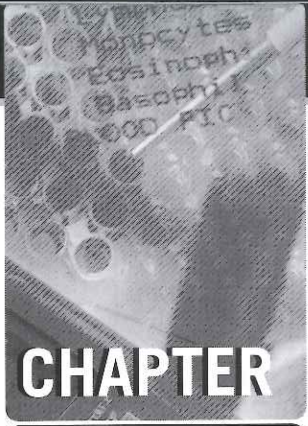

CHAPTER three

# Describing, explaining and evaluating

Once we have collected data, we will need to analyse them. In this chapter we will look at the three steps involved in analysing data.

- **Describing** trends and patterns.
- **Explaining** these trends and patterns in terms of biological knowledge.
- **Evaluating** and assessing the reliability of results and conclusions.

## Describing data

Red kangaroos are found in the hot, dry interior of Australia. They are very well adapted and have a number of ways in which they can stop their body temperature from increasing in these conditions. One of these is by sweating. Figure 3.1 on the next page shows the results of an investigation into sweaty kangaroos! More accurately, as the title tells us, it shows the effect of exercise on the rate of sweating.

What does this graph tell us? Let us start by looking for the basic pattern. Forget about all the small fluctuations, it is the main trends that we are interested in. You can see that during a period of exercise the rate of sweating increases. Once exercise stops, it falls again. We can link this overall pattern to particular figures. The resting level of sweat production is around $25\ cm^3\ m^{-2}\ h^{-1}$ and it rises to a peak value of about $200\ cm^3\ m^{-2}\ h^{-1}$. With this information we can produce a more detailed description of the way in which exercise affects the rate of sweating in red kangaroos:

> During a period of exercise, the rate of sweating increases from a value of $25\ cm^3\ m^{-2}\ h^{-1}$ to $200\ cm^3\ m^{-2}\ h^{-1}$. Once exercise stops, the rate of sweating falls to its resting value.

In the graph in Figure 3.1, the overall pattern is quite easy to see. In others, things are not quite so obvious. Look at Figure 3.2. This is a different sort of graph called a scatter diagram. It shows the different varieties of a common British snail, *Cepaea*

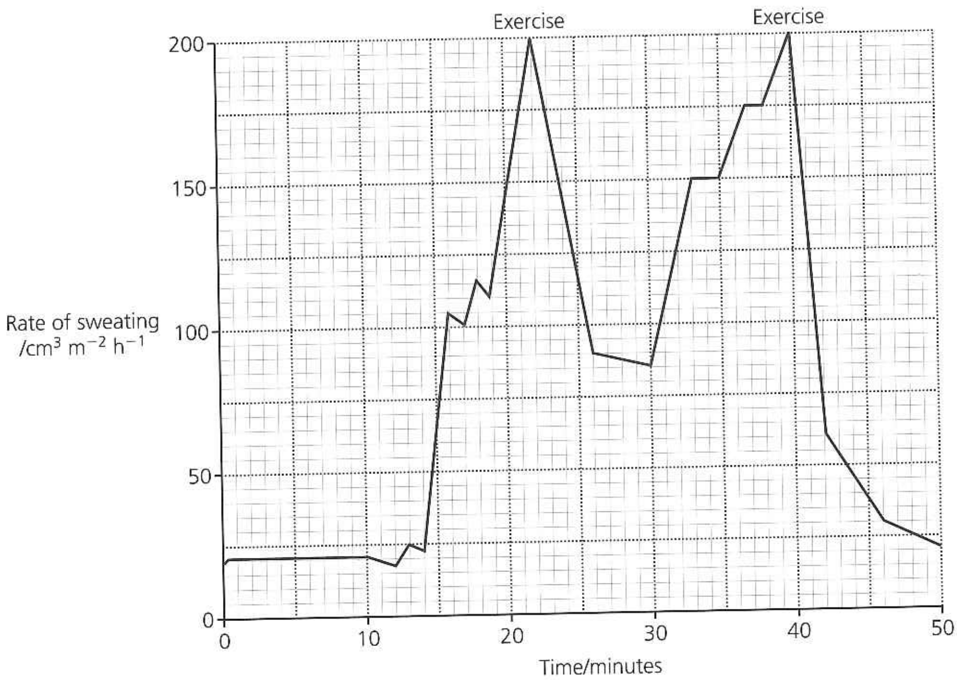


***Figure 3.1*** *The effect of exercise on the rate of sweating in a red kangaroo*

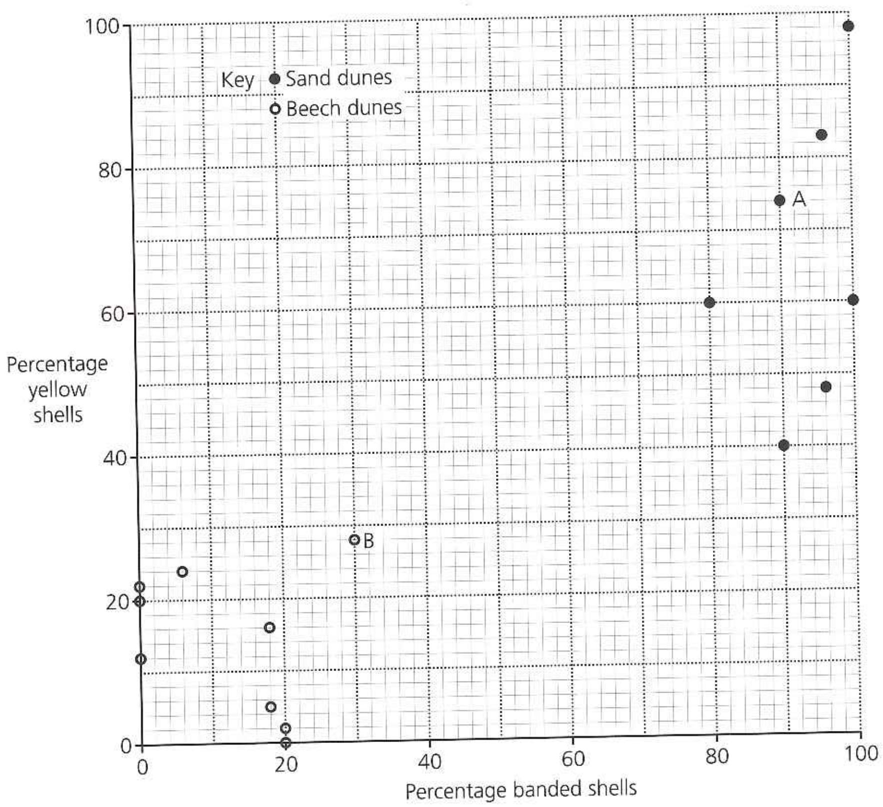


***Figure 3.2*** *The distribution of different varieties of the snail Cepaea nemoralis in sand dunes and beech woods*

*nemoralis*, found in different habitats. *Cepaea nemoralis* has a shell which can be yellow, pink or brown. Whatever the colour, the shell may have one or more black bands around it (banded shells) or it may not have any of these bands (unbanded shells).

Clearly, before we start to describe patterns, we must make sure that we understand what has been plotted. One helpful trick is to look at a specific point on the graph and try to explain exactly what it represents. Look at the point labelled A. It is a solid black spot so it represents a sample of snails collected in sand dunes. The *x*-axis shows us that in this sample 90 per cent of the snails had banded shells. The *y*-axis tells us that whether the shells were banded or not, 74 per cent of them were yellow in colour.

Q1 What percentage of shells in sample B were:

(a) yellow?
(b) pink or brown?
(c) banded?

Q2 Describe what the graph tells us about the snails in sample B.

This is quite a good technique and it can also be used when you are trying to make sense of information in a table. In this case you need to look at the figures in a particular row or column.

Box 7 summarizes the features you should bear in mind when describing information in a graph or a table.

## BOX 7 Describing data

- Start by making sure you understand the data concerned. Read the title carefully. If it is a graph, make sure that you understand the labels on the axes. If it is a table, make sure that you understand the headings of the rows and the columns. Then check your understanding by describing a particular point on the graph or column or row in the table.
- Concentrate on patterns and trends. Do not worry about minor fluctuations. With tables it is often helpful to sketch a quick graph. If a pattern exists, it will show up more clearly.
- Relate patterns and trends to values given in the table or the graph.

## Mean and standard deviation

We will now look at the raw data from which graphs are plotted. Soya beans are an important crop in parts of southern Africa. An investigation was carried out into the effect of altitude on crop yield. Sites were selected at different altitudes and, at each site, ten sample plots were planted with soya beans. These grew and were harvested. Table 3.1 shows some of the results of this investigation.

**Table 3.1 Yield of soya beans in plots at different altitudes in Zimbabwe**

| Site | Altitude/metres | Yield of soya beans in each plot/tonnes per hectare | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 1506 | 3.7 | 4.0 | 4.1 | 4.0 | 3.6 | 4.1 | 3.8 | 4.0 | 4.1 | 3.8 |
| B | 1338 | 4.4 | 4.4 | 4.5 | 4.3 | 4.1 | 4.5 | 4.4 | 4.4 | 4.1 | 4.3 |
| C | 1292 | 3.7 | 3.4 | 3.3 | 3.2 | 3.5 | 3.2 | 3.2 | 3.1 | 3.3 | 3.2 |
| D | 1157 | 3.3 | 3.0 | 2.8 | 3.1 | 3.0 | 3.0 | 3.0 | 3.0 | 2.7 | 2.8 |
| E | 992 | 3.0 | 3.0 | 3.1 | 2.8 | 2.9 | 2.9 | 2.9 | 2.9 | 3.0 | 2.7 |
| F | 881 | 2.0 | 2.1 | 2.3 | 2.3 | 2.4 | 1.6 | 2.2 | 2.0 | 1.9 | 2.0 |

It is difficult to see any obvious pattern when you look at this table. The information it contains needs simplifying in some way. A good starting point is to get some idea of the middle value of each set of plots. From a mathematical point of view, there are various ways in which this can be done. The most useful to a biologist is to calculate the **mean**. You can do this for site **A** by adding up all the individual figures for yield and then dividing the total by 10, the total number of plots at site **A**, or, if you have a calculator with a statistical mode, you can use that. The mean soya bean yield for site **A** is 3.9 tonnes per hectare. Now, look again at the results for this site. You will see that the yields of the different plots vary. They range from 3.6 to 4.1 tonnes per hectare. It would be useful to have a measure of how spread out the individual values are about the mean. We call this measure the **standard deviation (SD)**. It can be calculated from a formula but, if you have a suitable calculator, use this instead. It is much simpler and all you need to be able to do in an A-level Biology course. Table 3.2 shows the results from this same investigation but this time presented as the mean and standard deviation for each site.

We can plot the information in Table 3.2 as the graph shown in Figure 3.3. It shows the mean yield of soya beans plotted against the altitude. **Error bars** have been added for each value. Each error bar represents one standard deviation above and one standard deviation below the mean. So Figure 3.3 contains a lot of information. It not only shows us how the yield of soya beans varies with altitude but also shows us how much variation there is between the plots at each site.

**Table 3.2 Yield of soya beans in plots at different altitudes in Zimbabwe. Yields are given as mean and standard deviation**

| Site | Altitude/metres | Yield of soya beans in each plot/tonnes per hectare | |
|---|---|---|---|
| | | Mean | Standard deviation |
| A | 1506 | 3.9 | 0.2 |
| B | 1338 | 4.3 | 0.1 |
| C | 1292 | 3.3 | 0.2 |
| D | 1157 | 3.0 | 0.2 |
| E | 992 | 2.9 | 0.1 |
| F | 881 | 2.1 | 0.2 |

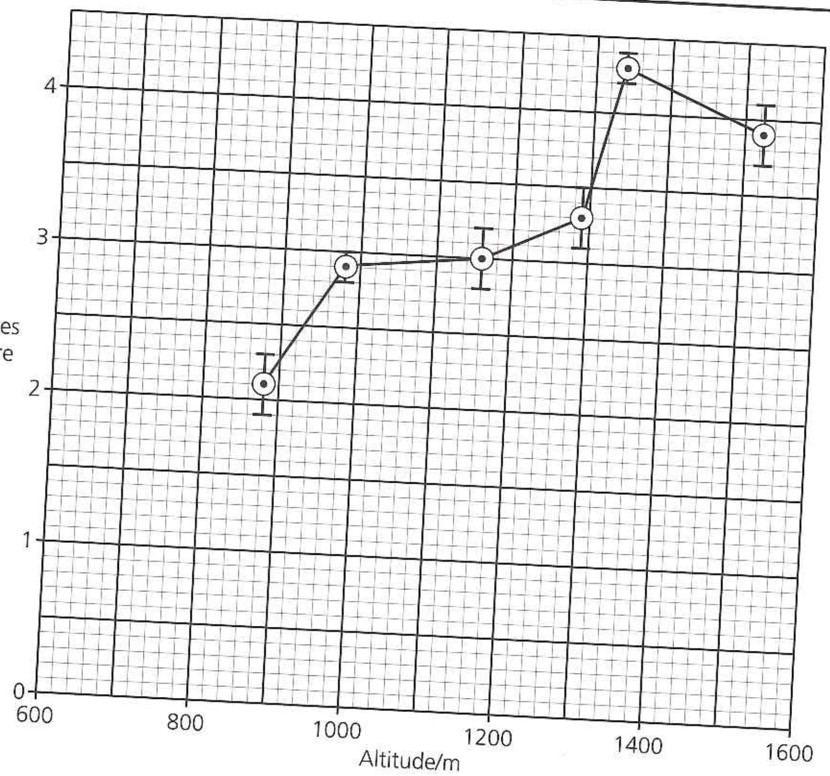


*Figure 3.3 Mean yield of soya beans in plots at different altitudes in Zimbabwe. The error bars represent one standard deviation on either side of the mean*

Q3 Use the graph in Figure 3.3 to describe how the yield of soya beans varies with altitude.

Q4 At what altitude or altitudes is the variation between the yield of soya beans in the different plots least.

## Looking for relationships

All living organisms respire and most of them need oxygen to do this. There are many factors which affect the rate of oxygen consumption. One of these is temperature. Different organisms consume different amounts of oxygen at different temperatures. Biologists investigating this want to know if there is an **association** between oxygen consumption and temperature. Once they have collected the necessary data, the first thing they might do is to plot a scatter diagram with oxygen consumption on one axis and temperature on the other. Look at Figure 3.4. It shows scatter diagrams for an insect, the Colorado beetle, and a chipmunk which is a small, squirrel-like mammal.

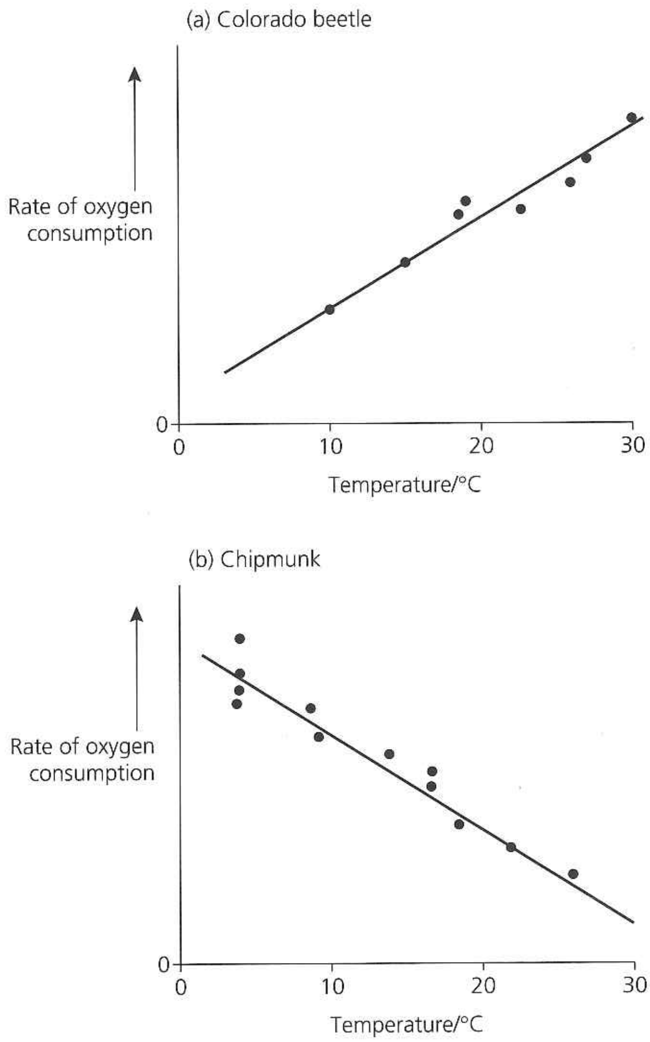


***Figure 3.4*** *Scatter diagrams showing associations between oxygen consumption and temperature in (a) Colorado beetle and (b) chipmunk*

Two different types of association are shown here. With the Colorado beetle, there is a **positive association**. In other words, as the temperature increases, so does the rate of respiration. A line of best fit will slope upwards. The scatter graph for the chipmunk, on the other hand, shows a **negative association**. As the temperature increases, oxygen consumption decreases, so a line of best fit slopes downwards. There is a third possibility not shown here. There may be **no association** in which case the points will be scattered randomly over the graph. It would not be possible to draw a line of best fit, or the line would run parallel to one of the axes.

## Explaining patterns

Flick through the pages of this book and look briefly at the exercises it contains. You will see many tables and graphs concerned with different aspects of biology. Each set of data that you encounter during your AS or A-level Biology course is likely to be different, so you obviously cannot offer the same explanation every time! What you can do, however, is to identify a number of general points which should always be bourne in mind when suggesting an explanation. These points are listed in Box 8.

### BOX 8 Explaining patterns

1. Take your time. Make sure you understand the data and identify obvious patterns before you start explaining.
2. The curves on many graphs are quite complex in shape. It often helps to break a complex curve down into its separate parts and look for an explanation of each part.
3. Explain means **give a reason**. It does not mean describe. If you are required to explain something, make sure that you really do give a reason.
4. You should be explaining a particular set of data so you must make sure that you have related your knowledge to the figures concerned.

We will apply these principles to a specific example. You may be familiar with the enzyme, amylase. This enzyme is found in saliva. It is also produced by fungi and by germinating seeds. It catalyses the chemical reaction in which starch is broken down to a sugar, maltose. Specific concentrations of amylase and starch were mixed and incubated at different temperatures. At 15 second intervals, samples were withdrawn from the mixture and tested for starch. The graph in Figure 3.5 shows the time taken for all the starch to disappear at different temperatures.

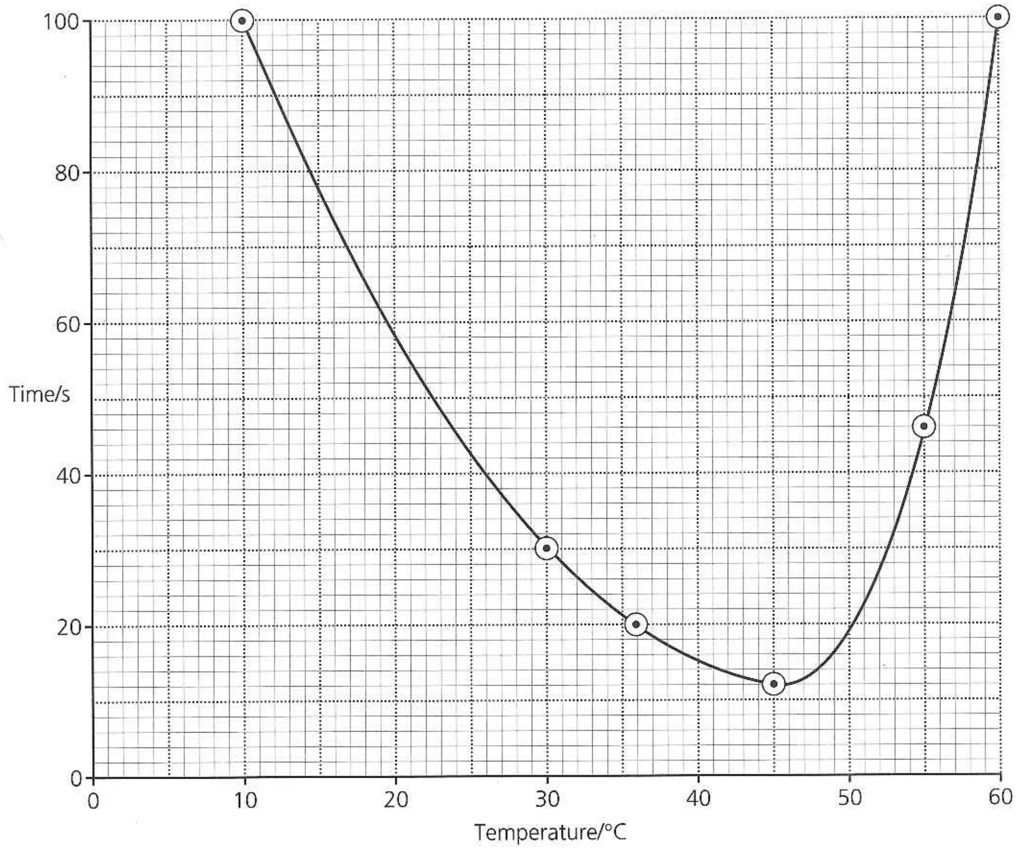


***Figure 3.5*** *The time taken for starch to disappear when starch and amylase were incubated at different temperatures*

If you have studied GCSE Science, you will probably be familiar with this enzyme, and should understand how temperature affects the rate of an enzyme-controlled reaction. We will look at the graph and show how the points listed in Box 8 may help to produce a comprehensive explanation of the shape of the curve. We will consider each of these points in turn.

1 The curve shows us how the rate of the reaction changed although its inverted shape may be unfamiliar. It is particularly important, therefore, that we understand the data before we attempt to explain them. At 10 °C, it takes 100 seconds for all the starch to disappear and be broken down to maltose. At 30 °C, it disappears much faster; it only takes 30 seconds. The rate of reaction is much faster at 30 °C than it is at 10 °C.

2 This curve clearly has two parts. It falls between 10 °C and 45 °C and then rises sharply. We should explain both of these aspects.

3 Now the explanation. We have to **give a reason** why the curve falls and why it rises sharply ...

4 ... and we need to relate this to the time taken; we shouldn't just write about the rate of the reaction.

Here is an explanation for the first part of the curve:

> Between 10 °C and 45 °C, the time taken for the starch to disappear gets less because the rate of reaction increases. As the temperature increases, the molecules of starch and amylase gain more kinetic energy. They therefore move faster and are more likely to collide and react.

**Q5 Give an explanation for the shape of the curve above 45 °C in the graph in Figure 3.5.**

Some curves will have shapes that you will meet frequently during your biology course. Figure 3.6 shows some results from a survey on ice cream sales and illustrates a particularly important point.

It is clear from this graph that there is positive association between ice cream sales and the incidence of sunburn – the greater the number of ice creams sold, the more cases of sunburn there are. We have to be very careful how we explain this. Obviously ice cream does not cause sunburn. The most likely explanation is that a third factor, temperature, is involved; the hotter the day, the greater the number of ice creams sold and the higher the number of cases of sunburn. The important thing to note is that two things may be associated but this does not necessarily mean that one causes the other.

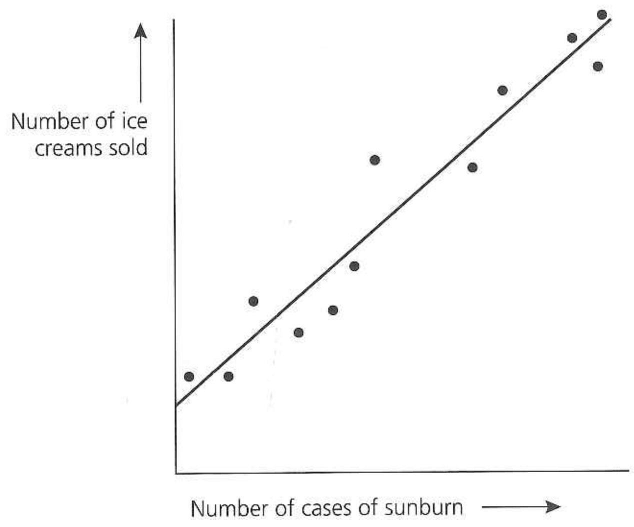


*Figure 3.6 Number of cases of sunburn plotted against ice cream sales*

Investigating the risk factors associated with disease can be quite tricky because of this. One particularly interesting example concerns the parasitic disease, schistosomiasis. This is a common disease in many parts of the tropics. People suffering from schistosomiasis are generally very lethargic and spend a lot of their time just sitting about. A study was carried out with seasonal workers on a very large sugar cane plantation. From the results of this study, a graph was plotted of the amount of sugar cane cut by each worker against the number of parasites in the worker's blood. The curve on this graph was the same shape as that in Figure 3.6. This came as a complete surprise to the research scientists because it appeared to show that having schistosomiasis made cane cutters more efficient! The real explanation was that a third factor was involved – previous experience. More experienced workers could cut more cane; they also had more parasites which they had picked up from the area round the plantation. Schistosomiasis did not make people more efficient at cutting cane after all.

We will now look at an example of another curve whose shape you will encounter frequently. This example has nothing to do with biology. Supporters are going to a football match. To get into the ground, they have to pass through turnstiles. In the graph in Figure 3.7, the rate at which supporters get into the ground has been plotted against the number of people outside trying to get in.

The curve has two main parts, labelled **A** and **B**. We will look at part **A** first. You can see that the rate of entry to the ground is directly proportional to the number of

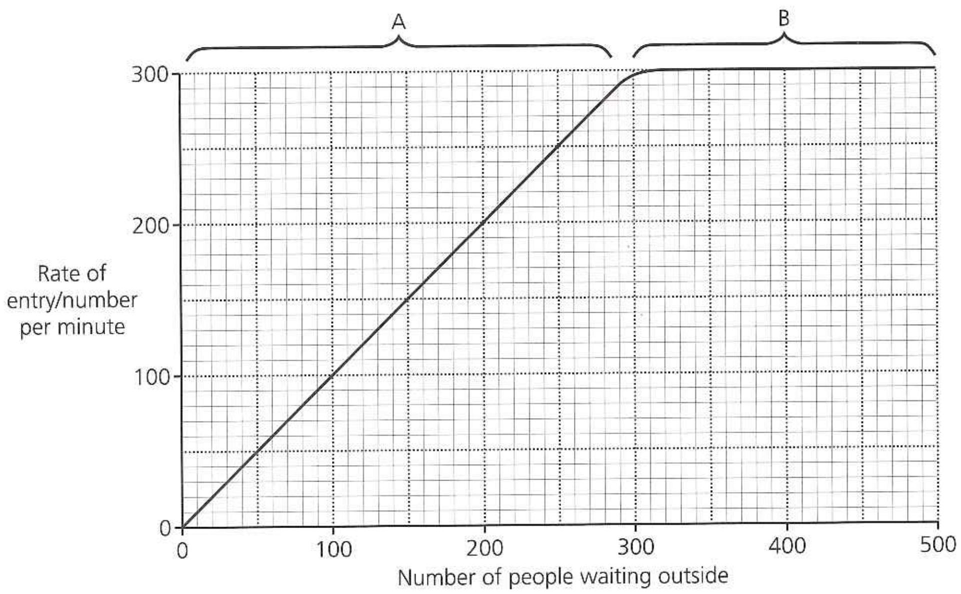


***Figure 3.7*** *The rate of entry to a football ground plotted against the number of people outside*

people outside. Three hours before the game starts very few people are trying to get in. They can walk straight up to a turnstile and enter. As more and more people arrive, the rate of entry to the ground increases. There comes a point, however, where there are so many people outside that all the turnstiles are working as fast as possible and queues start to build up. The rate of entry to the ground cannot get any faster. We are now on the part of the curve labelled **B**. We say that over part **A** of the curve the number of supporters trying to get in is the **limiting factor**. It limits the rate of entry into the ground. The curve levels out in part **B**. It does not matter how much faster supporters arrive at the ground, the rate of entry stays the same. Something else is acting as the limiting factor. It is probably the number of turnstiles. We will now look at a biological example of the same principle. The graph in Figure 3.8 shows how light intensity affects the rate of photosynthesis of a plant.

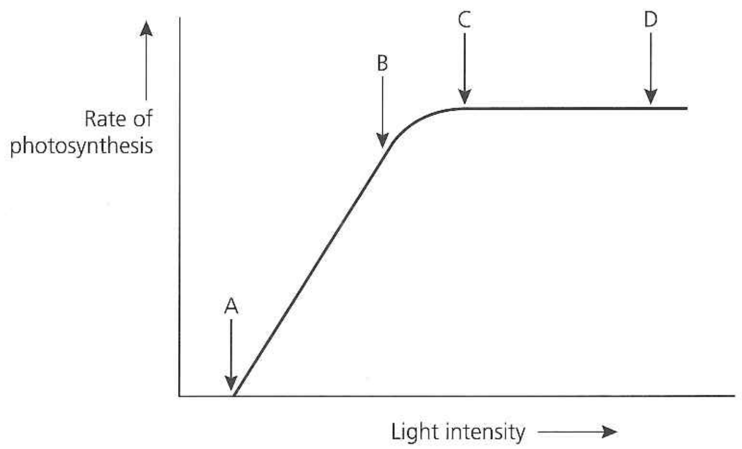


***Figure 3.8*** *The effect of light intensity on the rate of photosynthesis*

**Q6** **What factor limits the rate of photosynthesis between points A and B on the graph in Figure 3.8? Explain the evidence from the graph which supports your answer.**

**Q7** **Suggest a factor which might limit the rate of photosynthesis between points C and D.**

Watch for curves which have this shape. They are very common in biology and the explanation relies on the same principles every time.

## Evaluation

We are always making comparisons and drawing conclusions – my mobile phone is better than yours ... Manchester United is the best football team ... the MMR vaccine is dangerous. Unfortunately, many of these comparisons and conclusions are subjective. They are based on personal opinions and data that we cannot really trust. As scientists, we ought to look very carefully at our work. We need to **evaluate** it and make sure the data we collect are reliable and the conclusions we draw can be trusted.

In this section we will concentrate on evaluation of investigations and their results. All investigations have three main steps. We start by designing and planning the experimental work we need to do. We then carry it out and collect the raw data. Finally we analyse the data and draw any conclusions we can.

Let us start by thinking about the first two steps – planning and carrying out the experimental work. As A-level biologists, we will have learnt a lot about experimental design and our plan should be as good as we can make it. It is important to appreciate that evaluation is not about making a list of personal failings such as 'the thermometer should have been read more accurately', or 'I should have taken more readings'. If you could have worked more accurately and reliably, why didn't you? Evaluation is concerned with identifying the limitations which cannot be avoided if particular apparatus or techniques are used.

We will consider an actual investigation to show precisely what we mean. Figure 3.9 shows how the effect of light intensity on the rate of photosynthesis was investigated.

What might produce unreliable results? The lamp might not have been the exact distance from the pond weed or the bubbles might not have been counted accurately. The point about these two things is that the lamp should have been placed the exact

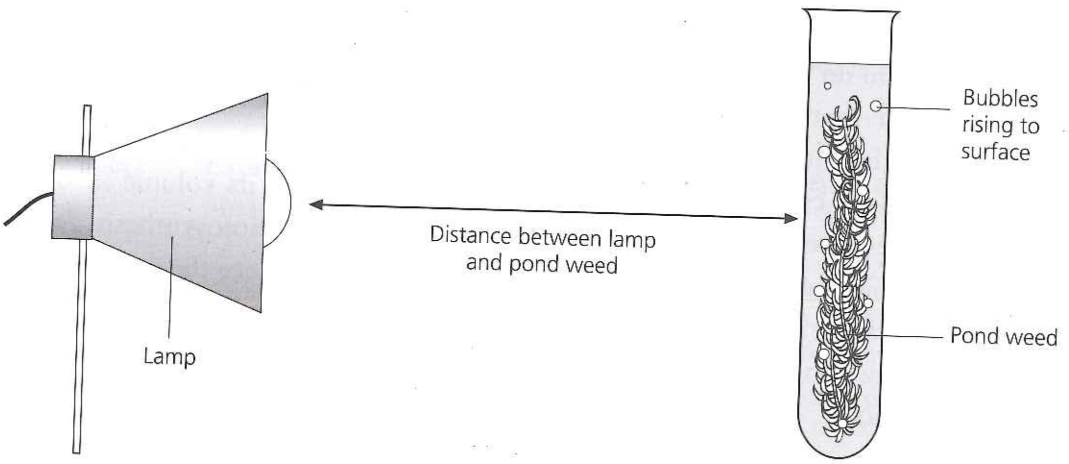


*Figure 3.9 The effect of light intensity on the rate of photosynthesis of pond weed*

distance away and the bubbles should have been counted accurately. Both features were within the control of the person carrying out the investigation so should not have caused a problem. These are not the sorts of things we are interested in evaluating in this investigation. There are other concerns. The lamp is likely to heat the contents of the tube and the rate of photosynthesis will be faster at higher temperatures. In addition, the bubbles of oxygen given off will not necessarily be leaving the cut end of the stem at the same rate, or be of the same size. These are the sorts of things about which we should be commenting. They are key sources of error resulting from the limitations of the apparatus and technique.

We need to do rather more than identify problems. There are four questions which we should ask ourselves.

1 **How will these sources of error affect our results?**
A good understanding of the way in which sources of error affect our results should help us to design ways of minimizing their influence.

2 **Which of these sources of error is the most important and which the least?**
Clearly we do not want to waste a lot of time trying to address sources of error which are not very important. We should look first at those which will have the greatest effect on the results we get.

3 **What could be done to minimize the influence of these sources of error?**
Obviously, anything we can do here will help to make the results more reliable. In the investigation we have been discussing, we could, for example, put a small glass tank of water between the lamp and the plant. This will act as a filter and absorb some of the heat from the lamp.

4 **What other investigations could be carried out that would provide us with more information on which to base our conclusions?**
Remember that we are particularly concerned about making our conclusions more reliable. So, if you think about the investigation we have just described, we could look at collecting the gas concerned and measuring its volume … or we could investigate the effect of temperature on the rate of photosynthesis. In this way we could see if the heating effect of the lamp did influence the results. What is not much use is to carry out a completely different experiment which would tell us nothing more about the conclusions we have drawn from our original investigation.

## Exercise 3.1 Evaluating experiments

1 In winter, small birds such as blue tits and great tits spend most of the daylight feeding. This is particularly important in very cold weather as they require a lot of energy to make up for heat lost overnight.

The relationship between the mean daily temperature and the mass of peanuts eaten by small birds visiting a garden peanut feeder was investigated. At exactly the same time each morning, the mass of nuts eaten in the previous 24 hours was measured together with the mean temperature for this period. The peanut feeder and some of the results obtained are shown in Figure 3.10.

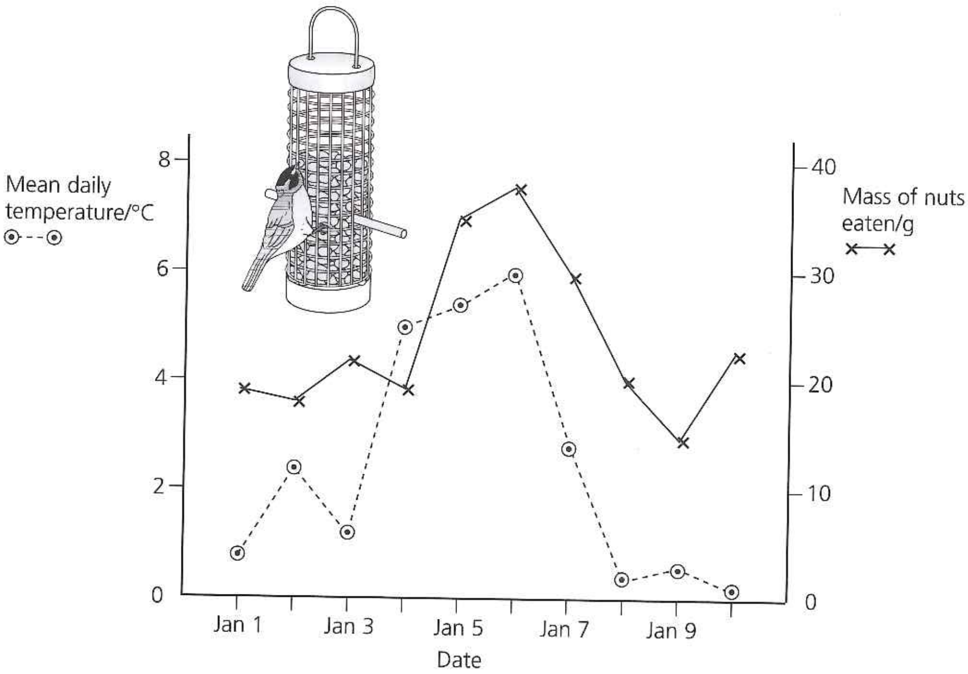


*Figure 3.10 The effect of mean daily temperature on the mass of peanuts eaten by small birds visiting a feeder*

(a) Explain how rain may have affected the reliability of the results obtained in this investigation.

*(2 marks)*

(b) The balance used in this investigation weighed to the nearest gram. Would there have been any advantage in using a more accurate balance? Explain your answer.

*(1 mark)*

**Exercise 3.1** ***continued***

2 Figure 1.1 on page 2 shows some fruits from a sycamore tree. When these fruits fall from the tree, they spin round and fall slowly to the ground. This means that the wind can blow them a long way from the parent tree. Several things influence the time taken for a particular fruit to fall to the ground. These include

- the mass of the fruit
- the surface area of the wing
- the height from which the fruit is released.

The effect of wing surface area on the time taken to fall to the ground was investigated. Fruits were taken and the surface area of the wing of each was measured by drawing round it on a sheet of graph paper. Each fruit was numbered with a felt pen. Fruits were then dropped from a height of 5 m and the time each took to fall to the ground was recorded. Each fruit was dropped five times in all and the mean value calculated.

(a) Describe how you could make sure that the mass of the fruit would not influence the results.

*(2 marks)*

(b) (i) What do you think is the greatest source of error in this investigation? Give a reason for your choice.

*(2 marks)*

(ii) Using the same apparatus, suggest how you could make the effect of this variable as small as possible.

*(1 mark)*

**Exercise 3.1** ***continued***

3 When a maggot moves, it wriggles. Each time it wriggles, the small black structure at its front end moves forward then back. By counting how often this happens in a given period of time, its rate of wriggling may be found. Figure 3.11 shows how the effect of temperature on the rate of wriggling of a maggot was investigated.

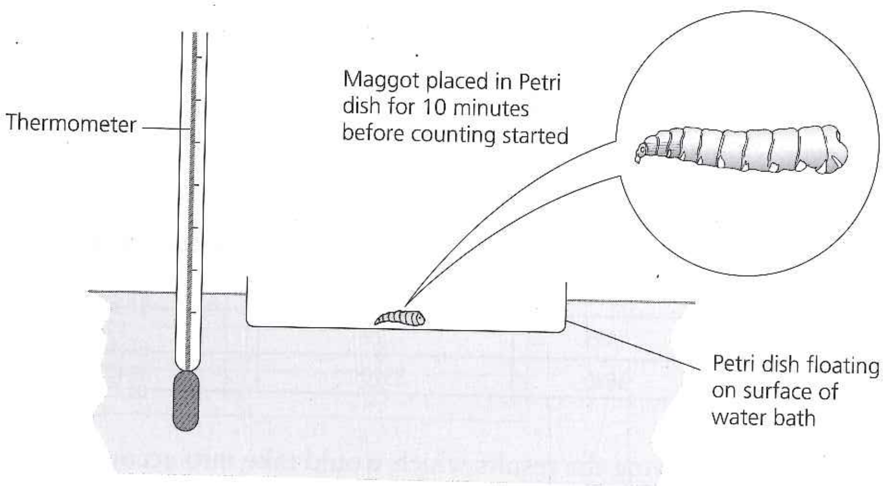


***Figure 3.11*** *Investigating the rate of wriggling of a maggot*

Table 3.3 shows some of the results obtained.

**Table 3.3 The effect of temperature on the rate of wriggling of maggots**

| Temperature/ °C | Rate of wriggling/wriggles minute$^{-1}$ |
|---|---|
| 11 | 46 |
| 16 | 92 |
| 22 | 148 |
| 27 | 212 |
| 34 | 206 |

(a) Give **two** features of this investigation which would have had an important effect on the reliability of the results.

*(2 marks)*

(b) Which of these two features do you think was more important? Give a reason for your answer.

*(2 marks)*