B1 L4 Revision notes 1 of 4

How small cells are, units, and the view down a microscope

1. How small are cells?

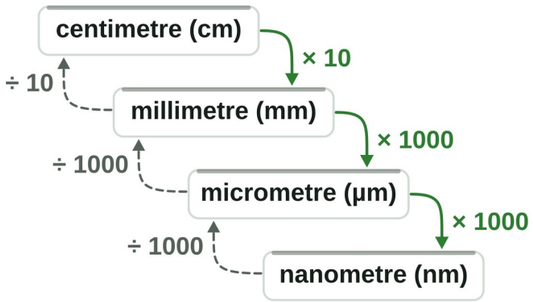
Most cells are far too small to see with your eyes alone. You need a microscope to see them, and very small units to measure them. Sizes vary, so these are typical values:

Thing	About how big
the width of a human hair	0.1 mm (100 µm)
an onion epidermis cell	0.2 mm (200 µm) long
a cheek cell	50 µm across
a chloroplast	5 µm
a bacterium	2 µm long
a mitochondrion	1 µm
a virus	100 nm
a ribosome	25 nm

2. Units for tiny things

- 1 cm = 10 mm
- 1 mm = 1000 µm (**micrometres**)
- 1 µm = 1000 nm (**nanometres**)

The prefix tells you the size: **centi** means one hundredth, **milli** one thousandth, **micro** one millionth and **nano** one billionth of a metre.



- To change to a **smaller** unit (down the staircase), **multiply**: 0.2 mm × 1000 = 200 µm.
- To change to a **bigger** unit (up the staircase), **divide**: 25 nm ÷ 1000 = 0.025 µm.

Watch out: to change µm into mm, divide by 1000. The number of mm is always smaller than the number of µm.

3. The view down a microscope

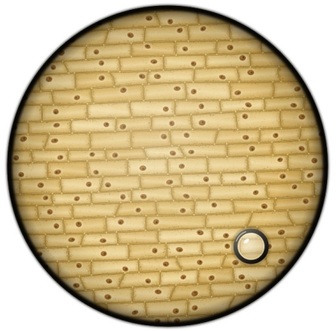
At × 100 (a × 10 eyepiece lens and a × 10 objective lens: B1 L3 Using a microscope) you see a round **field of view**, about 1.6 mm across. A slide of a thin layer of onion epidermis (skin), stained with iodine solution, shows:

- rows of brick-shaped cells, stained yellow-brown;
- a cell wall round each cell;
- a darker nucleus in most cells;
- sometimes an **air bubble**: a round shape with a thick dark edge. It is air trapped under the coverslip, not a cell.

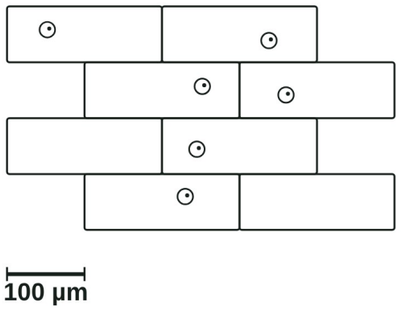
4. A real view and a biological drawing

Both show rows of brick-shaped cells with cell walls, and a nucleus in most cells.

Iodine stains the cells yellow-brown. The drawing adds a scale bar, so you can work out real sizes.



The view at × 100 (painting)



A drawing

Exam pictures of cells are usually **biological drawings**. A drawing is simplified on purpose:

- It has a **scale bar**, so you can work out real sizes. The view down the microscope has none.
- It shows only whole cells. Down the microscope, cells are cut off at the edge of the field of view.
- It tidies the cells into neat bricks. Real cells vary in size and shape.
- It leaves out air bubbles: they are not cells.
- It uses clear pencil lines, with no colour and no shading. The real cells are stained yellow-brown.

Watch out: an air bubble is not a cell. Leave air bubbles out of a biological drawing.

B1 L4 Revision notes 2 of 4

Magnification, the magnification equation and scale bars

5. What magnification means

Magnification is how many times bigger the image is than the real object. "× 400" means the image is 400 times bigger than the real object.

- Magnification has **no unit**. Write it with a times sign: × 400.
- A light microscope magnifies up to about × 1500. An electron microscope magnifies up to about × 2 000 000 (B1 L3).
- The total magnification of a light microscope is the eyepiece lens magnification × the objective lens magnification (B1 L3).

The equation below works for any image: a micrograph, a drawing, or a picture on a screen.

Watch out: magnification has no unit. Never write 400 mm or 400 µm for a magnification.

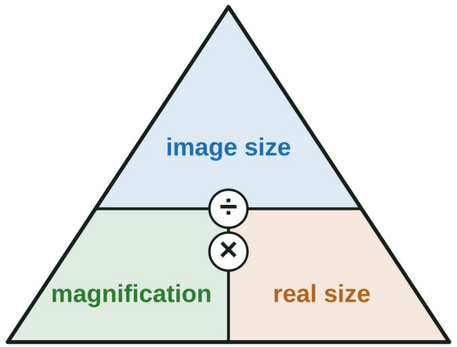
6. The magnification equation

magnification = size of image ÷ size of real object

Rearranged:

- **real size** = **image size** ÷ **magnification**
- **image size** = **real size** × **magnification**

Image size means the size of the image (measured with a ruler). Real size means the size of the real object.



How to answer a calculation:

1. Write the equation you need.
2. Put both sizes in the same unit (usually µm).
3. Put the numbers in and work it out. Type only the numbers into the calculator.
4. Give a unit (mm, µm or nm) for a size. Give no unit for a magnification.
5. Check: the real size must be smaller than the image.

7. Worked examples

Example 1: finding the magnification. An electron micrograph shows a mitochondrion. Its image is 30 mm long. The real mitochondrion is 1.5 µm long. Calculate the magnification.

Step 1: same unit: 30 mm = 30 × 1000 = 30 000 µm.

Step 2: magnification = size of image ÷ size of real object = 30 000 ÷ 1.5 = 20 000.

Answer: **× 20 000**. (Too high for a light microscope, as you would expect for an electron micrograph.)

Example 2: finding the real size. A drawing of a pollen grain is 45 mm wide. The magnification is × 1500. Calculate the real width in µm.

Step 1: real size = image size ÷ magnification = 45 ÷ 1500 = 0.03 mm.

Step 2: in µm: 0.03 × 1000 = **30 µm**.

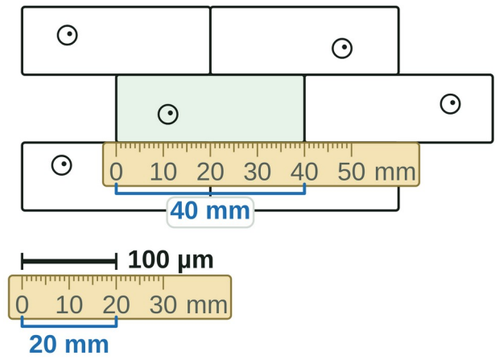
Check: 30 µm × 1500 = 45 000 µm = 45 mm, the size of the drawing.

8. Using a scale bar

A **scale bar** is a line on a picture that shows a real length, such as 10 µm.

1. Measure the scale bar with a ruler, in mm.
2. Measure the object, in mm.
3. real size = size on the picture ÷ length of the scale bar × value of the scale bar.

Example: in a drawing of onion cells, the 100 µm scale bar is 20 mm long and a cell is 40 mm long. 40 ÷ 20 × 100 = **200 µm**.



A scale bar is printed as part of the picture, so it stays right when the picture is printed bigger or smaller. A written magnification, such as × 200, is only right at the original size.

You can also find the magnification from a scale bar: 20 mm = 20 000 µm, and 20 000 ÷ 100 = × 200.

Watch out: measure the scale bar with a ruler. Do not use its label (100 µm) as its length.

B1 L4 Revision notes 3 of 4

Getting it right, the field of view, standard form and orders of magnitude

9. Getting it right

Watch out: change both sizes into the same unit before you divide. mm → µm: multiply by 1000. If you forget, your answer is 1000 times too small or too big.

Watch out: the real size is smaller than the image. If your answer is bigger, the equation is upside down: divide, do not multiply.

Watch out: do not type the × sign into your calculator. For × 1500, type 1500.

10. Estimating size from the field of view

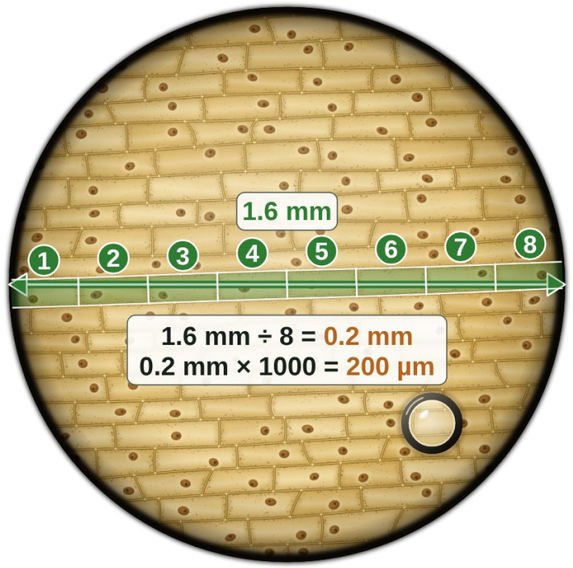
With a × 10 eyepiece lens:

Magnification	Width of the field of view
× 40	about 4.0 mm
× 100	about 1.6 mm
× 400	about 0.4 mm

size of one cell ≈ width of the field of view ÷ number of cells across

Example: at × 40, about 20 onion cells fit across the 4.0 mm field of view. 4.0 ÷ 20 = 0.2 mm = **200 µm**.

This is an **estimate**: cells vary in size, and cells at the edge are cut off. Use estimates to check that a calculated answer is sensible.



Which method? Three ways to find a real size

- **The magnification is given:** real size = image size ÷ magnification.
- **The picture has a scale bar:** real size = size on the picture ÷ length of the scale bar × value of the scale bar.
- **You can see the whole field of view:** size of one cell ≈ width of the field of view ÷ number of cells across. This is only an estimate.

11. Standard form

Standard form writes a very large or very small number as a number between 1 and 10 multiplied by a power of 10.

Length	In metres	Standard form
1 mm	0.001 m	1×10^{-3} m
1 µm	0.000 001 m	1×10^{-6} m
1 nm	0.000 000 001 m	1×10^{-9} m
an onion cell, 200 µm	0.0002 m	2×10^{-4} m
a bacterium, 2 µm	0.000 002 m	2×10^{-6} m

- Count how many places the decimal point moves to give a number between 1 and 10. That is the power.
- Small numbers (less than 1) have **negative** powers. Big numbers have positive powers: 2000 = 2×10^{3}.

Watch out: the first number must be between 1 and 10. 25 × 10^{-6} m is not standard form: write 2.5 × 10^{-5} m.

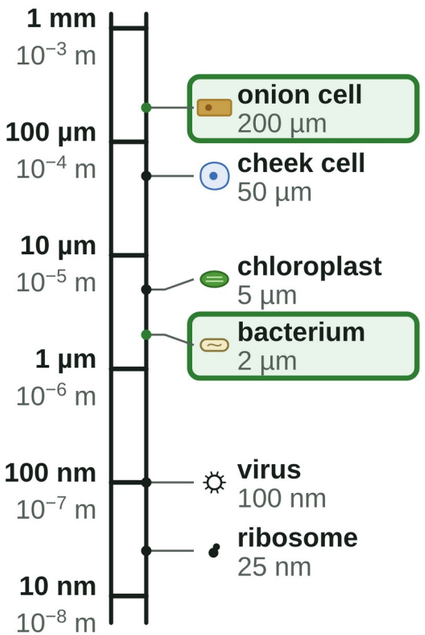
12. Orders of magnitude

An **order of magnitude** is a factor of 10. To compare two sizes:

1. Put them in the same unit.
2. Divide the bigger by the smaller.
3. Write the answer as a power of 10. The power is the number of orders of magnitude.

Example: a plant cell about 100 µm across and a bacterium about 1 µm long. 100 ÷ 1 = 100 = 10^{2}, so the plant cell is **2 orders of magnitude** bigger.

Watch out: two orders of magnitude is 10 × 10 = 100 times, not 20 times.



each rung is 10 times bigger

B1 L4 Revision notes 4 of 4

Key words, exam tips and check yourself

Key words

Estimate: a rough value worked out quickly, using simple numbers.

Field of view: the circle you can see when you look down a microscope.

Image size: the size of an object in a picture or drawing, measured with a ruler.

Light micrograph: a picture of something seen through a light microscope.

Magnification: how many times bigger the image is than the real object.

Micrometre (µm): one thousandth of a millimetre (1 mm = 1000 µm).

Nanometre (nm): one thousandth of a micrometre (1 µm = 1000 nm).

Order of magnitude: a factor of 10; one order of magnitude bigger means about 10 times bigger.

Real size: the actual size of the object, before it was magnified.

Scale bar: a line on a picture that shows a real length, such as 10 µm.

Stain: a dye that colours cells, or parts of cells, so they are easier to see.

Standard form: a way of writing a very large or very small number as a number between 1 and 10 multiplied by a power of 10, such as 2×10^{-6}.

Exam tips

- Learn the equation word for word: magnification = size of image ÷ size of real object.
- Put both sizes in the same unit before you divide, and show your working.
- Magnification has no unit: write × 400. A size always needs a unit: mm, µm or nm.
- Check your answer: the real size is smaller than the image, and a cell is usually 1 to 200 µm.
- With a scale bar, measure the bar and the object with a ruler, in mm.
- In standard form, the first number is between 1 and 10, and a small number has a negative power.

Common mistakes

- **Wrong:** 20 mm ÷ 2 µm, with two different units. **Right:** change both into µm first: 20 000 ÷ 2.
- **Wrong:** real size = image size × magnification. **Right:** real size = image size ÷ magnification.
- **Wrong:** using the label (100 µm) as the length of the scale bar. **Right:** measure the bar with a ruler.
- **Wrong:** 25×10^{-6} m. **Right:** 2.5×10^{-5} m: the first number is between 1 and 10.
- **Wrong:** two orders of magnitude is 20 times. **Right:** it is 10 × 10 = 100 times.

Check yourself

Cover the answers, then check.

1. Change 2.5 mm into µm.
2. Change 750 nm into µm.
3. What does a magnification of × 250 mean?
4. Write the equation for the real size of an object.
5. An image is 18 mm long. The real object is 0.09 mm long. Calculate the magnification.
6. A 5 µm scale bar is 10 mm long. A chloroplast in the same picture is 12 mm long. How long is the real chloroplast?
7. Write 0.0003 m in standard form.
8. One object is 10 000 times bigger than another. How many orders of magnitude bigger is it?

Answers

1. 2.5 × 1000 = 2500 µm.
2. 750 ÷ 1000 = 0.75 µm.
3. The image is 250 times bigger than the real object.
4. real size = image size ÷ magnification.
5. 18 ÷ 0.09 = × 200.
6. 12 ÷ 10 × 5 = 6 µm.
7. 3×10^{-4} m.
8. $10\,000 = 10^4$, so 4 orders of magnitude.

A worked answer: set out every step

A drawing of a cheek cell is 25 mm wide. The magnification is × 500. Find its real width.

1. **real size** = **image size** ÷ **magnification**
2. = 25 ÷ 500 = 0.05 mm
3. 0.05 mm × 1000 = **50 µm**

Check: 50 µm × 500 = 25 000 µm = 25 mm, the size of the drawing.

> In the exam, each step can earn a mark, so write every step and give the unit.