

1.1 The microscope in cell studies

Name: _____ Class: _____ Date: _____

Total: 19 marks

KEY WORDS microscope • eyepiece graticule • magnification
• stage micrometer • electron

Objective

Build the skills to answer exam questions on **the microscope in cell studies** – calculating **magnification** and actual size, calibrating an **eyepiece graticule**, and comparing magnification with **resolution**.

You must be able to:

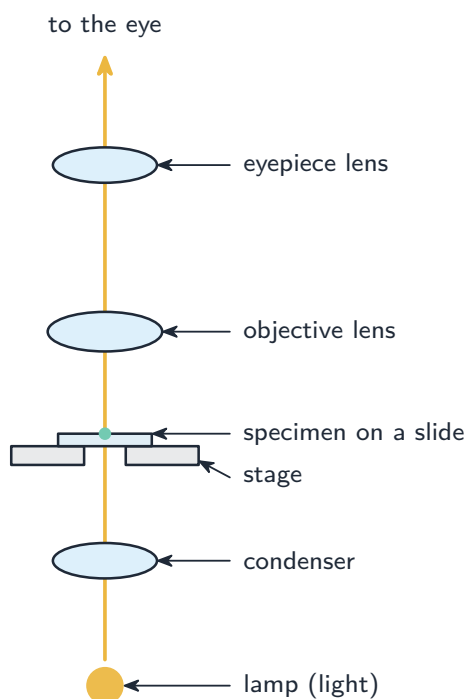
- use the magnification equation to find magnification, image size, or actual size (convert to the same unit first)
- convert between millimetre (mm), micrometre (μm) and nanometre (nm)
- calibrate an eyepiece graticule with a **stage micrometer**, then measure a cell
- define magnification and resolution, and explain why the electron microscope shows more detail

1 Key knowledge and worked examples

Study these first. Each one shows the **method** for a question type used later – examiners give marks for the working, not only the final number.

■ Magnification, image size and actual size

A **light microscope** forms an enlarged image of a thin **specimen**.
How many times larger the image is depends on the magnification.



A light microscope forms a magnified image of the specimen

These three quantities are linked by one equation:

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

Rearrange it to find whichever value is missing:

$$\text{actual size} = \frac{\text{size of image}}{\text{magnification}}, \quad \text{size of image} = \text{magnification} \times \text{actual size}.$$

The image size and actual size **must be in the same unit** before you divide. Cells are tiny, so work in small units:

$$1 \text{ mm} = 1000 \text{ } \mu\text{m}, \quad 1 \text{ } \mu\text{m} = 1000 \text{ nm}, \quad 1 \text{ mm} = 1\,000\,000 \text{ nm}.$$

Example. A **transmission electron micrograph** shows a mitochondrion 60 mm long at a magnification of $\times 30\,000$. Its actual length is

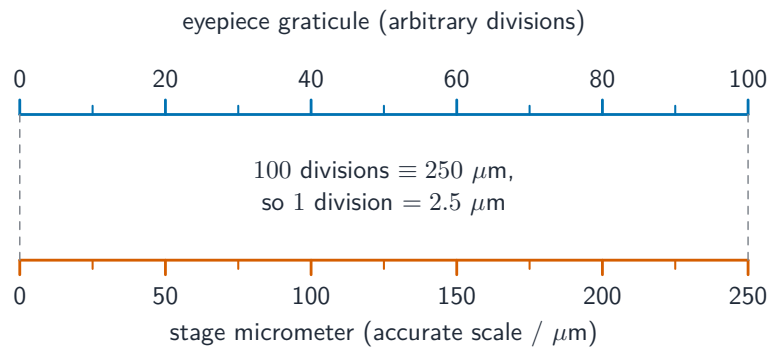
$$\frac{60 \text{ mm}}{30\,000} = 0.0020 \text{ mm} = 2.0 \text{ } \mu\text{m}.$$

Reverse example. A cell of actual width 8 μm is drawn at $\times 400$. The drawing width is $400 \times 8 \text{ } \mu\text{m} = 3200 \text{ } \mu\text{m} = 3.2 \text{ mm}$.

Tip: when a question says “to 3 significant figures”, keep the full value until the last step, then round.

■ Calibrating an eyepiece graticule

An **eyepiece graticule** is a scale inside the eyepiece. Its divisions have **no fixed size** – the real length of one division changes with the objective lens. A **stage micrometer** is a tiny ruler on a slide with **known** divisions. You use it to find the real size of one graticule division.



Calibrating the eyepiece graticule against the stage micrometer

Method: line the two scales up, count how many graticule divisions match a known length on the stage micrometer, then divide.

Example. In the figure above, 100 graticule divisions line up with 250 μm on the stage micrometer. So

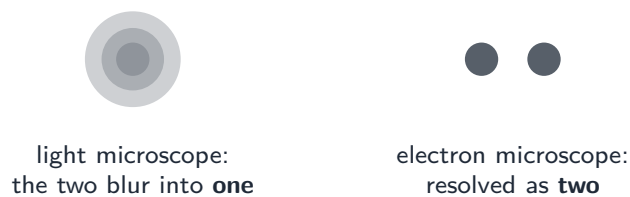
$$1 \text{ graticule division} = \frac{250 \mu\text{m}}{100} = 2.5 \mu\text{m}.$$

A cell now measured at 20 graticule divisions has an actual width of $20 \times 2.5 = 50 \mu\text{m}$.

Recalibrate whenever you change the objective lens.

■ Magnification versus resolution

- **Magnification** is how many times larger the image is than the object.
- **Resolution** is the smallest distance between two points that can still be seen as **separate**. It sets how much *detail* you can see.



A light microscope blurs two very close points into one; an electron microscope still resolves them

A light microscope resolves down to about 200 nm; a transmission electron microscope resolves to about 0.5 nm. Making an image bigger **without** better resolution just gives a larger blur ("empty magnification"). This is why small structures such as **ribosomes** (about 25 nm) are only seen with an electron microscope.

2 Practice

Now apply the methods above.

2.1 Convert each length.

[3]

length	convert to
0.005 mm	μm
2 μm	nm
1.5 mm	μm

2.2 A cell of actual width 50 μm is drawn 100 mm wide. Calculate the magnification of the drawing. (*Hint: put both sizes in μm first.*)

[2]

2.3 Using the same eyepiece graticule and objective, 100 graticule divisions line up with 1.0 mm on a stage micrometer.

(a) Calculate the actual length of **one** graticule division, in μm .

[2]

(b) A nucleus measures 8 graticule divisions across. State its actual width.

[1]

3 Exam-style questions

3.1 An electron micrograph printed at $\times 12\,000$ shows a **mitochondrion** that is 36 mm long. The actual length of the mitochondrion is: [1]

- ☐ **A** 0.3 μm
B 3 μm
C 30 μm
D 432 μm

3.2 Which structure can **only** be seen using an electron microscope, not a high-power light microscope? [1]

- ☐ **A** cell wall
B chloroplast
C nucleus
D ribosome

3.3 A student lines up an eyepiece graticule with a stage micrometer whose smallest divisions are 0.01 mm. The diagrams show that 40 graticule divisions cover 0.20 mm. The same eyepiece is used to view a blood smear, and a **lymphocyte** measures 2 graticule divisions across.

(a) Calculate the actual length of one graticule division, in μm . [2]

(b) Calculate the diameter of the lymphocyte, in μm . [1]

3.4 Fig. 3.1 is a scanning electron micrograph of a *Plasmodium* ring cell inside a red blood cell. The actual diameter of the ring cell is $2.0\text{ }\mu\text{m}$. In the image, this diameter measures 80 mm.

(a) Calculate the magnification of the image. Give your answer to 3 significant figures. [2]

(b) The ring cell could not be seen clearly with a light microscope. Use the idea of **resolution** to explain why. [2]

3.5 Define each term. [2]

(a) magnification

(b) resolution

Solutions

Each answer shows the steps, then the **result**.

2.1

- 1 mm = 1000 μm and 1 μm = 1000 nm
- 0.005 mm = **5** μm
- 2 μm = **2000** nm
- 1.5 mm = **1500** μm

2.2

- put both sizes in μm : image = 100 mm = 100 000 μm
- magnification = $\frac{\text{image size}}{\text{actual size}}$

$$\text{magnification} = \frac{\text{image size}}{\text{actual size}} = \frac{100\,000\ \mu\text{m}}{50\ \mu\text{m}} = \times\mathbf{2000}$$

2.3

(a)

- 100 divisions line up with 1.0 mm

$$\frac{1.0\ \text{mm}}{100} = 0.010\ \text{mm} = \mathbf{10}\ \mu\text{m}$$

(b)

- $8 \times 10\ \mu\text{m} = \mathbf{80}\ \mu\text{m}$

3.1 B

- actual size = $\frac{\text{image size}}{\text{magnification}}$

$$\frac{36\ \text{mm}}{12\,000} = 0.003\ \text{mm} = \mathbf{3}\ \mu\text{m}$$

- D multiplies by the magnification instead of dividing; A is $10\times$ too small; C is $10\times$ too large

3.2 D

- a ribosome ($\approx 25\ \text{nm}$) is far below the $\approx 200\ \text{nm}$ resolution of a light microscope
- A, B and C are large enough to see with a high-power light microscope

3.3

(a)

- 40 divisions = 0.20 mm

$$\frac{0.20\ \text{mm}}{40} = 0.005\ \text{mm} = \mathbf{5}\ \mu\text{m}$$

(b)

- $2 \times 5 \text{ }\mu\text{m} = \mathbf{10 \text{ }\mu\text{m}}$

3.4

(a)

- put both sizes in μm : image = 80 mm = 80 000 μm

$$\text{magnification} = \frac{\text{image size}}{\text{actual size}} = \frac{80\,000 \text{ }\mu\text{m}}{2.0 \text{ }\mu\text{m}} = 40\,000 = \times \mathbf{4.00 \times 10^4}$$

(b)

- the ring cell (2 μm) and its detail are near or below the light microscope's resolution ($\approx 200 \text{ nm} = 0.2 \text{ }\mu\text{m}$)
- the electron microscope has far higher resolution, so it shows the ring cell as a separate, detailed structure

3.5

(a)

- **magnification** is how many times larger the image is than the actual object

(b)

- **resolution** is the smallest distance between two points that can still be seen as two separate points