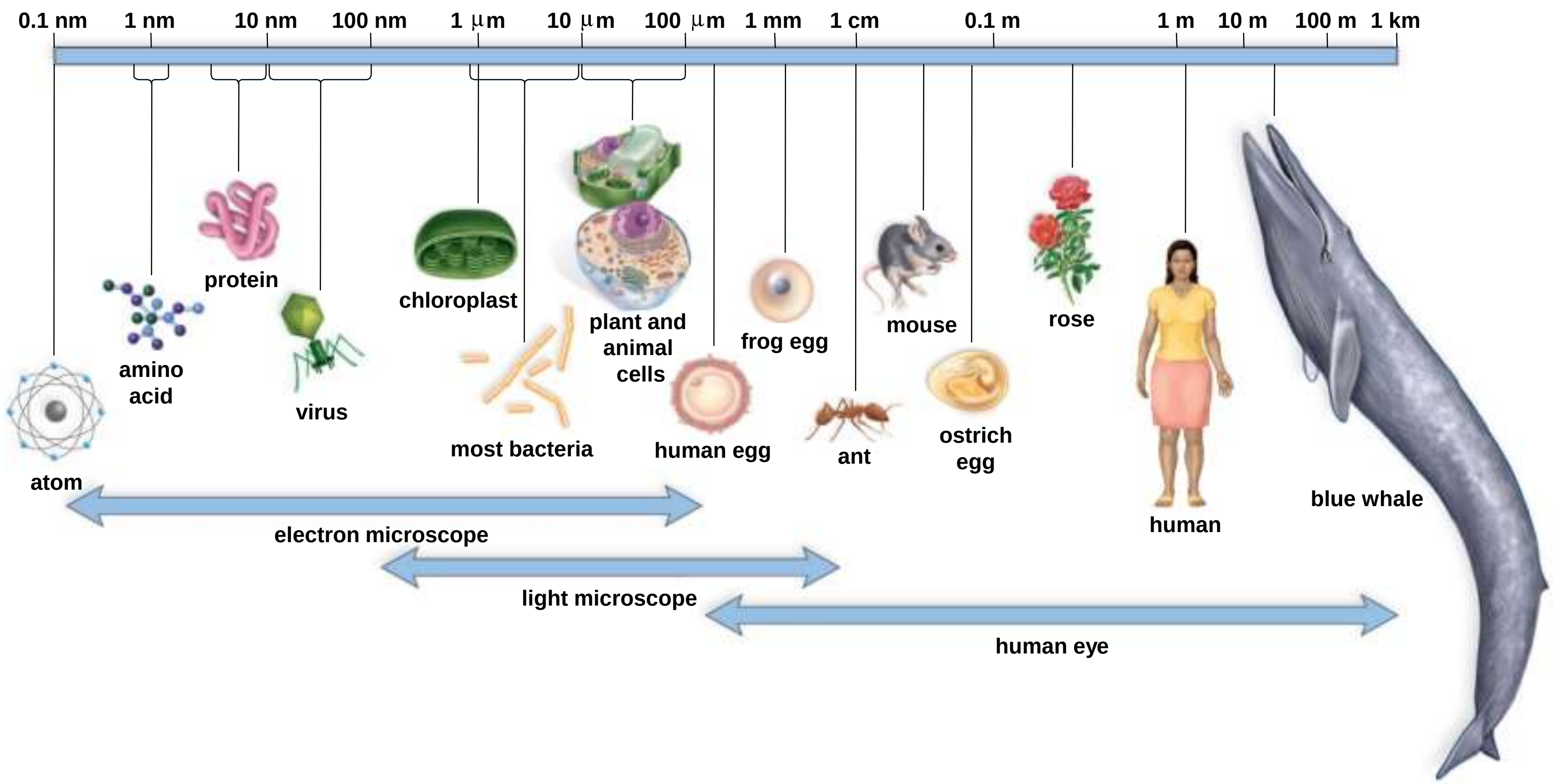
Cell size and measurement

Sizes of Living Things



Units of measurement

- Measurements in microscopy are…microscopic
- SI units=International System of Units
- Typical units in microscopy:
  - Millimetre=one thousandth=1/1000=10^{-3} m=mm
  - Micrometre=one ten millionth=1/10,000,000=10^{-6}m=µm
  - Nanometre=one thousand millionth=1/10,000,000,000=10^{-9}m=nm

Magnification x1500

Light microscope

Light passes through the specimen and then through the magnifying lenses so you can see the object much bigger

Magnification X2 000 000

Electron Microscope

Passes a beam of electrons through the specimen to magnify it

Magnification
x1500

Light microscope

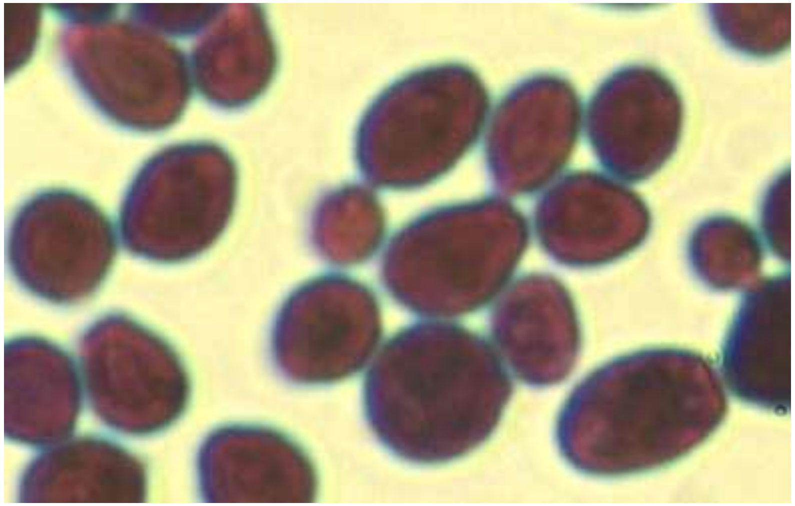
Much cheaper but lower magnification

Magnification
X2 000 000

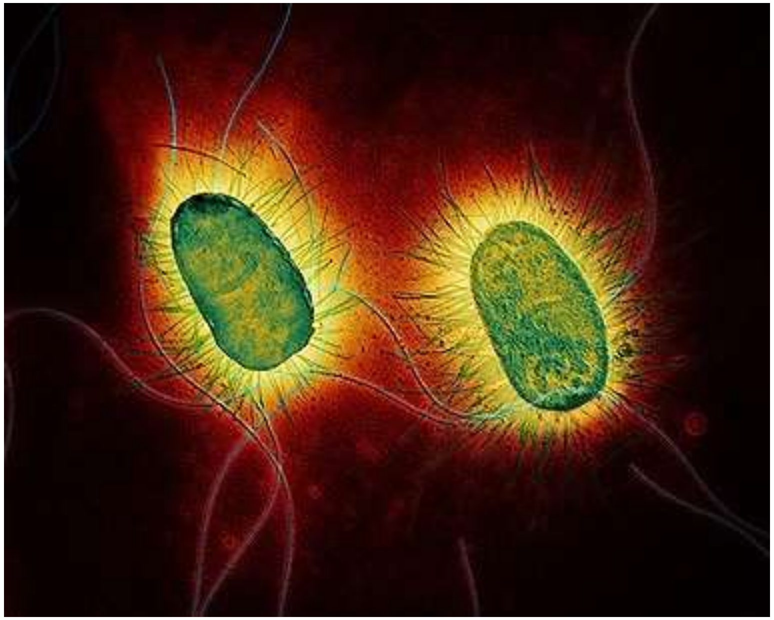
Electron Microscope

More expensive more high magnification
Gives a higher resolution.
This means you can tells the difference between 2 objects even if they are really close together.

A light microscope shows us bacteria don't have a nucleus



An electron microscope shows us that bacteria have two types of DNA, chromosomal and plasmid DNA.



Magnification

On an image of a specimen it is useful to show how much larger/smaller the image is than the real specimen. This is called magnification.

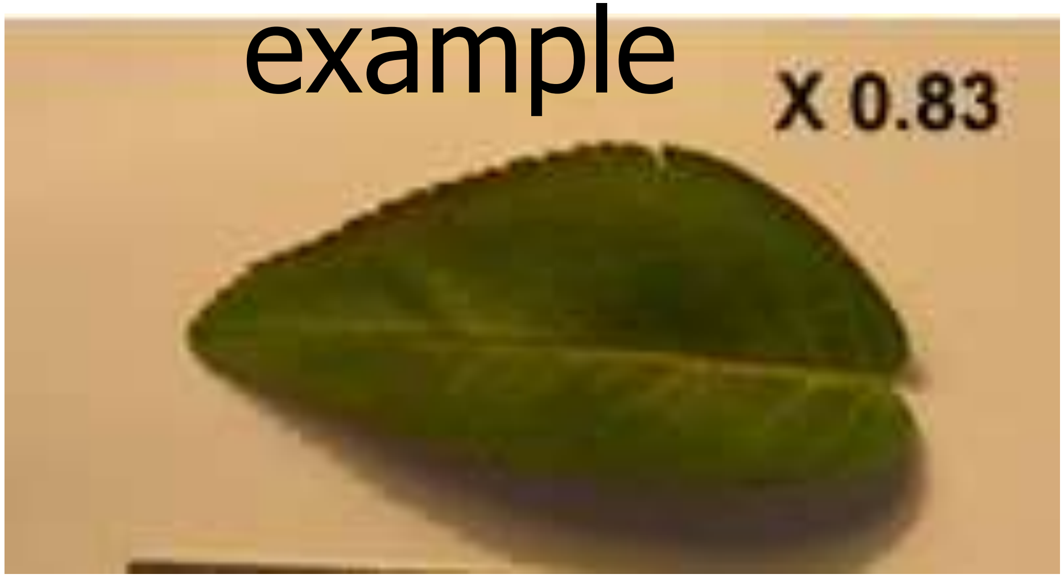
To calculate magnification

- using a ruler measure the size of a large clear feature on the image
- measure the same length on the specimen
- convert to the same units of measurement

Magnification **= length on the image /length on the specimen**

$$\text{Magnification} = \frac{\text{Measured size}}{\text{Actual size}}$$

example

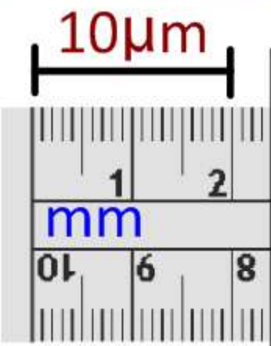


- In this example the image of a Rose leaf the magnification is X 0.83
- This tells us the image is smaller than the real specimen.
- The length of the real specimen = picture length/ 0.82 or 4.2cm/0.82 = **5.0 cm**

CALCULATING MAGNIFICATION

We might want to know how many times an image has been magnified.

The scale bar represents the 'real' size of the sample in the image, so we only need to work with the scale bar.



First convert your units so that they are all the same:

scale bar = µm, so convert ruler to µm

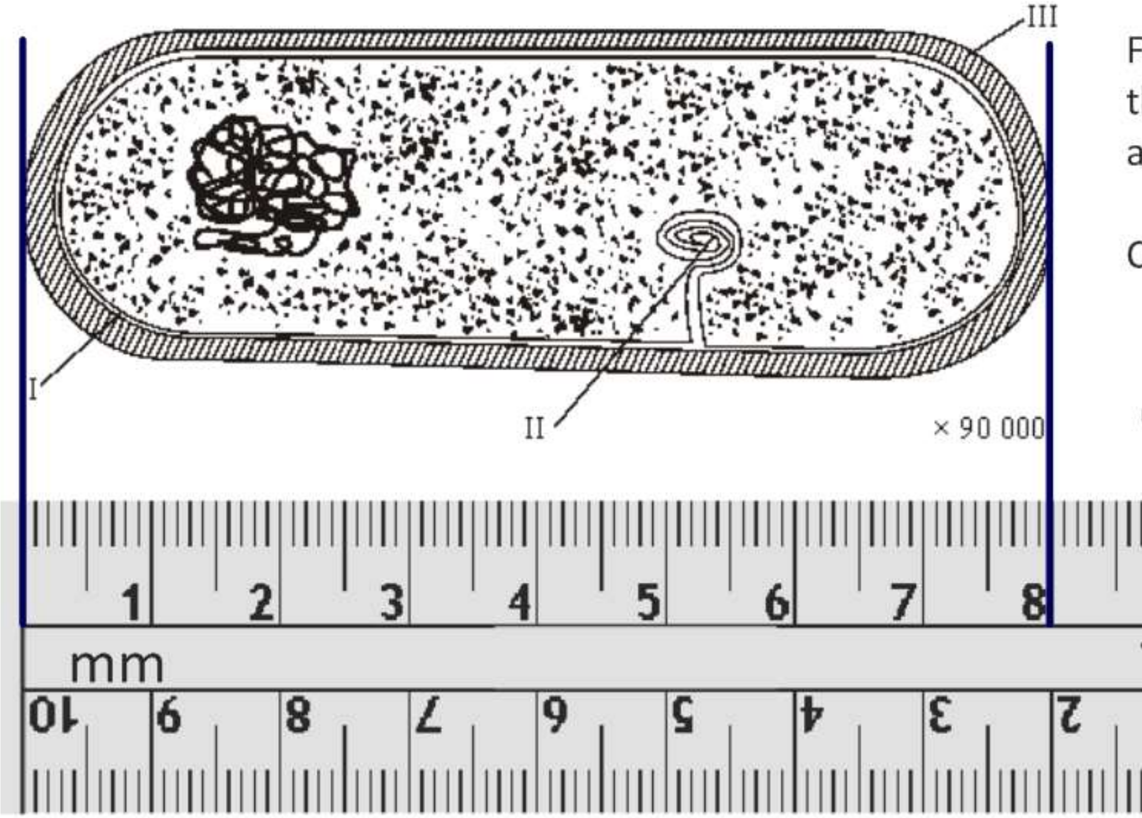
1 mm = 1,000 µm so 20mm = 20,000µm

Now we can calculate the magnification:

$$\frac{\text{scale bar measurement (we just measured)}}{\text{scale bar label ('real life' of sample)}} = \frac{20{,}000\ \mu m}{10\ \mu m}$$

magnification = 2,000 times

CALCULATING ACTUAL SIZE (NO SCALE BAR)



For this type of question, simply measure the part of the image you are instructed to and divide it by the magnification.

Convert to the most appropriate units.

e.g. $\dfrac{\text{measured length}}{\text{magnification}}$

$\dfrac{80\text{mm}}{90{,}000} = 8.9 \times 10^{-4}\text{mm}$

or 0.00089mm

converts to: 0.89µm

should have an integer on this side of the point →

this is best - gives us clear whole numbers → or 890nm

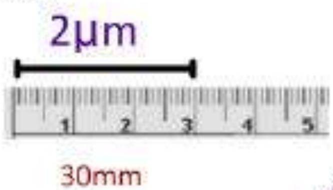
Calculations in microscopy

Use these calculations to find the magnifications or actual sizes of images.

1. Convert all units to make them the same (where appropriate)
2. Perform calculations
3. Convert answers to appropriate SI units, using scientific notation where needed.

$$\text{magnification} = \frac{\text{measured length}}{\text{scale bar label}}$$

e.g.



= ______

convert units

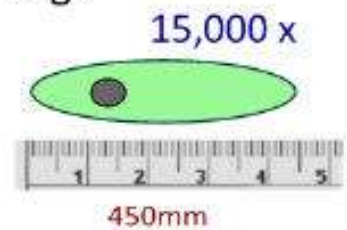
= ______

= ______

magnification =

$$\text{actual size} = \frac{\text{measured length}}{\text{magnification}}$$

e.g.



= ______

=

convert units
x1000 to go to µm

actual size =

Calculations in microscopy

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$$\text{magnification} = \frac{\text{measured length}}{\text{scale bar label}}$$

e.g.

2µm

30mm

$$= \frac{30\text{mm}}{2\mu\text{m}}$$

convert units

$$= \frac{30000\mu\text{m}}{2\mu\text{m}}$$

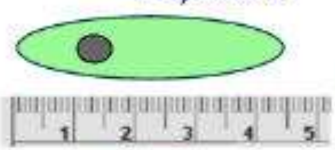
$$= \frac{30000\cancel{\mu\text{m}}}{2\cancel{\mu\text{m}}}$$

magnification = **15,000 x**

$$\text{actual size} = \frac{\text{measured length}}{\text{magnification}}$$

e.g.

15,000 x



450mm

$$= \frac{450\text{mm}}{15{,}000}$$

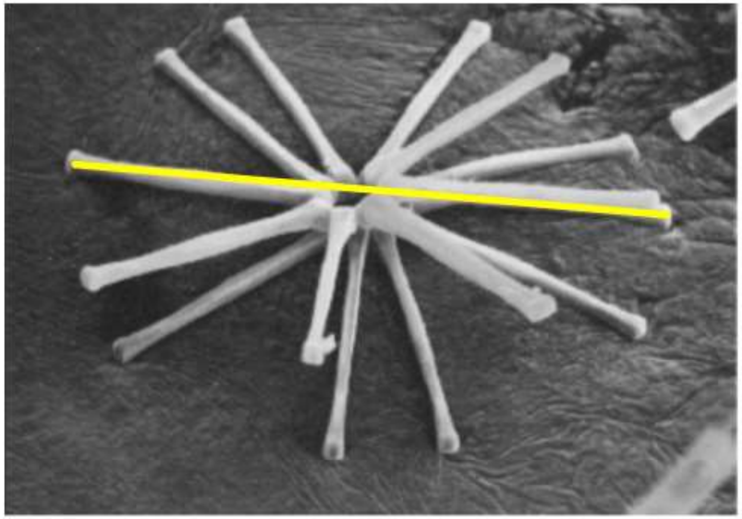
$$= 0.03\text{mm}$$

convert units
x1000 to go to µm

actual size = **30µm**

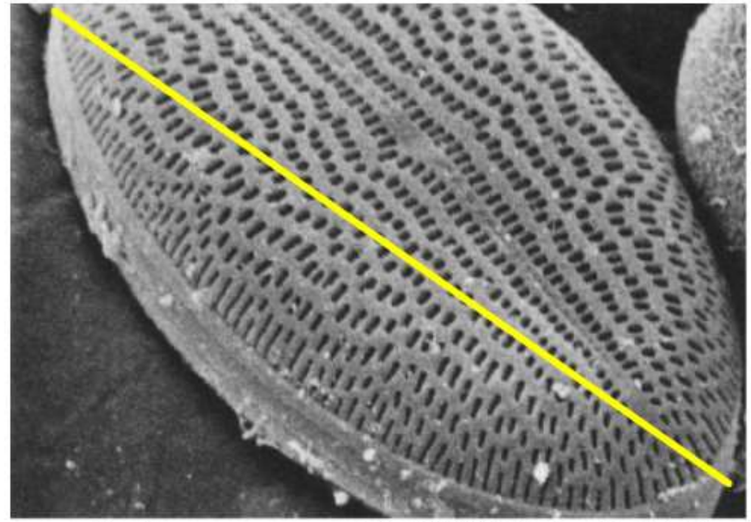
or $3.0 \times 10^2\mu\text{m}$

Diatom x 1,000



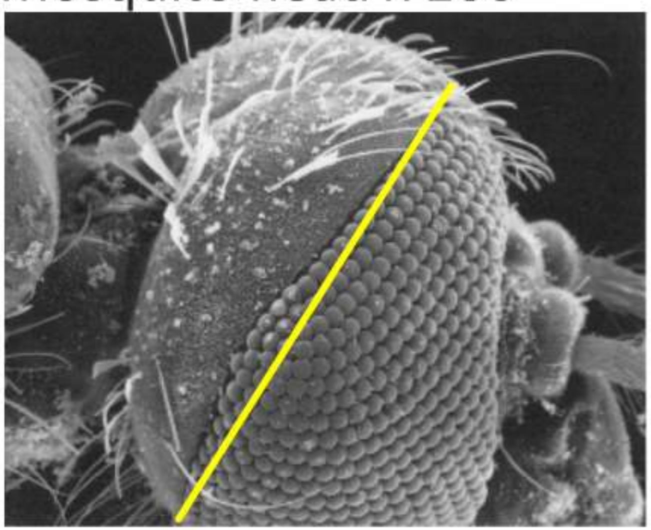
http://www.mos.org/sln/SEM/diatom.html

Diatom x 5,000



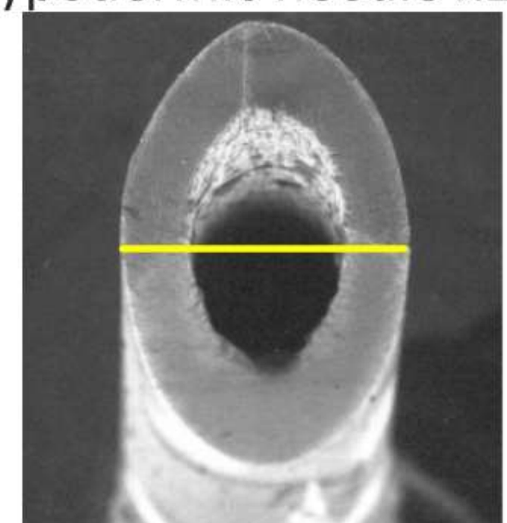
http://www.mos.org/sln/SEM/diatomb.html

Mosquito head x 200



http://www.mos.org/sln/SEM/mhead.html

Hypodermic needle x100



http://www.mos.org/sln/SEM/needle.html

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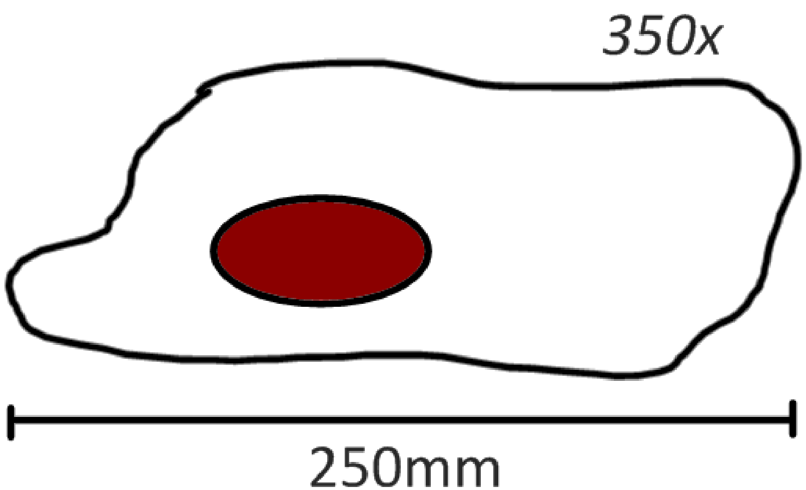
If you're stuck, draw it out...



$$\text{Actual length} = \frac{\text{image length}}{\text{magnification}}$$

$= 250mm/350$

$= 0.71mm$*

(or 710 μm)

* isn't that a bit big for a cell? More on size of cells later...

2.A sperm cell has a tail 50µm long. A student draws it 75mm long.
What is the magnification?

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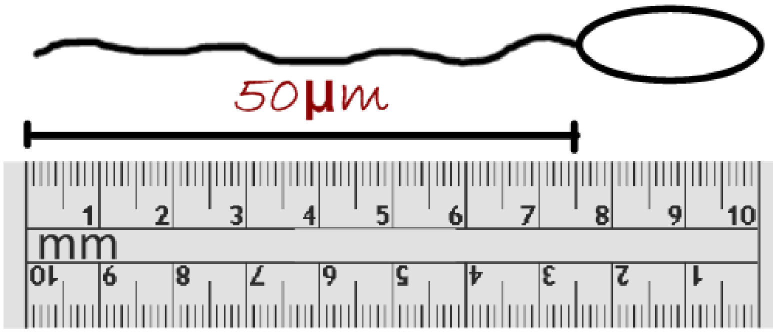


1. Convert mm to µm:

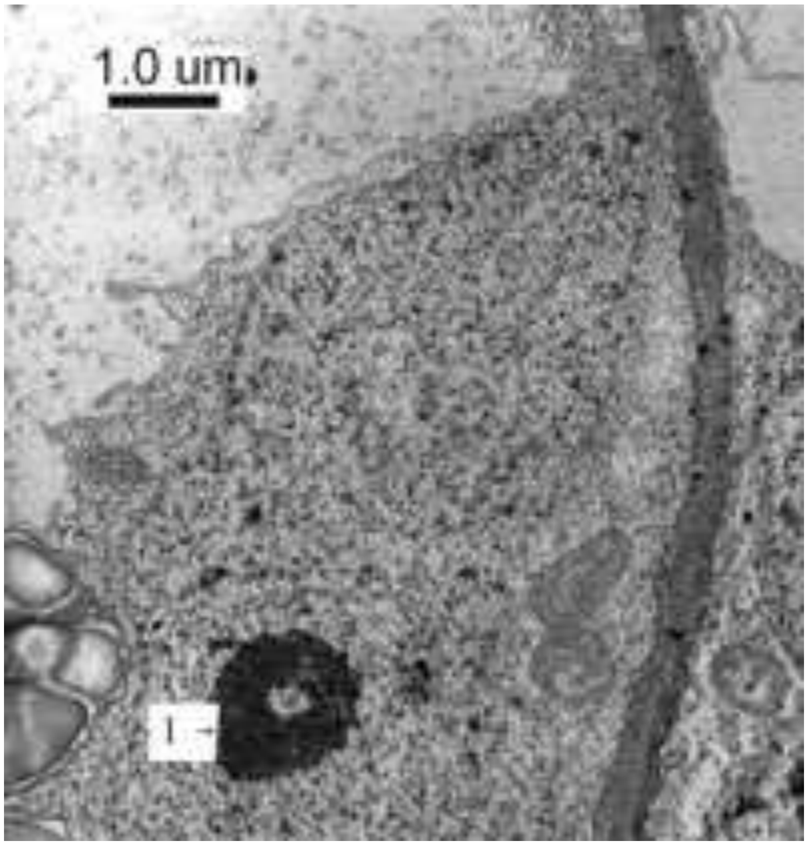
75mm = 75,000um

2. $\frac{\text{drawing length}}{\text{scale bar label}}$

= 75000/50

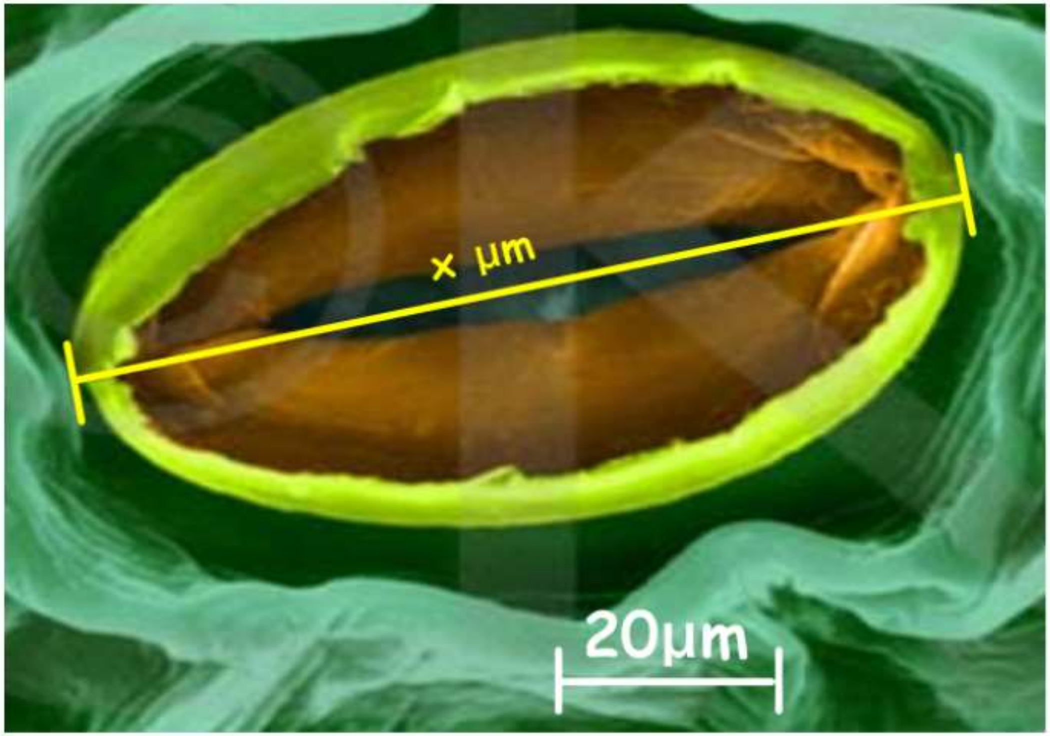
= 1500x magnification

Scale Bars



- A scale bar is a line added to a drawing, diagram or photograph to show the actual size of the structures.
- The scale bar in the picture allows you quickly to determine the approximate size of a feature.
- The main feature in the micrograph is a nucleus with a dark region called the nucleolus.
- Using the picture estimate the size of the nucleus and its nucleolus.

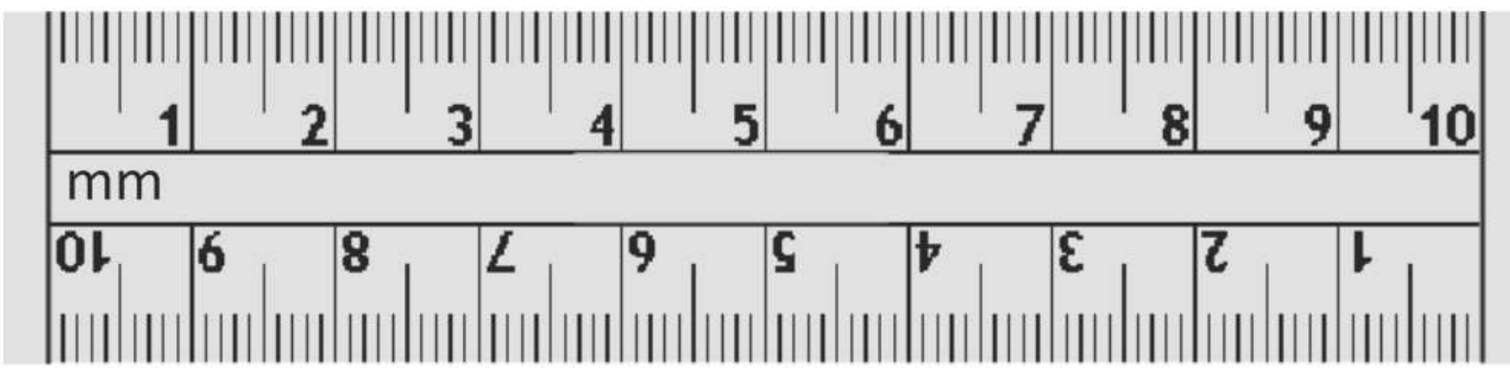
USING SCALE BARS



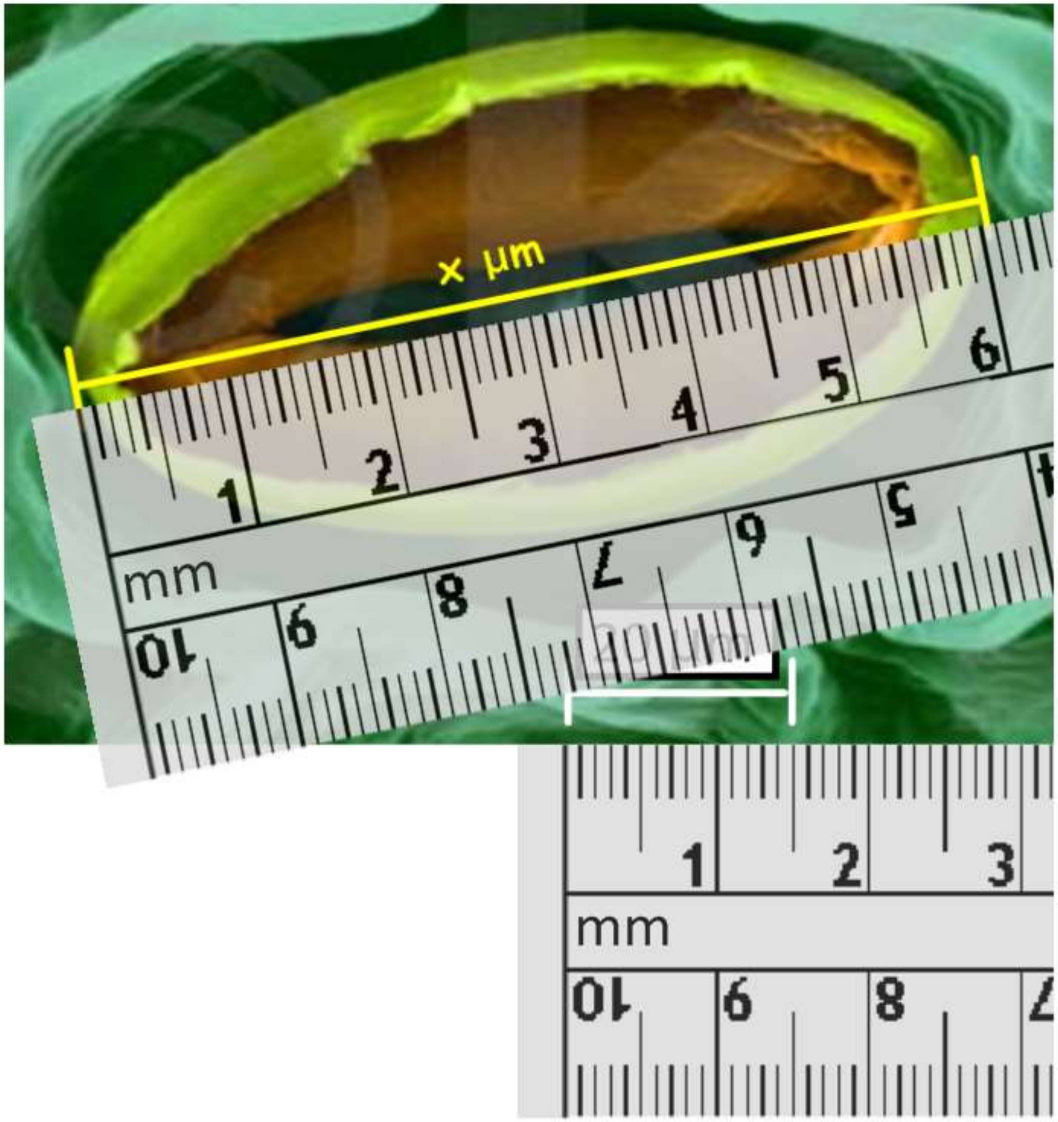
When asked to find the length of an object, look for the longest dimension.

Here the length of the stoma has been marked as xµm.

Our scale bar shows us 20µm in real life - so we can use a ruler or micrometer eyepiece to determine the actual size of the stoma.



USING SCALE BARS



First calculate the scale on the scale bar:

$$\frac{\text{scale length}}{\text{ruler length}} = \frac{20\ \mu m}{15mm}$$

= 1.33 µm per mm

(real life) (image)

Then measure the image with the ruler:

x µm is 60mm on the image.

Now calculate the true length:

1.33 x 60 = 80 µm

(scale) (image length)

Easier – Same units of measurement

Object	Image Size	Actual	
E Coli	20mm	0.002mm	x
Yeast Cell	10mm	0.006mm	x
Blood cell	300mm	0.01mm	
Pollen Grain	40mm	0.5mm	
Hair	6cm	3.5cm	

20 ÷ 0.002 = x10,000

10 ÷ 0.006 = x1,666.67

300 ÷ 0.0
x30,00

40 ÷ 0.5
x80

6 ÷ 3.5 = x1.7

Difficult – Different units of measurement

Object	Image Size	Actual size	Ma
Salmonella	1.5cm	0.003mm	x
Crystal	3cm	0.05mm	x
White Cell	20mm	20µm	x
Dust	25mm	0.1cm	x
Finger Nail	5mm	1.5cm	

15mm ÷ 0.003mm = x50

30mm ÷ 0.05mm = x600

20,000µ ÷ 20µ = x1000

25mm ÷ 1mm = x25

5mm ÷ 15mm = x0.3

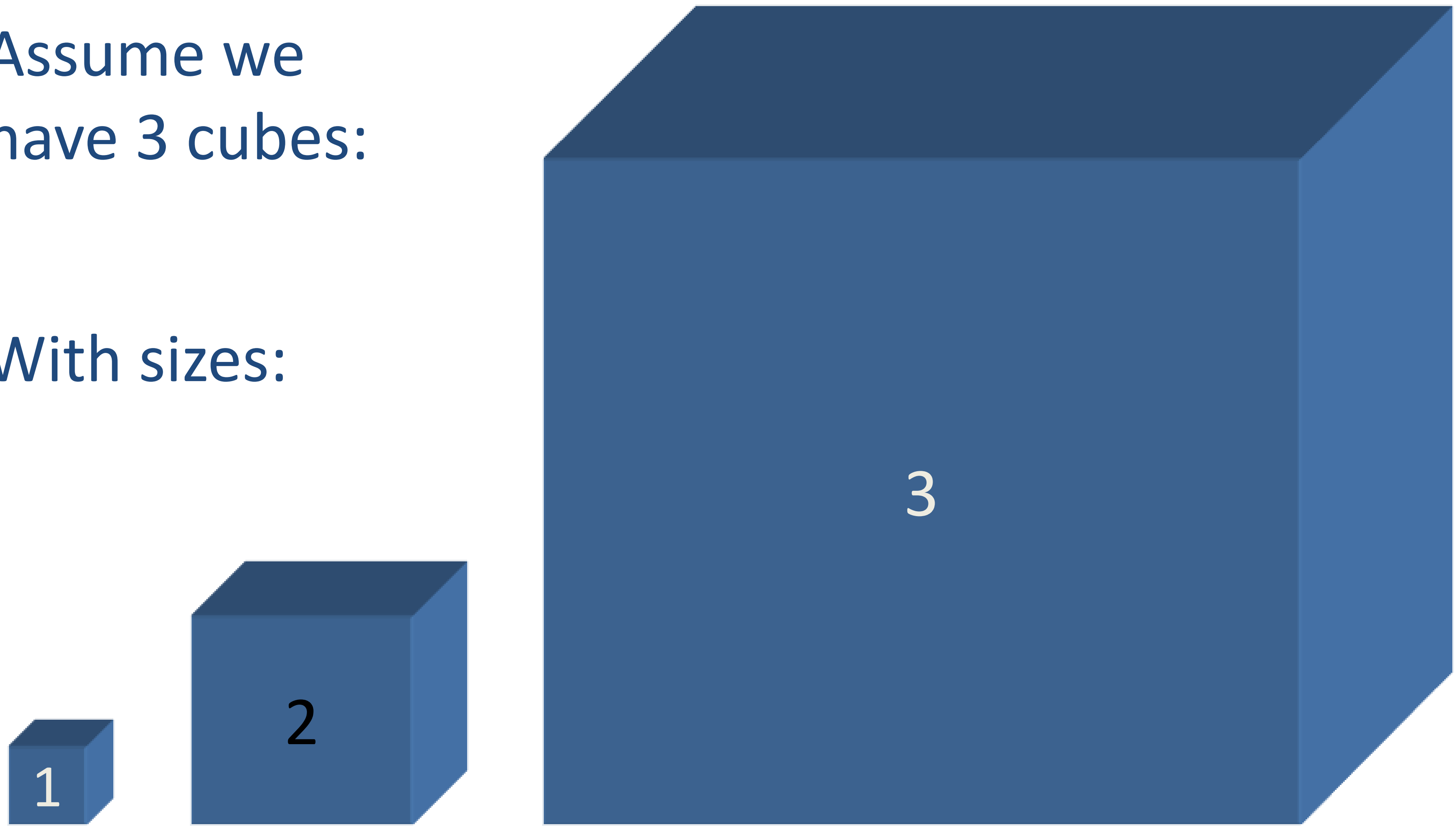
Surface area : Volume ratio and cell size

- All organisms need to exchange substances such as food, waste, gases and heat with their surroundings. These substances must be exchanged between the organism and its surroundings.
- As the size of a structure increases the surface area to volume ratio decreases.
- Therefore the rate of exchange (diffusion/radiation) decreases.
- This is true for organelles, cells, tissues, organs and organisms.

- The rate of exchange of substances therefore depends on the organism's surface area that is in contact with the surroundings.
- The exchange depends on the volume of the organism, so the ability to meet the requirements depends on , which is known as the surface area : volume ratio
- As organisms get bigger their volume and surface area both get bigger, but not by the same amount. This can be seen by performing some simple calculations concerning different-sized organisms.

Assume we have 3 cubes:

With sizes:



1 cm

10 cm

100 cm

What will happen to ratio between V and S.A. as their size increases?

Ratio of V:S.A.

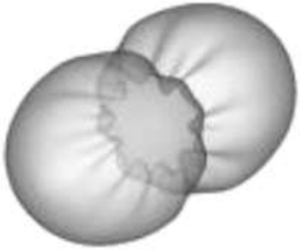
Cube	Side Length	Volume (x^3)	S.A. ($6x^2$)	Ratio (S.A./V)
1	1 cm	1 cm^3	6 cm^2	6
2	10 cm	1 000 cm^3	600 cm^2	0.6
3	100 cm	1 000 000 cm^3	60 000 cm^2	0.06

Example 2

Organism	Length	SA (m^2)	vol (m^3)	SA/vol (m-1)
1	1	6	1	6:1 = 6:1
2	2	24	8	24:8 =3:1
3	3	54	24	56:27 = 2:1
4	4	96	64	96:64 = 3:2
5	5	150	125	150:125= 6:5

Conclusions:•As the organism gets bigger its surface area : volume ratio decreases

So how do organisms maximise SA:Vol ratio?



As organisms grow, cells divide.
Two small cells are more efficient than one large cell.
This also allows for cell differentiation, specialised functions and more complex multicellular life.

http://www.a3243g.com/a3243g_images/mitochondria.gif

Cell compartmentalize they use membranes to carry out metabolic processes. In eukaryotes, these are called organelles.

Organelles themselves, like this mitochondrion, are also made up of membranes - maximising the surface area for reactions.

Some organs (such as the intestines) fold up to maximise SA:Vol ratio - making absorption of food molecule more efficient.
Alveoli in the lungs are thin membranes that maximise the surface for gas exchange.
Roots are long, and branched, with root hairs on the cells to maxiise the surface area for water uptake.