SURVIVAL RIVALS

EXPERIMENTS INSPIRED BY DARWIN

wellcome trust

I'M A WORM GET ME OUT OF HERE

TEACHER, TECHNICIAN AND STUDENT NOTES

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CONTENTS

Welcome to I'm a Worm, Get Me Out of Here!

This kit contains everything you need to carry out the 'I'm a Worm, Get Me Out of Here' protocol with your class, as well as this manual which will help you to get the most out of this resource. The RSPB Pocket Guide to British Birds and the Key to Identifying Common Birds will help you and your students to study the birds in your school grounds as you discover which ones are preying on your spaghetti 'worms'.

I'm a Worm, Get me Out of Here is part of the Survival Rivals series of experiments. There are three kits in this series:

I'm a Worm, Get Me Out of Here for 11-14 year olds
Brine Date for 14-16 year olds
The X-Bacteria for 16-19 year olds

Every secondary state school within the UK is entitled to one of each of these kits for free. You can find out more and order at www.survivalrivals.org.

Survival Rivals is designed to allow secondary schools to celebrate the 200th anniversary of Charles Darwin and the 150th anniversary of the publication of On the Origin of Species by Means of Natural Selection. The three kits enable young people of different ages to carry out practical investigations and to explore Darwin's ideas of evolution and selection.

In I'm a Worm, Get Me Out of Here, natural selection is explored by producing spaghetti 'worms' of different colours, observing which ones birds prefer to eat and monitoring how the populations change over time.

The Survival Rivals website (www.survivalrivals.org) is packed with additional resources and information to support you in delivering these experiments, including online games and videos filled with tips about carrying out the experiments.

For further support about the Survival Rivals experiments and about delivering evolution in the classroom, please see the Science Learning Centres website at www.slcs.ac.uk/darwin200 for details of their courses.

Survival Rivals is funded by the Wellcome Trust, who are also running a number of other Darwin-related initiatives. Find out more about the Great Plant Hunt for primary schools, an animated version of the Tree of Life and various other projects at www.wellcome.ac.uk/darwin200.

The Teachers notes (pages 3 to 13) contain all the information. The Technicians notes (pages 15 to 21) and Students notes (pages 22 to 25) contain extracts of the Teachers information for their use. Please photocopy the Technicians notes and Students notes and distribute accordingly.

Now Get Started With I'm a Worm, Get Me Out of Here...

Teacher Notes for I'm a Worm, Get Me Out of Here

Equipment and materials required

The following items are provided in the Survival Rivals: I'm a Worm, Get Me Out of Here kit:

Item No	✓	Description	Quantity
1	☐	Spaghetti	500g
2	☐	Food Colouring - Red	1
3	☐	Food Colouring - Green	2
4	☐	Food Colouring - Black	1
5	☐	5mL Pastettes	3
6	☐	RSPB Bird Identification Book	1
7	☐	Wild Bird Food	1
8	☐	Sealable Plastic Bags - 4" x 5.5"	100 pack
9	☐	Disposable Polythene Gloves	50 pairs
10	☐	Twine - Biodegradable	1
11	☐	Golf Tees	20
12	☐	Key to identifying common birds	1

If you have any items missing from your kit, please call **0845 120 4529**

You will also need

- Rulers, 150–300mm (for measuring the 'worms')
- Scissors or relatively blunt knives e.g. plastic picnic knives (for cutting spaghetti)
- Hand-washing facilities and paper towels

Optional items

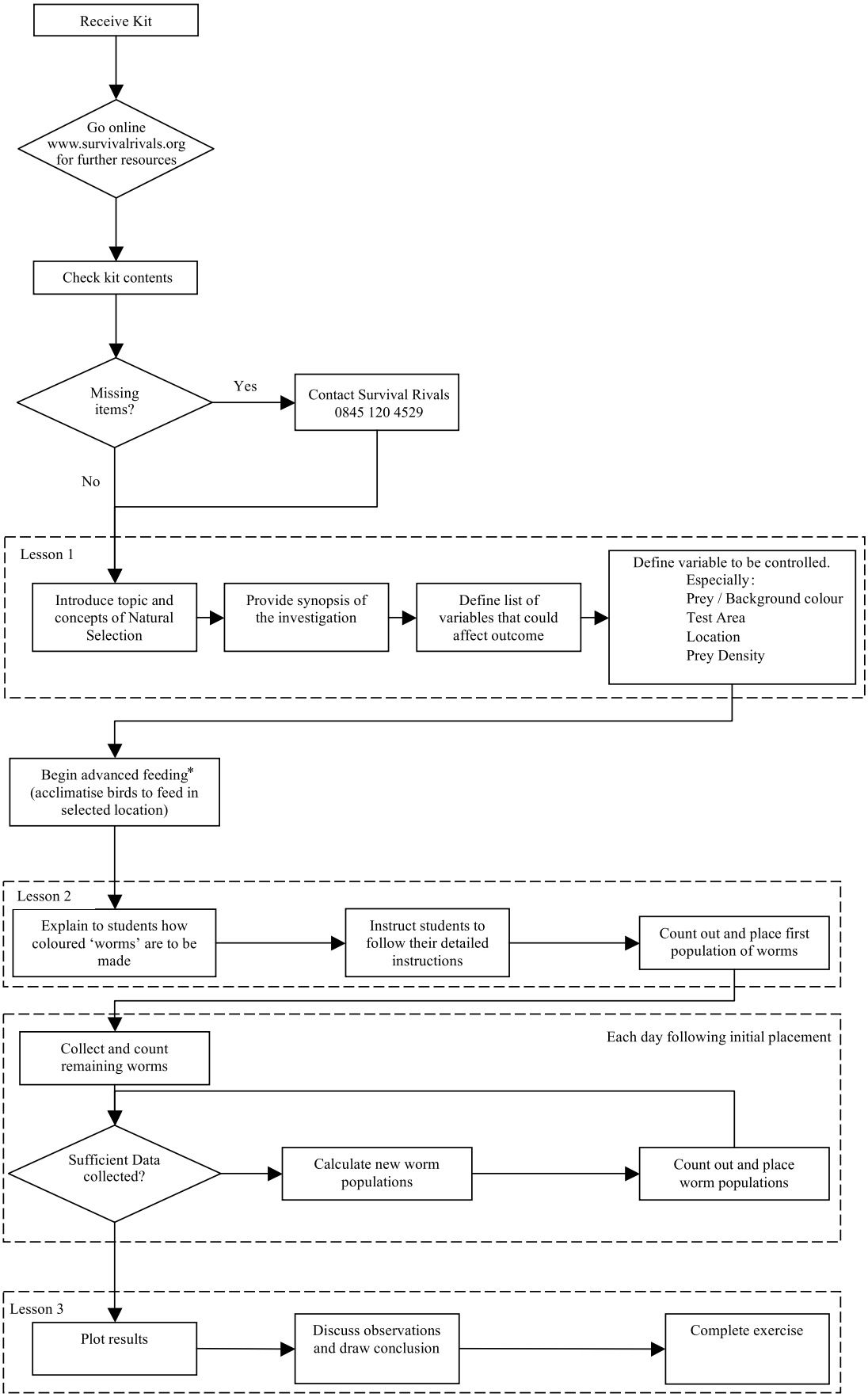
If students prepare their own worms:

- Bunsen burners
- Tripods and gauzes
- Heat-proof bench mats
- Eye protection

For setting up and observing/recording the investigation:

- Bird table
- Webcam and software, etc.

Detailed lesson-by-lesson instructions



* This can be started earlier if you wish

Introduction

How exceedingly stupid not to have thought of that

A hundred and fifty years ago, Charles Darwin published his explanation of why there are so many different living things on Earth, each of them so well adapted to its environment. Others had tried to explain this observation before but unlike them, Darwin had spent years collecting evidence to support his theory of evolution by natural selection.

Many people think that Darwin's explanation of how life has evolved (and continues to evolve) is the most important idea ever to occur to a scientist. Even so, it is really a very simple idea at heart — so simple in fact, that one of his friends, Thomas Henry Huxley, said, after reading On the Origin of Species: "... how exceedingly stupid not to have thought of that".

Darwin's principal idea to explain evolution was natural selection. He realised that:

- living things produce offspring which vary — they are not all the same;
- there is a shortage of resources (food, light, places to live, animals to mate with etc.);
- individuals that do best in this 'struggle for existence' will tend to leave more offspring, passing on their successful features to subsequent generations.

Therefore, over time, organisms with certain characteristics will become more common, while others will become less common and may die out. Over a long period of time, these small differences between individuals add up to large differences, and eventually new species that are no longer able to interbreed are produced. The practical investigation described here provides a simulation of natural selection, using birds to help in the process: it's bird-powered evolution.

Bird-powered evolution

The method described is based on a general technique developed by John Allen and his colleagues and students between the late 1960s and early 1990s to simulate several aspects of evolution by natural selection [1, 2]. The procedure uses different-coloured baits ('worms') that are selected and eaten by birds. Uneaten 'worms' are counted after predation and the 'worm' population is replenished in proportion to those colours which remain. After several cycles of predation and 'breeding', the proportions of the colours in the population change, simulating directional selection. This technique was at one time well-known and widely used in schools, where it formed a useful practical exercise to accompany the classic example of natural selection by predation that is often cited in textbooks, that of the peppered moth, *Biston betularia* [3].

This practical procedure has numerous advantages over other approaches to the teaching of evolutionary principles, such as computer simulations. These benefits include the active involvement of the students in planning the experimental design and analysing the data, the use of real organisms in the selection process, low cost and ease of preparation. The work is equally well-suited to schools in urban and rural areas, and provides opportunities for sharing data between schools or classes.

The exercise demonstrates selection, a key principle of Darwinian evolution, and could, through a consideration of avian vision and bird colouration, help to introduce students to Darwin's other great evolutionary principle, sexual selection [4].

Taking it further

Several variants of the procedure are possible: for example, coloured wool or dyed bread can be used in place of spaghetti baits, or students can act as the 'predators', catching as many 'worms' as possible in a limited time. Allen and his co-workers have suggested various additional ideas in their papers [5, 6], but at the simplest level students may just investigate differential selection of prey on various backgrounds without replacing the baits that have been removed [7].

An important development since the original experiments of this type were conducted is that it is now known that birds' vision is superior to humans' and in particular that many species can see in the UV-A (400–315 nm) range of the spectrum [8]. Students would therefore benefit from trying to appreciate how the world might appear to birds' senses rather than to humans' — although it is difficult to allow for this in the design of the current investigation.

IMPORTANT NOTE

A key requirement of this work is an area where the 'worms' can be placed, undisturbed, but observable by students, for the birds to prey upon. Without this (for example, if birds are scared away by human activity or by predators) the practical investigation will not be successful. For schools in many locations it may be necessary to set up a bird table, perhaps observed by a webcam, to carry out this work.

References

[1] Allen, J.A. and Clarke, B.C. (1968) Evidence for apostatic selection by wild passerines. Nature 220 501–502.
[2] Allen, J.A. (1976) Further evidence for apostatic selection by wild passerine birds — 9:1 experiments. Heredity 36 173–180.
[3] Majerus, M.E.N. (2008) Industrial melanism in the Peppered moth, *Biston betularia*: An excellent teaching example of Darwinian evolution in action Evolution: Education and Outreach 2 (1) DOI: 10.1007/s12052-008-0107-y [Available on-line at: http://www.springerlink.com/content/h7n4r6h026q1u6hk/fulltext.html]
[4] Bennett, A.T.D., Cuthill, C. and Norris, K.J. (1994) Sexual selection and the mismeasure of color. The American Naturalist 144 848–860.
[5] Allen, J.A., Cooper, J.M., Hall, G.J. and McHenry, C. (1993) 'Evolving pastry': a method for simulating microevolution. Journal of Biological Education 27 (4) 274–282. [This paper is provided as a supplement to these instructions.]
[6] Cooper, J.M., Raymond, D.L. and Allen, J.A. (1993) Birds, baits and boards: a method for investigating cryptic colouration. School Science Review 74 (268) 69–73.
[7] Allen, J.A., Anderson, K.P. and Tucker, G.M. (1987) More than meets the eye — a simulation of natural selection. Journal of Biological Education 21 (4) 301–305.
[8] Hart, N.S. and Hunt, D.M. (2007) Avian visual pigments: Characteristics, spectral tuning and evolution. The American Naturalist 169 Supplement pages S7–S26.

Outline of the practical activity

After acclimatising the local bird population to a new source of food, equal numbers of two different-coloured spaghetti 'worms' are presented to birds. Each day (or at regular intervals), the remaining 'worms' are allowed to 'breed' and the two colour morphs are replaced in proportion to those which remain. Over time, the proportion of the type of 'worms' that are left uneaten by the birds increases, thereby simulating directional selection.

Students should be actively involved in planning the experiment, setting it up, and collecting and analysing the data. It may also be necessary for them to carry out some initial investigations to determine which types of bait will be taken by the local bird population and the best location for the bird feeding area.

Who is this practical work suitable for?

We suggest that, as it is described here, the investigation is best suited to 11–14 year-old students. With modification, however, it could be used by much younger students, or with more advanced students if more complex experiments and analyses were carried out. The accompanying paper from the Journal of Biological Education provides additional ideas.

Planning and classroom organisation

When you receive the kit.

When you receive the kit, please check that everything is in the box (see the previous checklist). If you find that items are missing, please contact Survival Rivals on **0845 120 4529** immediately.

None of the items in the kit are perishable or require special storage conditions. In addition, none of the items in the kit present a recognised safety hazard.

It is also a good idea at this stage to check that you have all of the other equipment and materials that are required.

The lessons: an overview

IMPORTANT
Critical to the success of this investigation is the selection of a suitable area in which to feed the birds. Ideally, this should be close to a window (for easy observation) and near a hedge or trees so that birds can head for cover (many species do not like to be in the open for long). For birds to feed freely, the area must not be disturbed during the day, either by humans or predators such as domestic cats. If you find that the 'worms' disappear at night, the most likely cause is nocturnal animals such as foxes, cats or rats. If either of these factors is a problem, a solution may be to set up a bird table that is inaccessible to predators, and possibly overseen by a webcam so that the area can be observed without disturbing the birds.

Advice from the Royal Society for the Protection of Birds (RSPB)

The RSPB has kindly offered the following advice.

- It is recommended that the investigation is carried out between December and March, when wild food is scarce and birds will be more likely to take food that is put out for them.
- Sufficient food should be put out for only one day's feeding at a time; ideally food should not be left out overnight.
- Lacing the 'worms' with chilli powder will deter mammalian predators (birds cannot taste chilli).

Before you start: Advance feeding

Unless the area used for the work is one in which birds already feed, it will be necessary to teach the birds that food is available there. We suggest that food is placed in the feeding area every day for at least a week, and preferably two weeks before starting the experiment. For this purpose, a pack of wild bird food is provided in the kit. Additional wild bird food may be purchased from supermarkets, etc. if necessary. You may wish to supplement this food with bread or other food scraps to attract a wider range of species to the feeding area.

The investigation itself takes place over several lessons and it also presents opportunities for preparatory and follow-up tasks (for example, as homework).

Lesson 1: Planning the investigation

Students will need to be introduced to the principle of natural selection and be given a general outline of the practical investigation and its purpose. The students should then, as much as possible, be involved in planning the precise details of the investigation. Teachers may wish to allocate 'worm' production, data recording and other tasks to individuals or groups of students. It will also be necessary to organise maintenance of the 'worm' selection (bird feeding) area, including the replacement of the 'worms'.

Lesson 2: Preparing the spaghetti 'worms'

Spaghetti is a convenient, robust and inexpensive form of bait. The spaghetti 'worms' can be prepared in bulk by the students themselves or by a teacher or technician in advance. The spaghetti must be dyed at least two different colours as it is cooked, then cut into identical lengths (50mm is ideal). If time permits, students may place the first lot of worms in the feeding area during this lesson. Alternatively, the 'worms' may be stored in sealed containers or plastic bags either in a fridge (for no more than a few

days) or frozen until required. (If the spaghetti strands stick together during storage, they can be loosened with a little water.)

Students will need to understand how to calculate the numbers of worms that should be placed in the feeding area each day, and this can be explained during this lesson.

Daily: Counting and replacing the 'worms'

It will be necessary to organise a rota for students to count and replace the worms each day, in pairs or small groups. Students will probably have to do this in their lunch break or at another convenient time. The easiest way to count the worms is to collect all of the remaining worms and to subtract this number from the number of worms that were put out on the last occasion. Appropriate numbers of fresh 'worms' should then be placed in the feeding area. Note that it is therefore essential that the students understand how to calculate the replacement ratios.

Lesson 3: Analysing the data

Once data has been collected for a week or more, students plot the data graphically and interpret their results.

Group size

This work can be carried out by small groups of students but because the number of potential bird feeding sites will be limited it is probably best undertaken as a whole class investigation.

Scope for open-ended investigations

This work is ideal for open-ended investigations. Several suggestions are given in the detailed lesson descriptions below and in the accompanying paper from the Journal of Biological Education.

Lesson 1: Planning the investigation

The teacher should explain the process of natural selection and provide students with an outline of the investigation. As far as possible, students should plan the investigation themselves: this can be set in whole or in part as homework if appropriate. According to the ability and motivation of the group, the planning might involve all or some of the following:

- selection of suitable 'worm' colours;
- selection of suitable background colours;
- location of the bird feeding area;
- deciding how the worms are to be distributed within the feeding area, and how many are to be placed there;
- deciding on the length of the 'worms' (both to prevent birds selecting prey by size and also so that half-eaten 'worms' can be identified);
- the frequency of data recording and when records are to be taken;
- the method of counting 'worms' and replacing ones that have been eaten;
- the procedure for recording half-eaten or pecked 'worms';
- the procedure for counting 'worms' that have been thrown out of the feeding area;
- how to account for periods when counting is not possible, such as weekends;
- the procedure for observing bird feeding (if possible);
- the procedure for recording the results;
- how the results will be presented and analysed.

Prey and background colouration

Most of the investigations of this type reported in educational journals aim to study the effect of cryptic colouration rather than directional selection. Consequently the prey are usually replaced to maintain a constant 1:1 ratio of the two colours. In one investigation of crypsis, Allen, Anderson and Tucker [7] used wooden trays filled with painted stones and gravel as a background upon which pastry prey were placed. The authors noted that it was very laborious to produce these trays of stones and to match the colour of the prey to the backgrounds. Cooper, Raymond and Allen [6] later used plain and striped painted boards as a more convenient background. But as noted above, these attempts to match prey and background may have been ineffective due to differences between bird and human vision. Several studies have also noted that certain species may select particular colours of prey regardless of the background colour [1, 2].
In the current investigation, the aim is to simulate directional selection, so the background and prey colour is important only in so far as that there should be a difference between the rates at which the two types of prey are selected by birds. Colour, relative brightness, shape, size, smell and taste of the prey could all influence selection as well as factors such as prey movement (or lack of it). There is some recent evidence to suggest that the double cone structures in birds' eyes may help them to detect movement [8].

It will not be possible for students to allow for all of the factors that could influence prey selection. It is important from an educational point of view, however, that students recognise and attempt to control some of these factors. Students could prepare coloured or pattered boards on which to place the worms for example. Most people would not wish to go to this trouble however. An alternative is simply to use the ground (e.g. grass or bare soil) as Allen *et al* did in their original experiments, but if this is done it is essential to mark the area clearly so that it can later be searched for remaining 'worms'. A peg or golf tee at each corner with twine between them is sufficient to mark out the feeding area and ensure that the 'worms' are easily located for counting.

Allen *et al* reported that the birds in their studies generally preferred brown over green-coloured baits. They did not suggest a reason for this preference. To humans, green 'worms' are camouflaged against a grassy background, but birds see over a wider range of the electromagnetic spectrum. Green 'worms' may fluoresce brightly in ultraviolet light, making them easy for birds to spot. Students could research information about bird colour vision and choose the colours of their test 'worms' and the background on which they are to be displayed accordingly. They may wish to test whether particular colours fluoresce in UV light. Of course this only gives a very crude indication of how the 'worms' might appear to a bird — but it helps to emphasise to students the importance of such factors when designing the experiment.

If appropriate, students may wish to carry out an initial trial to help them select 'worm' and background colours for the experiment (for instance, our own tests show that pigeons tend to avoid bright red 'worms', whereas more than 50% of green 'worms' were eaten each day).

Test area

As various investigators have reported, the test area can be relatively small, even bird-table-sized e.g. 500mm x 500mm [6] or 410mm x 410mm [7]. In our trials we marked out two areas of grass: one 1m x 1m and another 2m x 2m. The larger plot was chosen so that numerous birds could feed in the area at the same time (a flock of large pigeons visited the area daily). In practice, it took a long time to collect and count the worms from this larger plot. This may not be a problem if a small group of students does the counting, but it is probably more convenient to use smaller, 1m x 1m, plots or an even smaller bird table.

Location

The test area can either be located on the ground or on a bird table (the latter would prevent predation). Locating the test area close to areas of human or predator activity may of course deter birds from feeding there. Ideally, the feeding area should be close to a window (for easy observation) and near a hedge or trees to provide cover for the birds (many species do not like to be in the open for long). The feeding area may be located where it can be observed by a webcam.

Prey density

To reduce the effect of sampling error that may occur with smaller numbers of 'worms', a high stocking density is preferred. In one investigation, Allen, Anderson and Tucker [7] placed 40 prey on 410mm x 410mm trays (20 'worms' of each colour), that is, a prey density of 238 per m^2, which they admit is far greater than would normally be encountered for cryptic prey. We suggest that the area and prey density are chosen to assist with data collection and later calculations by Key Stage 3 students (e.g. a round number of square metres and prey numbers that can readily be converted to percentages). Because the level of predation will vary, it is not possible to suggest a prey density that would be appropriate in all situations. We suggest that prey are scattered at random at a density of between 50 and 250 per m^2, depending upon the level of predation encountered and the frequency of data collection.

Lesson 2: Preparing the spaghetti 'worms'

The teacher should explain how the coloured pasta is prepared, cut into worm-sized lengths and stored. If appropriate, the students may cook and colour the spaghetti themselves. (It may be possible to 'borrow' a food preparation area with cookers and hotplates to do this rather than using Bunsen burners, tripods and beakers in a science lab.) Alternatively, the pasta can be cooked and coloured in advance by a teacher or technician, then students can cut it into worm-sized lengths.

The simplest and quickest method of colouring spaghetti is to add the food dye to the water in which the dried pasta is to be cooked (without adding oil to the cooking water). After simmering the pasta for 10–12 minutes, the coloured water can be disposed of. Although a second or third batch of pasta could be cooked in the same water, we do not recommend this as there is a progressive reduction in the intensity of the colour of the pasta which may lead to difficulties in reproducing the experiment should this prove necessary.

Pasta coloured in this way can be handled without excessive amounts of dye transferring to the hands. The dye binds to the pasta and does not readily wash out, even during heavy rainfall.

Individuals will no doubt wish to try different colours and colour intensities but for guidance we found that a grass-like green colour can be obtained by adding 15mL of green colouring to a litre of cooking water. Similarly, a dark red/brown colour can be achieved using a mixture of 5mL of black colouring and 10mL of red colouring in a litre of water. Should individual students or groups wish to experiment with their own colours these quantities can be reduced for convenience in the school laboratory e.g. using 250mL of coloured water in 500mL beakers.
Concentrated food colouring will stain skin, so those handling it may wish to wear protective gloves. If bench surfaces etc. are stained by the concentrated colouring, it can usually be removed using dilute bleach.

Sufficient 'worms' have to be prepared so that they can be replaced each time they are counted (see below). This should not be a problem, however, either practically or in terms of cost.

Equipment and materials
Required by each student or working group

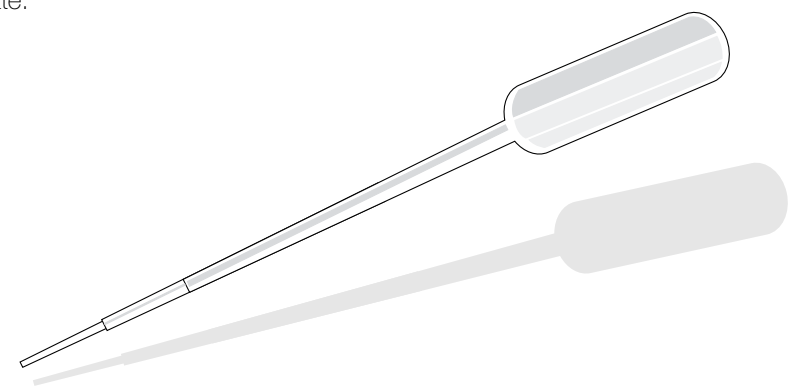
- Dried spaghetti (20 strands are sufficient for 100 x 50mm 'worms'). Note: 'Quick cook' spaghetti may not take up the food colouring before it becomes overcooked and therefore difficult to handle.
- Food colouring: 5mL of black, 10mL of red and 15mL of green were required to make brown and green 'worms' as described above.
- 5mL pastettes, for dispensing the food colouring (one for each type of food colouring)
- Bunsen burner, tripod and gauze or hotplate
- 500mL glass beakers or small saucepans, 2
- Glass rod, spoon or similar for stirring the spaghetti while it is cooking
- Safety glasses (if appropriate)
- Pair of scissors or blunt knife (such as a plastic picnic knife) for cutting the spaghetti into worm-length pieces
- Ruler for measuring the 'worms'
- Plastic bags or sealable containers for storing the 'worms'

Additional equipment required by the class

- Large plastic sieve or colander for straining the cooked 'worms'
- A clock to time the cooking
- Heat-proof gloves for handling the beaker of water
- Access to a fridge or freezer for storing the 'worms'
- Waterproof marker pen for labelling the bags of 'worms'
- OPTIONAL: Chilli powder to add to the 'worms' to deter predation by mammals

Students' procedure (these instructions are also included in the Students' notes)

1. If you have not been given ready-cooked and coloured spaghetti to cut up, use the 5mL pastettes to accurately dispense a known amount of food colouring into a measured volume of water (about 15mL of food colouring is generally required per litre of water). Hint: when you use the pastettes, it is easier to measure volumes accurately if you press the part of the bulb where it joins the stem of the pastette.



Your teacher may suggest the amounts of colouring to use to obtain particular colours.

2. Put on safety glasses.
3. Bring the water to the boil.
4. Add the spaghetti. As it softens, use a glass rod or a spoon to push the spaghetti strands under the water.
5. Turn down the heat so that the water just simmers gently. Cook the spaghetti for no more than 10–12 minutes, stirring occasionally to prevent the spaghetti from sticking to the bottom of the beaker or saucepan If you overcook the spaghetti, it will be soft and therefore difficult to handle without breaking; if you don't cook it for long enough, it will not take up sufficient colouring. It is important to time the cooking to get the worms 'just right'.
6. When the spaghetti has cooked, turn off the heat and carefully pour away the water, collecting the spaghetti in a sieve.
7. Use a ruler and pair of scissors or a knife to cut the spaghetti strands into equal lengths (each about 50mm long). Take care not to stretch the 'worms' as you cut them. Unless you have decided otherwise, they should all be the same length.
8. Store the spaghetti 'worms' in a labelled plastic bag to prevent them from drying out until they are needed. The 'worms' can be stored in a fridge for a few days or frozen for a longer period if you wish. If the 'worms' stick together during storage, they can be unstuck using a little water.

Safety

Commercial food dyes, such as those in this kit and similar products available from supermarkets are safe for students to handle. The Royal Society for the Protection of Birds (RSPB) has said that it has no objection to birds being fed pasta, coloured or otherwise.

Where necessary, students should wear eye protection when heating liquids which, of course, should always be properly supervised.

Between lessons: Placing, counting and replacing the 'worms'

There is one important disadvantage to using spaghetti rather than the pastry baits preferred by Allen *et al*. After 24 hours (or less, in sunny and/or windy conditions) spaghetti will dry out. In wet conditions, the 'worms' will begin to disintegrate after 48 hours. This means that the 'worms' have to be completely replaced every time they are counted (probably every day). This can be an advantage, as counting then merely consists of collecting all the remaining spaghetti 'worms' and subtracting their number from the number that were placed originally. This helps to overcome one of the practical problems identified by Allen, namely that 'worms' can be missed or counted repeatedly. (Allen suggested using a strip of wood or cane that was gradually moved over the test area and that prey were counted when the strip crossed over them.)

Equipment and materials

Required by each student or working group

- Golf tees and twine to mark out feeding area, or a bird table
- Metre rule or tape measure
- Two varieties of prepared worms e.g. two different colours
- Two containers in which to collect the worms e.g. jugs or plastic bags
- Disposable plastic gloves
- Soap, water and paper towels for hand-washing

Optional items

- Webcam and motion-triggered software for capturing images of birds taking 'worms' e.g. Macintosh: Evocam (www.evological.com/evocam.html); Windows: webcamXP (www.webcamxp.com)
- Digital camera for photographing the feeding area
- Binoculars

Students' procedure (these instructions are also included in the Students' notes)

A. Placing the 'worms'

1. Measure out a feeding area in which to place the 'worms', marking it, if necessary, with golf tees and twine (if you use a bird table, you won't need to do this).
2. Place equal numbers of each of the types of 'worms' in the feeding area. The 'worms' will probably be scattered at random.
3. OPTIONAL: Take a photograph of the area to record the positions and numbers of the 'worms'. Ensure that you identify the photograph e.g. by date. Note that this will only be practical for small feeding areas, such as a bird table.
4. OPTIONAL: Train a webcam on the area and set up the motion-detecting software so that photos are taken only when movement is detected in the feeding area, enabling you to identify which species of bird (or other animals) have visited the feeding area.

B. Counting and replacing the 'worms'

1. OPTIONAL: Photograph the feeding area and use the photo for counting the numbers of each type of 'worm' remaining. This will only be practical for small feeding area such as a bird table.
2. Put on plastic gloves. This is necessary because birds can spread disease.
3. Collect the 'worms' of each of the two types, putting them into separate containers or bags as you do so.
4. Count how many of each sort of 'worm' is present, then calculate the number of 'worms' that must have been eaten by subtracting the numbers you have counted from the numbers of 'worms' of both varieties that were originally placed in the feeding area.
5. Each 'generation' of 'worms' contains the same total number (the total population size does not change). However, the ratio of the two types changes in each generation according to how many have been taken by birds, and therefore how many worms' of each type are left to 'breed'. Calculate how many new 'worms' now need to be placed on the feeding area as follows:

Total number of 'worms' of both types placed in the last generation = N

Number of worms of Type 1 (e.g. brown) collected = a

Number of worms of Type 2 (e.g. green) collected = b

Total number of 'worms' collected (of both types) = a + b = n

Therefore the number of new worms of each type to be placed is:

New Type 1 (e.g. brown) 'worms' required = N x a ÷ n

New Type 2 (e.g. green) 'worms' required = N x b ÷ n

6. Place the correct numbers of new 'worms' at random in the feeding area.
7. Wash your hands.

This collection procedure should be repeated each day or more frequently as required.

Safety

Birds carry parasites and bacteria such as *Salmonella*. Therefore it is important that students wear disposable plastic gloves when handling food that birds and other animals might have been in contact with and that they wash their hands after doing so.

Lesson 3: Examining and interpreting the results

The results should be plotted as a graph of the number of each type of 'worm' present vs time.

CURRICULUM LINKS

The National Curriculum for England, Wales and Northern Ireland has relatively little specified biology content at Key Stage 3. Consequently this work can be used to augment existing studies with relative freedom. With an appropriate open-ended approach to planning the work, many of the statements in the 'How science works' section of the National Curriculum are relevant.

In addition to gaining a better understanding of the principle of natural selection, students will learn about the design of practical studies, the collection and analysis of data and some of the statistical problems inherent in such studies. They will begin to appreciate the need to understand and allow for animal perception and behaviour when planning and carrying out the investigation. Teachers can also use this work to introduce other aspects of evolution e.g. modern genetic studies that cast light on the evolution of colour vision, or the rôle of sexual selection.

The National Curriculum includes the following relevant statement describing the biology content:

Key Stage 3
- all living things show variation, can be classified and are interdependent, interacting with each other and their environment.

This is developed further at Key Stage 4 by the following two statements:
- organisms are interdependent and adapted to their environments.
- variation within species can lead to evolutionary changes and similarities and differences between species can be measured and classified.

In Scotland, the practical activity can be used to support the new Curriculum for Excellence (S1–S3). The entire Scottish 3-18 curriculum is being reviewed at time of print. Please see http://www.ltscotland.org.uk/curriculumforexcellence/outcomes/science/index.asp for information. The Survival Rivals website will be updated to show the specific links once the new Scottish curriculum is published. The cover paper from the new draft states that "The new draft experiences and outcomes are designed to allow teachers to 'raise the bar', permitting greater depth and challenging young people to be ambitious in their learning, whilst ensuring that learning is enjoyable. They are designed to encourage a range of learning and teaching styles, whilst at the same time actively encouraging participation and the development of a range of skills - particularly important given the recognition given to schools' contribution to skills development in the Scottish Government's recently published Skills Strategy." (http://www.ltscotland.org.uk/Images/overarching_cover_paper_tcm4-442673.pdf. Survival Rivals will provide teachers with resources to enable them to achieve this.

Post-2009 legacy

Because this work is relatively inexpensive and the resources required are readily available, it has the potential to be repeated in schools following the Darwin anniversary year. The legacy will be a novel protocol covering aspects of animal behaviour and evolution that has not hitherto formed part of the secondary school practical science repertoire. You can buy some of the items supplied in this kit from Philip Harris at www.philipharris.co.uk.

Technician Notes

Equipment and materials required

The following items are provided in the Survival Rivals: I'm a Worm, Get Me Out of Here kit:

Item No	✓	Description	Quantity
1	☐	Spaghetti	500g
2	☐	Food Colouring - Red	1
3	☐	Food Colouring - Green	2
4	☐	Food Colouring - Black	1
5	☐	5mL Pastettes	3
6	☐	RSPB Bird Identification Book	1
7	☐	Wild Bird Food	1
8	☐	Sealable Plastic Bags - 4" x 5.5"	100 pack
9	☐	Disposable Polythene Gloves	50 pairs
10	☐	Twine - Biodegradable	1
11	☐	Golf Tees	20
12	☐	Key to identifying common birds	1

You will also need

- Rulers, 150–300mm (for measuring the 'worms')
- Scissors or relatively blunt knives e.g. plastic picnic knives (for cutting spaghetti)
- Hand-washing facilities and paper towels

Optional items

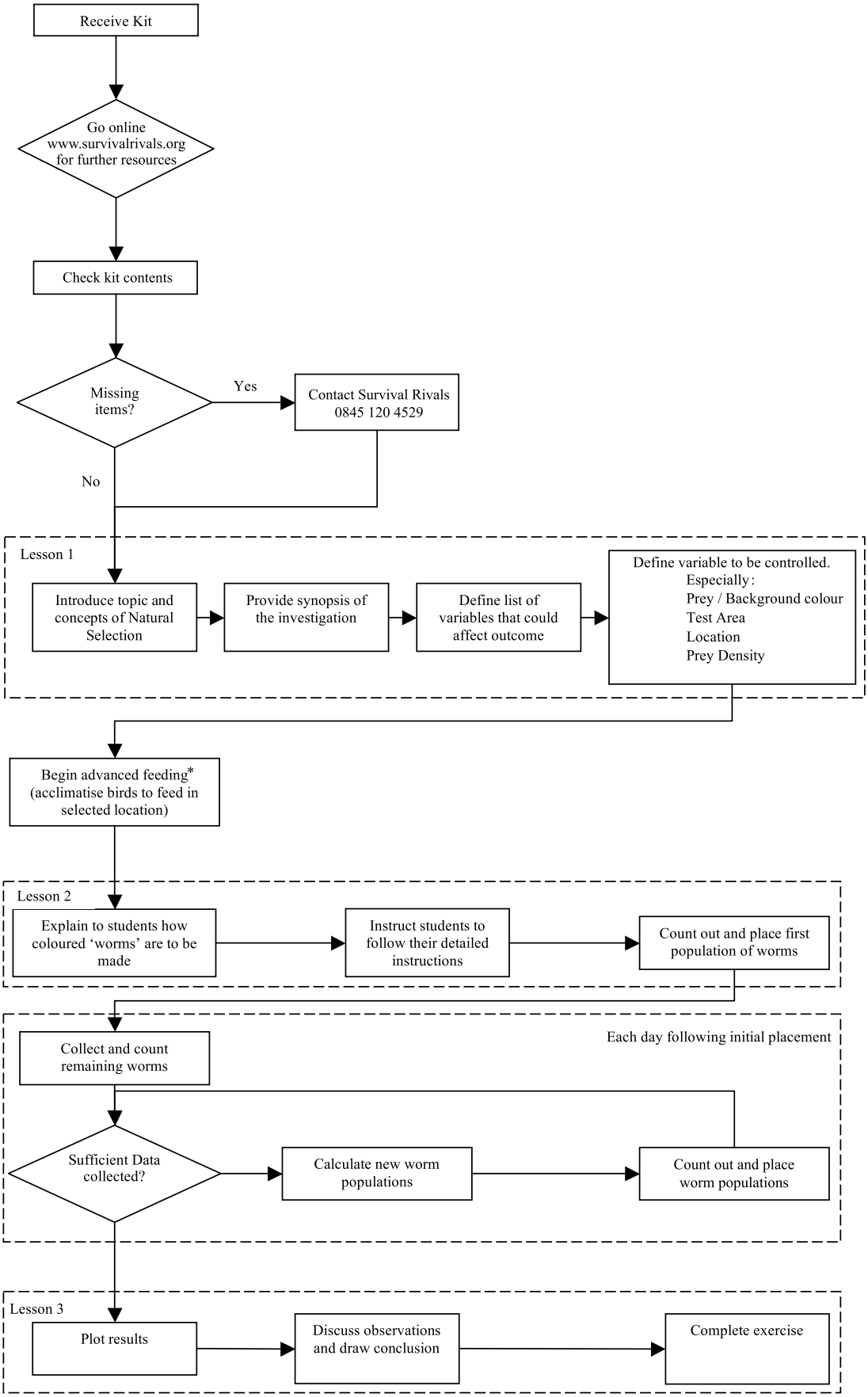
If students prepare their own worms:

- Bunsen burners
- Tripods and gauzes
- Heat-proof bench mats
- Eye protection

For setting up and observing/recording the investigation:

- Bird table
- Webcam and software, etc. e.g. Macintosh: Evocam (www.evological.com/evocam.html); Windows: webcamXP (www.webcamxp.com)

Detailed lesson-by-lesson instructions



* This can be started earlier if you wish

Introduction

Outline of the practical activity

After acclimatising the local bird population to a new source of food, equal numbers of two different-coloured spaghetti 'worms' are presented to birds. Each day (or at regular intervals), the remaining 'worms' are allowed to 'breed' and the two colour morphs are replaced in proportion to those which remain. Over time, the proportion of the type of 'worms' that are left uneaten by the birds increases, thereby simulating directional selection.

Students should be actively involved in planning the experiment, setting it up, and collecting and analysing the data. It may also be necessary for them to carry out some initial investigations to determine which types of bait will be taken by the local bird population and the best location for the bird feeding area.

IMPORTANT NOTE
A key requirement of this work is an area where the 'worms' can be placed, undisturbed, but observable by students, for the birds to prey upon. Without this (for example, if birds are scared away by human activity or by predators) the practical investigation will not be successful. For schools in many locations it may be necessary to set up a bird table, perhaps observed by a webcam, to carry out this work.

Who is this practical work suitable for?

We suggest that, as it is described here, the investigation is best suited to 11–14 year-old students. With modification, however, it could be used by much younger students, or with more advanced students if more complex experiments and analyses were carried out. The accompanying paper from the Journal of Biological Education provides additional ideas.

Planning and classroom organisation

When you receive the kit.

When you receive the kit, please check that everything is in the box (see the checklist above). If you find that items are missing, please contact Survival Rivals on **0845 120 4529** immediately.

None of the items in the kit are perishable or require special storage conditions. In addition, none of the items in the kit present a recognised safety hazard.

It is also a good idea at this stage to check that you have all of the other equipment and materials that are required.

The lessons: an overview

IMPORTANT
Critical to the success of this investigation is the selection of a suitable area in which to feed the birds. Ideally, this should be close to a window (for easy observation) and near a hedge or trees so that birds can head for cover (many species do not like to be in the open for long). For birds to feed freely, the area must not be disturbed during the day, either by humans or predators such as domestic cats. If you find that the 'worms' disappear at night, the most likely cause is nocturnal animals such as foxes, cats or rats. If either of these factors is a problem, a solution may be to set up a bird table that is inaccessible to predators, and possibly overseen by a webcam so that the area can be observed without disturbing the birds.

Advice from the Royal Society for the Protection of Birds (RSPB)

The RSPB has kindly offered the following advice.
It is recommended that the investigation is carried out between December and March, when wild food is scarce and birds will be more likely to take food that is put out for them.
Sufficient food should be put out for only one day's feeding at a time; ideally food should not be left out overnight.
Lacing the 'worms' with chilli powder will deter mammalian predators (birds cannot taste chilli).

Before you start: Advance feeding

Unless the area used for the work is one in which birds already feed, it will be necessary to teach the birds that food is available there. We suggest that food is placed in the feeding area every day for at least a week, and preferably two weeks before starting the experiment. For this purpose, a pack of wild bird food is provided in the kit. Additional wild bird food may be purchased from supermarkets, etc. if necessary. You may wish to supplement this food with bread or other food scraps to attract a wider range of species to the feeding area.

The investigation itself takes place over several lessons.

Lesson 1: Planning the investigation

Students will need to be introduced to the principle of natural selection and be given a general outline of the practical investigation and its purpose. The students should then, as much as possible, be involved in planning the precise details of the investigation. Teachers may wish to allocate 'worm' production, data recording and other tasks to individuals or groups of students. It will also be necessary to organise maintenance of the 'worm' selection (bird feeding) area, including the replacement of the 'worms'.

Lesson 2: Preparing the spaghetti 'worms'

Spaghetti is a convenient, robust and inexpensive form of bait. The spaghetti 'worms' can be prepared in bulk by the students themselves or by a teacher or technician in advance. The spaghetti must be dyed at least two different colours as it is cooked, then cut into identical lengths (50mm is ideal). If time permits, students may place the first lot of worms in the feeding area during this lesson. Alternatively, the 'worms' may be stored in sealed containers or plastic bags either in a fridge (for no more than a few days) or frozen until required. (If the spaghetti strands stick together during storage, they can be loosened with a little water.)

Daily: Counting and replacing the 'worms'

It will be necessary to organise a rota for students to count and replace the worms each day, in pairs or small groups. Students will probably have to do this in their lunch break or at another convenient time. The easiest way to count the worms is to collect all of the remaining worms and to subtract this number from the number of worms that were put out on the last occasion. Appropriate numbers of fresh 'worms' should then be placed in the feeding area. Note that it is therefore essential that the students understand how to calculate the replacement ratios.

Lesson 3: Analysing the data

Once data has been collected for a week or more, students plot the data graphically and interpret their results.

Group size

This work can be carried out by small groups of students but because the number of potential bird feeding sites will be limited it is probably best undertaken as a whole class investigation.

Lesson 1: Planning the investigation

The teacher should explain the process of natural selection and provide students with an outline of the investigation. As far as possible, students should plan the investigation themselves: this can be set in whole or in part as homework if appropriate. no special equipment will be required for this lesson, although teachers may wish to show students some prepared spaghetti 'worms'.

Lesson 2: Preparing the spaghetti 'worms'

The teacher should explain how the coloured pasta is prepared, cut into worm-sized lengths and stored. If appropriate, the students may cook and colour the spaghetti themselves. (It may be possible to 'borrow' a food preparation area with cookers and hotplates to do this rather than using Bunsen burners, tripods and beakers in a science lab.) Alternatively, the pasta can be cooked and coloured in advance by a teacher or technician, then students can cut it into worm-sized lengths.

The simplest and quickest method of colouring spaghetti is to add the food dye to the water in which the dried pasta is to be cooked (without adding oil to the cooking water). After simmering the pasta for 10–12 minutes, the coloured water can be disposed of. Although a second or third batch of pasta could be cooked in the same water, we do not recommend this as there is a progressive reduction in the intensity of the colour of the pasta which may lead to difficulties in reproducing the experiment should this prove necessary.

Pasta coloured in this way can be handled without excessive amounts of dye transferring to the hands. The dye binds to the pasta and does not readily wash out, even during heavy rainfall.

Individuals will no doubt wish to try different colours and colour intensities but for guidance we found that a grass-like green colour can be obtained by adding 15mL of green colouring to a litre of cooking water. Similarly, a dark red/brown colour can be achieved using a mixture of 5mL of black colouring and 10mL of red colouring in a litre of water. Should individual students or groups wish to experiment with their own colours these quantities can be reduced for convenience in the school laboratory e.g. using 250mL of coloured water in 500mL beakers.
Concentrated food colouring will stain skin, so those handling it may wish to wear protective gloves. If bench surfaces etc. are stained by the concentrated colouring, it can usually be removed using dilute bleach.

Sufficient 'worms' have to be prepared so that they can be replaced each time they are counted (see below). This should not be a problem, however, either practically or in terms of cost.

Equipment and materials
Required by each student or working group

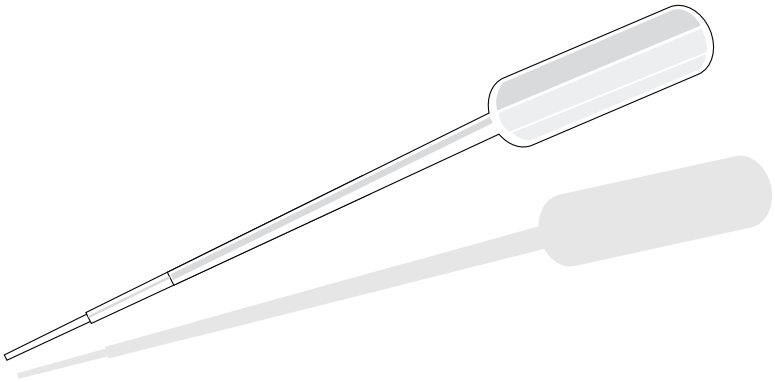
- Dried spaghetti (20 strands are sufficient for 100 x 50mm 'worms'). Note: 'Quick cook' spaghetti may not take up the food colouring before it becomes overcooked and therefore difficult to handle
- Food colouring: 5mL of black, 10mL of red and 15mL of green were required to make brown and green 'worms' as described above
- 5mL pastettes, for dispensing the food colouring (one for each type of food colouring)
- Bunsen burner, tripod and gauze or hotplate
- 500mL glass beakers or small saucepans, 2
- Glass rod, spoon or similar for stirring the spaghetti while it is cooking
- Safety glasses (if appropriate)
- Pair of scissors or blunt knife (such as a plastic picnic knife) for cutting the spaghetti into worm-length pieces
- Ruler for measuring the 'worms'
- Plastic bags or sealable containers for storing the 'worms'

Additional equipment required by the class

- Large plastic sieve or colander for straining the cooked 'worms'
- A clock to time the cooking
- Heat-proof gloves for handling the beaker of water
- Access to a fridge or freezer for storing the 'worms'
- Waterproof marker pen for labelling the bags of 'worms'
- OPTIONAL: Chilli powder to add to the 'worms' to deter predation by mammals

Students' procedure (these instructions are also included in the Students' notes)

1. If you have not been given ready-cooked and coloured spaghetti to cut up, use the 5mL pastettes to accurately dispense a known amount of food colouring into a measured volume of water (about 15mL of food colouring is generally required per litre of water). Hint: when you use the pastettes, it is easier to measure volumes accurately if you press the part of the bulb where it joins the stem of the pastette. Your teacher may suggest the amounts of colouring to use to obtain particular colours.



2. Put on safety glasses.

3. Bring the water to the boil.
4. Add the spaghetti. As it softens, use a glass rod or a spoon to push the spaghetti strands under the water.
5. Turn down the heat so that the water just simmers gently. Cook the spaghetti for no more than 10–12 minutes, stirring occasionally to prevent the spaghetti from sticking to the bottom of the beaker or saucepan. If you overcook the spaghetti, it will be soft and therefore difficult to handle without breaking; if you don't cook it for long enough, it will not take up sufficient colouring. It is important to time the cooking to get the worms 'just right'.
6. When the spaghetti has cooked, turn off the heat and carefully pour away the water, collecting the spaghetti in a sieve.
7. Use a ruler and pair of scissors or a knife to cut the spaghetti strands into equal lengths (each about 50mm long). Take care not to stretch the 'worms' as you cut them. Unless you have decided otherwise, they should all be the same length.
8. Store the spaghetti 'worms' in a labelled plastic bag to prevent them from drying out until they are needed. The 'worms' can be stored in a fridge for a few days or frozen for a longer period if you wish. If the 'worms' stick together during storage, they can be unstuck using a little water.

Safety

Commercial food dyes, such as those in this kit and similar products available from supermarkets are safe for students to handle. The Royal Society for the Protection of Birds (RSPB) has said that it has no objection to birds being fed pasta, coloured or otherwise.

Where necessary, students should wear eye protection when heating liquids which, of course, should always be properly supervised.

Between lessons: Placing, counting and replacing the 'worms'

There is one important disadvantage to using spaghetti. After 24 hours (or less, in sunny and/or windy conditions) spaghetti will dry out. In wet conditions, the 'worms' will begin to disintegrate after 48 hours. This means that the 'worms' have to be completely replaced every time they are counted (probably every day). This can be an advantage, as counting then merely consists of collecting all the remaining spaghetti 'worms' and subtracting their number from the number that were placed originally.

Equipment and materials

Required by each student or working group

- Golf tees and twine to mark out feeding area, or a bird table
- Metre rule or tape measure
- Two varieties of prepared worms e.g. two different colours
- Two containers in which to collect the worms e.g. jugs or plastic bags
- Disposable plastic gloves
- Soap, water and paper towels for hand-washing

Optional items

- Webcam and motion-triggered software for capturing images of birds taking 'worms' e.g. Macintosh: Evocam (www.evological.com/evocam.html); Windows: webcamXP (www.webcamxp.com)
- Digital camera for photographing the feeding area
- Binoculars

Students' procedure (these instructions are also included in the Students' notes)

A. Placing the 'worms'

1. Measure out a feeding area in which to place the 'worms', marking it, if necessary, with golf tees and twine (if you use a bird table, you won't need to do this).
2. Place equal numbers of each of the types of 'worms' in the feeding area. The 'worms' will probably be scattered at random.
3. OPTIONAL: Take a photograph of the area to record the positions and numbers of the 'worms'. Ensure that you identify the photograph e.g. by date. Note that this will only be practical for small feeding areas, such as a bird table.
4. OPTIONAL: Train a webcam on the area and set up the motion-detecting software so that photos are taken only when movement is detected in the feeding area, enabling you to identify which species of bird (or other animals) have visited the feeding area.

B. Counting and replacing the 'worms'

1. OPTIONAL: Photograph the feeding area and use the photo for counting the numbers of each type of 'worm' remaining. This will only be practical for small feeding area such as a bird table.
2. Put on plastic gloves. This is necessary because birds can spread disease.
3. Collect the 'worms' of each of the two types, putting them into separate containers or bags as you do so.
4. Count how many of each sort of 'worm' is present, then calculate the number of 'worms' that must have been eaten by subtracting the numbers you have counted from the numbers of 'worms' of both varieties that were originally placed in the feeding area.
5. Each 'generation' of 'worms' contains the same total number (the total population size does not change). However, the ratio of the two types changes in each generation according to how many have been taken by birds, and therefore how many 'worms' of each type are left to 'breed'. Calculate how many new 'worms' now need to be placed on the feeding area as follows:

- Total number of 'worms' of both types placed in the last generation = N
- Number of worms of Type 1 (e.g. brown) collected = a
- Number of worms of Type 2 (e.g. green) collected = b
- Total number of 'worms' collected (of both types) = a + b = n
- Therefore the number of new worms of each type to be placed is:
- New Type 1 (e.g. brown) 'worms' required = N x a ÷ n
- New Type 2 (e.g. green) 'worms' required = N x b ÷ n

6. Place the correct numbers of new 'worms' at random in the feeding area.
7. Wash your hands.

This collection procedure should be repeated each day or more frequently as required.

Safety

Birds carry parasites and bacteria such as *Salmonella*. Therefore it is important that students wear disposable plastic gloves when handling food that birds and other animals might have been in contact with and that they wash their hands after doing so.

Lesson 3: Examining and interpreting the results

The results should be plotted as a graph of the number of each type of 'worm' present vs time. Students will only require graph paper or appropriate software, etc.

Student Notes

Introduction

How exceedingly stupid not to have thought of that

A hundred and fifty years ago, Charles Darwin published his explanation of why there are so many different living things on Earth, each of them so well adapted to its environment. Others had tried to explain this observation before but unlike them, Darwin had spent years collecting evidence to support his theory of evolution by natural selection.

Many people think that Darwin's explanation of how life has evolved (and continues to evolve) is the most important idea ever to occur to a scientist. Even so, it is really a very simple idea at heart — so simple in fact, that one of his friends, Thomas Henry Huxley, said, after reading On the Origin of Species: "... how exceedingly stupid not to have thought of that".

Darwin's principal idea to explain evolution was natural selection. He realised that:

- living things produce offspring which vary — they are not all the same;
- there is a shortage of resources (food, light, places to live, animals to mate with etc.);
- individuals that do best in this 'struggle for existence' will tend to leave more offspring, passing on their successful features to subsequent generations.

Therefore, over time, organisms with certain characteristics will become more common, while others will become less common and may die out. Over a long period of time, these small differences between individuals add up to large differences, and eventually new species that are no longer able to interbreed are produced. The practical investigation you are going to carry out provides a simulation of natural selection, using birds to help in the process: it's bird-powered evolution.

Outline of the practical activity

After 'teaching' the local bird population that food is available, you will put two different-coloured spaghetti 'worms' out for them to feed on. Each day (or at regular intervals), the 'worms' that have not been eaten will be allowed to 'breed'. Over time, the numbers of the two different types of 'worms' will change, simulating directional selection.

First you will have to plan the experiment carefully. You may also carry out some initial experiments to discover which colour of 'worm' the local bird population prefers and the best location for the bird feeding area.

IMPORTANT

For this investigation to provide useful results, you will need to find a suitable area in which to feed the birds. Ideally, this should be close to a window (for easy observation) and near a hedge or trees so that birds can head for cover (many species do not like to be in the open for long). For birds to feed freely, the area must not be disturbed during the day, either by humans or predators such as domestic cats. If you find that the 'worms' disappear at night, the most likely cause is nocturnal animals such as foxes, cats or rats. If you have these problems, a solution may be to set up a bird table that is inaccessible to predators, and possibly overseen by a webcam so that the area can be observed without disturbing the birds.

Advice from the Royal Society for the Protection of Birds (RSPB)

The RSPB has kindly offered the following advice.

- It is recommended that the investigation is carried out between December and March, when wild food is scarce and birds will be more likely to take food that is put out for them.
- Sufficient food should be put out for only one day's feeding at a time; ideally food should not be left out overnight.
- Birds will not be harmed by eating spaghetti, whether it is coloured or not.
- Lacing the 'worms' with chilli powder will deter mammalian predators (birds cannot taste chilli).

Before you start: Advance feeding

Unless the area used for the work is one in which birds already feed, it will be necessary to teach the birds that food is available there. We suggest that food is placed in the feeding area every day for at least a week, and preferably two weeks before starting the experiment. You may wish to provide extra food such as bread or other food scraps to attract a wider range of species to the feeding area.

Lesson 1: Planning the investigation

You will first need to plan the investigation carefully. Your teacher may set part of this job as homework. When making your plan, will need to:

- choose suitable 'worm' colours (for example, camouflaged against the background);
- choose suitable background colours if you are not going to put the food on grass or soil;
- find a good place for the bird feeding area;
- decide how the worms are to be distributed within the feeding area (for example, in rows or some other pattern or at random);
- decide how many 'worms' to put in the feeding area;
- decide on the length of the 'worms' (if the worms are different sizes, the birds may just eat the big ones);
- how often and when you are going to count the worms (your teacher may suggest that different people do this job each time);
- decide on a method of counting 'worms' and replacing ones that have been eaten;
- decide whether you count half-eaten or pecked 'worms';
- decide what to do about 'worms' that have been thrown out of the feeding area;
- what to do when counting is not possible (for example, at the weekend);
- decide how you are going to record the results and pass on the numbers to other students who may need them;
- decide how the results will be presented and analysed (for example in graphs or tables, or on a spreadsheet).

Lesson 2: Preparing the spaghetti 'worms'

Your teacher will explain how the coloured spaghetti is made, cut into worm-sized lengths and stored. You may be asked to cook and colour the spaghetti yourself, or it may be given to you ready to cut into worm-sized lengths.

You will need sufficient 'worms' so that they can be replaced each time they are counted.

Equipment and materials
Required by each student or working group

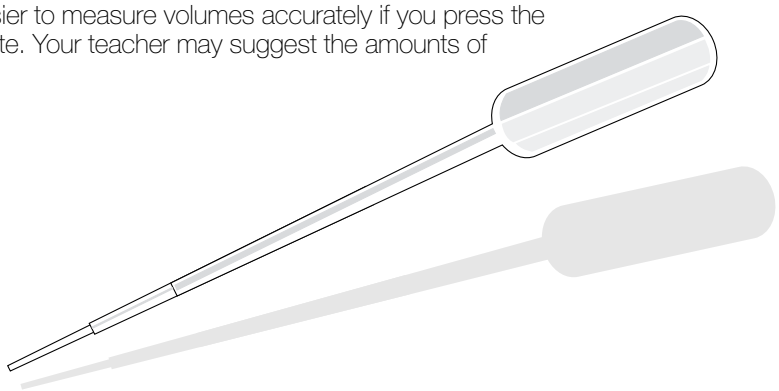
- Dried spaghetti (20 strands are sufficient for 100 x 50mm 'worms')
- Food colouring
- 5mL pastettes, for dispensing the food colouring (one for each type of food colouring)
- Bunsen burner, tripod and gauze or hotplate
- 500mL glass beakers or small saucepans, 2
- Glass rod, spoon or similar for stirring the spaghetti while it is cooking
- Safety glasses (if appropriate)
- Pair of scissors or blunt knife (such as a plastic picnic knife) for cutting the spaghetti into worm-length pieces
- Ruler for measuring the 'worms'
- Plastic bags or sealable containers for storing the 'worms'

Additional equipment required by the class

- Large plastic sieve or colander for straining the cooked 'worms'
- A clock to time the cooking
- Heat-proof gloves for handling the beaker of water
- Access to a fridge or freezer for storing the 'worms'
- Waterproof marker pen for labelling the bags of 'worms'
- OPTIONAL: Chilli powder to add to the 'worms' to deter predation by mammals

Procedure

1. If you have not been given ready-cooked and coloured spaghetti to cut up, use the 5mL pastettes to accurately dispense a known amount of food colouring into a measured volume of water (about 15mL of food colouring is generally required per litre of water). Hint: when you use the pastettes, it is easier to measure volumes accurately if you press the part of the bulb where it joins the stem of the pastette. Your teacher may suggest the amounts of colouring to use to obtain particular colours.



2. Put on safety glasses.
3. Bring the water to the boil.
4. Add the spaghetti. As it softens, use a glass rod or a spoon to push the spaghetti strands under the water.
5. Turn down the heat so that the water just simmers gently. Cook the spaghetti for no more than 10–12 minutes, stirring occasionally to prevent the spaghetti from sticking to the bottom of the beaker or saucepan. If you overcook the spaghetti, it will be soft and therefore difficult to handle without breaking; if you don't cook it for long enough, it will not take up sufficient colouring. It is important to time the cooking to get the worms 'just right'.
6. When the spaghetti has cooked, turn off the heat and carefully pour away the water, collecting the spaghetti in a sieve.
7. Use a ruler and pair of scissors or a knife to cut the spaghetti strands into equal lengths (each about 50mm long). Take care not to stretch the 'worms' as you cut them. Unless you have decided otherwise, they should all be the same length.
8. Store the spaghetti 'worms' in a labelled plastic bag to prevent them from drying out until they are needed. The 'worms' can be stored in a fridge for a few days or frozen for a longer period if you wish. If the 'worms' stick together during storage, they can be unstuck using a little water.

Safety

Commercial food dyes, such as those in this kit and similar products available from supermarkets are safe to handle. The Royal Society for the Protection of Birds (RSPB) has said that it has no objection to birds being fed pasta, coloured or otherwise.

Where necessary, you should wear eye protection when heating liquids.

Between lessons: Placing, counting and replacing the 'worms'

After 24 hours (or less, in sunny and/or windy conditions) the spaghetti 'worms' will dry out. In wet conditions, the 'worms' will begin to disintegrate after 48 hours. This means that the 'worms' have to be completely replaced every time they are counted (probably every day).

Equipment and materials
Required by each student or working group

- Golf tees and twine to mark out feeding area, or a bird table
- Metre rule or tape measure
- Two varieties of prepared worms e.g. two different colours
- Two containers in which to collect the worms e.g. jugs or plastic bags
- Disposable plastic gloves
- Soap, water and paper towels for hand-washing

Optional items

- Webcam and motion-triggered software for capturing images of birds taking 'worms'
- Digital camera for photographing the feeding area
- Binoculars

Procedure

A. Placing the 'worms'

1. Measure out a feeding area in which to place the 'worms', marking it, if necessary, with golf tees and twine (if you use a bird table, you won't need to do this).
2. Place equal numbers of each of the types of 'worms' in the feeding area. The 'worms' will probably be scattered at random.
3. OPTIONAL: Take a photograph of the area to record the positions and numbers of the 'worms'. Ensure that you identify the photograph e.g. by date. Note that this will only be practical for small feeding areas, such as a bird table.
4. OPTIONAL: Train a webcam on the area and set up the motion-detecting software so that photos are taken only when movement is detected in the feeding area, enabling you to identify which species of bird (or other animals) have visited the feeding area.

B. Counting and replacing the 'worms'

1. OPTIONAL: Photograph the feeding area and use the photo for counting the numbers of each type of 'worm' remaining. This will only be practical for small feeding area such as a bird table.
2. Put on plastic gloves. This is necessary because birds can spread disease.
3. Collect the 'worms' of each of the two types, putting them into separate containers or bags as you do so.
4. Count how many of each sort of 'worm' is present, then calculate the number of 'worms' that must have been eaten by

subtracting the numbers you have counted from the numbers of 'worms' of both varieties that were originally placed in the feeding area.

5. Each 'generation' of 'worms' contains the same total number (the total population size does not change). However, the ratio of the two types changes in each generation according to how many have been taken by birds, and therefore how many 'worms' of each type are left to 'breed'. Calculate how many new 'worms' now need to be placed on the feeding area as follows:

- Total number of 'worms' of both types placed in the last generation = N
- Number of worms of Type 1 (e.g. brown) collected = a
- Number of worms of Type 2 (e.g. green) collected = b
- Total number of 'worms' collected (of both types) = a + b = n
- Therefore the number of new worms of each type to be placed is:
- New Type 1 (e.g. brown) 'worms' required = N x a ÷ n
- New Type 2 (e.g. green) 'worms' required = N x b ÷ n

6. Place the correct numbers of new 'worms' at random in the feeding area.
7. Wash your hands.

This collection procedure should be repeated each day or more frequently as required.

Safety

Birds carry parasites and bacteria such as *Salmonella*. Therefore it is important that you wear disposable plastic gloves when handling food that birds and other animals might have been in contact with and that you wash their hands after doing so.

Lesson 3: Examining and interpreting the results

The results should be plotted as a graph of the number of each type of 'worm' present vs time. You may be asked to do this using a spreadsheet or other software.

Acknowledgements

Wellcome Trust

The Wellcome Trust is the most diverse biomedical research charity in the world. It spends £600 million every year in the UK and around the world to support and promote research that will improve the health of humans and animals. The Trust's funding has supported the work of scientists that has helped to expand our understanding of evolution in humans and other species. For example, research on the human genome has revealed patterns of human migration and ancestry. As part of Darwin 200, the Wellcome Trust is engaging with the public in educational, broadcast and cultural activities.

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Website: www.wellcome.ac.uk

wellcome trust

Philip Harris

Philip Harris has an outstanding heritage in education, dating back to 1817. They are the science education market leader both in the UK and internationally, with an unbeatable range. Their science resources cover Early Years right through to Further Education and are for teachers and technicians who want good value innovative resources, relevant to the changing demands of the science curriculum.

Philip Harris are producing and distributing the three kits for Survival Rivals.
Thanks to Emma Markey, Sharon Hawksworth, John Cotton and John Hurst.

Website: www.philipharris.co.uk

philip harris

National Centre for Biotechnology Education, University of Reading

National Centre for Biotechnology Education, University of Reading was the first school biotechnology centre in the world. Since its establishment in 1984-5, the NCBE has gained an international reputation for the development of innovative educational resources.

The NCBE has produced detailed protocols for Survival Rivals activities for secondary students, advised in the pilot stage of the project and written resources to accompany the experiments.
Thanks to Dean Madden and John Schollar.

Website:www.ncbe.reading.ac.uk

University of Reading

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Wellcome Trust Education Activities

The Wellcome Trust is committed to engaging with the public on science and has a strong interest in supporting science teachers through initiatives such as the National Science Learning Centre (http://www.sciencelearningcentres.org.uk). The Trust also produces a twice-yearly publication, the Big Picture, for science teachers and there is an edition of this all about evolution which is free to download or order at www.wellcome.ac.uk/bigpicture/evolution.

To celebrate 200 years since the birth of Charles Darwin, the Wellcome Trust is commissioning, developing and funding a unique and ambitious set of projects to engage the widest UK public with Darwin, his ideas, and his influence on contemporary science and culture.

The Trust is providing Darwin-inspired practical activity kits for every state school in the UK. Survival Rivals is the Wellcome Trust's offering for secondary schools. The Great Plant Hunt is the equivalent programme for primary schools.
See www.greatplanthunt.org for more information.

The Trust has developed the Tree of Life – an interactive fly-through of evolution on Earth, narrated by Sir David Attenborough- as well as Darwin-inspired visual arts, poetry and short film projects, placing Darwin and evolution into contemporary culture.
See www.wellcometreeoflife.org for more information.

Working with the BBC, the Wellcome Trust is highlighting a series of short visual clips, that help teachers to teach evolution related topics, available on BBC Learning Zone Broadband www.bbc.co.uk/learningzone.

DNA to Darwin is an education project funded by the Wellcome Trust and run by the NCBE (National Centre for Biotechnology Education). DNA to Darwin will allow 16-19 year old biology students to explore the molecular evidence for evolution by using computers to analyse DNA and protein sequence data. Each of the student activities centre around an engaging story from recent research in molecular genetics encompassing microbiology, plant and animal biology and human evolution.
See www.dnadarwin.org.

Find out more about all the Wellcome Trust's Darwin projects at www.wellcome.ac.uk/darwin200.

Other Links

Great Plant Hunt, Survival Rivals equivalent offering for primary schools, in partnership with Kew Gardens www.greatplanthunt.org

BBC Learning Zone includes clips on evolution www.bbc.co.uk/learningzone

Tree of Life An interactive fly-through of evolution on Earth, narrated by Sir David Attenborough. www.wellcometreeoflife.org

DNA to Darwin free resources for 16-19 year olds around molecular evidence of evolution www.dnadarwin.org

Wellcome Trust's Darwin projects www.wellcome.ac.uk/darwin200

Darwin200 is a national programme of events celebrating Charles Darwin's scientific ideas and their impact around his two hundredth birthday on 12 February 2009 www.darwin200.org

Evolution Megalab Did you know that thanks to a common little snail that you can find in your garden, in the park or under a hedge, you can see evolution in your own back yard? www.evolutionmegalab.org

CREST Awards to accredit young people's work in science and technology www.britishscienceassociation.org/crest

Royal Society for the Protection of Birds Information about birds, including education pages www.rspb.org.uk

Society for General Microbiology Information about microbiology, including educational resources www.sgm.ac.uk

Singtastic Featuring the Mr Darwin song www.singtastic.com

Teachers TV have produced a range of programmes for Darwin200 www.teachers.tv/evolution

Practical Biology Find lots of other investigations to carry out in school www.practicalbiology.org

Association for Science Education helping teachers teach science www.ase.org.uk

Your Genome Educational information from the Sanger Centre www.yourgenome.org

Inside DNA A genomic revolution www.insidedna.org.uk

ANY QUESTIONS, PLEASE CALL:

0845 120 4529

OR VISIT:

www.survivalrivals.org

THE KITS ARE FUNDED BY

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