GCSE to A-Level Biology Transition

Lesson 10

Units / prefixes / powers / conversions / Decimals / standard form / sig figs

Learning Objectives

- To review some of the Mathematical requirements for GCSE Science.
- To recap key mathematical skills such as using units, prefixes, powers and indices.
- To be able to convert between different units of measurement as required in A-Level Biology.
- To confidently use standard form and significant figures.

Starter

- What is the definition of a metre? Research this online using the url below!

- https://www.npl.co.uk/si-units/metre

You've already done a lot of it!

9 Mathematical requirements

Students will be required to demonstrate the following mathematics skills in GCSE Combined Science assessments.

Questions will target maths skills at a level of demand appropriate to each subject. In Foundation Tier papers questions assessing maths requirements will not be lower than that expected at Key Stage 3 (as outlined in *Mathematics programmes of study: Key Stage 3* by the DfE, document reference DFE-00179-2013). In Higher Tier papers questions assessing maths requirements will not be lower than that of questions and tasks in assessments for the Foundation Tier in a GCSE Qualification in Mathematics.

1	Arithmetic and numerical computation
a	Recognise and use expressions in decimal form
b	Recognise and use expressions in standard form
c	Use ratios, fractions and percentages
d	Make estimates of the results of simple calculations

2	Handling data
a	Use an appropriate number of significant figures
b	Find arithmetic means
c	Construct and interpret frequency tables and diagrams, bar charts and histograms
d	Understand the principles of sampling as applied to scientific data (biology questions only)
e	Understand simple probability (biology questions only)
f	Understand the terms mean, mode and median
g	Use a scatter diagram to identify a correlation between two variables (biology and physics questions only)
h	Make order of magnitude calculations

Units & Prefixes

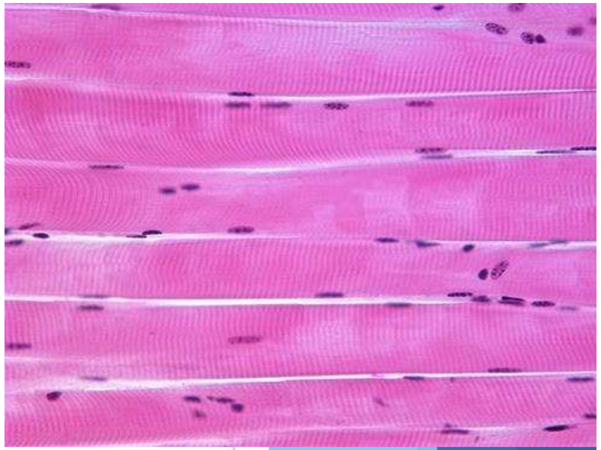
A key criterion for success in biological maths lies in the use of correct units and the management of numbers. The units scientists use are from the *Système Internationale* – the SI units. In biology, the most commonly used SI base units are metre (m), kilogram (kg), second (s), and mole (mol). Biologists also use SI derived units, such as square metre (m^2), cubic metre (m^3), degree Celsius (°C), and litre (l).

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 the table below.

Multiplication factor	Prefix	Symbol
10^9	giga	G
10^6	mega	M
10^3	kilo	k
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n

We will mainly work with these prefixes

Units & Prefixes – Worked Example



An average single skeletal muscle cell is about 3cm long (they are very large cells!).

What would 3cm be in micrometres (μ)?

1cm = 10,000**μm**

This is because we are going from a multiplication factor of 10^{-2} to a multiplication factor of 10^{-6} (as we need to multiply our original number by a factor of 4, which is 10,000).

3cm = 30,000μm

There is more on Powers & Indices on the next couple of slides

Powers & Indices

Ten squared = 10 × 10 = 100 and can be written as 10^2. This is also called 'ten to the power of 2'.

Ten cubed is 'ten to the power of three' and can be written as $10^3 = 1000$.

The power is also called the index.

Fractions have negative indices:

one tenth = $10^{-1} = 1/10 = 0.1$
one hundredth = $10^{-2} = 1/100 = 0.01$
Any number to the power of 0 is equal to 1, for example, $29^0 = 1$.

If the index is 1, the value is unchanged, for example, $17^1 = 17$.

When multiplying powers of ten, you must *add* the indices.

So 100 × 1000 = 100 000 is the same as $10^2 \times 10^3 = 10^{2+3} = 10^5$

Powers & Indices

When dividing powers of ten, you must *subtract* the indices.

So 100/1000 = 1/10 = 10^{-1} is the same as $10^2/10^3 = 10^{2-3} = 10^{-1}$

But you can only do this when the numbers with the indices are the same.

So $10^2 \times 2^3 = 100 \times 8 = 800$

And you can't do this when adding or subtracting.

$10^2 + 10^3 = 100 + 1000 = 1100$

$10^2 - 10^3 = 100 - 1000 = -900$

Remember: You can only add and subtract the indices when you are multiplying or dividing the numbers, not adding or subtracting them.

Powers & Indices – Worked Examples

Example 1:

- $10^8 \times 10^3 = 10^{11}$

Example 2:

- $10^7 \times 10^2 \times 10^3 = 10^{12}$

Example 3:

- $10^3 + 10^3 = 1000 + 1000 = 2000$

Example 4:

- $10^2 - 10^{-2} = 100 - 0.01 = 99.99$

Converting between units

When doing calculations, it is important to express your answer using sensible numbers. For example, an answer of 6230 μm would have been more meaningful expressed as 6.2 mm.

If you convert between units and round numbers properly, it allows quoted measurements to be understood within the scale of the observations.

To convert 488 889 m into km:

A kilo is 10^3 so you need to divide by this number, or move the decimal point three places to the left.

$488\,889 \div 10^3 = 488.889$ km

However, suppose you are converting from mm to km: you need to go from 10^3 to 10^{-3}, or move the decimal point six places to the left.

333 mm is 0.000 333 km

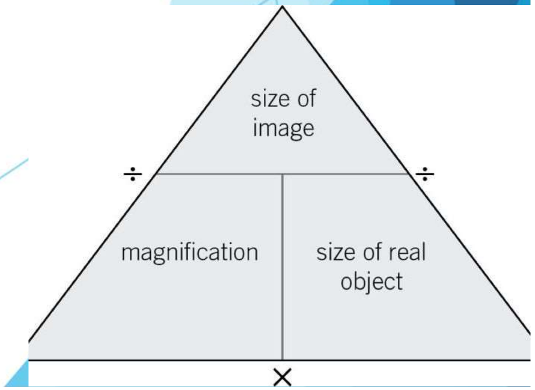
Alternatively, if you want to convert from 333 mm to nm, you would have to go from 10^{-9} to 10^{-3}, or move the decimal point six places to the right.

333 mm is 333 000 000 nm

Converting between units

- Whenever you get a calculation question in A-Level Biology, it is ALWAYS best to convert between units as soon as possible.

- E.g. magnification involves dividing the Size of the Image by the Size of the real object.
- If you were asked to calculate magnification, it would be easier to perform the calculation with both numbers being in the same units.



Converting between Units – Worked Examples

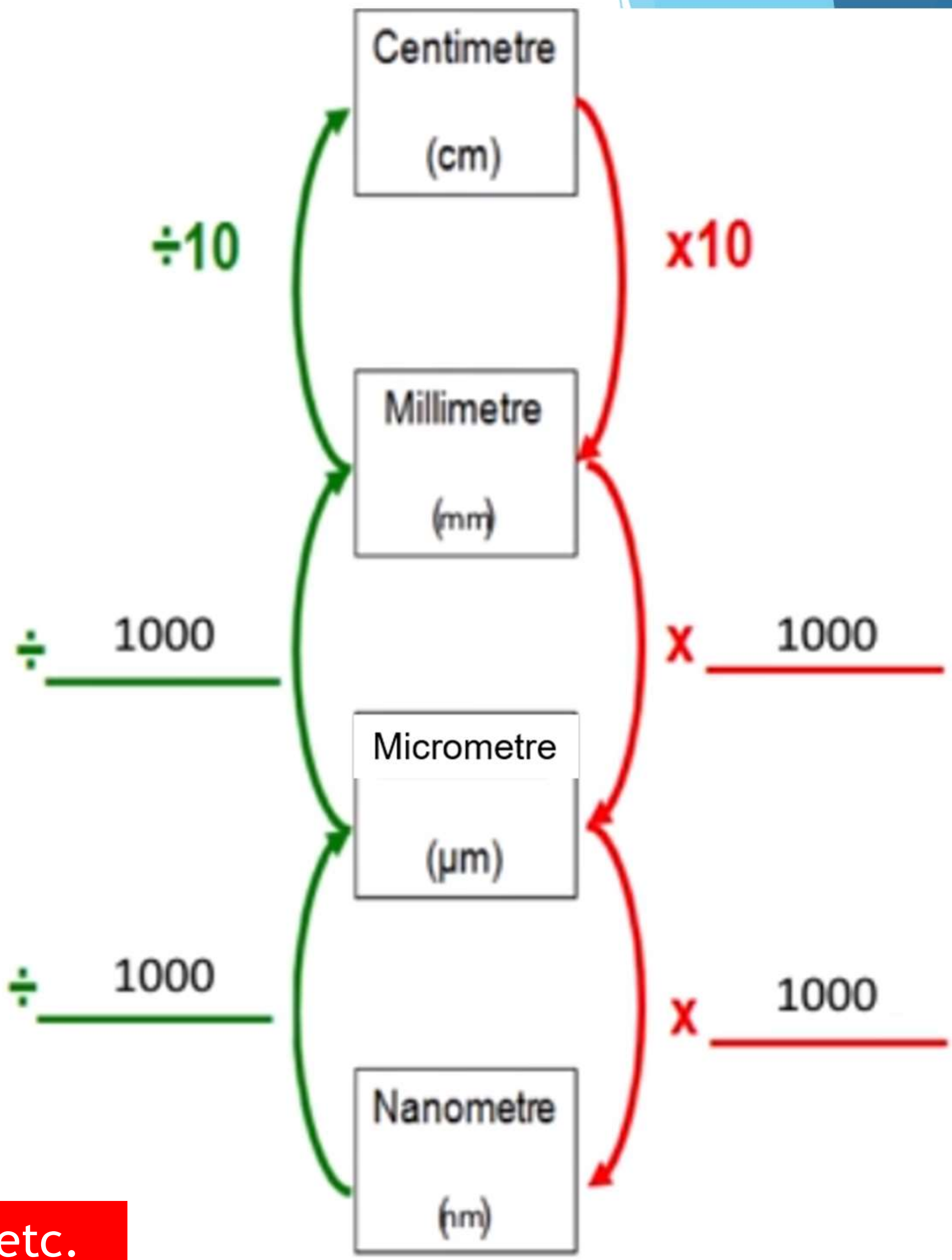
To convert 2.5cm into nanometres:

- Multiply by 10 -> 25mm
- Then multiply by 1000 -> 25,000µm
- Then multiply by 1000 -> 25,000,000nm

To convert 8nm into centimetres:

- Divide by 1000 -> 0.008µm
- Then divide by 1000 -> 0.000008mm
- Then divide by 10 -> 0.0000008cm

This could be applied to grams, seconds etc.



Decimals

A decimal number has a decimal point. Each figure *before* the point is a whole number, and the figures *after* the point represent fractions.

The number of decimal places is the number of figures *after* the decimal point. For example, the number 47.38 has 2 decimal places, and 47.380 is the same number to 3 decimal places.

In science, you must write your answer to a sensible number of decimal places.

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 the numbers to be written easily.

Standard form is expressing numbers in powers of ten, for example, 1.5×10^{7} microorganisms.

Look at this worked example. The number of cells in the human body is approximately 37 200 000 000 000. To write this in standard form, follow these steps:

Step 1: 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 3.72

Step 2: 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:

until the end of the number is reached.

In this example that requires 13 shifts, so the standard form should be written as 3.72×10^{13}.

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}.

Standard Form – Worked Example

- To convert 0.000005m into standard form:
- **Step 1 - write down the smallest number between 1 and 10 that can be derived from this number -> 5**
- **Step 2 - write the number of times the decimal place will have to shift to expand this to the original number as powers of ten.**
- The decimal place must be moved 6 places to the right to get from 0.000005 to 5, therefore the answer would be:
- $0.000005\text{m} = 5 \times 10^{-6}$ m

Significant Figures

When you use a calculator to work out a numerical answer, you know that this often results in a large number of decimal places and, in most cases, the final few digits are 'not significant'. It is important to record your data and your answers to calculations to a reasonable number of significant figures. Too many and your answer is claiming an accuracy that it does not have, too few and you are not showing the precision and care required in scientific analysis.

Numbers to 3 significant figures (3 s.f.):

7.88 25.4 741

Bigger and smaller numbers with 3 significant figures:

0.000 147 0.0147 0.245 39 400 96 200 000 (notice that the zeros before the figures and after the figures are *not* significant – they just show you how large the number is by the position of the decimal point).

Numbers to 3 significant figures where the zeros *are* significant:

207 4050 1.01 (any zeros between the other significant figures *are* significant).

Standard form numbers with 3 significant figures:

9.42×10^{-5} 1.56×10^{8}

If the value you wanted to write to 3.s.f. was 590, then to show the zero was significant you would have to write:

590 (to 3.s.f.) or 5.90×10^{2}

Remember: For calculations, use the same number of figures as the data in the question with the lowest number of significant figures. It is not possible for the answer to be more accurate than the data in the question.

Significant Figures – Worked Example

To write 8755g to 2 s.f. ->

- 8700g

To write 8755g to 3 s.f. ->

- 8750g

Complete the worksheet THEN self-mark