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AS and A LEVEL

Delivery Guide

BIOLOGY A

H020/H420
For first teaching in 2015

Cell Structure 2.1.1

Version 2

Introduction

AS and A LEVEL *BIOLOGY A*

Delivery guides are designed to represent a body of knowledge about teaching a particular topic and contain:

- Content: A clear outline of the content covered by the delivery guide;
- Thinking Conceptually: Expert guidance on the key concepts involved, common difficulties students may have, approaches to teaching that can help students understand these concepts and how this topic links conceptually to other areas of the subject;
- Thinking Contextually: A range of suggested teaching activities using a variety of themes so that different activities can be selected which best suit particular classes, learning styles or teaching approaches.

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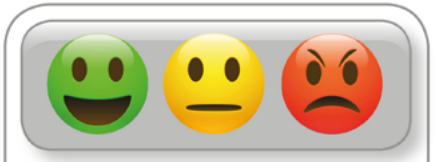

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Curriculum content

2.1.1 Cell structure

(a)	the use of microscopy to observe and investigate different types of cell and cell structure in a range of eukaryotic organisms s	To include an appreciation of the images produced by a range of microscopes: light microscope, transmission electron microscope, scanning electron microscope and laser scanning confocal microscope. HSW1, HSW7
(b)	the preparation and examination of microscope slides for use in light microscopy	Including the use of an eyepiece graticule and stage micrometer. **PAG1** HSW4
(c)	the use of staining in light microscopy	To include the use of differential staining to identify different cellular components and cell types. **PAG1** HSW4, HSW5
(d)	the representation of cell structure as seen under the light microscope using drawings and annotated diagrams of whole cells or cells in sections of tissue	**PAG1**
(e)	the use and manipulation of the magnification formula	*magnification = image size / object size* *M0.1, M0.2, M0.3, M1.1, M1.8, M2.2, M2.3, M2.4*
(f)	the difference between magnification and resolution	To include an appreciation of the differences in resolution and magnification that can be achieved by a light microscope, a transmission electron microscope and a scanning electron microscope. *M0.2, M0.3* HSW7, HSW8
(g)	the ultrastructure of eukaryotic cells and the functions of the different cellular components	To include the following cellular components and an outline of their functions: nucleus, nucleolus, nuclear envelope, rough and smooth endoplasmic reticulum (ER), Golgi apparatus, ribosomes, mitochondria, lysosomes, chloroplasts, plasma membrane, centrioles, cell wall, flagella and cilia. *M0.2*
(h)	photomicrographs of cellular components in a range of eukaryotic cells	To include interpretation of transmission and scanning electron microscope images.
(i)	the interrelationship between the organelles involved in the production and secretion of proteins	No detail of protein synthesis is required.
(j)	the importance of the cytoskeleton	To include providing mechanical strength to cells, aiding transport within cells and enabling cell movement. HSW2
(k)	the similarities and differences in the structure and ultrastructure of prokaryotic and eukaryotic cells.	**PAG1**

Starting the course with this topic provides an ideal opportunity to do the following:

- Provide a gentle transition from GCSE to A Level with plenty of practical work
- Teach important practical skills such as use of the light microscope (**PAG1**), preparation of temporary mounts and the use of stains to identify biochemical constituents of specimens
- Teach, monitor and develop practical drawing skills
- Encourage student choice and build up awareness of biodiversity and cell diversity by providing a range of microscopy options for students to experiment with.

Resources for this sort of practical-led approach are listed under 'Thinking Contextually'. Online resources to help teach the theory of microscopy and cell structure are listed here.

Activities

Activity 1
Cell Structure interactive and study resources (Cells Alive)
http://www.cellsalive.com/index.htm

This website provides a range of interactive animations (such as 'Cell models' and 'How big?'), and free study aids, such as worksheets, puzzles and quizzes. The online cell puzzles could be used in class to build up familiarity with cell vocabulary if done as a team. The small section on microscopy provides a historical context (HSW7).

Activity 2
Light Microscopy video (Wellcome Trust)
https://www.youtube.com/watch?v=Xo7mr90GYLA&list=PL343000004E5AA238&index=14&t=0s&app=desktop

This video showing the use of the light microscope is 7 minutes long.

Activity 3
Scanning Electron Microscopy Video (Wellcome Trust)
https://www.youtube.com/watch?v=pT-tnPiDjoo&feature=emb_logo

This video showing the use of the electron microscope is 3 minutes long.

Activity 4
Prokaryotes vs Eukaryotes
https://www.youtube.com/watch?v=zZtcMBTQaS4

A video that describes the two type of cells; eukaryotes and prokaryotes by looking at the similarities and differences in their structure.

Article on Eukaryotes (Nature)
https://www.nature.com/scitable/topicpage/eukaryotic-cells-14023963

A scientific article which introduces the concept of eukaryotic cells and the function of each organelle. This can be part of independent study that the students can do.

Activity 5
Measuring Techniques D3 (University of Michigan)
https://www.yumpu.com/en/document/read/48719133/measuring-techniques-d3-university-of-michigan

This PowerPoint style pdf explains clearly how to calibrate an eyepiece graticule, using the term 'ocular micrometer'. The specification uses the term 'eyepiece graticule' so this will need to be explained. The first 2 or 3 slides are not relevant to A Level teaching but the slides that follow are well-illustrated and the practice questions at the end provide useful class practice.

Activity 6
Calibration of eye piece graticule with stage micrometer video
https://www.youtube.com/watch?time_continue=309&v=9haN53mojnI

This video explains how to calibrate an eyepiece graticule with a stage micrometer and how this can be used to calculate the actual size of a specimen.

Activity 7
Practical Support 9 Size and Scale (University of York Science Education group)
https://gwhsasbiology.files.wordpress.com/2013/09/siz-and-scale.pdf

This is a worksheet explaining how to calibrate an eyepiece graticule using a stage micrometer in order to measure specimens under the microscope. It also gives practice questions and answers.

Activity 8
Practicals using microscopes (Royal Society of Biology and Nuffield Foundation)
https://pbiol.rsb.org.uk/cells-to-systems/cell-structures/a-closer-look-at-blood
https://pbiol.rsb.org.uk/exchange-of-materials/transpiration-in-plants/a-window-on-the-past-measuring-stomatal-density?highlight=WyJ0ZW1wZXJhdHVyZSJd

These excellent resources give detailed practicals which can be used when teaching microscope skills.

Thinking conceptually

Approaches to teaching the content

Students meet some significant mathematical conceptual challenges in this module, including measuring under the microscope **2.1.1(b)**, using the magnification formula **2.1.1(e)** and using and converting to microscopic units. To allow students to gain a real understanding of magnification and the terms object and image it might be necessary to go back to basics and begin with hand lenses rather than the light microscope itself, as in the first two activities listed below.

Common misconceptions or difficulties students may have

Students may find it hard to cope with the use and spelling of the extensive new biological vocabulary of sub-cellular structure. Keeping a glossary list of new words and their definitions is one approach. The 2.1.1 glossary sheet provided below also lists difficult plurals (eg mitochondria) and adjectival forms. It could act as a model for students to develop their own glossary of terms as they progress through the course. A link to an online Biology dictionary is provided for students to check up on definitions of unfamiliar words.

Another difficulty is in students being able to conceptually relate to, or imagine, structures and events at a tiny scale. The 'Nanosense' and 'Secret Worlds' resources help to build familiarity with the logarithmic scale of measurement and the relationship of different SI units.

Conceptual links to other areas of the specification – useful ways to approach this topic to set students up for topics later in the course

These learning outcomes require knowledge and skills from this unit and can also be used to reinforce microscopy skills (**PAG1**), mathematical calculation skills (eg *M0.1*, *M1.8*, *M2.2*) and drawing skills:

- 2.1.5(e) osmosis eg in red onion bulb epidermis
- 2.1.6(d) plant cell mitosis eg onion root tip squash
- 2.1.6(h) specialised cells
- 2.1.6(i) tissues
- 3.1.1(c), (g) and (h) lung, gill and insect tracheal structure
- 3.1.2(c) blood vessel histology
- 3.1.3(b) plant vascular tissue
- 4.1.1(e) phagocytes and blood smears
- 4.2.2(c) cell structure of five kingdoms
- 5.1.2(b) liver histology
- 5.1.2(c) kidney histology
- 5.1.4(c) pancreas histology
- 5.1.5(l) muscle structure
- 5.2.1(b) chloroplast structure
- 5.2.2(b) mitochondrion structure.

Activities

Learner Activity 1
From Jam Jar to Microscope

Learner Resource 1

This outlines preliminary work with a jam jar or glass beaker to explain how the lenses in a microscope work. Its aim is to establish a conceptual understanding of magnification and to simplify the idea of how the light microscope works.

Learner Activity 2
The Object and the Image

Learner Resource 2

This is another preliminary task that helps students understand the terms 'object' and 'image' by working with a magnifying glass or hand lens. Students find it easier to distinguish between these terms when they are presented in this scenario away from the microscope and when the object is in the normal size range of things that they can see and handle. Suggested biological specimens are seeds, leaves and shells but anything small enough to fit in the first box on the sheet can be used. The binomial name of the specimen should be available to give to students (linking to 4.2.2). The magnification formula is introduced here (linking to maths skill *M2.2*) without the need for students to convert units (maths skill *M0.1*).

Learner Activity 3
Magnification Formula Calculations Guidance Sheet

Learner Resource 3

This worksheet develops the idea taught in 'The Object and the Image' and gives clear guidelines on using the magnification formula (linking to maths skills *M1.8, M2.2*) in examination questions, with some practice questions and organelle identification.

Learner Activity 4
Magnification Java Tutorial (Olympus America Inc.)

https://www.olympus-lifescience.com/en/microscope-resource/primer/virtual/magnifying/

The onion root mitosis sample can be selected and viewed at six magnifications (x25 to x1000). The large range of magnifications and the fact that all students are accessing the same images lends itself to setting homework using this web link. Students could practise using the magnification formula to check on the real object size of a selected cell at two or three different magnifications. They could also calculate the mean cell length from three or more cells in each image (maths skills *M1.2, M1.6*) and be asked to give the answer to an appropriate number of significant figures (maths skill *M1.1*). As the specimen is microscopic, students will need to combine understanding of the magnification formula with an understanding of micrometres and the ability to convert mm to µm (maths skill *M0.1*).

Learner Activity5
Scale of Objects Worksheet and Card Sorting Activities (Nanosense)

http://www.exo.net/~pauld/summer_institute/Nano%20Institute/Day1%20Scale/SM_Lesson2Student.pdf

This 18 page resource explains units smaller than a millimetre and the use of standard form (maths skill *M0.2*) and provides a range of class activities exploring the concept. Three activities are included so teachers might like to pick and choose between the student reading material and the card sorting activities on offer.

Learner Activity 6
Secret Worlds - the Universe Within (Molecular Expressions™, Florida State University)

http://micro.magnet.fsu.edu/primer/java/scienceopticsu/powersof10/

This is an interactive Java tutorial with a sequence of images going from the milky way to a single carbon atom nucleus and beyond in orders of magnitude. In the automated play form it could be shown to a class. In manual form clicking up through the images could be used to highlight the normal range of sizes of interest in biology. The labelling of each picture in metres in standard form on the left and units appropriate to the size of the subject matter on the right could be used to teach or class-test standard form and the SI units in the range metre, millimetre, micrometre and nanometre (maths skill *M0.1*).

Activities

Learner Activity 7
2.1.1 Glossary

Learner Resource 4

Students fill in descriptions of the structure and function for each entry, and may fill in the easy plurals and adjectives if they wish. It might help to draw attention to common patterns such as words ending with '-um' forming a plural ending in '-a' and so on, so that as well as becoming familiar with the terms in this section of the specification, students can deal appropriately with terms they meet in the future.

Learner Activity 8
Biology Reference (Advameg, Inc)

http://www.biologyreference.com/

This is an online dictionary of biology that could be used by students to fill in the glossary sheet.

Thinking contextually

Activities

A list of suggested contexts for introductory practical work with the light microscope is provided in the first resource, including a hay infusion to culture protoctists, which is detailed in a separate resource. A checklist of drawing skills is also included here.

After exploring a range of biological materials using prepared and temporary slides with the light microscope, students need to gain practice with a range of electron micrographs. Websites supplying useful images are listed below. Asking students to put together their own collection of images of various cell types imaged in different ways, which they then annotate, gives them the chance to be creative. In the form of a PowerPoint this resource can be shared with the class and will give the student or students who created it a chance to talk through the vocabulary of cells and microscopes. While the false colour scanning electron microscope images have instant appeal, it is important to provide print-outs of a selection of black and white transmission electron micrographs to give students practice in identifying organelles, measuring them, and calculating real object sizes.

The importance of the cytoskeleton can be enlivened by the use of videos showing its role in the movement of organelles (eg the Harvard video detailed below) and of specific cells, such as slime mould cells.

Activities

Learner Activity 1
Microscopy Activities Checklist for Teachers

Teacher Resource 1

This lists materials that can be used to teach microscopy skills and see a range of protoctist, plant and animal cells (**PAG1**).

Learner Activity 2
Microorganisms from a hay infusion

https://www.sciencelessonsthatrock.com/blog/setting-up-a-hay-infusion-for-your-microscope-unit

This blog describes how to set up a hay infusion to observe microorganisms (**PAG1**).

Learner Activity 3
Biological Drawing Handbook (OCR)

https://www.ocr.org.uk/Images/251799-biology-drawing-skills-handbook.pdf

This handbook gives great detail on accurate biological drawing including a checklist which can be used for marking drawings on page 17.

Learner Activity 4
Exploring eukaryotic cells (American Society for Cell Biology)

http://www.cellimagelibrary.org/

Students can click on labels on 'Explore the Eukaryotic Cell' to see the relevant structures highlighted on the diagram. The site provides an easy way to search for images and videos of particular cell structures, cell types and cell processes. It could be used by students to explore, or in class to provide a range of images to support teaching.

Learner Activity 5
Photomicrographs of micro-organisms and specialised cells (Dennis Kunkel)

http://www.denniskunkel.com

This site specialises in false-colour scanning and transmission electron micrographs and provides an inspiring gallery of images to show in class or for students to explore, relating to learning outcome **2.1.1(a)** and linking synoptically to cell diversity, for example **2.1.6(h)**.

Learner Activity 6
Inner life of the cell (Harvard College)

https://www.youtube.com/watch?time_continue=156&v=wJyUtbn0O5Y?

While the details are beyond A Level, the quality of this animation makes it worth sharing with a class for them to get a feel
for the three-dimensional architecture and the dynamic activity of the inside of a cell. The movement of a secretory vesicle along a cytoskeleton microtubule is a highlight, while the fluidity of the plasma membrane (synoptic link **2.1.5(b)**) is also shown well.

Learner Resource 1

From Jam Jar to Microscope

Activity: Place the curved bottom of a jam jar or glass beaker over this worksheet and look through it, moving the jar nearer to and further away from the text to see what effect this has.

1. Describe what you see happen.

Explanation: This shows that a **lens** is simply a piece of curved glass. It works by bending the light rays reflected off the page towards the eye so that the black letters between the white expanses look bigger.

The microscope simply contains two of these lenses in sequence. One is in the **eyepiece** and one is in the **objective lens** (there is a choice of these on the rotating nosepiece).

Total magnification is obtained by **multiplying** (not adding) the figures from the two lenses. This is usually a fixed x10 for the eyepiece lens, and x4, x10 or x40 for the objective lens.

Activity: Now look at the structure of a laboratory light microscope.

2. Identify and describe the objective lenses (length, colour, magnification figure).

3. Unscrew the eyepiece and use it as a hand-held lens over the worksheet. How does it compare to the jar or beaker you used first?

4. What is the highest magnification available on your microscope? Remember to calculate a figure including the effect of the eyepiece lens as well as the objective lens.

5. List the range of magnifications available with your microscope. If there are three, they are usually referred to as low, medium and high power.

Learner Resource 2

The Object and the Image

1. You have been provided with a small biological specimen. This may be a seed like an acorn or broad bean, a small leaf or a shell. Carefully draw around the outside of your object with a sharp pencil here:

object length = ...mm

Use a ruler to draw a line across the longest part of your picture and label this '**object** length'. Measure this line in millimetres and fill in your measurement in the box.

2. Now observe the specimen with a hand lens or magnifying glass. Use the space below (or a sheet of plain paper) to try to draw it roughly the size it appears to you now. Draw a line across the longest part of this picture and label it 'magnified **image** length'. Measure this line in millimetres and fill in your measurement in the box.

magnified image length =.....mm

3. How many times bigger is the magnified **image** compared to the real **object** ? Try to estimate and guess by eye first and write your figure here. For two times bigger write 'x2', three times bigger 'x3', etc.

4. To find out accurately, you can substitute your **object** length and **image** length figures into an equation called the magnification formula. The equation is simply:

MAGNIFICATION = IMAGE SIZE / OBJECT SIZE

M = I / O

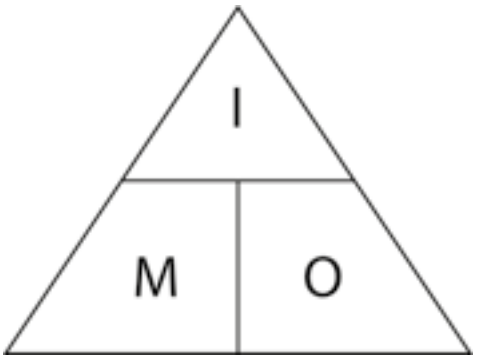
If you remember the word 'Mio' you will remember the order of the terms in the equation.

$$\textit{Magnification} = \frac{\textit{(I)}}{\textit{(O)}}$$

= x.....

5. Explain whether or not the figure you arrive at is the same as the figure written on the hand lens or magnifying glass. If it is not, can you explain why?

6. You may find a triangle diagram like this helpful if you need to change the subject of the 'Mio' formula. Locate the term you want to calculate and see how the other two relate to each other eg if you want to find ***M***, you must put ***I*** over ***O***, that is divide ***I*** by ***O***. If you want to find ***I*** then as ***M*** and ***O*** are side by side in the triangle you multiply them together.



7. Living organisms have common and binomial names. Ask your teacher for the names of the species from which your specimen derives and write them here.

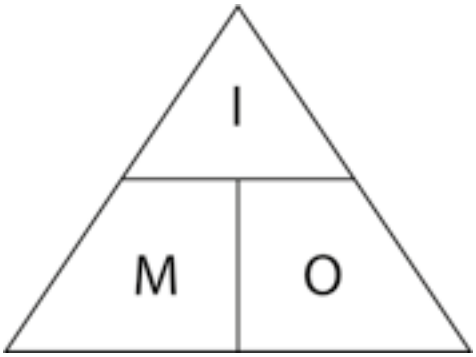
Common name .....

Binomial name ....

The first part of the binomial name (the genus) must start with a capital letter. The second part (the species name) always starts with a small letter.

Learner Resource 3

Magnification Formula Calculations Guidance Sheet



MAGNIFICATION = IMAGE SIZE / OBJECT SIZE

M = I / O

Exam questions that require you to use the 'Mio' formula generally provide an image, which may be a photomicrograph taken with a light or electron microscope, or a diagram.

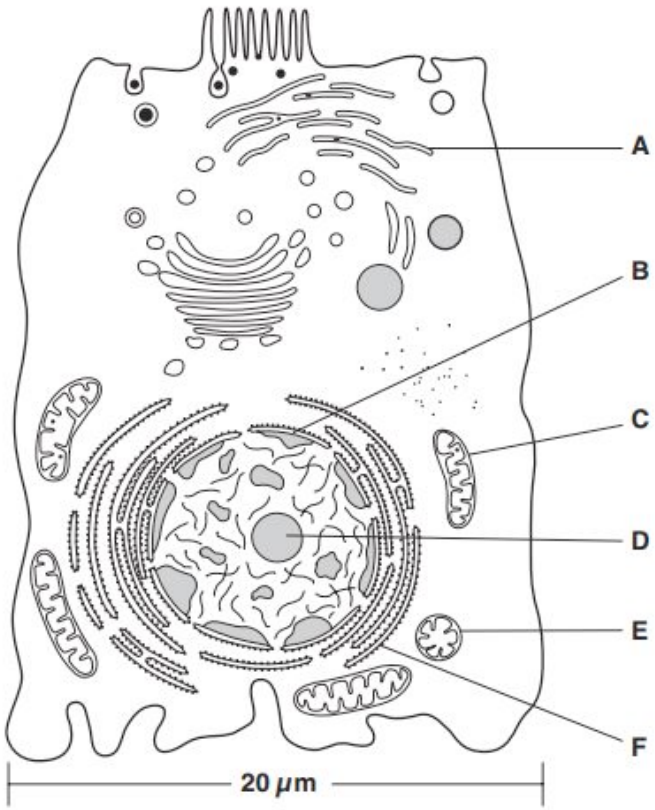


Fig 1.1 Diagram of an animal cell

In order to use the formula, you have to have two pieces of information, so as well as the image (which you measure yourself with a ruler). The question must tell you either:

- the magnification **OR**
- the real object size.

In the diagram of the animal cell above, the magnification is x4000.

The triangle arrangement of the magnification formula shows us that the image size must be divided by either the magnification or the real object size, whichever is given to you. However, it is essential that the image size and object size are in the same units. Generally, microscopic structures are measured in micrometres (μm) but the smallest unit available for measuring the image on the paper is with a ruler in millimetres. So, follow these golden **rules** :

1) **Measure the image in millimetres.**
2) **Multiply the measured image size by 1000 (to convert it to micrometres).**
3) **Divide this image size by the second term given, either the magnification or the real object size.**

Complete the following table concerning organelles on Fig. 1.1.

	Name	Length / μm
B		
C		
D		
E		

Fig. 1.1 was originally presented on an exam paper with just its scale bar. To find the length of a structure such as a microvillus at the top of the cell with only the scale bar to help, two steps need to be carried out.

- First the scale bar is measured (image) and divided by 20 μm (object) to find out the magnification of the diagram (x4000). Check this for yourself.
- Then, follow the golden rules and measure the microvillus in millimetres, multiply by 1000 to convert to μm, and divide by the magnification.

length of microvillus .....

Learner Resource 4

Glossary

Singular noun	Plural noun	Adjective	Description of structure	Description of function
cytoplasm	X	cytoplasmic		
plasma membrane		X		
cell wall		X		
nucleus	nuclei	nuclear, nucleate, enucleate		
nucleolus	nucleoli	nucleolar		
nuclear membrane		X		
ribosome		ribosomal		
lysosome		lysosomal		
chromosome		chromosomal		

Singular noun	Plural noun	Adjective	Description of structure	Description of function
chromatin	X	X		
endoplasmic reticulum (ER)	X	X		
rough ER	X	X		
smooth ER	X	X		
Golgi apparatus		X		
cytoskeleton		cytoskeletal		
microtubule		microtubular		
microfilament				
spindle apparatus	X	X		

Singular noun	Plural noun	Adjective	Description of structure	Description of function
mitochondrion	mitochondria	mitochondrial		
chloroplast		X		
vesicle		vesicular		
centriole		centriolar		
flagellum	flagella	flagellar, flagellate		
cilium	cilia	ciliar, ciliated		
undulipodium	undulipodia			
microscope		microscopic		
microscopy	X	microscopic		

Singular noun	Plural noun	Adjective	Description of structure	Description of function
micrograph		X		
magnification	X	magnified		
resolution	X	resolved		
eukaryote		eukaryotic		
prokaryote		prokaryotic		
plasmodesma	plasmodesmata	X		
vacuole		vacuolar		

Teacher Resource 1

Microscopy Activities Checklist for Teachers

Practical resources for teaching the use of the light microscope and for giving opportunities to practise drawing and labelling skills in section 2.1.1 could include the following:

- Prepared stained slides of protoctists (*Amoeba, Paramecium, Volvox*)
- Prepared blood smear slide (red and white blood cells)
- Prepared plant slides such as transverse sections of dicotyledonous stem, root and leaf
- Making temporary wet mounts of single moss, *Elodea* or maidenhair fern leaflets (*Adiantum veneris-capillis*) as the edges of these structures are one cell thick allowing cell walls and chloroplasts to be seen
- Making onion bulb epidermal peels
- Making squashes of small pieces of banana fruit to include lengths of xylem visible in the 'strings' of the peeled banana
- Making human cheek cell smears stained with methylene blue
- Opportunities to experiment with staining these and other specimens with methylene blue (to show acidic areas such as the nucleus), iodine (to show starch grains) and borax carmine
- Pondwater or a hay infusion to see movement and structure of live protoctists
- Stage micrometers, clear plastic rulers and eyepiece graticules to be used in conjunction with prepared slides
- Lily pollen mounted in sucrose solution (to show growth of pollen tubes).

Learning objectives **(a)** to **(e)** can be taught through using successive practical sessions to move through the following skills and levels of difficulty:

- The rules of setting up and using the microscope (eg always start on low power and obtain a clear white field of view before putting the slide on the stage. Focus on the edge of the cover slip first. Adjust the focus as little as possible when moving up from one objective lens to another).
- How a drawing is marked (see Learner Resource 5 Drawing Skills).
- See large individual cells (eg prepared stained protoctists like *Amoeba* or *Paramecium*).
- See smaller individual cells (eg blood smear, cheek cell smear), focusing on the edge of the cover slip on low power and then moving to medium power.
- See identical joined cells (moss, *Elodea* or maidenhair fern leaf) explaining how the middle lamella is inferred and two cell walls are shown in a drawing of adjacent plant cells.
- See more complex slides showing different tissues (plant organ sections) and explain the idea of a low power tissue plan.
- Measure structures under the microscope by calibrating the eyepiece graticule with a stage micrometer. It helps if students measure the line visible to the naked eye on the stage micrometer first with a ruler, so they know how long it is 'in the real world'. Alternatively they can try to calibrate the eyepiece graticule with the marks on a clear plastic ruler to be able to relate real-life measurements to the virtual world under the microscope lens.
- Measure several cells (eg *Paramecium*) and calculate a mean (maths skill *M1.2*).

Did you know?

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