A* upgrade

Watch it

Bill Indge explains the importance of making and recording observations

I have reached a stage in life where my A-levels were a very long time ago. However, I can recall one particular episode because it was, in many ways, instrumental in creating for me what has been a lifelong interest in the natural world.

Key words

Observation
Data
Mean
Recording

Finding out how science works

We were working our way through osmosis by looking at the effects of different concentrations of sucrose on cylinders cut from potatoes. We were asked to bring our own potatoes and most of my fellow students brought in robust specimens. My mother gave me a couple of old ones which had shoots several centimetres long.

We did the usual practical work: cut cylinders from the potatoes, weighed them and put them in sucrose solutions of different concentration. We were then required to note the concentration of sucrose in which the potato did not change in mass. The figures entered were remarkably consistent — at least everyone else's were. My result was way off. I was uncertain as to what to do. Should I cheat and give a value more in keeping with the others? I am glad now that I didn't because my anomalous result led me to appreciate that the starch stored in potatoes is hydrolysed to soluble sugars as potatoes start to sprout and this resulted in a low water potential.

This brings me to the point that I really want to make in this column. Biology differs from other sciences such as physics and chemistry in that the way is much more open for you to make discoveries for yourself. Admittedly, you are not likely to make a fundamental breakthrough in human physiology or molecular genetics but there are aspects of the subject, particularly in areas such as ecology, where you can make a genuinely original observation. Biology is much more than a body of factual knowledge; it is a science and, as a science, it involves investigating the real problems that stem from observations. This is why the emphasis on 'how science works' is so important at A-level. Here we will concentrate on just one aspect of the way in which science works — making and recording observations.

Recording the information

It has been estimated that 50% of the adult human population in the UK put out food for wild birds during the winter months. I certainly do. I have a number of bird feeders outside my lounge window and I have spent a considerable amount of time this winter observing the birds at these feeders. I will use my observations to provide some examples for this *Upgrade*.

Figure 1 A dunnock feeding underneath a bird feeder

Table 1 Records made of dunnock feeding activity for the first 3 days of observation

<table>
<tr><th rowspan="2">Date</th><th colspan="2">Temperature/°C</th><th colspan="3">Number of times dunnocks were</th></tr>
<tr><th>At start of period of observation</th><th>At end of period of observation</th><th>Feeding less than 1 m from feeders</th><th>Feeding more than 1 m from feeders</th><th>Not present in garden</th></tr>
<tr><td>5 Jan</td><td>1.3</td><td>2.3</td><td>卌 |||</td><td>||</td><td>||</td></tr>
<tr><td>6 Jan</td><td>6.8</td><td>6.7</td><td>||</td><td>卌 |||</td><td>||</td></tr>
<tr><td>7 Jan</td><td>8.4</td><td>8.5</td><td>||||</td><td>卌 ||</td><td>|</td></tr>
</table>

Further reading

Indge, B. (2009) 'The luck of the draw: chance, probability and statistics', Biological Sciences Review, Vol. 22, No. 1, pp. 25–27.

I will start with the dunnock (or hedge sparrow, see Figure 1). This is an unobtrusive but common bird, widespread in its distribution; even the largest UK cities have dunnocks breeding in their parks and gardens. I have been watching the dunnocks in my garden and it seemed to me that the colder the morning, the greater the time they spent feeding near the feeders rather than round the edge of the garden. But was my impression correct? I decided to collect some data. Every 5 minutes for an hour each day during January, I recorded where the first dunnock I saw was feeding. Table 1 shows my observations for the first 3 days.

This table is by no means a complete set of my observations. This does not matter because I am not concerned here with drawing conclusions but with recording results.

- **Observations should be quantitative.** With the data I have collected, I can point to a given date and say that a specific number of dunnocks were seen feeding within 1 metre of the feeders at a particular mean temperature. Observations like this are objective and only one interpretation is possible. Once you start introducing subjective terms, such as counting the number of birds 'near to the feeders', then your data are open to different interpretations. How near is near? There can be no doubt about less than 1 metre.
- **Observations should be honest.** Look at the results in Table 1 for 7 January. It was fairly mild for a mid-winter day but the first four birds that I recorded were all less than 1 metre from the feeders. This was not what I had anticipated would happen and it would have been all too easy to have made excuses and tinkered with the results. But scientists are in a position of trust and must report their observations honestly.
- **Observations should be methodical.** The key here is that you should be able to come back to a set of observations on a later occasion and there should be no doubt in your mind about what you did and what you saw. Many have been the times when I have walked round a practical class and seen a list of scribbled figures on a scrap of paper. This will mean nothing when it comes to reporting and analysing observations later. It is worth spending a little time before you start work in planning your approach, rather than a lot of time later trying to fathom out what you meant.

Figure 2 A female house sparrow on a bird feeder

No magic numbers

We all realise that you cannot draw meaningful conclusions based on a single observation. You need repeats, but how many? We will look at an actual example, again taken from the bird feeders in my garden. One of these feeders contains sunflower seeds (see Figure 2). Watching the activity at the feeder one cold January morning, I was intrigued by the different feeding strategies adopted by different species of bird. Watching rapidly turned into observing and collecting data. I used a stopwatch to determine the time each bird spent on the feeder. To keep everything simple, we will consider just one of the species involved, the house sparrow.

A single record obviously tells me very little but what about three? The number three has almost become a standard answer to questions set in the context of both GCSE and A-level practical work and students usually link this with the statement that it 'allows anomalies to be identified'. If you are carrying out, say, a titration in chemistry, then it might be sensible to take three readings. After all, you are using the same solutions and the same apparatus, so you should not be expecting much variation. But we are considering biology, and one of the key features of this subject is that living organisms vary. We must accept that if we are looking for a reliable mean value, we are probably going to have to collect considerably more than three results, holding other variables (such as time of day) as constant as possible.

Let's look at some of the results that I collected. The first three were: 5.2 seconds, 21.7 seconds and 4.3 seconds. The approach that is all too familiar in sloppy investigations argues that 5.2 and 4.3 are close together so we will accept them and dismiss 21.7 as an anomaly. This is absolute nonsense. We must not take figures that do not fit our preconceived idea of what ought to happen and simply dismiss them. The sparrow concerned did spend 21.7 seconds on the feeder so we must not ignore this. In addition, we have only three results. It could be that 21.7 seconds is more typical of the time spent by a sparrow on the feeder than the two shorter times. Maybe the shorter times are the anomalies.

How many readings do I need?

Clearly, we need more than three results, but how many? One way of getting an idea of the number of results required is to calculate and then plot a graph of the running mean. Every time you collect a result, you re-calculate the mean to include this figure. The graph in Figure 3 shows this. If you look at it carefully you will see that the mean varies in value considerably at the start but, after 20 readings, the values settle down and level out. In other words, after 20 readings you have a more reliable mean, one that is a much better indicator of what really happens.

So, how many results should you collect? There is no one answer to this. The greater the variation in the figures, the more results you need to collect. It is effectively a

Table 2 The time spent by house sparrows and goldfinches on consecutive visits to a bird feeder

Visit number	Time spent on feeder/seconds	
	House sparrow	Goldfinch
1	5.2	126.1
2	21.7	24.5
3	4.3	48.2
4	7.3	71.1
5	12.0	41.3
6	6.3	108.1
7	6.1	52.4
8	7.3	76.5
9	4.6	137.7
10	5.2	46.4

compromise. You need enough to give you a reliable mean. On the other hand, there is only so much time available so this will impose an upper limit. In this particular case, I would collect at least 20 readings; I certainly would not go for three. There is a second, equally important, reason for collecting enough data. We will return to the feeders. As well as house sparrows, other species also visited them. These included goldfinches (see Figure 4). Table 2 shows my first ten records for house sparrows and for goldfinches visiting the feeder.

If you cast your eye rapidly over the figures in the table, they look very different. That difference may be attributable to one of two things: there may be a biological explanation for the difference (e.g. goldfinches spend more time feeding, once they have arrived and consider themselves safe, than sparrows do), or it may simply be due to chance. It looks here as though there is a real likelihood that there is a biological explanation for the difference but suppose that we just had the first set of figures, those in the pink boxes. Could you really decide that these results were not just due to chance; that the house sparrow just happened to spend a very short time on the feeder while the goldfinch spent an abnormally long time? You could not decide on this evidence.

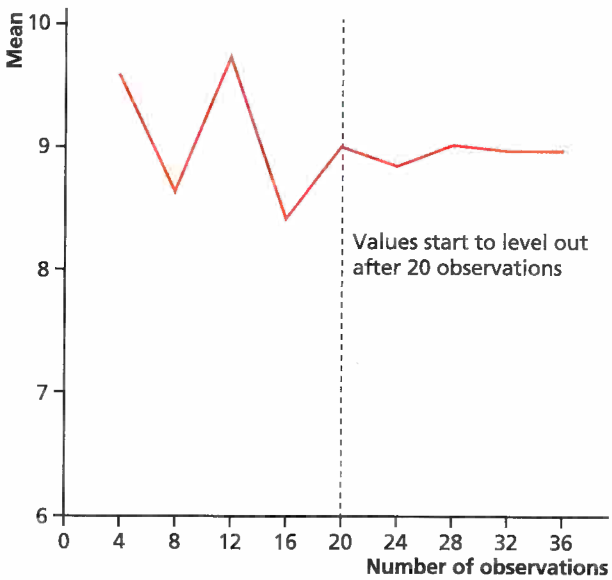

Figure 3 Graph showing the running mean calculated for different numbers of readings

Figure 4 A goldfinch

If you collect enough data, you can carry out a statistical test. Statistical tests are mathematical tests that are designed to calculate the probability of a particular set of data being determined by chance and you cannot carry out statistical tests if you have insufficient data.

Following it up

I have always felt disappointed when I ask A-level students why they have chosen to study biology and receive the response that they 'need' the subject for their career. Biology is a great subject and the more you discover, the more fascinating it becomes. Making observations of your own provides a starting point for going a little further than the specification requires. Schools and colleges rarely have access to scientific papers but you can try going online and using Google Scholar as your search engine. This will allow you to see what professional scientists have found out about the subject of your observations...and it will mean that you should get much more out of your study than just the grade you need.

Bill Indge has had many years' experience as a senior examiner in A-level biology. He is a member of the Biological Sciences Review editorial board and the author of a number of books, including the *Biology A–Z Handbook*. Visit **www.hoddereducation.co.uk** for more information and to see Bill's other publications.