Microscopes and magnification

Specification reference

- *2.1.1 (b)*
- *2.1.1 (e)*
- *2.1.1 (f)*

Learning outcomes

After completing the worksheet you should be able to:

- understand the different units of measurement involved in microscopy, and be able to convert from one to another
- perform calculations using a formula to obtain the magnification or the actual size of an object as seen by any type of microscope.

Introduction

Microscopes are a basic and fundamental piece of biological equipment. They function by producing a magnified image of the object, such as a cell or tissue, which allows a biologist to examine the object in more detail.

It is important to know how much an object has been magnified, and to be able to calculate the actual size of the object. This allows us to make more accurate descriptions of a structure and to give comparisons with other structures visible.

There is a formula which we can use, which allows us to calculate the magnification and real size of objects. This sheet will give you a clear guide as to how to tackle a question on calculations involving the microscope.

Background

Microscopes are used to enlarge images of small objects. They are a major piece of equipment used by the biologist. There are many different types of microscopes. You need to know about the four most commonly used. You can read about the differences between these types of microscopes in Topic 2.1 and 2.2.

Below is a summary of the types of microscopes giving their uses, advantages, and disadvantages.

microscope	uses	advantages	disadvantages
light microscope	Uses light rays to observe object.	Can observe living things Does not use harsh chemicals Easy to set up and use Cheap and portable	Low magnification (up to 2000 times) Low resolution

<table>
<tr><th>microscope</th><th>uses</th><th>advantages</th><th>disadvantages</th></tr>
<tr><td colspan="4">Electron microscopes (EM)</td></tr>
<tr><td>Transmission EM</td><td>Uses focused beams of electrons through sections of tissues.</td><td>High magnification (up to 5000 000 times)
High resolution
Can see details inside cells</td><td rowspan="2">Can only see dead material
Harsh chemicals used in preparation which can cause artefacts
Expensive</td></tr>
<tr><td>Scanning EM</td><td>Uses focused beams of electrons reflected off the tissues.</td><td>High magnification (up to 5000 000 times)
High resolution
Can see details of the surfaces of structures</td></tr>
<tr><td>Laser scanning confocal microscope</td><td>Uses a laser beam of light to illuminate chemical stains within the specimen. These then fluoresce.</td><td>Can see living cells.
Can observe cell processes by tracking molecules.
Higher resolution than light microscopes.</td><td>More expensive than light microscope.
More complex than light microscope.</td></tr>
</table>

You could be given images of objects like cells, organelles, or organs, photographed, or drawn using either a light microscope or the different types of electron microscopes. Images photographed using a microscope of any type will have very small sizes, usually smaller than a millimetre.

There are three units you may encounter in microscopy:

- a millimetre (mm)
- a micrometre (µm)
- and, less commonly, a nanometre (nm).

You might find it difficult to convert a measurement taken in one unit to a different unit. Try the rule of thousands.

1 metre = 1000 mm

1 mm = 1000 µm

1 µm = 1000 nm

If you need to convert down the size range, multiply the larger size by 1000.

If you need to convert up the size range, divide by 1000.

Here are some examples.

1 The diameter of an arteriole is 1.5 mm, how many µm is it?

You are converting down the size range, so multiply by 1000.

$1.5 \times 1000 = 1500$ µm

2 A mitochondrion is 2 µm long, how many nm is it?

You are converting down the size range, so multiply by 1000.

$2 \times 1000 = 2000$ nm

3 A chloroplast is 10 500 nm, what size is it in µm?

You are converting up the size range, so divide by 1000.

$\frac{10\,500}{1000} = 10.5$ µm

Now try questions 1 and 2 in the task. Once you feel confident with the conversion of units look at the next section on the use of a formula to calculate size.

Using a formula to calculate size

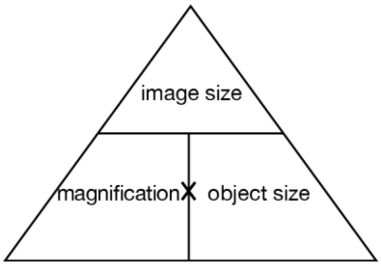
You may be asked to calculate the magnification used for a specimen or to calculate the actual size of a specimen.

The formula for these calculations is:

$$\text{Magnification} = \frac{\text{image size}}{\text{object size}}$$

or $$\text{Object size} = \frac{\text{image size}}{\text{magnification}}$$

You should be able to manipulate the formula. Some students find this triangle helpful:



When attempting these questions try using the following step by step approach:

Step 1 – measure the object or scale bar in mm.

Step 2 – If you have two measurements of size, convert them to the same units.

Step 3 – Select the correct version of the formula.

Step 4 – Substitute the figures into the formula.

Step 5 – Use your calculator to calculate the unknown.

Step 6 – Check you answer is in the correct units and is the correct number of decimal places.

Task

1 If the width of a mitochondrion is 0.5 µm, what is the width in nm?

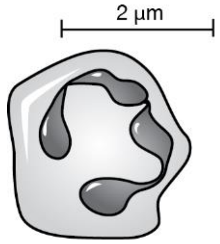
2 A student measured the maximum width of an open stomata and found it to be 3.5 µm. what was the width in mm?

3 A student drew a picture of a palisade cell from a leaf. The drawing measured 100 mm and the real size of the cell was 0.2 mm. Use the formula to calculate the magnification of the drawing.

4 A student saw a diagram of an artery in a text book that was magnified 15 times. The image size in the book was 75 mm. Calculate the actual size of the real artery.

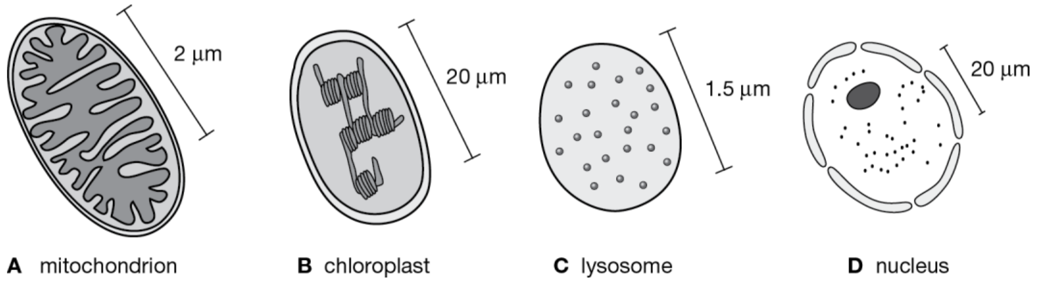
5 A student made a drawing of a red blood cell from the microscope. The cell was 7.5 µm in diameter and the drawing was 60 mm in diameter. Calculate the magnification the student had used for the drawing.

6 Below is a drawing of a phagocyte. Use the scale bar to calculate the magnification of the image.



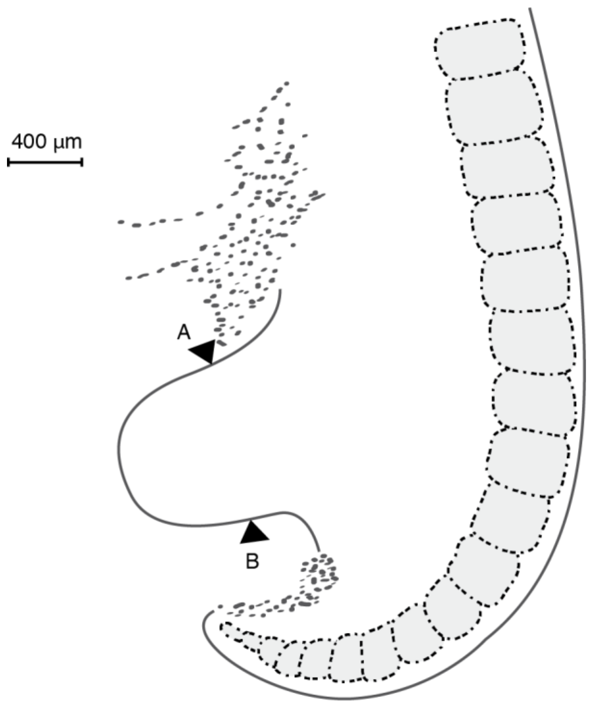
Questions

1 Below are four diagrams of different organelles in the animal cell. Each drawing has been made the same size. Study the diagrams and the information given and state which drawing has been most magnified.



(*1 mark*)

2 The figure below shows the leg bud of a chick embryo at about four days of incubation.



a Calculate the magnification of the image. Show your working. (*2 marks*)

b Calculate the actual size of the limb bud from A to B. Give your answer in µm. (*2 marks*)

