Introduction to Maths skills for A level Biology

Numbers and units

Working with numbers and units

Table 1 Divisions of some units of measurement

Division	Prefix	Length		Mass		Volume		Time	
one thousand millionth	nano	nanometre	nm	nanogram	ng	nanolitre	nl	nanosecond	ns
one millionth	micro	micrometre	μm	microgram	μg	microlitre	μl	microsecond	μs
one thousandth	milli	millimetre	mm	milligram	mg	millilitre	ml	millisecond	ms
one hundredth	centi	centimetre	cm						
whole unit		metre	m	gram	g	litre	dm^3	second	s
one thousand times	kilo	kilometre	km	kilogram	kg				

A key criterion for success in biological maths lies in the use of correct units and the management of numbers. The units we use are from the Système Internationale – the SI units. In biology, we most commonly use the SI base units metre (m), kilogram (kg), second (s) and mole (mol). Biologists also use SI derived units, such as square metre (m^2), cubic metre (m^3), degree Celsius (°C) and litre (dm^3). To accommodate the huge range of dimensions in our measurements they may be further modified using appropriate prefixes. For example, one thousandth of a second is a millisecond (ms). Some of these prefixes are illustrated in Table 1.

When doing calculations, it's also important to express your answer using sensible numbers. For example, Mike worked out an answer of 6230 μm. It would have been more meaningful for Mike to express that answer as 6.2 mm. If you convert between units and round numbers properly it allows quoted measurements to be understood within the relevant scale of the observations.

WORKED EXAMPLE

To convert between units on the nano-, micro-, milli- and kilo- scale divide or multiply by 1000.

If you divide (to make the number more sensible by making it smaller), then you look **down** Table 1 for the next unit (e.g. going from μm to mm).

If you multiply (making a number bigger to make it more sensible) then look **up** Table 1 to the next unit (e.g. going from m to mm).

An exception is converting to centimetres. A centimetre is one hundredth rather than one thousandth of a metre.

For example:

a) to convert 0.006 dm^3 into millilitres, you multiply by 1000 to give 6 ml

b) to convert 6000 μg into milligrams, you divide by 1000 to give 6 mg

c) to convert 6000 m into km, you divide by 1000 to give 6 km.

Take care when using cubed units. A metre cubed means a cube with each side length 1 m or 1000 mm. The cube of 1000 is $1000 \times 1000 \times 1000 = 1\,000\,000\,000$. So $1\ m^3 = 1\,000\,000\,000\ mm^3$. Therefore, to convert between volumes expressed as cubed distances, your conversion factor is 1 000 000 000, rather than just 1000.

This means that:

a) 5 000 000 mm^3 is equivalent to 0.005 m^3

b) 6 420 000 mm^3 is equivalent to 0.00642 m^3

c) 0.000 056 m^3 is equivalent to 56 000 mm^3

Similarly, when converting between squared units, we need to do the same thing. For example, imagine converting from m^2 to mm^2. One square metre is $1000 \times 1000 = 1\,000\,000\ mm^2$. Therefore, to convert between areas, your conversion factor is 1 000 000, rather than just 1000.

WORKED EXAMPLE

Rounding

The rules for rounding are simple. Look at the figure to the right of the least significant figure you want to round to. If this figure is 5 or greater, round up. If this figure is less than 5, round down. For example:

a) 3.142 rounds to 3.14 (3 s.f.), rounds to 3.1 (2 s.f.) and rounds to 3 (1 s.f.).

b) 5.448 rounds to 5.45 (3 s.f.), rounds to 5.4 (2 s.f.) and rounds to 5 (1 s.f.).

> **REMEMBER:**
> **Significant figures**
> The first significant figure in a number is the first digit that is not zero. In 2.34 it is 2 and there are three significant figures; in 0.0056 it is 5 and there are two significant figures.

SUMMARY QUESTIONS

1 Undertake the following conversions:
- **a** 0.0062 mm into µm
- **b** 7928 ml into dm^3
- **c** 213 ml into dm^3
- **d** 4 000 000 ns into s
- **e** 727 m into km
- **f** 0.002 km into mm.

2 Undertake the following conversions:
- **a** 1 000 000 000 mm^3 into m^3
- **b** 0.000 001 km^3 into m^3
- **c** 0.000 001 m^3 into mm^3.

3 Convert the following values so they make more sense to the reader. Choose the final units yourself. (Hint: make the final number as close in magnitude to zero as you can. For example, you would convert 1000 m into 1 km.)
- **a** 0.000 000 000 1 kg
- **b** 1 000 000 000 mg
- **c** 0.000 000 3 dm^3
- **d** 77 890 122 nm

4 Convert the following:
- **a** 1000 mm^2 into m^2
- **b** 0.6 m^2 into mm^2.

5 Round the following numbers:
- **a** 98.4478 to three significant figures
- **b** 1 298.444 444 4 to four significant figures
- **c** 5.555 55 to four significant figures
- **d** 0.358 to one significant figure
- **e** 0.000 464 8 to two significant figures.

> **REMEMBER:**
> **Write down the units!**
> When you do a calculation, it is very easy to forget to give the units. A number on its own makes no sense, unless the reader knows what the units are!
> Also, remember to put units only in headings in tables, **not** next to every figure entered.

> **REMEMBER:**
> **Units**
> It is common to use cm^3 in place of ml in biology. These units are in fact the same measurement. Occasionally cc is used to mean ml or cm^3.

Decimals and standard form

Working with decimals and standard form

Sometimes biologists need to work with numbers that are very small, such as dimensions of organelles, or very large, such as populations of bacteria. In such cases the use of scientific notation or standard form is very useful, because it allows such numbers to be written easily.

WORKED EXAMPLE

Write down 63 900 000 000 as standard form.

Step 1 is to write down the smallest number between 1 and 10 that can be derived from the number to be converted. In this case it would be 6.39

Next write the number of times the decimal place will have to shift to expand this to the original number as powers of ten. On paper this can be done by hopping the decimal over each number like this:

6.3900000000

until the end of the number is reached.

In this example that requires 10 shifts, so the standard form should be written as 6.39×10^{10}.

For very small numbers the same rules apply, except that the decimal point has to hop backwards. For example 0.000 000 45 would be written as 4.5×10^{-7}.

So positive superscripts indicate the number of shifts forward and negative superscripts the number of shifts backwards.

REMEMBER: Standard form is expressing numbers in powers of ten.

SUMMARY QUESTIONS

1 Convert the following numbers to standard form.

- **a** 100
- **b** 1000
- **c** 10 000
- **d** 0.1
- **e** 0.01
- **f** 0.001
- **g** 21 000 000
- **h** 435 000 000 000 000
- **i** 0.000 000 003 9

2 Write the following as decimals.

- **a** 10^6
- **b** 4.7×10^9
- **c** 1.2×10^{12}
- **d** 7.96×10^{-4}
- **e** 0.83×10^{-2}
- **f** 4.1×10^{-12}
- **g** 3.9×10^{-9}

3 Convert the following units to metres and write them in standard form.

- **a** 1 mm
- **b** 1 nm
- **c** 1 μm
- **d** 1 cm
- **e** 27 mm
- **f** 5647 mm
- **g** 399 cm
- **h** 29 000 000 μm

Data in line graphs

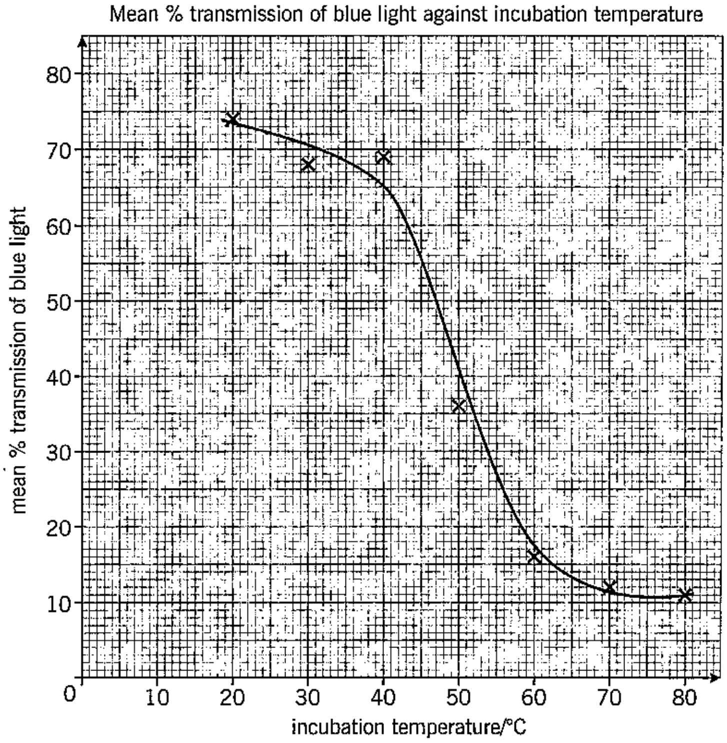
Presenting data in line graphs

The purpose of a line graph is to allow visualisation of a trend in a set of data. The graph can be used to make calculations, such as rates (see page 56) and also to judge the correlation between variables (see page 94). The certainty of the positions of the points can also be visualised by using confidence intervals (page 28). It is simple to draw such a graph but also quite easy to make simple mistakes.

WORKED EXAMPLE

Consider the set of colorimeter data below, collected from an experiment to investigate membrane damage and consequent pigment leakage from beetroot cells incubated at different temperatures.

Incubation temperature/°C	Mean % transmission of blue light by samples of beetroot pigment
20	74
30	68
40	69
50	36
60	16
70	12
80	11



The rules when plotting the graph are:

- Ensure that the graph occupies the majority of the space available (in exams this means more than half the space).
- Mark axes using a ruler and divide them clearly and equidistantly (i.e. 10, 20, 30, 40 not 10, 15, 20, 30, 45.
- Ensure that the dependent variable that you measured is on the y-axis and the independent variable that you varied is on the x-axis.
- Ensure that both axes have full titles and units clearly labelled, e.g. pH of solution, not just 'pH'.
- Plot the points accurately using sharp pencil x marks so the exact position of the point is obvious.
- Draw a neat best fit line, either a smooth curve or a ruled line. It does not have to pass through all the points. Alternatively use a point to point ruled line, which is often used in biology where observed patterns do not necessarily follow mathematically predictable trends!
- Confine your line to the range of the points. Never extrapolate the line beyond the range within which you measured. Extrapolation is conjecture!
- Distinguish separate plotted trend lines using a key.
- Add a clear concise title.
- Where data ranges fall a long way from zero, a broken axis will save space. For example, if the first value on the y-axis is 36, it may be sensible to start the axis from 34 rather than zero. This will avoid leaving large areas of your graph blank.

REMEMBER: Take care, use only pencil and check the positions of your points!

SUMMARY QUESTIONS

1 Plot suitable line graphs to illustrate the following sets of data. Use the graphs to answer the questions.

Turbidity of casein samples at different pH	
pH	**% transmission (blue light)**
9.00	99
8.00	99
6.00	87
5.00	67
4.75	26
4.50	30
4.00	24
3.75	43
3.50	64

Sucrose concentration /moles per litre	% change of mass of potato samples
0.9	−28.0
0.7	−16.7
0.5	−8.0
0.3	0.8
0.1	15.4
0.0	36.2

Sodium bicarbonate concentration /%	Rate of oxygen production by pondweed/$mm^3\ s^{-1}$
6.5	1.6
5.0	2.1
3.5	1.2
2.0	0.8
1.0	0.5
0.5	0.2

2 At the isoelectric point amino acids carry both positive and negative charge. Suggest the pH at which this occurs.

3 Estimate the sucrose concentration that is isotonic with the cell cytoplasm.

4 Suggest a possible optimum sodium bicarbonate concentration. How would you find this more precisely?