UPCSE Biology –
Basic Statistic course

On conversion of units, numbers in standard form
and reading from micrographs

Introduction

- Today we look at
  - converting between powers of 10 (say from millimetres to metres),
  - expressing numbers in something called *standard form*
  - reading the true size of objects from electron micrographs

Conversion of units

Factor	Prefix	Symbol	Numerical value
10^{-9}	nano	n	0.000 000 001
10^{-6}	micro	μ	0.000 001
10^{-3}	milli	m	0.001
10^{-2}	centi	c	0.01
10^{-1}	deci	d	0.1
10^{0}	–	–	1

Conversion of units

Factor	Prefix	Symbol	Numerical value
10^1	deca	da	10
10^2	hecto	h	100
10^3	kilo	k	1000
10^6	mega	M	1,000,000
10^9	giga	G	1,000,000,000

Conversion of units

- In the hard sciences the metre (m) is the standard unit of length. This means that any number not written in metres has to be converted into metres.
- This means converting between powers of 10, the obvious effect of which is to change either the number of 0s in, or the position of the decimal point of, a number.
- Such an effect relates to multiplying or dividing by a power of 10.

Conversion to a higher unit

- To convert a number from a lower unit to a higher unit (say, from cm to m) we

divide the number by the change in scale
it takes to get to the larger unit.

Conversion to a higher unit

- *Example 1:* Consider converting 1cm into m. We know there are 100cm in 1m, and we only want 1cm. So we only have one-hundredth of a metre, i.e. 0.01m, so the change in scale is 100 or 10^2.

  What we have done is to divide the number 1cm by 100, i.e. by 10^2. This give $1 \div 10^2 = 0.01$m

Conversion to a higher unit

- *Example 2:* To convert 5 milligrams (mg) into grams (g) notice that the change in scale from mg to g is 10^3. So divide the number by 10^3. This give $5 \div 10^3$ = 0.005g

- *Example 3:* To convert 3.5 nmol into μmol notice that the change in scale from nmol to μmol is 10^3. So divide the number by 10^3. This give $3.5 \div 10^3$ = 0.0035 μmol

Conversion to a lower unit

- To convert a number from a higher unit to a lower unit (say, from m to mm)

Multiply the number by the change in scale it takes to get to the lower unit.

- *Example 1:* What is 0.0035m in cm? Here the change in scale from m to cm is 10^2. So multiply the number by 10^2. This give $0.0035\times10^2 = 0.35$cm

Conversion to a lower unit

- *Example 2:* To convert 0.5 g into mg notice that the change in scale from g to mg is 10^3. So multiply the number by 10^3. This gives $0.5 \times 10^3 = 500$mg.

Checking your conversions

- In order to get a feel for whether or not you have converted your numbers the right way remember this:
  - When you convert a number to a larger scale (say mm to m) your number will “look” smaller;
  - When you convert a number to a smaller scale (say m to mm) your number will “look” bigger;

Checking your conversions

- I say “look” because your number won’t really be smaller or bigger than what it was originally. The units tell you how “big” the number is:

3.5g = 3500mg = 0.0035 kg !

Conversion of units

Units	Number	Comment
nm	3, 500, 000, 000	3.5m = 3,500,000,000 nm
µm	3,500,000	3.5m = 3,500,000 µm
mm	3500	3.5m = 3500mm
cm	350	3.5m = 35cm ← **No. Why?**
m	3.5	This is the unit we use as the basis for our measurement
km	0.0035	3.5m = 0.0035km
Mm	0.0000035	3.5m = 0.0000035Mm
Gm	0.0000000035	3.5m = 0.000000003Gkm

Standard form

- "Standard form" refers to a particular way of writing numbers as powers of 10.
- For example, instead or writing 73.29 we could write 7.329×10^1. This is the standard form version of 73.29
- But we would never bother writing 73.29 in standard form. Why? Because it is easy to write 73.29 as 73.29.
- Standard form is usually used only when dealing with very large numbers or very small numbers.

Standard form

- One example of this is Avogadro's number. This is written (approximately) as

$$6.02214076 \times 10^{23} \text{ /mol.}$$

- We would never write this as

$$602,214,076,000,000,000,000,000.$$

- Hence the usefulness of writing numbers in standard form.
- Note that a number in standard form is a number where the mantissa is always between 1 and 9.

Standard form

- Other examples of numbers in standard form include the universal constants.

The International System of Units, the SI, is the system of units in which

- **the unperturbed ground state hyperfine transition frequency of the caesium 133 atom, $\Delta\nu_{Cs}$, is 9 192 631 770 Hz,**
- **the speed of light in vacuum, *c*, is 299 792 458 m/s,**
- **the Planck constant, *h*, is $6.626\ 070\ 15 \times 10^{-34}$ J s,**
- **the elementary charge, *e*, is $1.602\ 176\ 634 \times 10^{-19}$ C,**
- **the Boltzmann constant, *k*, is $1.380\ 649 \times 10^{-23}$ J/K,**
- **the Avogadro constant, N_A, is $6.022\ 140\ 76 \times 10^{23}$ mol^{-1},**
- **the luminous efficacy of monochromatic radiation of frequency 540×10^{12} Hz, K_{cd}, is 683 lm/W,**

Standard form

Examples

Convert the following into standard form

a) 52,300,000

b) 0.000718

c) 150,000,000 which is the distance from the Earth to the Sun in km

d) 93,000,000 which is the distance from the Earth to the Sun in miles.

Standard form

Examples

For a) we have

$$\begin{aligned} 52{,}300{,}000 &= 5{,}230{,}000 \times 10 \\ &= 523{,}000 \times 100 \\ &= 52{,}300 \times 1000 \\ &= \ldots = 5.23 \times 10{,}000{,}000 \\ &= 5.23 \times 10^7 \end{aligned}$$

← answer in standard form

Standard form

Examples

For b) we have

$$0.000718 = 0.00718 \div 10$$

$$= 0.0718 \div 100$$

$$= 0.718 \div 1000$$

$$= 7.18 \div 10000 = 7.18 \div 10^4$$

$$= 7.18 \times 10^{-4}$$ ← answer in standard form

Standard form

Examples

For c) we have

$$
\begin{aligned}
150{,}000{,}000 &= 15{,}000{,}000 \times 10 \\
&= 1{,}500{,}000 \times 100 \\
&= 150{,}000 \times 1000 \\
&= \ldots = 1.5 \times 100{,}000{,}000 \\
&= 1.5 \times 10^8
\end{aligned}
$$

← answer in standard form

Standard form

Examples

For d) we first have to convert to km:

$$93{,}000{,}000 \text{ miles} = 93{,}000{,}000 \times 1.60934 \text{ km},$$

then continue as for the previous slide.

Standard form

Exercises

Convert the following into standard form.

$270{,}000$	31415×10^{-5}
0.000079	48×10^{5}
920	0.68×10^{3}
1.3	0.68×10^{-3}
0.701	290×10^{2}

Standard form

<u>Exercises</u>

a) The diameter of an electron: 0.00000000000001m. Convert this number into standard form.

b) Large liver cells have a diameter range of between 0.00005m to 0.0001m.

- What is the range in μm?
- Convert this range into standard form.

Standard form

Exercises

Arrange the following numbers in ascending order

a) 0.029

b) 2.9×10^{-3}

c) 0.00029×10^{2}

d) 209×10^{-5}

Conversion of units: Areas and volumes

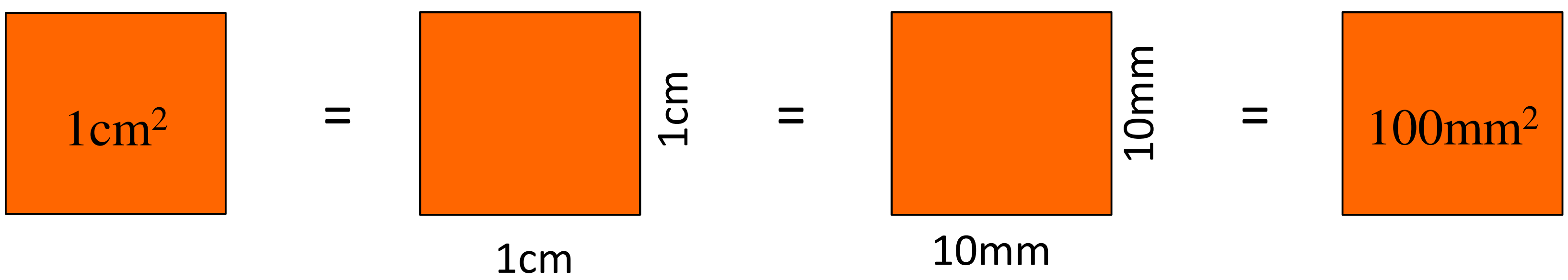
- **Example**

$1cm^2 \neq 10\ mm^2$. Why?

Because $1cm^2 = (1cm)^2 = (1cm)\times(1cm)$

$= (10mm)\times(10mm)$

$= 100mm^2$.



Conversion of units: Areas and volumes

- This idea applies to all area and volume conversions.

$$1\ \mathrm{cm}^2 = 100\ \mathrm{mm}^2$$

$$1\ \mathrm{m}^2 = 10,000\ \mathrm{cm}^2$$

$$1\ \mathrm{m}^2 = 1,000,000\ \mathrm{mm}^2$$

$$1\ \mathrm{hectare\ (ha)} = 10,000\ \mathrm{m}^2$$

$$1\ \mathrm{km}^2 = 1,000,000\ \mathrm{m}^2$$

$1\ cm^3 = 1000\ mm^3 = 0.000001\ m^3$

$1\ m^3 = 1{,}000{,}000\ cm^3$

$1\ cm^3 = 0.000001\ m^3 = 1 \times 10^{-6}\ m^3$

1000 millilitres = 1 litre

100 millilitres = 0.1 litre

10 millilitres = 0.01 litre

Conversion of units: Areas and volumes

- *<u>Examples:</u>* Convert the following as required:

1) A floor is 9m long and 2 m wide. Find the area of the floor in cm^2.

2) A hallway has floor area of $16m^2$. What is it's area in cm^2?

3) An A4 sheet of paper measures 210mm by 297mm. Find the area in cm^2.

4) An A3 sheet of paper has area $1247.4cm^2$. What is its area in cm^2?

Conversion of units: Areas and volumes

- *Exercises: Answers*

1) 9m = 900cm, and 2m = 200cm. So the area of the floor is $900 \times 200\text{cm}^2 = 180000\text{cm}^2 = 1.8 \times 10^5\text{cm}^2$

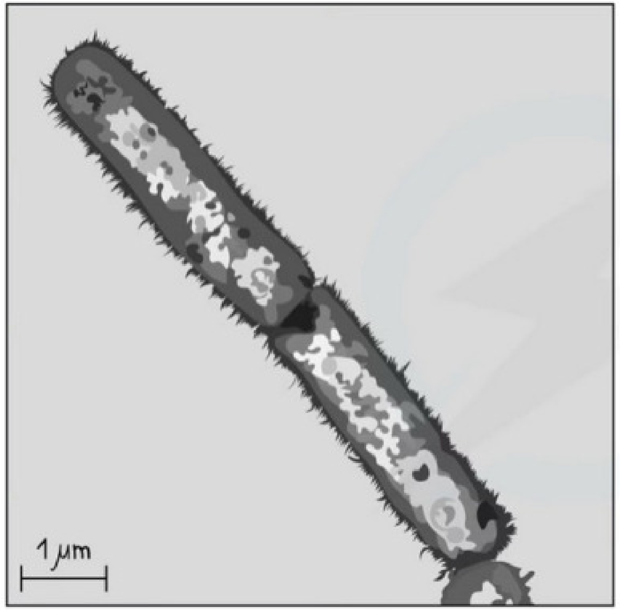
2) $16\text{m}^2 = 4\text{m} \times 4\text{m} = 400\text{cm} \times 400\text{cm} = 160000\text{cm}^2$ $= 1.6 \times 10^5\text{cm}^2$

3) 210mm = 21cm, and 297mm = 29.7cm, so the area of an A4 sheet of paper is $21 \times 29.7\text{cm}^2 = 623.7\text{cm}^2$

4) $1247.4\text{cm}^2 = 1247.4 \times 1\text{cm}^2 = 1247.4 \times (1\text{cm}) \times (1\text{cm})$
$= 1247.4 \times (10\text{mm}) \times (10\text{mm}) = 124740\text{mm}^2$

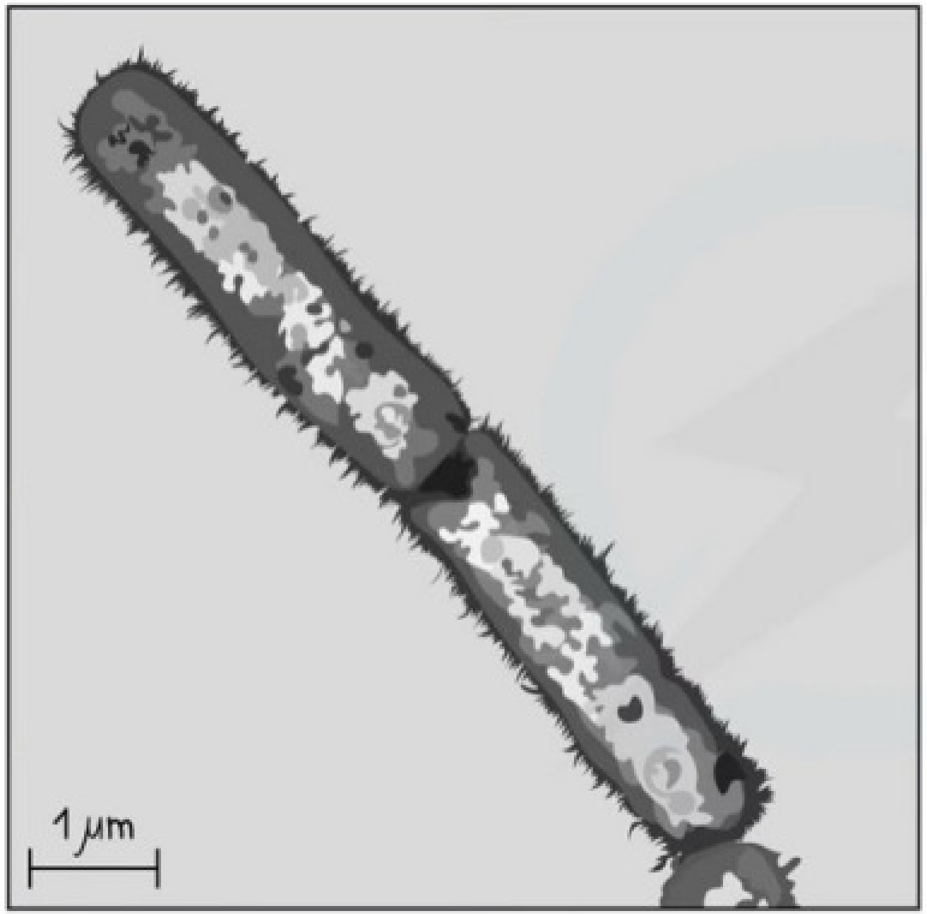
Measuring from electron micrographs

- Here we look at how to measure the real sizes of cells from photographs.
- In the photograph we will be given a scale bar. This is simply a straight line of a certain length which specifies the real size for the magnitude of the photo.
- For example, in the image on the right the length of the scale bar is supposed to represent a real size of 1μm.



Measuring from electron micrographs

- So the question is, what is the real size of the cell in the image?
- In order to answer this type of question we need to compare the real size of the bar and cell with their apparent sizes (taken by measuring these with a ruler)

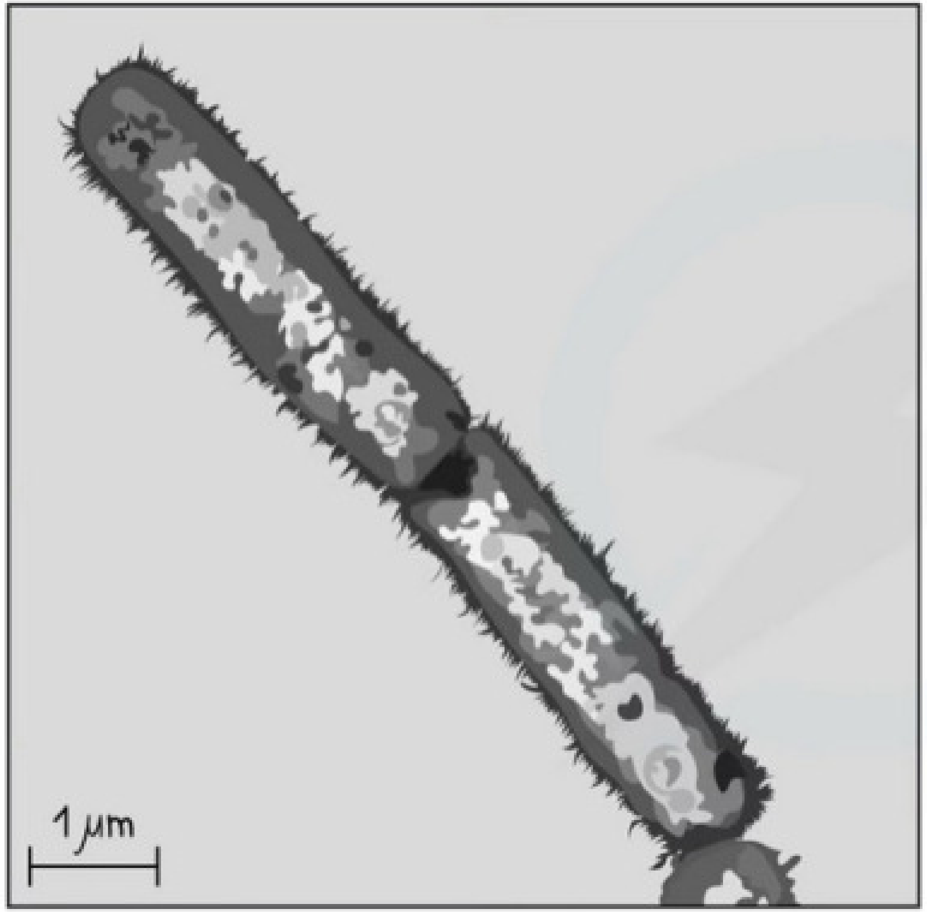


Measuring from electron micrographs

- The formula which does this comparison is

$$\frac{scale\ bar_{real}}{scale\ bar_{measured}} = \frac{cell\ length_{real}}{cell\ length_{measured}}$$

where we want to find "cell $length_{real}$".



Measuring from electron micrographs

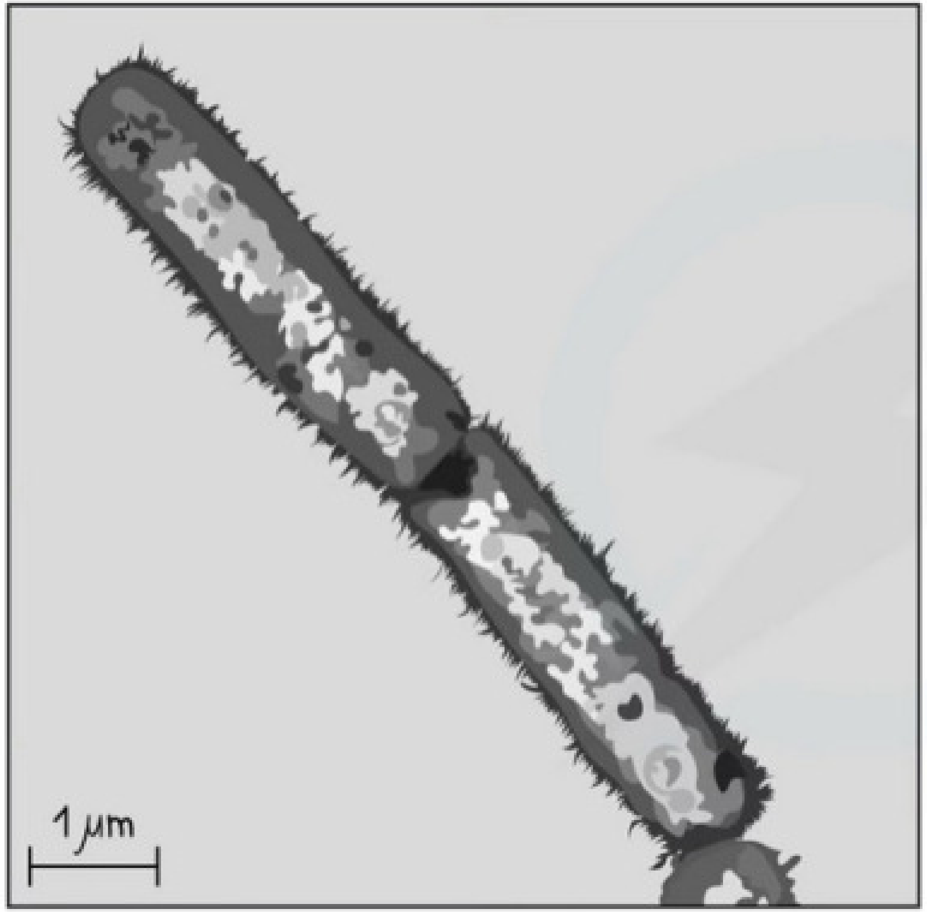
- At a zoom level of 90% on powerpoint I get the following real and measured reading:

$$scale\ bar_{real} = 1\mu m$$

$$scale\ bar_{measured} = 1.1cm = 11000\mu m$$

$$cell\ length_{real} = x\ \mu m$$

$$cell\ length_{measured} = 8.7cm = 87000\mu m$$

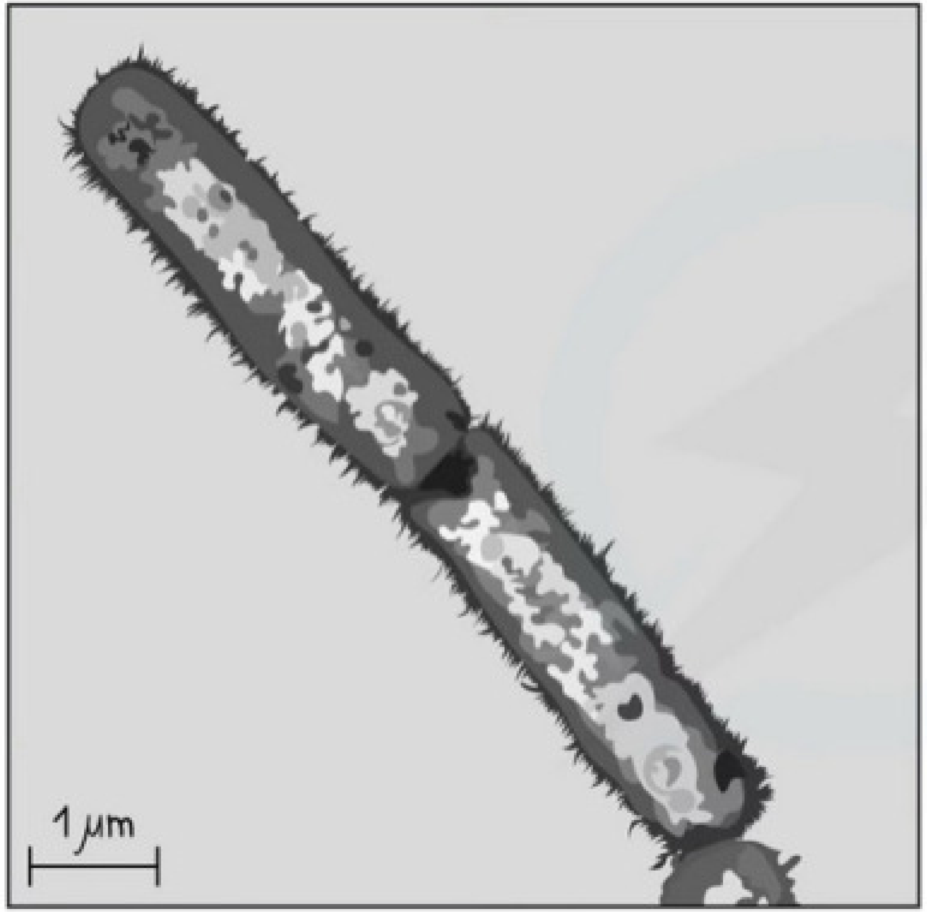


Measuring from electron micrographs

- Therefore

$$\frac{1\mu m}{11000\mu m} = \frac{x\ \mu m}{87\mu m}$$

Hence x = 7.9µm



Measuring from electron micrographs

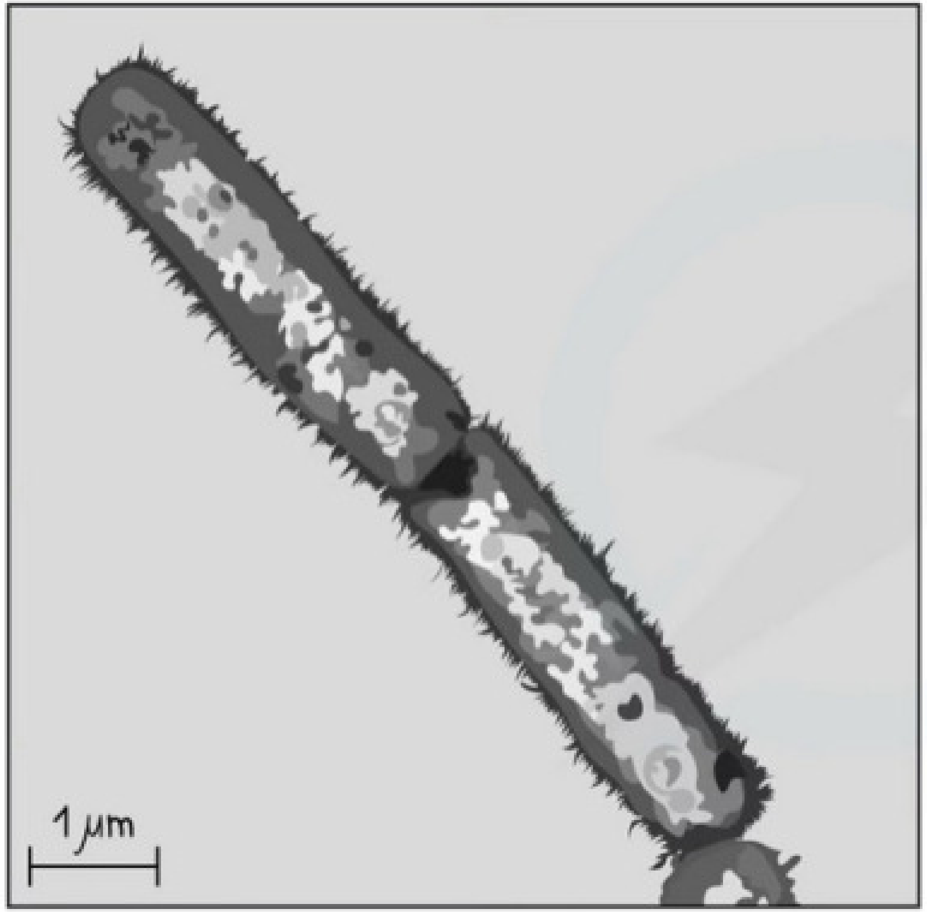
- At a zoom level of 120% on powerpoint I get the following real and measured reading:

$$scale\ bar_{real} = 1\mu m$$

$$scale\ bar_{measured} = 1.4cm = 14000\mu m$$

$$cell\ length_{real} = x\ \mu m$$

$$cell\ length_{measured} = 10.9cm = 109000\mu m$$



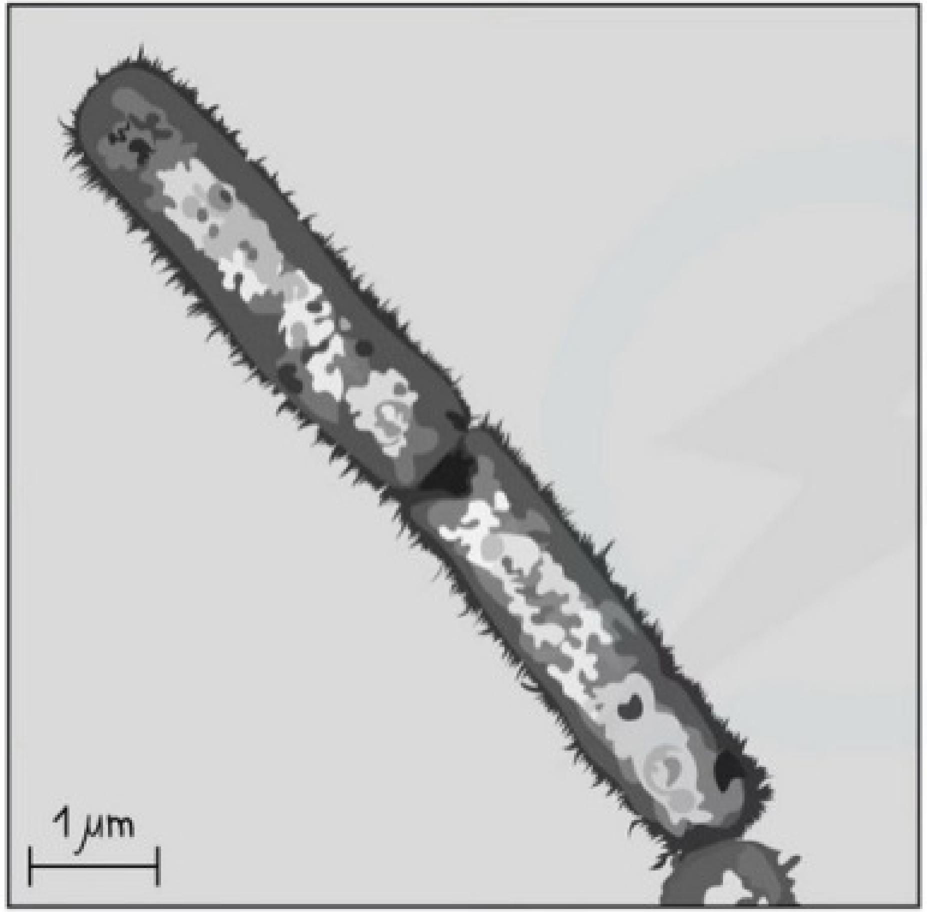
Measuring from electron micrographs

- Therefore

$$\frac{1\mu m}{14000\mu m} = \frac{x\ \mu m}{109000\mu m}$$

Hence x = 7.8μm

The reason for the difference in values is simply due to measurement error. It is not easy to measure things off a computer screen.

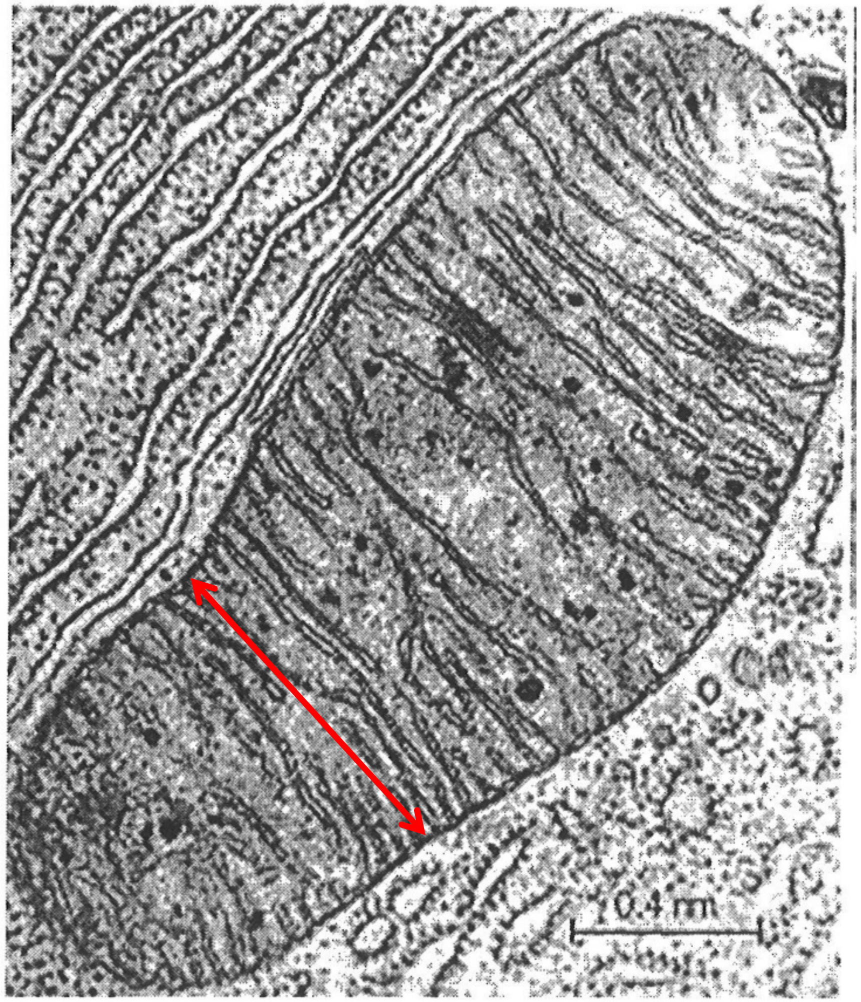


Measuring from electron micrographs

The scale bar shown is 4nm (nanometres)

Again we want to find "cell length_{real}" in the formula

$$\frac{\text{scale bar}_{real}}{\text{scale bar}_{measured}} = \frac{\text{cell length}_{real}}{\text{cell length}_{measured}}$$



Measuring from electron micrographs

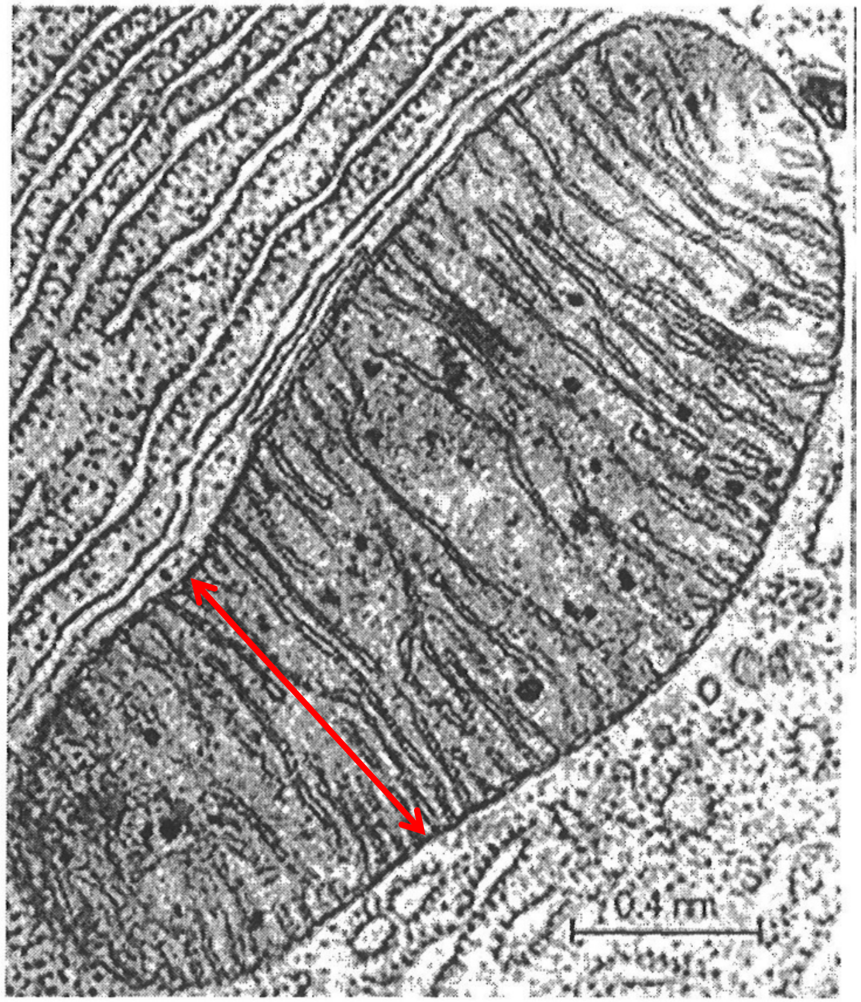
At a 90% zoom level on powerpoint I get the following readings off the image:

$$scale\ bar_{real} = 0.4\ nm$$

$$scale\ bar_{measured} = 1.7cm = 1.7 \times 10^7 nm$$

$$cell\ length_{real} = x\ nm$$

$$cell\ length_{measured} = 3.8cm = 3.8 \times 10^7 nm$$

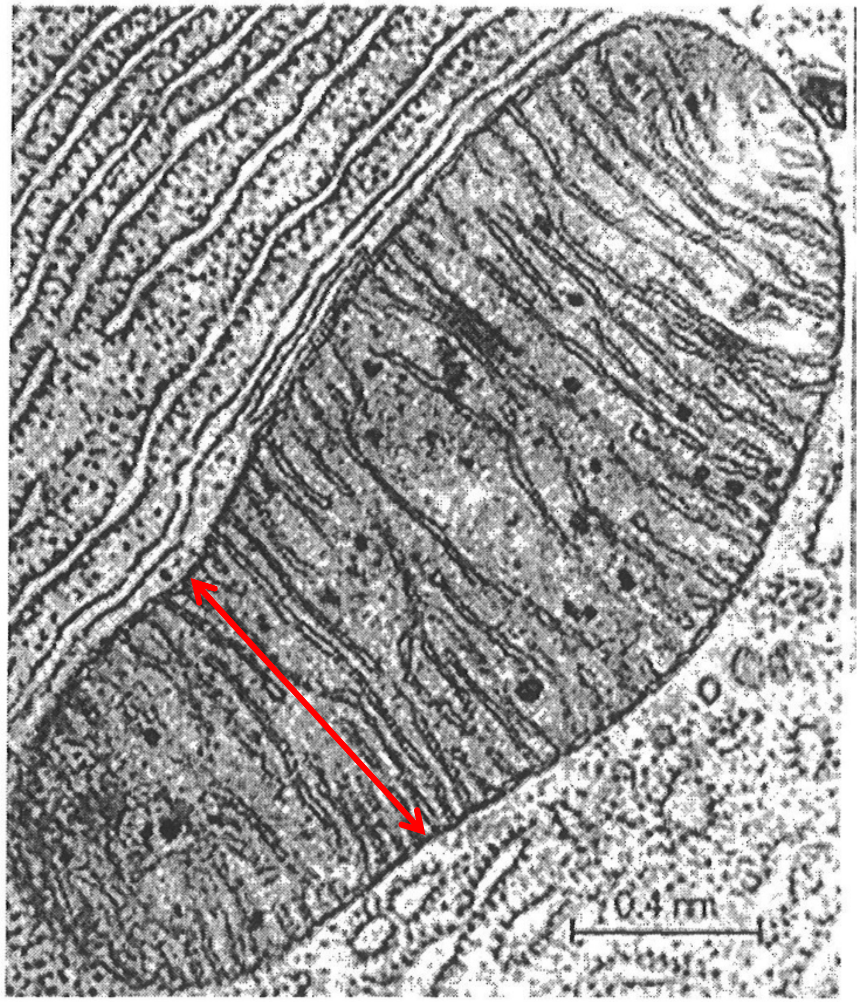


Measuring from electron micrographs

Hence

$$\frac{0.4nm}{1.7\times10^{7}nm} = \frac{x\ \text{nm}}{3.8\times10^{7}nm}$$

So x = 0.9 nm.

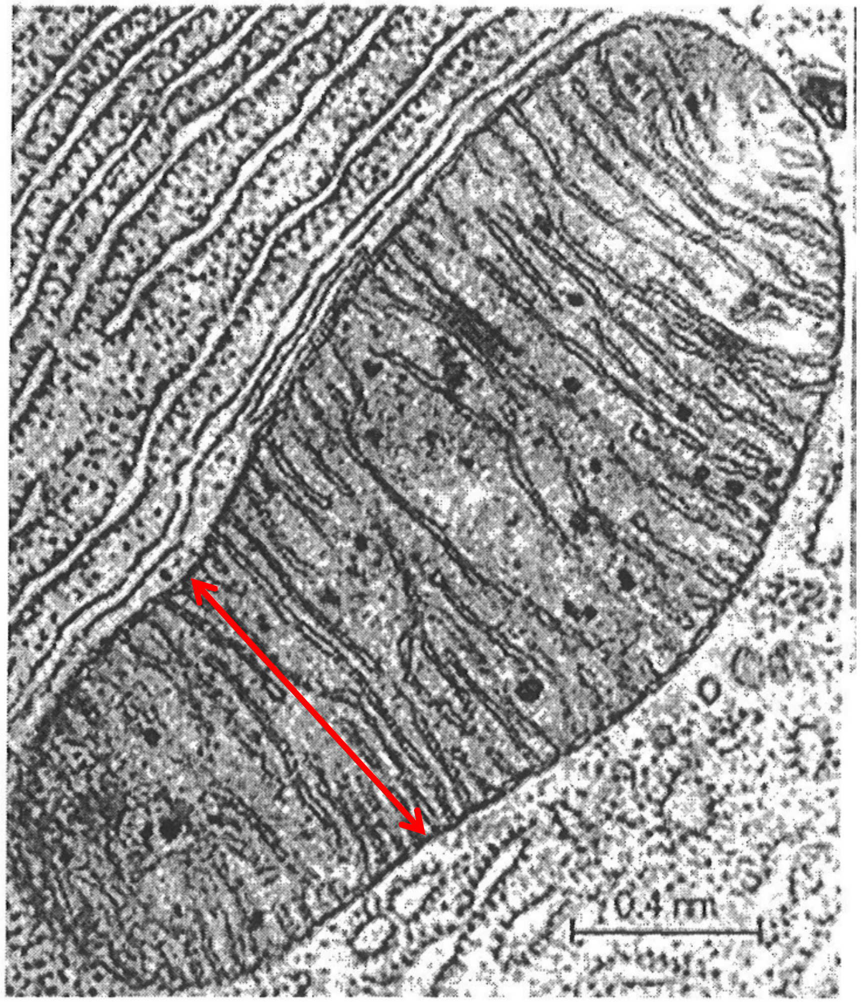


Measuring from electron micrographs

At a 120% zoom level on powerpoint I get the following answer:

So x = 0.7 nm.

This is a noticeable difference compared to the previous answer. This might be due to the way powerpoint scales-up (and not just to measurement error).



Measuring from electron micrographs

The scale bar shown is 1 μm.

What is the real length of the red arrowed line?

We want to find "cell length$_{real}$" in the formula:

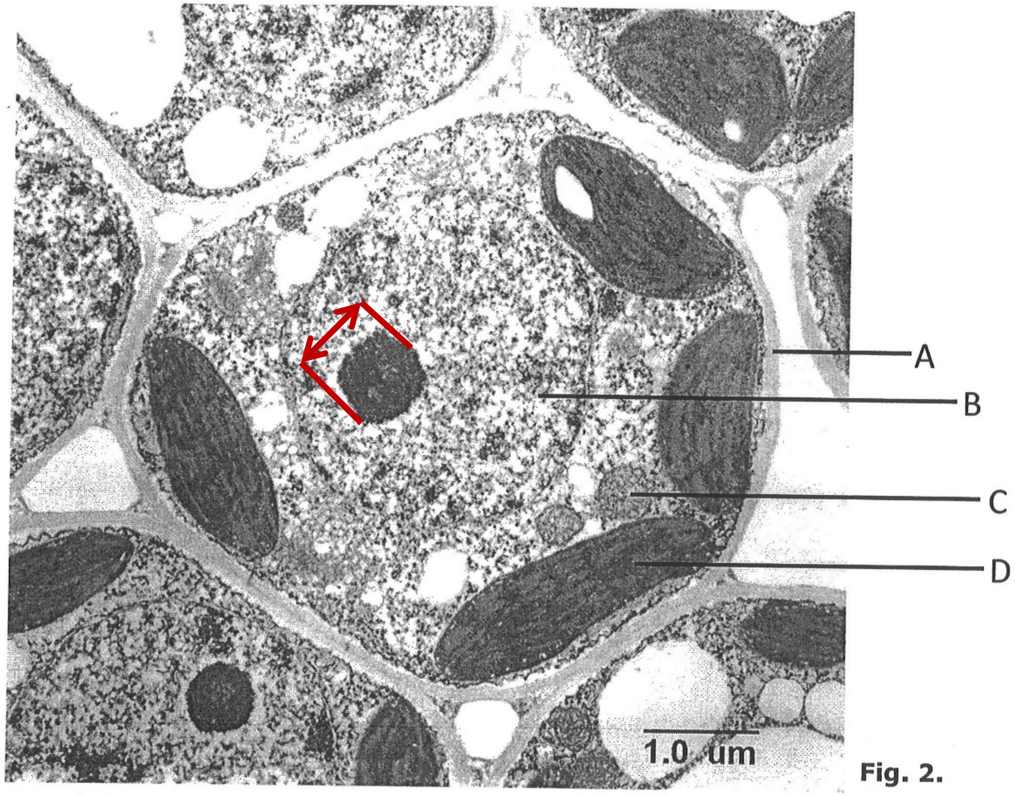


Fig. 2.

$$\frac{scale\ bar_{real}}{scale\ bar_{measured}} = \frac{cell\ length_{real}}{cell\ length_{measured}}$$

Measuring from electron micrographs

I printed this out on A4 paper. Then, my own recorded lengths were

$$scale\ bar_{real} = 1\mu m$$

$$scale\ bar_{measured} = 2cm = 20000\mu m$$

$$cell\ length_{real} = x\ \mu m$$

$$cell\ length_{measured} = 1.4cm = 14000\mu m$$

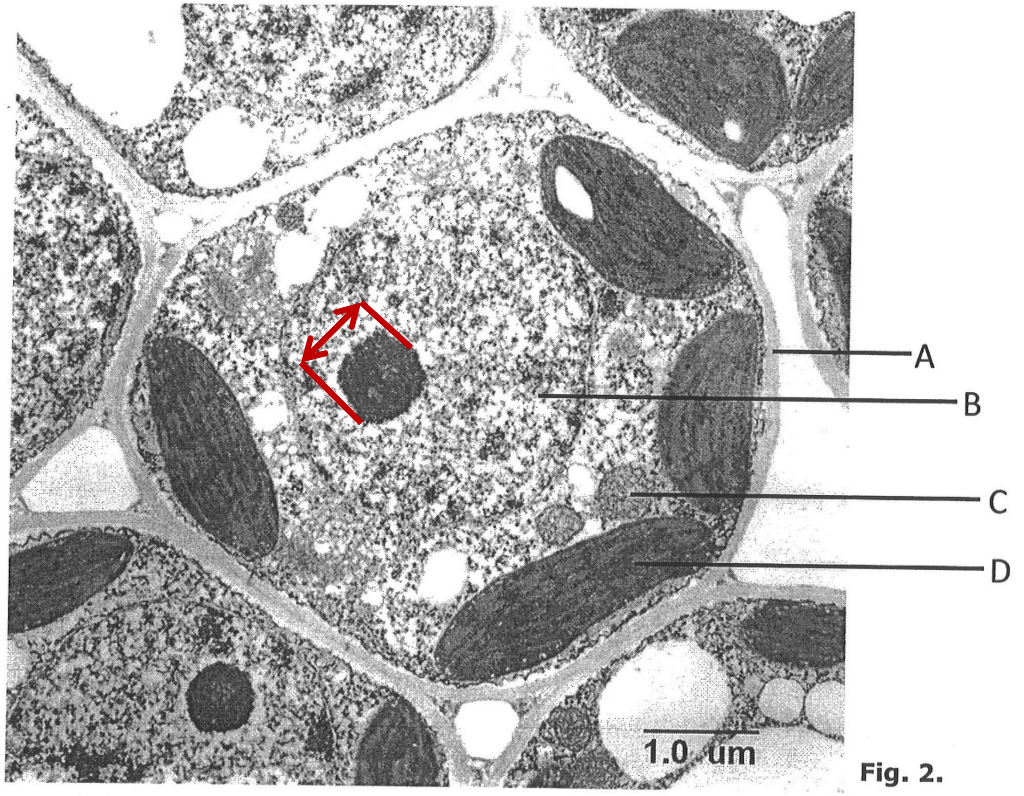


Fig. 2.

Therefore

$$\frac{1\mu m}{20000\mu m} = \frac{x\ \mu m}{14000\mu m}$$

Hence x = 0.7 mm

Measuring from electron micrographs

The scale bar shown is 0.2 μm (black line top right of photo).

What is the real length of the red arrowed line?

By what we have done before I get

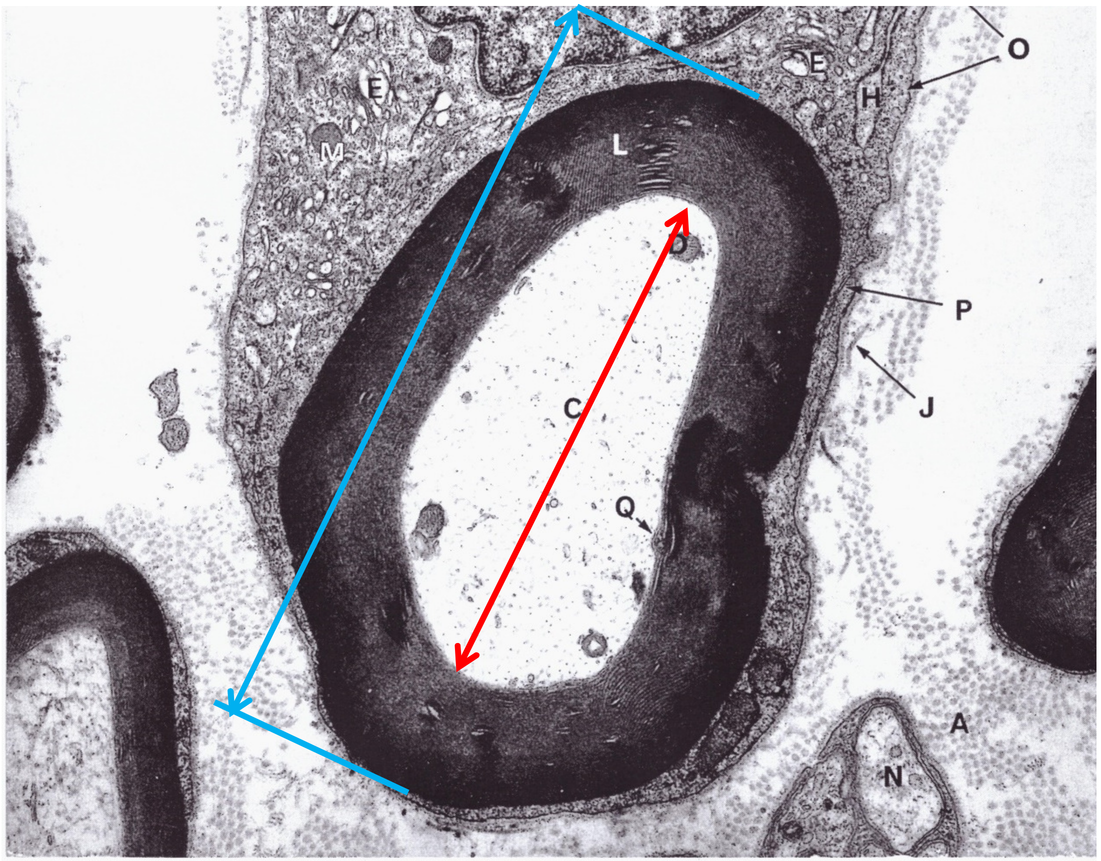
$$x = 118000 \times \frac{0.2}{15000} = 1.57\mu m$$

Measuring from electron micrographs

Consider the following micrograph of rat nerve cells of magnification x21000.

What is the real length shown in red?

What is the real length shown in blue?



Measuring from electron micrographs

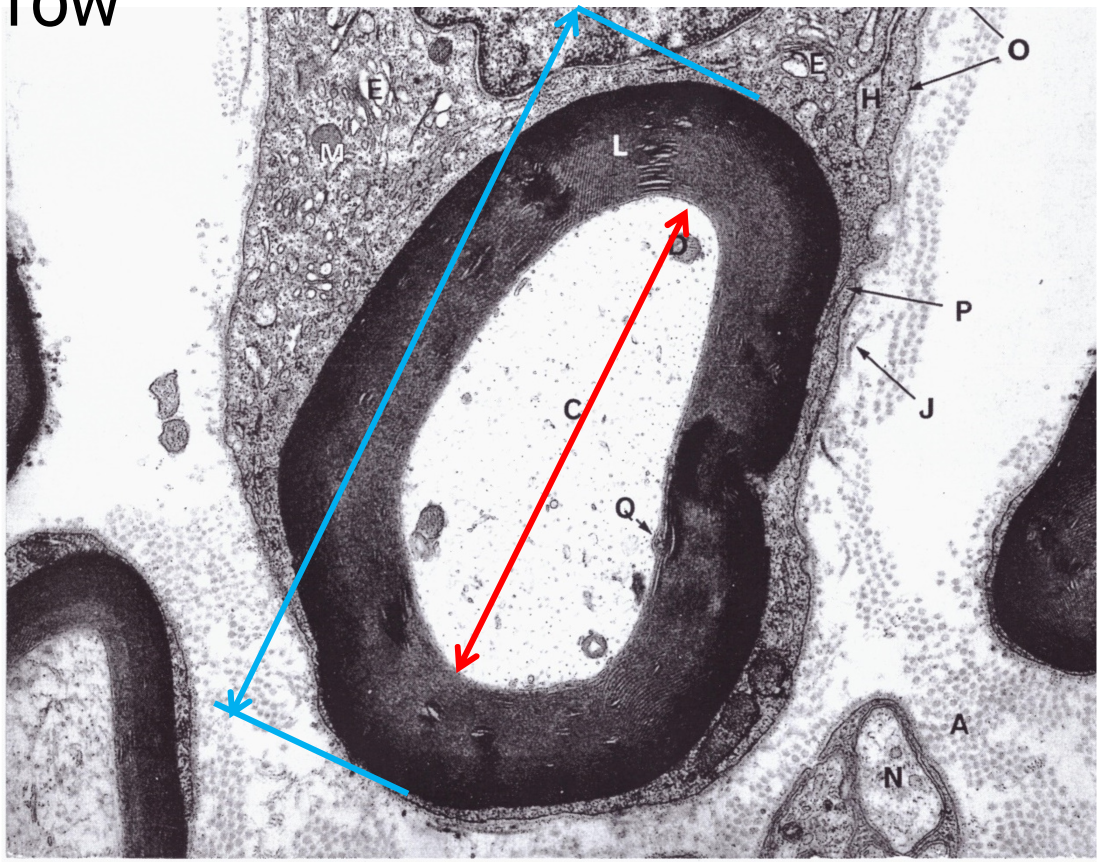
1) Measure it on the image (at powerpoint zoom of 79%): I get 6.1cm = 0.061m for the blue arrow and 3.9cm = 0.039m for the red arrow

2) These are 21000X larger than normal.

3) So real size is 0.061÷21000m = 2.9 μm

and

0.039÷21000m = 1.86 μm



Measuring from electron micrographs

Important note

- The magnification of 21000 for the image on the previous slide applies only to the size of the image you see on the screen. This size relates to a "zoom to fit" scale on powerpoint.
- Given the size of my screen the zoom-to-fit is 79%. A zoom-to-fit on your PC or table will have a different percentage.
- So, if you zoom out or zoom in from zoom-to-fit, your measurements will change, as well as the magnification. So the magnification of 21000 will no longer apply.

Measuring from electron micrographs

Important note

- So, if you get a micrograph image on A4 paper and it says that the magnification is n%, this magnification only applies to the size of the image on the A4 paper, not to the size of the image if it were printed on A3 or A5.