Exercise walk-through

The microscope in cell studies ▪ 1.1

eXercise

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 载物台测微尺**, then measure a cell
- define magnification and resolution, and explain why the electron microscope shows more detail

Method — Magnification, image size and actual size

A **light microscope 光学显微镜** forms an enlarged image of a thin **specimen 标本**. How many times larger the image is depends on the magnification. 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:

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

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

Method — Magnification, image size and actual size

$$1 \text{ mm} = 1000 \text{ µm}, \qquad 1 \text{ µm} = 1000 \text{ nm}, \qquad 1 \text{ mm} = 1\,000\,000 \text{ nm}.$$

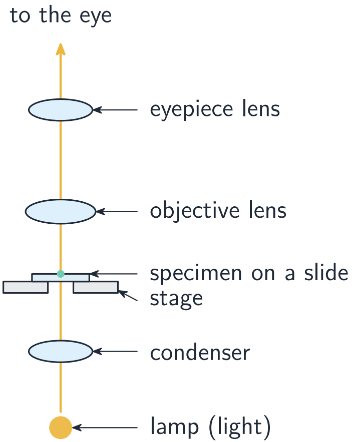
Example. A **transmission electron micrograph 透射电子显微照片** shows a mitochondrion 60 mm long at a magnification of $\times 30\,000$. Its actual length is

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

Reverse example. A cell of actual width 8 µm is drawn at $\times 400$. The drawing width is 400×8 µm $= 3200$ µm $= 3.2$ mm.

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

Method — Magnification, image size and actual size



Method — 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.

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

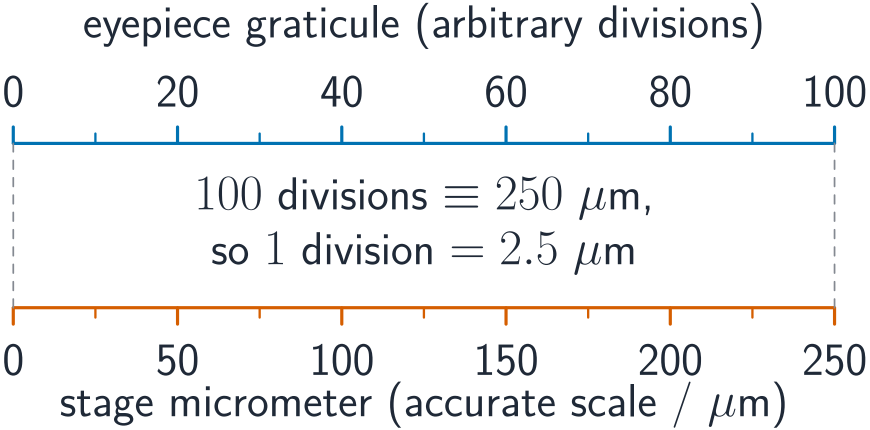
Example. In the figure above, 100 graticule divisions line up with 250 μm on the stage micrometer. So

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

A cell now measured at 20 graticule divisions has an actual width of $20 \times 2.5 = 50$ μm.

Recalibrate whenever you change the objective lens.

Method — Calibrating an eyepiece graticule

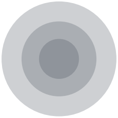


Method — Magnification versus resolution

- **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 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 核糖体** (about 25 nm) are only seen with an electron microscope.

Method — Magnification versus resolution



light microscope:
the two blur into **one**

electron microscope:
resolved as **two**

Practice 2.1 ▪ 3 marks

Convert each length.

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

Solution 2.1

Worked steps

0.005 mm $= 5$ µm; 2 µm $= 2000$ nm; 1.5 mm $= 1500$ µm **B1** *each*.

Practice 2.2 ▪ 2 marks

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.)*

Solution 2.2

Method: Magnification, image size and actual size

Worked steps

Both in μm: image $= 100$ mm $= 100\,000$ μm **M1**. magnification $= \dfrac{100\,000}{50} = \times 2000$ **A1**.

Practice 2.3 ▪ 2 marks

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.

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

Solution 2.3

Method: Calibrating an eyepiece graticule

Worked steps

(a) $\dfrac{1.0\ \text{mm}}{100} = 0.010\ \text{mm} = 10\ \mu\text{m}$ **M1** **A1**.

(b) $8 \times 10 = 80\ \mu\text{m}$ **A1**.

Exam-style 3.1 ▪ 1 mark

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

A 0.3 µm

B 3 µm

C 30 µm

D 432 µm

Solution 3.1

Method: Magnification, image size and actual size

A 0.3 µm

B 3 µm ✓

C 30 µm

D 432 µm

Worked steps

B. $\dfrac{36 \text{ mm}}{12\,000} = 0.003 \text{ mm} = 3$ µm. **D** is the trap: it multiplies by the magnification instead of dividing.

Exam-style 3.2 ▪ 1 mark

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

A cell wall

B chloroplast

C nucleus

D ribosome

Solution 3.2

Method: Magnification versus resolution

A cell wall

B chloroplast

C nucleus

D ribosome ✓

Worked steps

D. A ribosome (≈ 25 nm) is far below the ≈ 200 nm resolution of a light microscope; the others are large enough to see.

Exam-style 3.3 ▪ 2 marks

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 淋巴细胞** measures 2 graticule divisions across.

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

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

Solution 3.3

Method: Calibrating an eyepiece graticule

Worked steps

(a) 40 divisions $= 0.20$ mm, so 1 division $= \dfrac{0.20}{40} = 0.005$ mm $= 5$ µm **M1** **A1**.

(b) $2 \times 5 = 10$ µm **A1**.

Exam-style 3.4 ▪ 2 marks

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 μm. In the image, this diameter measures 80 mm.

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

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

Solution 3.4

Method: Magnification, image size and actual size

Worked steps

(a) Same unit: image $= 80$ mm $= 80\,000$ µm M1. magnification $= \dfrac{80\,000}{2.0} = 40\,000$, i.e. $\times 4.00 \times 10^4$ A1.

(b) The ring cell (2 µm) and its detail are near or below the light microscope's resolution (≈ 200 nm $= 0.2$ µm) M1; the electron microscope has far higher resolution, so it shows the ring cell as a separate, detailed structure A1.

Exam-style 3.5 ▪ 2 marks

Define each term.
(a) magnification
(b) resolution

Solution 3.5

Method: Magnification versus resolution

Worked steps

(a) magnification = how many times larger the image is than the actual object **B1**.
(b) resolution = the smallest distance between two points that can still be seen as two separate points **B1**.