

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:

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

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

Method — Magnification, image size and actual size

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

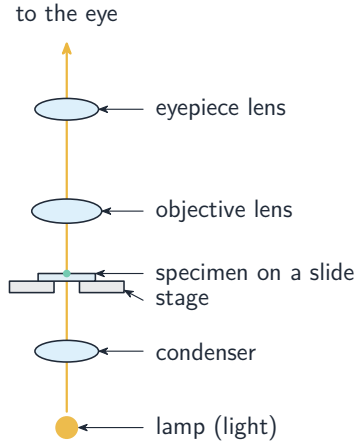
Example. A **transmission electron micrograph** 透射电子显微照片 shows a mitochondrion 60 mm long at a magnification of $\times 30\,000$. Its actual length is

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

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.

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.

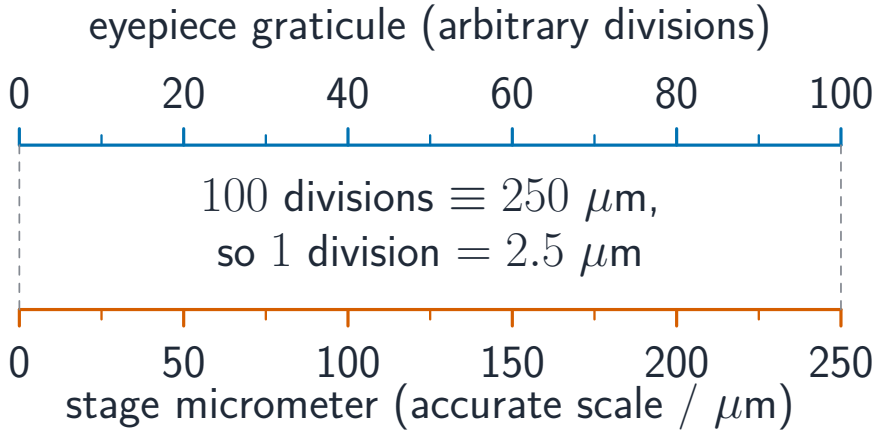
Example. In the figure above, 100 graticule divisions line up with 250 μm on the stage micrometer. So

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

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.

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

$0.005 \text{ mm} = 5 \text{ }\mu\text{m}$; $2 \text{ }\mu\text{m} = 2000 \text{ nm}$; $1.5 \text{ mm} = 1500 \text{ }\mu\text{m}$ **B1** *each*.

Practice 2.2 ■ 2 marks

A cell of actual width $50\text{ }\mu\text{m}$ 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 = $100 \text{ mm} = 100\,000 \mu\text{m}$ (M1). magnification = $\frac{100\,000}{50} =$
 $\times 2000$ (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

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

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

Exam-style 3.1 ■ 1 mark

In a photomicrograph of magnification $\times 5000$, a **chloroplast** 叶绿体 measures 25 mm in diameter. The actual diameter of the chloroplast is:

A 0.5 μm

B 5 μm

C 50 μm

D 125 μm

Solution 3.1

Method: Magnification, image size and actual size

A 0.5 μm

B 5 μm



C 50 μm

D 125 μm

Worked steps

B. $\frac{25 \text{ mm}}{5000} = 0.005 \text{ mm} = 5 \mu\text{m}.$

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 = $\frac{0.20}{40} = 0.005 \text{ mm} = 5 \text{ }\mu\text{m}$ **M1** **A1**.

(b) $2 \times 5 = 10 \text{ }\mu\text{m}$ **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 $2.0\text{ }\mu\text{m}$. In the image, this diameter measures 80 mm.

- (a) Calculate the magnification of the image. Give your answer to 3 significant figures.
- (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 = $\frac{80\,000}{2.0} = 40\,000$, 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 ($\approx 200\text{ nm} = 0.2\text{ }\mu\text{m}$) (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**.