Laterality in leaves

This lesson idea covers the concepts of symmetry and laterality in organisms, using holly leaves and hedges as a case study. Laterality refers to sidedness, showing a preference for one side of a plant or the body of an animal rather than the other.

Developed by Dr Michael Dockerty and Peter Cosen, the lesson will build student's skills in sampling skills, data collection and manipulation and graphical representation of data. It is designed for KS3 level students.

Please see below for the lesson resources.

Investigation of laterality in holly leaves (see end of pdf)

Tables and check sheets for holly study (see end of pdf)

[Text for holly study investigation/web resource]

Investigation of laterality in holly leaves

Dr Michael Dockery and Peter Costen

Introduction

Laterality refers to sidedness, showing a preference for one side of a plant or the body of an animal rather than the other. Rogers (1989) defined laterality as "functional differences between the right and left sides". Laterality is, thus, asymmetrical bias.

Organisms can show three basic kinds of symmetry: these are spherical, radial and bilateral. Spherical symmetry is seen when any plane passing through the centre divides the two parts into identical halves. For example, any plane passing through the centre of a *Volvox* alga. Radial symmetry is seen when any plane passing through the central axis divides the organism into two halves that are mirror images of each other. For example, animals such as jellyfish (*Chrysaora* spp.) and flower heads such as daisy (*Bellis perennis*). Bilateral symmetry is seen when only one plane divides the organism into two identical parts, a right and a left half. Humans and spiders are bilaterally symmetrical. Some animals, however, show clear asymmetry. For example, male fiddler crabs (*Uca* spp.), see Figure 1, have either an enlarged right or left claw, which they use in competitive bouts with other males and for signalling to other male and female fiddler crabs. Male fiddler crabs have an enlarged right or left claw and so all will show laterality. They also show asymmetry as they have one large claw and one small claw.

Figure 1 A male fiddler crab with an enlarged left claw.

Many native British trees have bilaterally symmetrical leaves, such as alder (*Alnus glutinosa*), hazel (*Corylus avellana*), beech (*Fagus sylvatica*) and oak (*Quercus robur* and *Q. petraea*). [Most tree leaves are, in practice, rarely exactly bilaterally symmetrical as when folded over down the mid-rib there is invariably a small degree of overlap.] The leaves of some trees, such as English elm (*Ulmus procera*), may initially look symmetrical but they are not: one side of the base of the leaf is longer than the other side. The leaves of the holly tree (*Ilex aquifolium*) have prickles on both sides of the leaf. At first glance it might appear as though the number of prickles on each side of the mid-rib is the same - but is it? Is there variation in the number of prickles on each side of a holly leaf?

This suggestion for a practical exercise for Key Stage 3 students will focus on the number of prickles on holly leaves. [It also provides an opportunity to develop sampling skills, methods of data collection and the manipulation and graphical representation of data.] If students are asked to draw a holly leaf from memory they usually draw one with a similar number of prickles on each side. But do holly leaves have the same number of prickles on each side? This investigation will test the hypothesis that "the number of prickles on the left side and on the right side of the mid-rib are the same". If this is not the case then holly leaves will show laterality with one side, left or right, having more prickles than the other.

The investigation will focus on the following learning objectives. The pupils will learn:

1. that the individual members of the same species (holly) differ in a number of ways (here, the number of prickles on each side of the mid-rib);
2. to carry out a means of collecting data using a sufficiently robust sample size;
3. to pool data and construct a table from which graphs can be drawn and conclusions reached;
4. to offer some degree of confidence in the relationship evident from a graph (if this aspect of the investigation is carried out);
5. to offer suggestions for the data and the graphs regarding the possible causes of the variation in the number of prickles on the two sides of a holly leaf.

Figure 2 Holly bushes along a coastal path at Pleinmont, Guernsey.

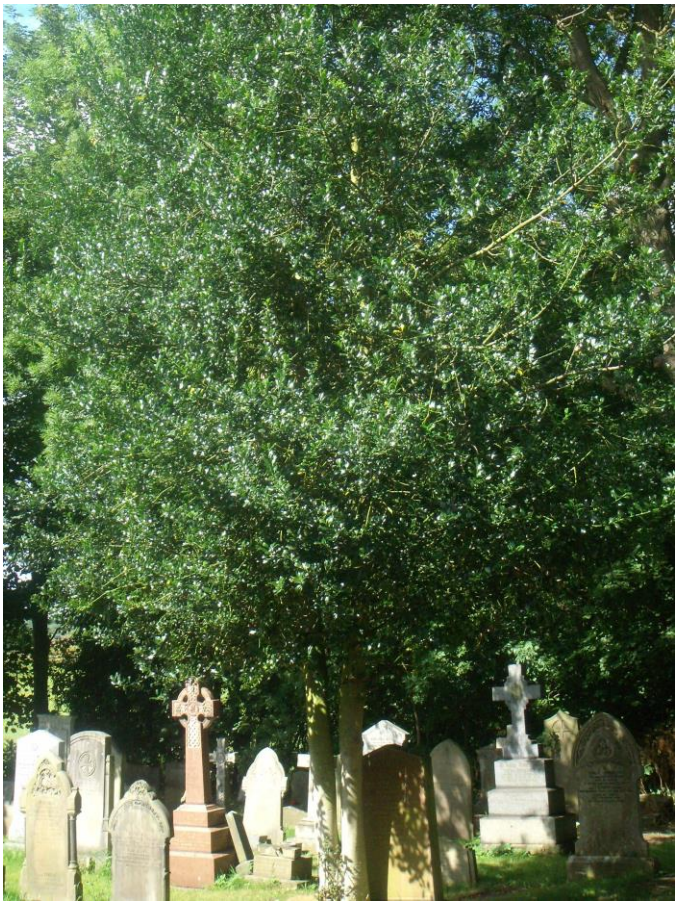

Figure 3 A holly tree in the parish churchyard in Flixton, Manchester.

Figure 4 A typical holly leaf showing laterality regarding the number of prickles on the left hand side and right hand side of the mid-rib.

What to do

Holly is a common hedgerow tree and so may well be found in school grounds. To collect leaves for this study a total of 20 – 40 leaves would represent a suitable sample size. Ideally one leaf would be taken from 20 – 40 separate holly trees or bushes which schools may have in their grounds: if the number of holly trees or bushes is less than this then hopefully the sample will be at least 15.

To collect a sample leaf, the students should approach a tree and take a leaf, without conscious bias, about 1.5 m above the ground. This should be a convenient height for KS3 students. Taking the leaf from the tree with a pair of scissors may reduce the chance of scratches to hands. Each leaf can be placed in a suitable container, such as a tin or wooden box, and transferred to the classroom/laboratory. [If schools have very few holly trees, then rather than removing leaves from trees they could identify which leaves they have sampled (for example, by tying a piece of coloured wool to the leaf) and then after collecting data in the field they can return to the

laboratory to process their data.] If leaves have been collected, then each pair of students could take 2 or 3 leaves and carry out the task, wearing rubber gloves if desired. They would need to count the number of prickles on the left side and on the right side of the mid-rib when they are viewing the leaf with the glossy surface uppermost and the central prickle at the point of the leaf furthest away from the observers. So, for the leaf illustrated in Figure 4 the answers would be 7 prickles on the left side and 8 prickles on the right. The data can be recorded in Table 1, Appendix A.

[If an extension exercise was considered to be valuable, the length of leaf along the mid-rib could also be determined using a 30 cm ruler or a sheet of 1 mm graph paper. The lengths, and total number of prickles per leaf, can be recorded in Table 2, Appendix A.]

In almost any biological investigation, such as the determination of wing lengths of a sample of blackbirds, the masses of a sample of cockle shells on a beach or the heights of a sample of dandelion stems on a sports field, researchers will record observations that clearly indicate that the individual lengths, masses and heights do not all have the same value: they vary. This variation in the observations could be due to a variety of factors: thus the height of plants stems on a sports field could be due to soil depth, nutrient status of the soil, genetics, mowing pressure, etc..

The investigation suggested here is a very simple one that can be carried out in schools at almost any time of the year and illustrates variation in biological data and if laterality is shown in one characteristic of a holly leaf. Analysis of the data collected allows for calculations of central tendency and range, the graphical representation of data and, for the suggested extension exercise, a graphical technique that suggests whether an association (correlation) exists between two variables, viz., the lengths of holly leaves and the number of prickles on the leaves.

Analysis

Students would first need to pool the data for the class, see Table 1 in Appendix A. Initially analysis could focus on the number of prickles on the left (L) and right (R) sides of each holly leaf. The total, mean and range for each set of prickles could be determined to describe the data. Then attention could be given to L – R, the arithmetic difference between the number of prickles on the left and right sides of each leaf. This will produce a series of numbers that are either positive or negative or are zero. Holly leaves with a difference of zero show no lateral bias, i.e. the number of prickles is the same on both the left and right side of the leaves. Any leaves with a negative number are those with more prickles on the right side and those with a positive number have more prickles on the left side: both show asymmetry and laterality. If the total number of prickles per leaf is determined a graph would be a convenient way to represent these data. Students should then be able to make comments on their descriptive statistics and their graphs.

[For the suggested extension exercise, the lengths of the leaves along the mid-rib could be correlated with the total number of prickles on each leaf to determine if the number of prickles on holly leaves are associated with leaf length. It would be suitable to plot the length of the leaves (cm) on the horizontal axis and the number of prickles on the vertical axis. Other possible exercises could be carried out too. A comparison could be made between leaves from the native British holly and a variegated form, if one or more trees are available, to assess if leaf laterality is similar. If the school grounds have several holly trees it might be possible to introduce a pruning

regime on, say, three trees and compare leaf laterality with three non-pruned trees. The holly leaf-miner is a species of fly that lays its eggs on the surface of holly leaves so it might stimulate the interest of students to investigate the pattern of infestation on several holly trees. For example, is infestation higher/lower on the north-facing or south-facing branches of holly trees?]

Results for two samples of holly leaves from trees in Urmston/Flixton, Manchester and from five parishes on Guernsey are included in Appendix B so that school-derived data can be compared with that obtained from two locations in the British Isles.

Students may observe that a particular holly leaf may show no sign of laterality (i.e. there may be the same number of prickles on each side of the mid-rib) but the leaf is not necessarily symmetrical, i.e. one half is not a mirror image of the other half so that when folded along the mid-rib the prickles do not overlap fully. They may wish to follow this up in a further study. A rough guide to the degree of asymmetry might be to note the number of prickles on each side that overlap fully and the number that do not. So if leaf A has six prickles on each side of the mid-rib and two match exactly and another leaf, leaf B, has five prickles on each side and again two match exactly, then leaf A is less symmetrical than leaf B since 2/6 is smaller than 2/5.

Why do holly leaves have prickles?

It has been proposed (Ehrlich and Raven, 1967 and Grubb, 1992) that the function of prickles, thorns and spines, is to deter attack by herbivores. The evidence is equivocal. Experimental work with mammalian herbivores in South Africa (Cooper and Owen-Smith, 1986) found that the inhibitory effect of prickles on species such as *Acacia* was greater for larger animals, such as kudu (*Tragelaphus strepsiceros*), than for smaller ones, such as impala (*Aepyceros melampus*). Milewski *et al*. (1991) in Kenya found that cut branches of *Acacia seyal* that had their thorns removed had greater losses than branches without the thorns removed when the foragers were a tethered domestic goat and free-ranging giraffes (*Giraffa camelopardalis*). In addition, thorn length was found to increase on vegetation within the reach of giraffes. Similar results were reported by Takeda *et al*. (2003) when sika deer (*Cervus nippon*) were foraging on an evergreen shrub (*Damnacanthus indicus*). Obeso (1997) studied the effects of grazing by ungulates (cattle *Bos taurus*, goats *Capra hircus*, horses *Equus caballus* and roe deer *Capreolus capreolus*) on European holly (*Ilex aquifolium*). The findings suggest that the number of prickles/leaf (spinescence) deters browsing by ungulates and is induced by browsing. In a control area where browsing was prevented the spinescence decreased. In the United Kingdom the impact of mammalian browsers (cows and sheep) on holly has been recorded by Peterken and Lloyd (1967) in the New Forest.

European holly has also been shown to increase spinescence on the lower branches (Crawley 1983 and Supnick 1983), though prickles can readily be seen on holly leaves above the browsing height of animals such as red deer (*Cervus elaphus*). The distance between the prickles on holly leaves is apparently too far apart to deter insect herbivores, like caterpillars. For example, Potter and Kimmerer (1988) found this to be the case for the fall webworm *Hypantria cunea*, a caterpillar feeding on American holly leaves. Research by Heads and Lawton (1983) found that the number of prickles on holly leaves had no effect on the abundance of the holly leaf-miner (*Phytomyza ilicis*), nor did the number of prickles affect the intensity of attack by blue tits (*Cyanistes caeruleus*) on the leaf miners. Further research is needed for a fuller explanation of why holly leaves have prickles.

Hedges in schools

Many secondary schools will have hedges in their grounds and since holly trees are a common hedge species, and in fact are one of a number of species recommended by the British Ecological Society (BES) for establishing a hedge in schools [for details see the BES poster available from the BES website www.britishecologicalsociety.org], this practical suggestion should be able to be completed fairly easily. Hopefully, the maintenance of a hedge would be achieved by ground staff and advice could also be sought from organizations such as the Royal Horticultural Society, County Wildlife Trust or even your local garden centre.

Appendix A

Table 1 Check sheet for recording the number of prickles on the sample of holly leaves at the school/college. [Excel spreadsheet attached.]

Table 2 Check sheet for recording the length of the mid-rib and the total number of prickles on the sample of holly leaves at the school/college. [Excel spreadsheet attached.]

Appendix B

Table 1 shows the total number of prickles, the number of left and right prickles and the means (x) and ranges for the two locations, Guernsey in the Channel Isles and Urmston/Flixton (Urm/Flix) in Greater Manchester.

Location number	Total left side	Number on right side	Number on holly leaves	Number of
Guernsey	387	199 (x = 7.65)	198 (x = 7.62)	26
Urm/Flix	563	276 (x = 6.73)	287 (x = 7.00)	41

Ranges

Location	Total number	Number on left side	Number on right side
Guernsey	(10 – 21)	(5 – 11)	(5 – 10)
Urm/Flix	(0 - 21)	(0 – 11)	(0 – 10)

Table 2 Frequencies of the differencies in the number of prickles on the left and right sides (L – R) of the leaves for the two locations, Guernsey in Channel Isles and Urmston/Flixton (Urm/Flix) in Greater Manchester.

Difference (L – R)	Frequency Guernsey	%	Frequency Urm/Flix	%
- 3	1	3.9	2	4.9
- 2	5	19.2	3	7.3
- 1	2	7.7	11	26.8
0	7	26.9	14	34.2
1	8	30.8	8	19.5
2	1	3.9	3	7.3
3	2	7.7	0	0.0
	26		41	

Table 3 Frequencies of differences (negative difference, no difference and positive difference) for the two locations, Guernsey in Channel Isles and Urmston/Flixton (Urm/Flix) in Greater Manchester.

Differences (L – R)	Guernsey	Urm/Flix
Negative	8	16
No	7	14
Positive	11	11
	26	41

[So, on Guernsey more holly leaves had a positive difference (i.e. more leaves had a greater number of prickles on the left side of the mid-rib) whilst in Urmston/Flixton more leaves had a negative difference (i.e. more leaves had a greater number of prickles on the right side of the mid-rib).]

Table 4 Total number of prickles on the left and right side of holly leaves for the two locations, Guernsey in Channel Isles and Urmston/Flixton (Urm/Flix) in Greater Manchester.

	Frequency	
Total number	Guernsey	Urm/Flix
0 – 4	0	2
5 – 9	0	2
10 – 14	11	20
15 – 19	14	14
20 – 24	1	3
	26	41

Table 5 Correlation coefficients (Spearman rank correlation coefficients) between the total number of prickles and the lengths of holly leaves for the two locations, Guernsey in Channel Isles and Urmston/Flixton (Urm/Flix) in Greater Manchester.

Guernsey	r = 0.30	N = 26
Urm/Flix	r = 0.31	N = 41

[Neither correlation coefficient is statistically significant so there was no significant association between the leaf length and the number of prickles on the samples of holly leaves in both locations.]

Acknowledgements

We thank Karen Devine (the Education Officer of the British Ecological Society) for her very helpful comments on an earlier draft of the manuscript. Peter Costen, Michael Dockery and Mick Hoult supplied the images.

References

Cooper, S. M. & Owen-Smith, N. 1986. Effects of plant spinescence on large mammalian herbivores. *Oecologia*, **68**, 446 – 455.

Crawley, M. J. 1983. *Herbivory: the dynamics of animal-plant interactions*. Blackwell Scientific Publications, Oxford.

Ehrlich, P. R. & Raven, P. H. 1967. Butterflies and plants. *Scientific American*, **216**, 104 – 131.

Grubb, P. J. 1992. A positive distrust in simplicity – lessons from plant defences and from competition among plants and among animals. *Journal of Ecology*, **80**, 585 – 610.

Heads, P. A. & Lawton, J. H. 1983. Tit predation on the holly leaf-miner: the effect of prickly leaves. *Oikos*, **41**, 161 – 164.

Milewski, A. V., Young, T. P. & Madden, D. 1991. Thorns as induced defences: experimental evidence. *Oecologia*, **86**, 70 – 75.

Obeso, J. R. 1997. The induction of spinescence in European holly leaves by browsing ungulates. *Plant Ecology*, **129**, 149 – 156.

Peterken, G. F. & Lloyd, P. S. 1967. Biological flora of the British Isles: *Ilex aquifolium* L. *Journal of Ecology*, **55**, 841 – 858.

Potter, D. A. & Kimmerer, T. W. 1988. Do holly leaf spines really deter herbivory? *Oecologia*, **75**, 216 – 221.

Rogers, L. J. 1989. Laterality in animals. *International Journal of Comparative Psychology*, **3**, 5 – 25.

Supnick, M. 1983. On the function of leaf spines in *Ilex opaca*. *Bull. Torrey Bot. Club*, **110**, 228 – 230.

Takeda, M., Asada, M. & Miyashita, T. 2003. Can spines deter deer browsing? *Journal of Forestry Resources*, **8**, 321 – 323.

Figure titles

Figure 1 A male fiddler crab with an enlarged left claw. (© Mick Hoult)

Figure 2 Holly bushes along a coastal path at Pleinmont, Guernsey. (© Peter Costen)

Figure 3 A holly tree in a churchyard in Flixton, Manchester. (© Michael Dockery)

Figure 4 A typical holly leaf showing laterality regarding the number of prickles on the left hand side and right hand side of the mid-rib. (© Michael Dockery)

Table titles

Appendix A

Table 1 Check sheet for recording the number of prickles on the sample of holly leaves at the school/college.

Table 2 Check sheet for recording the length of the mid-rib and the total number of prickles on the sample of holly leaves at the school/college.

Appendix B

Table 1 shows the total number of prickles, the number of left and right prickles, the means (x) and the ranges for the two locations, Guernsey in the Channel Isles and Urmston/Flixton (Urm/Flix) in Greater Manchester.

Table 2 Frequencies of the differencies in the number of prickles on the left and right sides (L – R) of the leaves for the two locations, Guernsey in Channel Isles and Urmston/Flixton (Urm/Flix) in Greater Manchester.

Table 3 Frequencies of differences (negative difference, no difference and positive difference) for the two locations, Guernsey in Channel Isles and Urmston/Flixton (Urm/Flix) in Greater Manchester.

Table 4 Total number of prickles on the left and right side of holly leaves for the two locations, Guernsey in Channel Isles and Urmston/Flixton (Urm/Flix) in Greater Manchester.

Table 5 Correlation coefficients (Spearman rank correlation coefficients) between the total number of prickles and the lengths of holly leaves for the two locations, Guernsey in Channel Isles and Urmston/Flixton (Urm/Flix) in Greater Manchester.

Leaf	Length of mid-ribs of leaves (cm)	Total no. of prickles (L + R)
A		
B		
C		
D		
E		
F		
G		
H		
I		
J		
K		
L		
M		
N		
O		
P		
Q		
R		
S		
T		
U		
V		
W		
X		
Y		
Z		
AA		
BB		
CC		
DD		
EE		
FF		
GG		
HH		
II		
JJ		
KK		