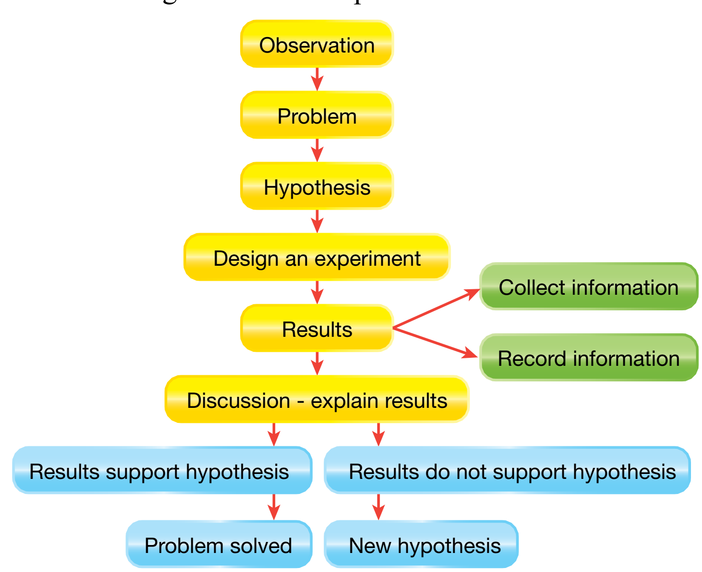


Figure 2.3 Scientific method.

Explain how this process relates to writing practical reports.

3 The Modern Light Microscope

The compound light microscope operates on the main principle that an objective lens with a very short focal length can form a highly magnified real image of the object. Visible light passes through the specimen and then a series of lenses. The resolution of the microscope is limited by the shortest wavelength of light used to view the specimen.

Images from a light microscope can be captured with a camera to produce a **photomicrograph**. Digital images can be shown directly on a computer screen.

Table 3.1 Features of the modern light microscope.

Feature	Light microscope
Magnification	Effective up to 1000×.
Resolution	Up to 0.2 μm.
Stains	Allows the use of many different coloured stains to identify substances, structures and provide contrast for easier viewing.
Living specimen	The light microscope allows viewing of living specimen and processes occurring within a cell or within an organism.
Mounting	The specimen is mounted on a glass slide in air.
Focusing	By glass lenses.
Energy source for viewing	A beam of light is passed through the specimen.

How a light microscope works

The objective lens is brought close to the specimen to create an enlarged image of the object. The image is inverted. In most modern light microscopes the eyepiece is a compound lens near the back of an eyepiece tube. Light travels from the light source up the microscope to form an image at the eye.

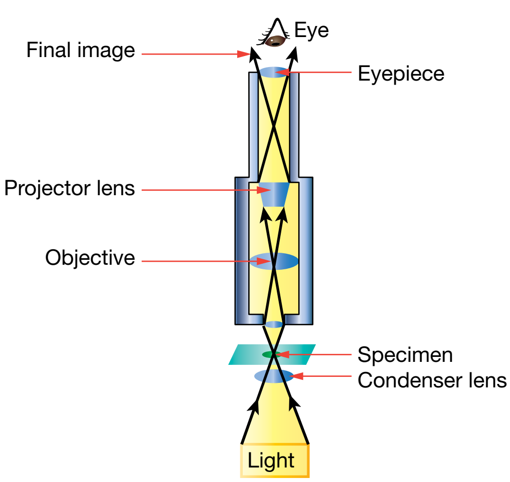


Figure 3.1 How light travels through a light microscope.

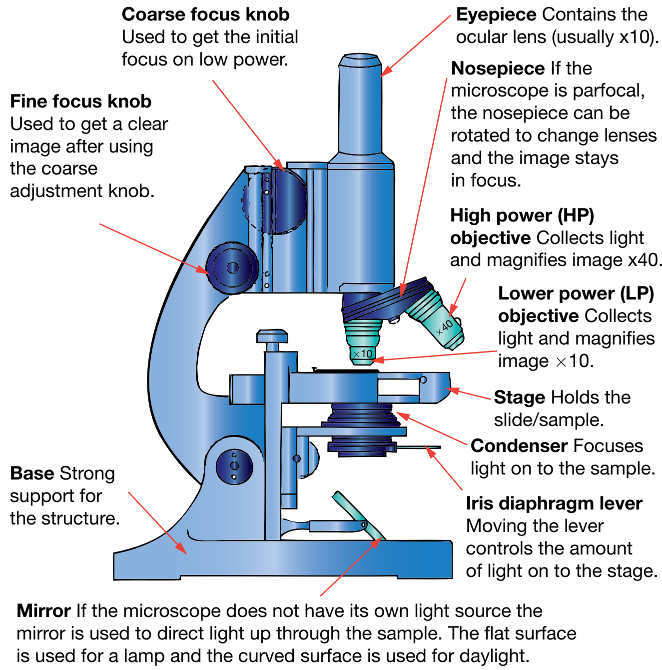


Figure 3.2 Features of the modern light microscope.

Advantages of a light microscope

The main advantages of light microscopes are that:

- Living cells can be observed.
- Coloured stains can be used.
- The specimens are easy to prepare.
- The microscopes are relatively inexpensive (compared to the cost of an electron microscope).
- Their size means they are relatively easy to store.

Disadvantages of a light microscope

The main disadvantages of the light microscope are:

- Its limited magnification (effective magnification begins to reduce after 1000×).
- Its limited resolution.

During the 20th century many different illumination techniques and other developments have increased the detection power of the light microscope for observing living cells.

Phase contrast microscopes

The phase contrast microscope uses interference rather than absorption of light to increase the contrast in unstained cells by amplifying variations in density within the cell. It improves our ability to study living, unpigmented cells in biological and medical research. Many dyes and stains stop chemical processes in cells which means the phase contrast microscope has improved our ability to see detail in living cells, e.g. the process of cell division. Frits Zernike was awarded with the Nobel Prize in Physics, 1953 for the development of phase contrast illumination.

Fluorescence microscopes

In the fluorescence microscope the specimen is illuminated through objective lenses with a narrow set of light wavelengths. The specimen either fluoresces in its natural form, e.g. chlorophyll or has been treated with fluorescing chemicals or antibodies. The fluorescent substances absorb UV light and emit visible light so that the fluorescence shows the location of specific molecules in the cell.

Other illumination techniques

Other illumination techniques include:

- **Bright field** – passes light through the specimen and contrast comes from the absorbance of light in the specimen. If the specimen is unstained or unpigmented there is little contrast.
- **Cross-polarised** – contrast occurs when polarised light is rotated through the sample.
- **Confocal** – is a type of fluorescence microscopy using optical sectioning by scanning lasers of fluorescently-stained specimens.

Stains and dyes used with the light microscope

There are many stains that are used to highlight structures being viewed under a light microscope.

- **Gram staining** – uses several stains, e.g. crystal violet, iodine, fuchsin or safranin to stain cell cells to differentiate bacteria into Gram positive (purple/blue colour occurs) and Gram negative (pink/red colour occurs). This is usually the first step in identifying bacteria.
- **DAPI** – is a fluorescent nuclear stain that shows a blue fluorescence when bound to DNA and viewed with ultraviolet light.
- **Eosin** – is used as a counterstain with haematoxylin in H&E staining and gives a pink/red colour to cytoplasmic material, red blood cells and cell membranes.

QUESTIONS

1. Outline the basic principle behind the operation of a light microscope.
2. When using a light microscope identify the function of:
   (a) The condenser.
   (b) The iris diaphragm.
3. What restricts the resolution of the light microscope?
4. Construct a table to compare the advantages and disadvantages of a light microscope.
5. What is a photomicrograph?
6. Outline the benefit of the phase contrast microscope.
7. Outline the benefit of fluorescence microscopy.
8. The table shows some objects and their sizes.

Object	Size (μm)
Frog egg	1100
Paramecium	100
Plant epithelial cell	60
Human ovum	10
Red blood cell	7 to 8
Mitochondrion	1.1
Nanobes	0.025

Identify which objects could be seen with the naked eye and/or light microscope.

9. Use an example to show how the use of stains and the light microscope have increased our understanding of processes in cells.
10. Most modern light microscopes in schools have at least two different objectives. Name objectives you have used and state the purpose of each objective.
11. What is a parfocal microscope?
12. The diagram shows red blood cells as seen and as drawn by a Human Biology student using a light microscope.

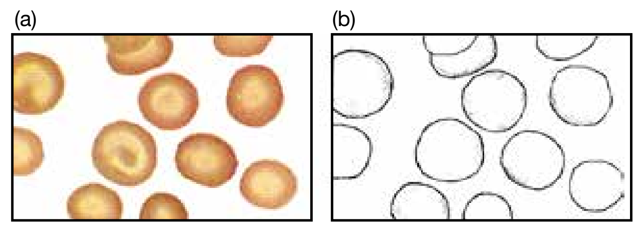


Figure 3.3 Red blood cells seen using a light microscope. (a) Seen under a light microscope. (b) As drawn by a student.

Red blood cells are usually about 6 to 8 micrometres in diameter.
Which objective would the student most likely have been using to view these cells as seen in the diagram? Explain your answer.

13. Explain why the Gram stain is used.
14. What is the correct order of the movement of light when an object is viewed under a light microscope?
   (A) Light → condenser → objective → eyepiece → eye
   (B) Light → objective → condenser → eyepiece → eye
   (C) Light → objective → eyepiece → condenser → eye
   (D) Eye → eyepiece → objective → condenser → light
15. What is the limit of resolution of a light microscope?
   (A) 0.2 centimetres
   (B) 0.2 millimetres
   (C) 0.2 micrometres
   (D) 0.2 nanometres

4 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 microscope

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 4.1 Features of the electron microscope.

Feature	Electron microscope
Magnification	Up to 300 000×
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 microscope

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

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

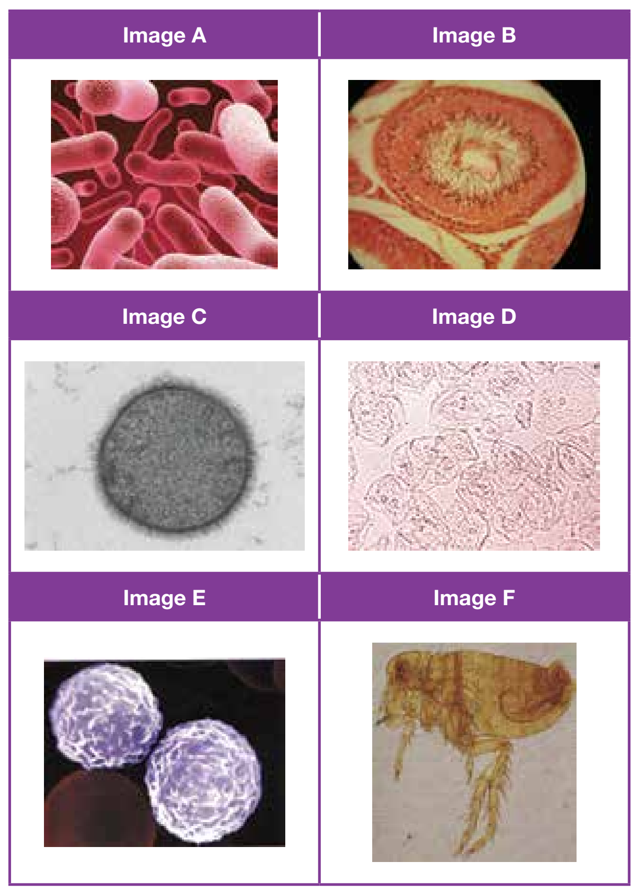


Figure 4.1 Images from different types of microscopes.

7. 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

5 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.

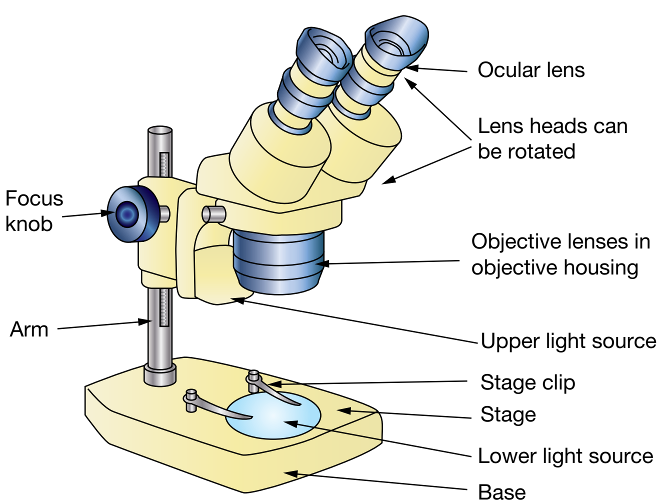


Figure 5.1 Stereo microscope.

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× to 40×.

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.

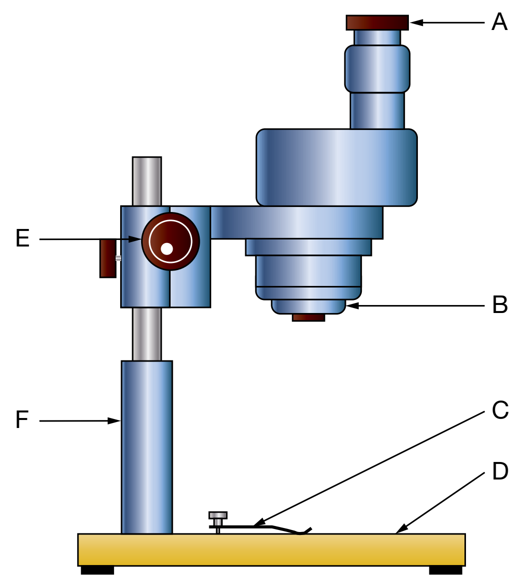


Figure 5.2 Side view of a stereo microscope.

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.

6 Experiment – The 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× and some microscopes have interchangeable eyepieces, e.g. 5× or 10×. There is usually a choice of at least two objective lenses, for example 10× and 40×. 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× 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 Figure 6.1.

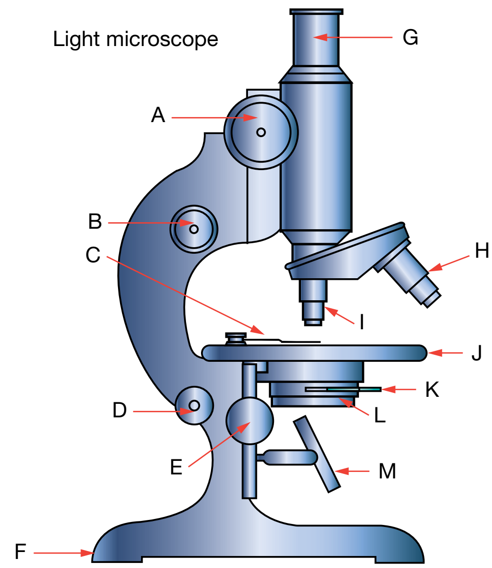


Figure 6.1 Compound light microscope.

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×, what is the overall magnification for each of these objective lenses?
   (a) Low power objective 10×.
   (b) High power objective 40×.
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.

7 Experiment – 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 μm and can effectively magnify objects up to 1000×. Many light microscopes used by students in schools are only equipped with lenses that allow up to 400× 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. Figure 7.1 shows a section of minigrid with a central mm square divided into 0.1 mm divisions.

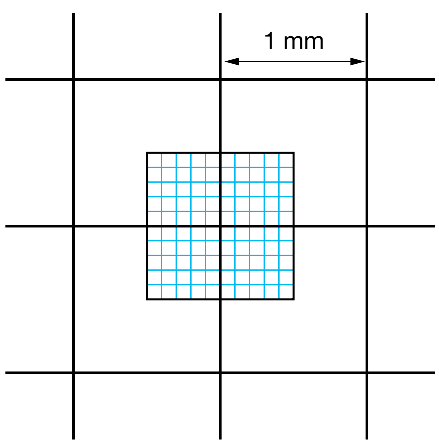


Figure 7.1 Section of a minigrid with the central area subdivided into 0.1 mm divisions.

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. Figure 7.2 shows a minigrid under lower power of a light microscope using an eyepiece 10× and a low power objective 10×.

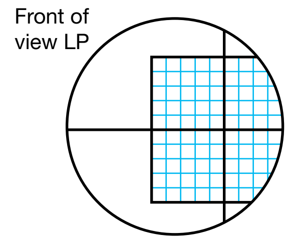


Figure 7.2 Minigrid under a light microscope.

   (a) Estimate the diameter of the field of view in millimetres and micrometres.
   (b) If the high power objective (40×) was used on this microscope, what would be the diameter of the field under high power?

3. Figure 7.3 shows the appearance of the letter 'e' as seen under low power of a light microscope.

Figure 7.3 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. Figure 7.4 shows a plant root hair as seen under a light microscope that has a minigrid.

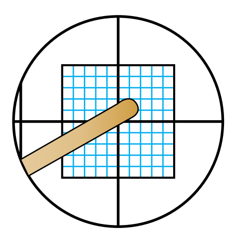


Figure 7.4 Root hair and minigrid under a light microscope.

   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?

8 Cells, Tissues, Organs and Systems

Multicellular organisms consist of many cells and many require specialised cells to carry out particular jobs. Specialisation allows a more efficient supply of nutrients, removal of wastes, and the other processes essential to life.

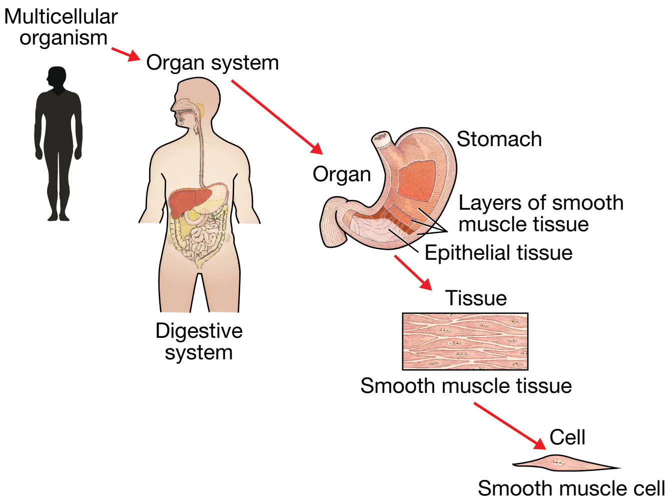


Figure 8.1 Levels of organisation.

The **cell** is the basic unit of life. Many cells are specialised to carry out particular tasks, e.g. red blood cells carry oxygen. This means that specialised cells often have a distinct shape and special kinds of chemical reactions occur in their cytoplasm.

A **tissue** is a group of cells with similar structure and function. For example, muscle tissue is made of many aligned muscle cells which are long cells able to shorten to produce movement. There are four main types of tissues – epithelial tissue, connective tissue, muscle tissue and nervous tissue. Tissue regeneration can occur when some of the original cells are present and can replicate by mitosis.

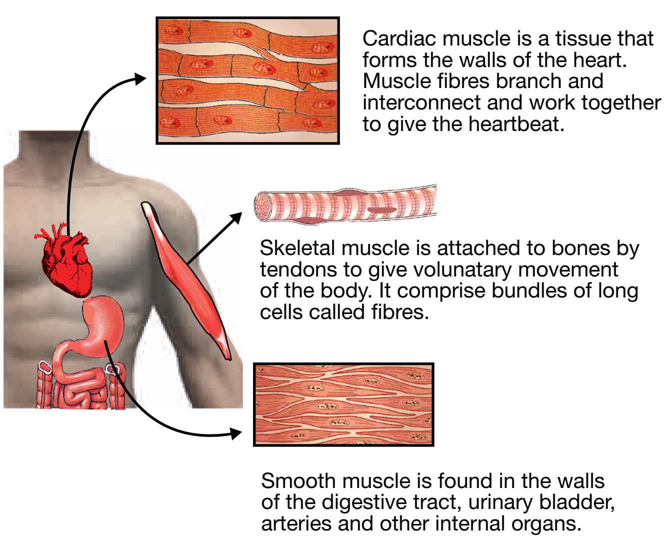


Figure 8.2 Muscle tissue.

Muscle tissue generates motion and generates force. It can also generate heat and help maintain body temperature in endotherms. The three different types of muscle tissue are found in different organs and different systems.

An **organ** is a group of tissues grouped together to make a structure with a special function. For example, the stomach is an organ which has an epithelial lining, gland tissue and muscle layer supplied with blood vessels and nerves.

A **system** is usually a group of organs whose function is closely related, for example the stomach and intestines.

QUESTIONS

1. Define the following terms.
   (a) Cell
   (b) Tissue
   (c) Organ
   (d) System
2. Give an example of each of the following.
   (a) Organ
   (b) Tissue
   (c) Specialised cell
3. Describe how the different types of muscle tissue are in different systems but they have a similar general function.
4. The kidneys, certain nerves, bladder, urethra and ureters cooperate to remove chemical wastes from the body. Identify the level of organisation for this cooperation.
   (A) Tissue
   (B) Organ
   (C) System
   (D) Cell
5. The diagram shows two types of cells.

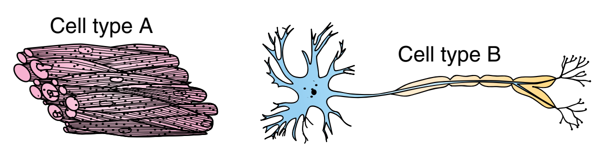


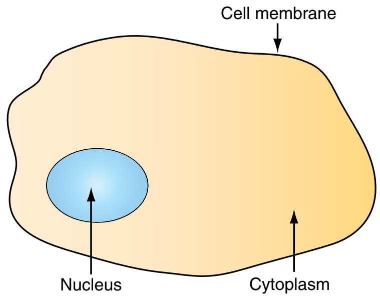
Figure 8.3 Two types of cells.

   What is the importance of cells having different shapes?
   (A) More cells can fit into the same space.
   (B) Different cell shape is related to different function.
   (C) Cell shape indicates different species.
   (D) Different cell shape shows evolutionary relationships.
6. What is the correct order from smallest to largest level of organisation?
   (A) System → organ → tissue → cell
   (B) Organ → system → tissue → cell
   (C) Cell → tissue → system → organ
   (D) Cell → tissue → organ → system

Answers

1 Assumed Knowledge

1. The cells of living things have a cell membrane, cytoplasm and DNA.
2. Human epithelial cheek cell.



3. A = eye of person using the light microscope, B = ocular lens, C = objective lens, D = specimen, E = condenser lens, F = light source.
4. When using a light microscope, you should always wear shoes with covered toes, as the microscope is heavy and if you drop it you could damage exposed skin on your feet.
5. The nucleus stores information needed to control all cell activities.
6. The cell membrane surrounds the cell contents from the external environment and controls the substances that can leave or enter the cell.
7. Cytoplasm is a general term for the contents of a cell outside the nucleus and within the cell membrane.
8. Protoplasm is the semifluid transparent substance that makes up the living matter of plant and animal cells including the nucleus and cytoplasm.
9. Cytosol is the semifluid part of the cytoplasm.
10. The circulatory system is the transport system of the body, e.g. it carries the glucose and oxygen to the cells and distributes heat around the body.
11. Vas/vaso means vessel. Vasoconstriction means a decrease in the diameter of a superficial blood vessel. The vas deferens is the tube in the male reproductive system that carries sperm from the epididymis to the urethra.
12. Blood consists of plasma and blood cells and transports substances around the body through a large network of blood vessels.
13. Blood vessels include arteries, veins and capillaries.
14. The heart is a muscular pump that uses metabolic energy to maintain blood pressure causing blood to flow down the pressure gradient through blood vessels.
15. The human circulatory system consists of the heart and blood vessels, e.g. arteries, veins and capillaries and blood.
16. Respiration is the chemical reactions in which cells obtain energy from food.
17. In humans, the respiratory system consists of the lungs and passages which bring air into and out of the lungs, e.g. trachea, bronchi and alveoli.
18. The function of the respiratory system is the intake, expulsion and exchange of oxygen and carbon dioxide.
19. Lymph vessels are part of the lymphatic system beginning as blind-ended tubes in the spaces between tissue cells and blood vessels.
20. Metabolism is the sum of all chemical reactions in an organism.
21. The four basic groups of organic compounds are proteins, carbohydrates, lipids and nucleic acids.
22. Inorganic compounds are molecules that do not contain carbon (excluding some carbonates and simple oxides of carbon).
23. The function of the digestive system is to break down ingested food into smaller particles so that nutrients can be absorbed into the body.
24. Food is needed to provide – 1. The chemical substances which can be built into large molecules that make up the structure of cells. 2. Chemical substances that can be oxidised to yield energy. The energy is needed for movement, for synthesis of large molecules from simple molecules and in endotherms for the production of heat.
25. An enzyme is an organic catalyst that changes the rate of a reaction without being consumed by the reaction.
26. The prefix hepat- refers to the liver, e.g. hepatitis is a disease of the liver and the hepatic portal vein goes to the liver.
27. Anabolism is the building of large, complex molecules from simpler compounds while catabolism is the breaking down of substances to provide energy and raw materials.
28. A = salivary glands, B = oesophagus, C = stomach, D = liver, E = gall bladder, F = pancreas, G = large intestine, H = small intestine, I = appendix, J = anus.
29.

Part	Structure	Function
Mouth	Has teeth and openings from salivary glands	Teeth break food into small pieces and salivary enzymes begin chemical digestion
Oesophagus	Long tube	Moves food to stomach by peristalsis
Stomach	Muscles and glands in wall	Churns food and produces digestive enzyme to digest protein
Small intestine	Long thin tube with villi and glands	Digestion is completed and nutrients absorbed through walls
Large intestine	Long tube	Water, salts and vitamins absorbed
Anus	Muscular ring	Eliminates faeces

30. (a) (i) Carbohydrates are broken down into glucose.
(ii) Proteins are broken down into amino acids.
(iii) Fats are broken down into fatty acids.
(b) Scientists make simple models to make it easier to understand complex systems providing, as in this case of the model of the digestive system, a basic idea of the structure and functioning of a multifaceted body system. The diagram shows the digestive system as a long tube through the body that acts as a a functional unit of life.
31. The excretory system regulates the chemical composition of body fluids by removing metabolic wastes and retaining the proper amounts of water, salts and nutrients.
32. The excretory system consists of the kidneys, liver, lungs and skin functioning at the organ level.
33. The muscular system is organised to maintain posture and produced movement.
34. Movement is needed for obtaining food, reproduction and avoiding injury.
35. Muscle tissue consists of long muscle cells that are able to contract when stimulated.

2 Writing a Practical Report

1. (a) A suitable hypothesis could be 'Exercise causes an increase in heart rate.'
(b) The independent variable is before/after exercise. The dependent variable is the heart rate.
(c) To test their hypothesis the students would need to: 1. Use the same test person. 2. Temperature of area before/after. 3. Other room conditions need to be constant, e.g. humidity, wind exposure. The only factor that should vary is before/after exercise.
2. (a) A suitable aim would be –'To use a light microscope to determine the size of red blood cells and white blood cells'.
(b) Red blood cells are approximately 6 to 8 micrometres in diameter. A high power objective is needed to clearly see red blood cells to determine their dimensions.
(c) The students would need a light microscope with lamp, lens tissues and a prepared slide of blood.
(d) When using a light microscope you need to carry it using two hands to avoid dropping it as it is heavy and if dropped could hurt legs and feet. If using a separate microscope lamp you should take care to not touch the hot lamp to avoid burns and wait till the lamp is cool before packing away.
3. The independent variable is time and the dependent variable is the average weight gain.

4. The experiment is not valid as variables were not sufficiently controlled in the design of the experiment. Different sets of students were used to gather data about normal breathing rate, inspiratory reserve volume and expiratory reserve volume. This invalidates the average vital lung capacity data that was calculated.
5. A practical report follows the process of scientific method and should be written in the same sequence of events. If a hypothesis is proved correct, then it can be developed into a theory and then a law.

3 The Modern Light Microscope

1. The compound light microscope passes visible light through the specimen and then through a series of lenses. It operates on the main principle that an objective lens with a very short focal length can form a highly magnified real image of the object.
2. (a) The condenser focuses light on to the sample.
   (b) The iris diaphragm controls the amount of light on to the stage.
3. The resolution of the microscope is limited by the shortest wavelength of light used to view the specimen (wavelengths of visible light are 400 to 700 nm).
4.

Advantages of light microscope	Disadvantages of light microscope
Can view living specimens and observe processes in cells and within an organism. Allows the use of many different coloured stains to identify substances, structures and provide contrast for easier viewing. Specimens are easy to prepare, stain and observe in a short time frame. Relatively inexpensive and class sets can be purchased for use in schools. Light microscopes are not particularly large and are easy to store, e.g. in schools.	Limited magnification, e.g. effectively up to 1000×. Resolution limited to 0.2 micrometres.

5. A photomicrograph is a photograph made through a microscope.
6. The main benefit of the phase contrast microscope is that it increases the contrast in unstained cells. It improves our ability to study living, unpigmented cells in biological and medical research. Many dyes and stains stop chemical processes in cells which means the phase contrast microscope has improved our ability to see detail in living cells, e.g. the process of cell division.
7. The main benefit of fluorescence microscopy is that the fluorescence shows the location of specific molecules in the cell. Natural fluorescing substances, e.g. chlorophyll can be located or the specimen can be treated with fluorescing chemicals or antibodies to locate other particular section or substances in cells.
8.

Object	Size (μm)	Viewing
Frog egg	1100	Naked eye and light microscope
Paramecium	100	Light microscope
Plant epithelial cell	60	Light microscope
Human ovum	10	Light microscope
Red blood cell	7 to 8	Light microscope
Mitochondrium	1.1	Light microscope
Nanobes	0.025	Cannot be seen under a light microscope – need an electron microscope

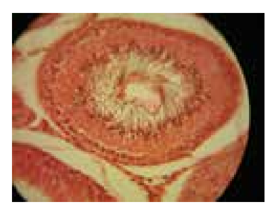
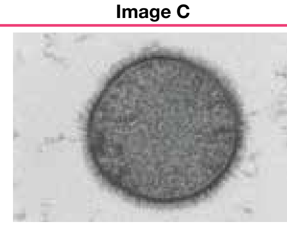
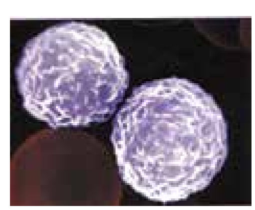
9. Stains and the light microscope have greatly increased our understanding of the processes in cells. For example, pH indicators which will show acidic or basic conditions can be used to show how the activity of micro-organisms change the pH balance of their environment such as bacterial action causing the souring of milk.
10. Objectives found on school light microscopes include 10× and 40×. The 10× objective is a low power lens used for first viewing the specimen to locate the area to be examined. The 40× objective is a high power lens and is used to make detailed observations of the specimen.
11. A parfocal microscope allows you to quickly focus using the lower power objective and then swivel the nosepiece to observe the specimen under a higher power objective without only minimal adjustment of the fine focus knob.
12. Red blood cells are very small – they have a diameter of 6 to 8 micrometres. This means the student would have been using a high power objective, e.g. 40× in the light microscope set-up to clearly observe these cells as seen in the diagram.
13. The Gram stain is usually used as the first step in identifying bacteria. It differentiates bacteria into two groups – Gram negative and Gram positive.
14. A
15. C

4 The Electron Microscope

1. The electron microscope has better resolution than the light microscope as it uses a beam of electrons to view the specimen. 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. Resolution is inversely related to the wavelength of radiation used by the microscope for imaging.
2. 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.
3.

Advantages of electron microscope	Disadvantages of electron microscope
Increased magnification, e.g. up to 300 000×. Increased resolution, e.g. approximately 0.0005 μm. SEM shows a three-dimensional image of the specimen.	Cannot view living specimens and observe processes happening in cells. Cannot use coloured stains. Relatively expensive and are not available in schools.

4. The main benefit of the TEM is that it shows the internal ultrastructure of cells at higher magnification and resolution than the light microscope. You can see objects to the order of a several nanometres (10^{-9} m) which means new organelles have been discovered using the TEM, e.g. ribosomes and there is an increased capacity for medical, biological and materials research.
5. The main benefit of the SEM is that it gives a three-dimensional detailed view of the surface of the specimen. The image has great depth of field and gives a view of the actual appearance of the specimen.
6.

Image A	Image B
 Scanning electron microscope	 Light microscope
Image C	**Image D**
 Transmission electron microscope	 Light microscope
Image E	**Image F**
 Scanning electron microscope	 Light microscope

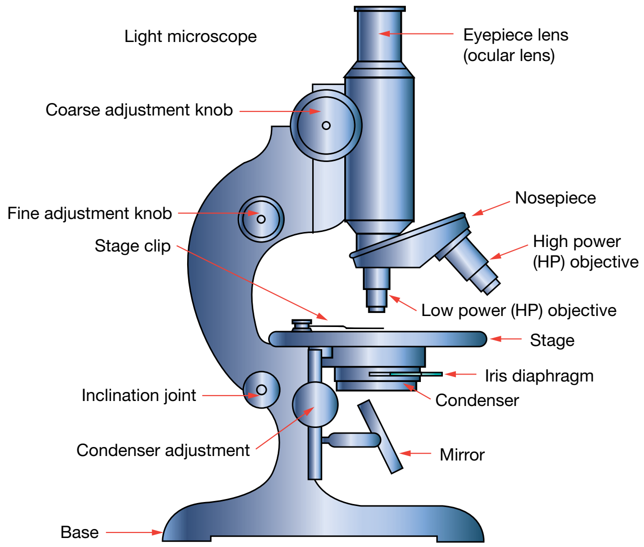
7. D

5 The Stereo Microscope

1. The stereo microscope is easily identified as it has two ocular eyepieces that each view the object from different angles. There are two separate optical paths for viewing.
2. You are likely to use a stereo microscope when dissecting small organisms or when you need to observe the external features of a specimen.
3. The parts of the stereo microscope are:
   A = ocular lens
   B = objective lens
   C = stage clip
   D = stage
   E = focus knob
   F = arm
4. If a compound microscope has two eyepieces which give the same image then the image will not be three-dimensional and give a 'stereo' image. To provide a three-dimensional image there must be two images each from slightly different viewing angles.
5. In a stereo microscope the lens is a distance away from the object and this gives poor resolution.
6. A typical school stereo microscope has a magnification ranging from 10× to 40× while a typical school monocular microscope has a magnification from 40× to 400×.
7. Salt crystals are light coloured and usually translucent. The dark colour beneath the crystal is needed to provide contrast so that the crystal can be properly viewed.
8. When using a stereo microscope some parts of an organism may not be in focus as the specimen is three-dimensional with several levels. The microscope is focusing on one level making other levels appear out of focus.
9. A

6 Experiment – The Light Microscope

1.



2. It is important to always use two hands when carrying a light microscope as they are heavy and if dropped could damage skin and feet. If dropped the fall will likely irreparably damage sections of the microscope and the school may not be able to replace the equipment. You should *never* swing a microscope and hold it with one hand.
3. It is very important to always view the stage from the side when lowering the low power objective as many microscopes allow the lens to be lowered as far as the slide and even lower, which can break the slide. Cut glass can pierce skin and potentially cause infection if it is not clean. By always raising the lens away from the slide you reduce the possibility of breaking the glass slide.
4. (a) Using the low power objective (10×) gives an overall magnification of $10 \times 10 = 100\times$.
   (b) Using the high power objective (40×) gives an overall magnification of $10 \times 40 = 400\times$.
5. The iris diaphragm controls the amount of light reaching the stage and passing through the specimen.
6. When changing objective lenses it is usually necessary to adjust the amount of light as higher magnification lenses require more light and you need the correct amount of light to see details in the specimen. When changing from high power to low power a decrease in the amount of light is usually needed.
7. A stereo microscope is usually a low powered microscope that has two eyepieces and provides a stereoscopic view of the specimen. It is usually used for looking at organisms or parts of organisms, e.g. in dissections and does not use thin sections on a microscope slide as used by light compound microscopes.
8. If you touch the lens with your finger you will leave a print that has body oil which smudges the glass. If the oil is on the glass for a lengthy time period, it can etch the glass. Lens paper must be used to clean the lens. Other types of paper, e.g. paper towel, tissues, toilet paper scratch the lens.

7 Experiment – Using a Light Microscope

1. Magnification refers to the ratio between the size of the image (the apparent size of the object under the microscope) and the actual size of the object. Resolution is the ability to distinguish between two points as separate.
2. (a) The diameter of the field of view under low power is 1.4 mm which is 1400 μm.
   (b) If the high objective lens (40×) is used then the change is from an overall magnification of 100× to 400×.

   $$\text{New diameter field of view} = 1400 \times \frac{100}{400} = 350\ \mu\text{m}$$
3. The letter 'e' as seen under the microscope is upside down and back to front. This horizontal and vertical inversion of the image means that when you are viewing a slide and wish to see another part of the slide a movement of the slide to the left moves the image to the right and if you move the slide away from your body the image moves towards you. This makes it important to make sure a very small object is in the centre of the field of view before you swap from low power to high power.
4. To determine the position of different organelles in a large unicellular being viewed under a light microscope you would focus up and down using the fine adjustment knob and carefully observe the order of appearance of each organelle in the depth of field.
5. The width of the root hair is 0.3 mm or 300 μm.
6. To record your observations when using a light microscope you need to draw a circle to represent the field of view. The observed structures should be in the position and proportionally the same size as you see them. The diagram requires a statement of the magnification and a title for the slide. Any identifiable features should be labelled.
7. If you have raised the body tube so that the objective lens is more than 2 cm above the slide, you need to start focusing again by looking at the stage and lowering the objective to just above the slide. You must not lower the objective lens while looking down the eyepiece.

8 Cells, Tissues, Organs and Systems

1. (a) A cell is the basic unit of life.
   (b) Tissue is a group of cells with similar structure and function.
   (c) Organ is a group of tissues grouped together to make a structure with a special function.
   (d) System is usually a group of organs whose function is closely related.
2. (a) Organs include heart, stomach, kidney, lung, ovary, skin, liver.
   (b) There are four main types of tissues – epithelial tissue, connective tissue, muscle tissue and nervous tissue.
   (c) Epidermal cell in the epidermis, red blood cell, white blood cell.
3. There are three types of muscle tissue – smooth muscle, skeletal muscle and cardiac muscle. These tissues are in different systems, e.g. cardiac muscle is in the cardiovascular system, skeletal muscle is in the muscular system and smooth muscle is in a variety of systems, e.g. digestive system along the alimentary canal and cardiovascular system in the walls of arteries. Although these muscles in these systems have their own specific functions, they all have the general purpose being used to generate force that leads to motion of some kind.
4. C
5. B
6. D