Developing independent thinking

Whilst there are many individual skills to be developed it is very important to remember they are not isolated parts. All are linked to how we investigate things scientifically, so this is a good place to start.

We have already touched on what it means to be a scientist in the introduction. It is important to explain this a little more here.

Scientists work by creating models which are ideas about how and why things might happen. To form useful models they need imagination, ingenuity and a good deal of background knowledge. Almost all scientists work in groups, both together in one laboratory and with other groups worldwide. From these models they make predictions and only then do they design investigations to test these predictions. As the number of investigations which confirm these predictions increases then the model explanation becomes more widely accepted in the scientific community. However it only takes one well-designed investigation that contradicts expectations to destroy the idea.

Notice scientists are very careful not to claim they have 'proved' something and are very cautious in their language. They are very unlikely to refer to anything as a 'fact'.

Here is how Watson and Crick reported one of the most important discoveries of the 20th century: 'For the moment the general scheme we have proposed for the reproduction of deoxyribonucleic acid must be regarded as speculative. Even if it is correct then much remains to be discovered. Despite these uncertainties we feel that our proposed structure may help to solve one of the fundamental biological problems.'

Scientists are human. It is not uncommon for different groups to have conflicting ideas and to argue strongly. It then takes time for evidence to accumulate in support of one or the other.

So how does this affect you? Obviously you are unlikely to be involved in research at this level and be much more interested in achieving a good grade in your examinations. The answer is quite simple. You do need to begin to think like a scientist and to question things more carefully, even when carrying out simple core practicals. Your ability to do this will be tested in examination papers.

Question 1 – How do we know that? Thinking more scientifically.

(a) Read the article entitled 'How to read the health news' to be found at http://www.nhs.uk/news/Pages/Howtoreadarticlesabouthealthandhealthcare.aspx

(b) On the same web page you will find an archive with reviews of many claims made discoveries relating to health issues. Almost every week, newspapers report on new findings; often with remarkable claims. Take any one that you find and research the science behind it. What did the actual research really show? Does it match the claims in the newspaper?

If you cannot find your own question try the following:

(i) There are many scientific papers showing garlic has antibacterial properties but does this mean that this is a useful way of solving the problem of bacterial resistance to antibiotic?

(ii) If you wish the same question can be asked about 'Manuka' honey.

Biology practical skills: scientific methods and practices

This section of the Guide will consider a number of key skills and practices that you develop and use as you progress through your A level.

Designing investigations

Some of the core practicals offer you the opportunity to go beyond simply learning a technique by applying your knowledge to the design of an investigation. You will have met many of the requirements at GCSE level but during the two years of your A level course you will be expected to have a much more accurate understanding of the details. You might start as follows.

- Exactly what is to be measured? Is this the correct dependent variable, does it match the hypothesis and how can it be measured as accurately as possible?
- Can a single independent variable be measured or controlled accurately?
- Is it possible to control all other variables? If not, which ones are the most important to control and can we monitor others?
- How much data will be needed to come to some meaningful conclusions?

Now try the following.

Question 2 – Thinking about experimental design

A student decides to investigate the effect of light and shade on the size of leaves of one species of plant. Their initial plan is to measure the length of leaves on two sides of a single bush, one side which they can see is shaded and the other which is in full sunlight.

(a) The dependent variable chosen is length of leaf.

(i) Name three other possible leaf measurements which might provide information on size.

(ii) Which of these measurements would you select to provide the most useful scientific data? Give reasons for your answer.

(b) Name three other variables which need to be controlled when collecting these data.

(c) The student chose a bush with a shaded side and a sunlit side. Give three reasons why simply selecting differences in light intensity by observation might not give reliable information on 'light' and 'shade'.

Presenting data

Tables

Remember, the basic rules are really important.

- You must include all of your raw data even though you manipulate it in some way later.
- Think about designing your table to make any trends and patterns clear and show any data you might use to draw graphs.
- Include correct S.I. units.
- Use a consistent number of significant figures. Remember figures such as 2 and 2.0 are not the same.
- The number of significant figures must be justified by the method of measurement. Calculating averages or means does not increase the number of significant figures that can be supported. e.g. measuring with a 30 cm ruler allows a maximum accuracy of about 0.5 mm. Simply calculating an average of a set of measurements does not increase this to 0.05 mm or more.

Graphs

You will be expected to understand the use of different forms of graphs and be able to select the most appropriate, scientifically valid format. This means your choice must match your data but, above all, it must be directly linked to your hypothesis. You are drawing a graph to help analyse your data and illustrate important trends.

The main rules and uses of graphs do not change when you study biology, physics or chemistry but the type of graph you choose and the information we can get from it may be very different.

Bar graph	The simplest form of graph with separate columns but can only be used when the data is categorical. This means completely separate sets of counts e.g. counts of blood groups or flower colour.
Histogram	This is a special form of bar graph where the columns are touching each other. The horizontal axis is normally continuous and the columns represent sets of readings covering a small range.
Scattergram	This is simply a set of points on a pair of axes and is normally used to show a pattern of correlation between the two variables. Note this does not include a line.
Line of 'best fit'	This needs to be treated carefully. Where a scattergram shows a possible straight line relationship it might be relevant, but simply wobbling your ruler around until you think you might have the best place to draw a line is scientifically very dubious. You are simply guessing and it is unlikely that some other person with the same data will draw exactly the same line.
Line graph	In biology we often collect data where the values might rise and fall or show big variations. Drawing guesswork curves or links is not at all objective. In these cases, biologists sometimes simply join the points with straight lines. This might give some indication of important trends but it is normally a sign that we are not making any assumptions about them.

It is expected that all students will be aware of the basic rules of graph drawing.

- Axes are clearly labelled with units. The title and units are separated by a solidus (/).
- The scale is chosen to ensure the graph covers at least half of the paper and the *y*-axis intercept where appropriate.
- The axis shows the full scale with any breaks clearly indicated.
- The independent variable is on the *x*-axis and the dependent variable is on the *y*-axis.

Question 3 – Spot the errors

The graph shown below was drawn by a student from data obtained from an investigation to compare the distribution of a black lichen on rocks in two different shores, one exposed to the waves and another sheltered.
25 **random** samples were taken on each shore. The horizontal axis is random sample number and the vertical axis is % cover. The bars at the top of each column are meant to show the variability in the data.

(a) The graph obviously has no labels or units which is a major error but not the most important one.

(i) Give two reasons why this graph is scientifically meaningless.

(ii) Sketch the format of graph which could be used to illustrate the difference in distribution of the lichen on the two shores.