BIODIVERSITY

Biodiversity is one of a series of enquiries and additional resources which together form **Beyond fair testing: Teaching different types of scientific enquiry,**

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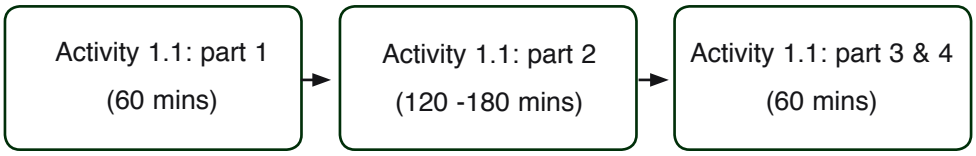
BIODIVERSITY: OVERVIEW

Enquiry type: This enquiry is fairly open, allowing pupils to choose a question to investigate. Likely enquiry types that pupils might choose are exploring, pattern seeking, fair testing and designing a system.
Suggested year group or KS: This enquiry is designed for use with KS3 students, but can also be used effectively with students at KS4.

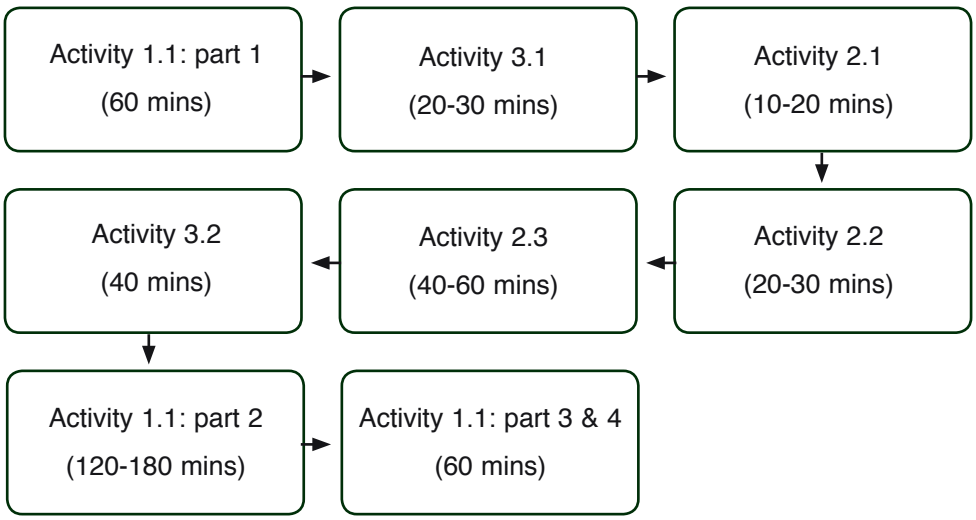
Section	Activity	Links to KS3 PoS/ Scheme of work	Links to KS4 PoS/ Scheme of work	Learning objectives Students will be able to:	Assumed prior Knowledge and Understanding
1. Core enquiry	1.1	**Sc1: investigative skills:** Planning Obtaining and presenting evidence, Considering evidence, Evaluating	**How science works:** Data, evidence, theories and explanations Practical and enquiry skills Communication skills	• generate a suitable question for a scientific enquiry, • decide on an approach to enquiry that matches their research questions, • make decisions about what to observe or measure and how to - make those observations or measurements.	• Different kinds of enquiry. • How to obtain reliable evidence • Background knowledge needed will depend on the enquiry chosen.
2. Background knowledge	2.1	**Sc2: Living things in their environment QCA SoW:** 7C Environment and feeding relationships 8D Ecological relationships 9M Investigating scientific questions	**Organisms and health** (5a and 5b)	• explain and use scientific words relating to the school field as an ecosystem.	
	2.2			• describe what worms eat, their habitat and the effects worms have on the ecosystem.	
	2.3			• describe the key features of grass and dandelion plants, • apply their knowledge of the features of plants to explain why certain plants may not survive well on a school field.	
3. Procedural understanding	3.1	**Sc1 Investigative Skills:** Planning	**How science works:** Data, evidence, theories and explanations. Practical and enquiry skills Communication skills	• ask questions that can be investigated scientifically and decide on an appropriate approach to find the answers.	
	3.2	**Sc1 Investigative Skills:** Planning		• look at a research question and identify what must be measured, • identify criteria to be used in deciding how to measure biological variables.	

BIODIVERSITY: ROUTES

Route 1
(assumes students have already identified skills and knowledge to begin activity 1.1)
Overall time is roughly 4 to 5 hours.



Route 2
(uses all activities from sections 2 and 3 to provide relevant knowledge and procedural understanding to begin core enquiry in section 1)
Overall time is roughly 5 to 8 hours.



HEALTH AND SAFETY

For practical activities, the Science Enhancement Programme has tried to ensure that the experiments are healthy and safe to use in schools and colleges, and that any recognised hazards have been indicated together with appropriate control measures (safety precautions). It is assumed that these experiments will be undertaken in suitable laboratories or work areas and that good laboratory practices will be observed. Teachers should consult their employers' risk assessments for each practical before use, and consider whether any modification is necessary for the particular circumstances of their own class/school. If necessary, CLEAPSS members can obtain further advice by contacting the Helpline on 01895 251496 or e-mail science@cleapss.org.uk.

ACTIVITY 1.1:
INVESTIGATING THE SCHOOL FIELD ECOSYSTEM
(CORE ENQUIRY ACTIVITY)

WHAT STUDENTS DO

This enquiry is more open than others in this series. Students are introduced to the school field as an ecosystem. They are presented with a wide range of questions about life in the school field that they can try to answer and are given opportunities to come up with their own questions. Students decide what question they will investigate and decide on an appropriate approach for the investigation (**Activity 3.1**, Section 3 provides support for this). They research background information to help them clarify their research questions and plan how they will carry out their enquiries.

Note: *Since ecological enquiries are best studied 'in the field', this activity is best done in the summer term or early in the autumn term.*

The range of questions that can be asked is enormous and for each question students will need to know something about the living organisms being studied. The activities in Section 2 introduce students to background knowledge about worms and two plants (grass and dandelions) and we recommend that you limit students to these areas when you try this activity for the first time. Other obvious topics for investigation are soil and identifying plants (by their common name), but no materials are provided here to support work in these areas.

Learning objectives
There are some core learning objectives for **'Biodiversity'** and there will also be specific learning objectives related to specific kinds of enquiry.

Core learning objectives
Students will be able to:

- generate a suitable question for a scientific enquiry,
- decide on an approach to enquiry that matches their research questions,
- make decisions about what to observe or measure and how to make those observations or measurements.

Specific learning objectives

In addition to the objectives above, different approaches, or kinds of enquiry, lend themselves to targeting certain specific objectives. We suggest that the following objectives should also be emphasised for specific kinds of enquiry:

- **fair testing:** students will be able to identify the independent variable and the dependent variable and control all other relevant variables.
- **pattern-seeking (surveys):** students will be able to select samples that will allow exploration of possible factors affecting a dependent variable.
- **identifying and classifying:** students will be able to construct a series of questions that are suitable for placing living things into groups or which identify individual members of a group.
- **exploring:** students will be able to select suitable factors to observe over time and design appropriate ways of recording the data.
- **investigating models:** students will be able to formulate explanations that can be tested empirically.
- **designing a system:** students will be able to design techniques for making reliable measurements.

Resources needed

Student Activity 1.1: *Investigating the school field ecosystem.*
Student Activity 1.1, *Evaluation sheets a (advice), b and c: (the evaluation).*

The apparatus needed will vary according to the questions that students investigate. The following list is therefore a list of core apparatus.

- beakers
- callipers
- electronic balance (accurate to 0.01g)
- light meter
- measuring cylinders
- oven (at 110°C) for drying plant matter to measure biomass
- protractors
- quadrats
- rulers
- scissors
- biodegradable detergent solution
- stop clocks
- thermometers
- There are also possibilities in this enquiry for the use of remote sensing using data logging equipment to measure variables such as light and temperature.
- Access to IT facilities (optional) for students to write up their enquiries and complete the evaluation sheets.

NOTES AND SUGGESTIONS FOR CLASSROOM ACTIVITIES

Depending on the enquiries students decide to carry out, we estimate that the enquiry will take between 4 and 8 hours to complete.

The enquiry falls into four parts:
1 Planning
2 Obtaining the evidence
3 Considering evidence
4 Evaluating

Part 1: Planning

Part 1 A: Start by introducing students to the school field ecosystem.

Group work:
Divide the class into groups of 3 or 4. Ask students to 'brainstorm' what lives in the school field. Give them two minutes only. Everyone in the group should make suggestions, and one person in the group should write them down.

Plenary:
Collect some suggestions on the board. As you write on the board, begin to place interdependent living organisms together. When you have collected enough living organisms on the board, ask the class to describe how they are linked.

Part 1B: Generating research questions

Group work:
Ask the students to 'brainstorm' questions that could be asked about the livings organisms on the school field. Again, one person in the group should write down their suggestions.

Plenary:
Collect a good range of questions on the board.
Note: **Activity 3.1** introduces students to a range of questions and different possible approaches to answering them. We recommend you do this activity before moving on.

After students have considered questions and possible approaches to answering them, they can select a question to investigate.
You will need to make clear to the students the constraints that they are working under:

- If you are going to limit students' enquiries to worms, grass and dandelions, you will need to make this clear to students.
- Students will need to be reminded that their enquiry must be able to be carried out with normal school apparatus.
- Students will need to know how long they have got to collect evidence. We suggest about 2 to 4 hours.

Part 1C: Obtaining relevant background knowledge and procedural understanding

Students will need some background knowledge on the question they are going to research; they will also need to know what they need to measure and how to measure it.
You may need to select further activities from Sections 2 and 3 at this stage to ensure that students have the relevant background knowledge and procedural understanding before moving on:

Activity 2.1 introduces some scientific vocabulary related to ecology and is recommended for all groups; **Activities 2.2 and 2.3** can be selected for different groups according to the specific research question they have chosen; **Activity 3.2** is designed to help students to clarify what they are going to observe or measure and how they are going to do it.

Specific practical techniques for particular enquiries

It may be useful to introduce some specific practical techniques for particular enquiries:
Collecting worms: Worms should be handled with care and should not be left in strong sunlight or dry conditions which they will not survive. Worms can be collected by pouring a weak solution of detergent over soil or turf: earthworms will come to the surface. These should then be rinsed with a little water to get rid of the detergent. After study, the worms should be returned to the soil. To improve the chances of students successfully collecting some worms, it is also helpful to identify suitable areas before beginning this aspect of the enquiry.

Wormeries: Many biology departments have a wormery. This could be a useful tool for studying worms. Wormeries could be set up with a choice of food on the surface to see which foods worms eat. Alternatively, one end of the wormery could be kept damp and the other end dry to see if worms have a preference for these environments.

Growing plants: If students want to look at the effect of one variable on plant growth, it may be best to complement field work by setting up a fair test in the laboratory. For example, 'Do dandelions in the shade have longer leaves than those in the light?' may be best answered by a fair-test. You could anticipate possible student enquiries and grow some dandelion and grass plants from seeds prior to the enquiries.

Part 1D: Reformulating the research question

Once students have familiarised themselves with basic knowledge in the area of their question, they will need to revisit the research question (and perhaps reformulate it) before planning what apparatus they will need, and how they will collect the data they need.

You will need to ensure that each group has a clear research question and practical plans before they go on.

Part 2: Obtaining evidence

We recommend at least two to four separate sessions for this part of the enquiry.

Managing the class on the school field is an important issue.
You will need to:

- know what data each group is collecting and what apparatus they plan to use
- where they plan to work, and
- set time limits for completion of each round of data collection.

Make sure you know who else may be working on the field - and where- during these sessions, as well as identifying any potential hazards or features which would make adequate supervision difficult.

Part 3: Considering evidence

The last two parts of the enquiry may take about 1 hour to complete.

Students should describe their analysis and write their conclusion, if their data allows them to reach one.

Part 4: Evaluating

Student groups will be involved in writing up their enquiry, evaluating another group's enquiry and improving and evaluating their own enquiry based on their peers' evaluation.

Note: *This is easier to do without risk to original versions if students are able to produce their reports using a word-processing package.*

Group work:
Different groups will be carrying out different enquiries. Ask the students to write up their enquiries in a way that will make it easy for other groups to understand what they have done. They do not need to include an evaluation at this stage. Get groups with different research questions to swap their write-ups with one another.

Group work:
Each group should study the write up and use Student **Activity 1.1, *Evaluation sheets a, b and c*** to formulate questions to:

- clarify how data have been collected
- judge how reliable the evidence is
- evaluate how well the conclusions drawn are supported by evidence.

Each group should select one group member who will explain these questions and comments to their partner group.

Group work:
Students should be given time to improve their write-ups and to write an evaluation of the enquiry. (Again, this is easier and quicker if the reports and evaluations have been produced and stored on a computer).

Further reading

You can find additional support for teaching students some of the procedural knowledge in **Investigations: Developing Understanding**, by A. Goldsworthy, V.Wood-Robinson, and R.Watson (published by ASE, Hatfield, 2000).

The following units are likely to be particularly useful:

- Unit 8 about range interval and number of values,
- Units 9 and 19 about sample characteristics,
- Units 10, 11, 17 and 18 about repeat measurements, accuracy and reliability.
- Unit 14 about describing relationships and patterns,
- Unit 15 about relating evidence to scientific knowledge.

ACTIVITY 2.1:
THE SCHOOL FIELD ECOSYSTEM

WHAT STUDENTS DO

Students read a passage about the school field as an ecosystem and use it to match scientific words to their definitions.

Learning objectives

Students will be able to

- explain and use some scientific words related to the school field as an ecosystem.

Resources needed

- **Student Activity 2.1: *The school field ecosystem***
- (Optional) Access to computers to allow students to carry out the word-matching task as a drag-and-drop or copy-and-paste activity using the word version available on the CD.
- (Optional) Access to scientific dictionary or to online reference material such as Encarta

NOTES AND SUGGESTIONS FOR CLASSROOM ACTIVITIES

This is an introductory activity to familiarise students with some of the concepts used throughout the enquiry. The text should provide enough information to match the words to the definitions.

The activity could be used for whole class discussion with an interactive whiteboard or data projector, for individual or group work on paper, or may be set as a paper-based homework. If students are going to complete the word-matching task at a computer it is still advisable to give students a printed copy of the passage to refer to.

ANSWERS

Scientific term	Definition
Environment	All of the external factors affecting an organism. These factors may be other living organisms (biotic factors) or nonliving variables (abiotic factors), such as temperature, rainfall, day length, wind, ocean currents.
Trampling	Walking over plants. Grasses are adapted to withstand being trodden on.
Biomass	Abbreviation for biological mass, the amount of living material provided by a given area of the earth's surface.
Angiosperms	Flowering plants, the dominant form of plant life.
Annelid	Name for about 9,000 species of worm-like invertebrate animals with well-developed segmentation.
Photosynthesis	Process by which green plants and certain other organisms use the energy of light to convert carbon dioxide and water into the simple sugar glucose.
Quadrat	A piece of apparatus made from plastic or metal. It is used to identify a specific area of ground, usually 1 square metre, for ecological study.
Ecosystem	Organisms living in a particular environment, such as a forest or a coral reef, and the parts of the environment that affect them.
Ecology	The study of the relationship of plants and animals to their physical and biological environment.

ACTIVITY 2.2:
WORMS

WHAT STUDENTS DO

Students use the internet to find facts about earthworms. They then organise sentences about worms and write paragraphs about the feeding of worms, their benefit to the soil and their habitat.

Learning objectives

Students will be able to:

- describe what worms eat, their habitat and the effects worms have on the ecosystem.

Resources needed

- **Student Activity 2.2: *Worms.***
- Access to the internet (for Part A).
- Scissors.

NOTES AND SUGGESTIONS FOR CLASSROOM ACTIVITIES

***Note:** If you have access to computers, you may prefer to use the word version of part B of this activity to allow students to drag the text boxes into groups and write in the correct label for each group.*

This activity may be given to students who decide to engage in an enquiry involving worms.

Answers to questions

Part B

1. The statements can be grouped as follows:

- Feeding: A, E, G, I
- Benefit to the soil: A, C, D, F, K, L
- Habitat: B, C, H, J

ACTIVITY 2.3:
PLANTS

WHAT STUDENTS DO

Students use the internet to find out about plants. They then read a passage and use it to identify the parts of plants and what plants need to help them survive. Next, they use textual information to label a diagram of a dandelion. Finally, they use what they have learnt in the previous part of the activity to compare and contrast grass and dandelions and to predict whether a plant shown in a diagram will survive being mown.

Learning objectives

Students will be able to:

- describe the parts of grass and dandelions,
- apply their knowledge of the features of plants to explain why certain plants may not survive well on a school field.

Resources needed

- **Student Activity 2.3: *Plants.***
- Access to the internet (for Part A).
- Access to computers (optional) for students to use the word version of **Student Activity 2.3: *Plants*** to complete parts B to E.
- Black, red and blue pens or pencils for part B.

Notes and suggestions for classroom activities

This activity may be given to students who decide to engage in an enquiry involving plants found on a school field.

ANSWERS

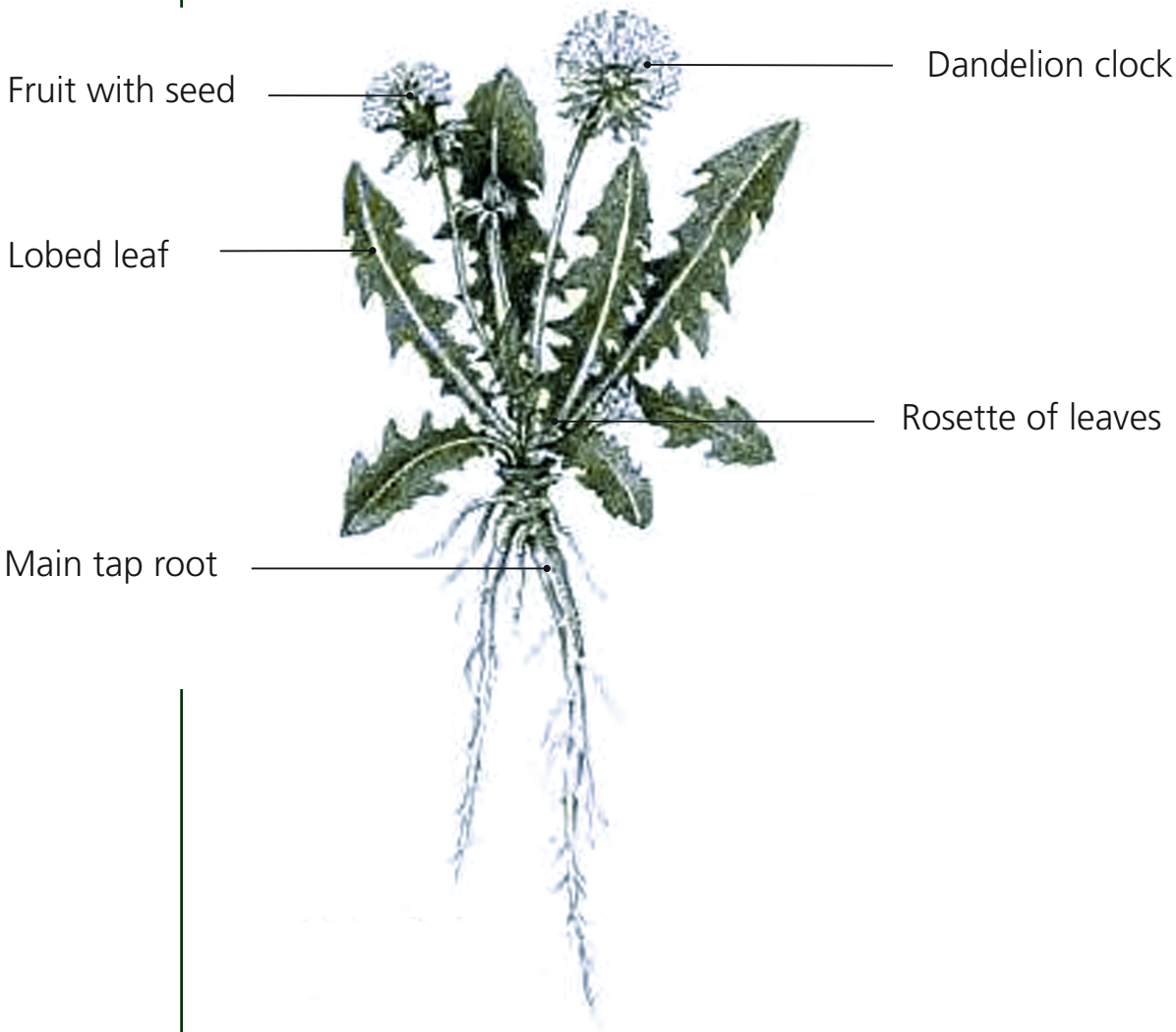
Part B

There are many different grasses. Some are short and only grow to a few centimetres, whereas others like bamboo can grow to several meters. Grasses have the same basic structure. The stems are made of cellulose. Cellulose is a polymer made by molecules of sugar (glucose) reacting together. Bamboo has a hollow stem whilst maize has a softer 'pithy' stem. The main roots are usually fibrous. Secondary roots, called adventitious roots, start from the nodes (joints) of the stems.

Grass germinates from a seed, which has been dispersed by the wind. Germination requires water (to allow enzymes to go into solution), the correct temperature and oxygen (for respiration). After the plant has broken through the surface of the soil, light is also needed for photosynthesis to take place. Photosynthesis converts water and carbon dioxide into glucose and oxygen. The glucose is used to build the cells of the plant. Biological growth is best thought of as an increase in cells, although a plant will also increase in 'wet biomass' as it takes in water.

The leaf blade is usually long and narrow, with parallel veins, but the shape and size of leaf blades vary a lot. The leaf blade also has a growing area (called a meristem) near the point where it joins the stem. Growth occurs in this area rather than at the leaf tip. This is different from most plants. In most plants growth is at the leaf tip. This means that even if the upper end of a grass leaves are cut off, for example, when the school field is mown, the blades can continue to grow. The growing area, the meristem, is unaffected by cutting off the end of the leaves. This feature, together with the fact that grasses branch near the ground, enables grass to withstand a lot of rough treatment. Grasses are adapted to withstand burning, grazing, and trampling. Different species have been developed to be grown for football pitches, golf courses and, of course, the school field.

Part C



Part D

Feature	Grass	Dandelion
Description of leaf	Long and narrow, with parallel veins	Broad and lobed
Position of leaf	Leaves grow straight up	Close to the ground in a rosette
Description of main roots	The main roots are usually fibrous	Main tap root grows down vertically and is strong
Description of stem	Strong and made of cellulose	Does not have one
Dispersal of seeds	By wind	By wind

Note: for some students, it may be appropriate to introduce the terms **monoctyledonous** (for plants with long and narrow leaves, with parallel veins) and **dicotyledonous** (for plants with broad, lobed leaves).

Part E

Reasons for not surviving:

- Most of the leaves will be lost during mowing
- No tap root
- No rosette of leaves close to the ground

After considering the reasons that students give for the plant not surviving you could discuss how the following two factors affect its chances of survival:

- The roots: the long branched root system might help it to survive.
- the location of its meristem: if the meristem was at the base of the stem it would make it more likely to survive.

ACTIVITY 3.1:
DIFFERENT KINDS OF QUESTION - DIFFERENT KINDS OF ENQUIRY

WHAT STUDENTS DO

Students study different research questions and decide what type of scientific enquiry could be used to find answers to each question.

Learning objectives
Students will be able to:
- ask questions that can be investigated scientifically and decide on an appropriate approach to find the answers.

Resources needed
- **Student Activity 3.1:** ***Different kinds of Question – Different kinds of Enquiry.***
- Scissors
- Poster paper and glue sticks (to present the results as posters)

NOTES AND SUGGESTIONS FOR CLASSROOM ACTIVITIES

Sort the class into groups of three or four students. Give each group a set of **'How can we find answers to the questions?'** and a set of **'Question cards'** from **Student Activity 3.1**. You may want to select a smaller set of questions for particular groups.

Plenary:
Explain to the class that there are different kinds of enquiry. Many will be familiar with fair tests, but may be less familiar with the other types of enquiry. Ask students to decide how they could find the answers to the questions on the question cards. Emphasise that they are not being asked to answer the questions.

Group work:
Ask students to arrange the cards under the headings from the sheet **'How can we find answers to the question?'** Encourage them to discuss and be ready to explain their arrangement in class.

Plenary:
Collect and compare students' ideas and discuss similarities and differences in the groups' arrangements.

ANSWERS

The table below gives the types of enquiry which could be used to answer each question and suggests what students might do to find answers to the question.

Question	How can we find answers to the question?
1. How big are earthworms?	**Exploring:** Collecting earthworms from different parts of the school-field and measuring their size. This involves considerations about the sample size.
2. Is the height of plants different in different quadrats?	**Exploring:** Measuring the height of different plants in different quadrats. **Pattern-seeking (survey):** Collecting plants from different quadrats and measuring their height. Students could also collect data about the conditions in different quadrats to look for factors that affect the height of plants.
3. Is the variety of plants different in different quadrats?	**Identifying and classifying:** Identifying the different types of plants in each quadrat and counting how many different types are found in each quadrat.
4. How does mowing affect the number of dandelions growing in the school-field?	**Fair-testing:** Selecting two matched parts of the field (mown and un-mown), then counting the number of dandelions in the part that is mown and comparing it to the number in the un-mown part. **Pattern-seeking (survey):** Comparing the number of dandelions that are found in different parts of the school field, parts that that are mown and parts that are not mown. Students could also collect data about other factors that might affect the numbers of dandelions.
5. Do worms prefer to be in wet, damp or dry conditions?	**Fair-testing:** Using controlled conditions in a laboratory and seeing where worms go. **Pattern-seeking (survey):** Looking at the distribution of worms in their natural environment and collecting data on moisture levels as well as other factors that might affect where worms live.
6. How does a dandelion plant change as it grows?	**Exploring:** Observing a plant over time and noting changes.
7. Why is grass green?	**Investigating models:** Providing an explanation for the green colour and then collecting data to test the explanation.
8. What makes grass grow quickly?	**Fair-testing:** This could be done in the laboratory in controlled conditions where one variable at a time can be changed. **Pattern-seeking (survey):** Students could collect data from the natural environment in order to look for factors that correlate with the rate of growth of grass.
9. Are worms nice?	**Opinion:** Answer depends on feelings.
10. What do worms eat?	**Fair-testing:** Using choice chambers to see what worms eat.
11. Do plants' leaves move during the day?	**Designing a system:** First, students need to design a way of measuring movement of leaves. **Exploring:** Recording movement of leaves over time.
12. What effect does trampling have on the plants in the school-field?	**Pattern-seeking (survey):** Comparing plants in a quadrat that has been trampled and one that has not. Students should also collect data on a range of factors - as well as trampling - that might affect the plants.
13. Do dandelions in the shade have longer leaves than those in the light?	**Fair-testing:** Planting seeds in shady and light conditions and comparing the size of the leaves of the same age plants. **Pattern-seeking (survey):** Measuring the lengths of leaves in different locations and collecting data on a range of other factors that may affect leaf length.
14. How can the speed of worms be measured?	**Designing a system:** Designing a way of measuring speed of movement of worms.
15. How can the rate of growth of grass be measured?	**Designing a system:** Designing a way of measuring growth of grass.
16, 17 & 18	Take time to discuss some of the students' own questions and how students might try to answer them.

ACTIVITY 3.2:
WHAT TO OBSERVE? WHAT TO MEASURE? HOW TO MEASURE?

WHAT STUDENTS DO

Students consider some of the difficulties about measuring variables in living organisms and make judgments about the quality of data collection methods described to compare the height of plants in different quadrats. They then consider how to measure biological variables in three other situations.

Learning objectives

Students will be able to:

- look at a research question and identify what must be measured,
- identify criteria to be used in deciding how to measure biological variables.

Resources needed

- **Student Activity 3.2:** ***What to observe? What to measure? How to measure?***

NOTES AND SUGGESTIONS FOR CLASSROOM ACTIVITIES

Question 1

The purpose of this part is to teach students the criteria for judging how biological variables have been measured.

Group work:

Put students in groups of two or three to discuss students' answers for Question 1. Ask them to discuss each student answer in turn and write down the good and bad points about the answer. When they have looked at all six answers they should try putting them in order.

Plenary:

Repeat this process in a feedback session.

The final order of students' answers is not important. What is important are the criteria by which they judge the quality of answers. The following criteria are important:

- whether it is clear what is to be measured and whether measurements are made,
- the size of the sample and whether this is representative,
- whether measurements have been manipulated appropriately (e.g. taking an average).

Once you have discussed these criteria with the class, an issue that needs addressing is how students would select the plants to be measured. If students decide that 10 plants is an appropriate number in each quadrat, then they would need either to

- select plants randomly, e.g. by pouring 10 small balls onto the ground and choosing the nearest plant to each ball, or
- select plants systematically at predetermined points within the quadrat.

Question 2
In principle, measuring the increase in biomass is simple. In practice there are many practical difficulties to solve. (For example, the cut parts of the grass contain water. In order to eliminate variability in the amount of water in the cuttings, one may measure the biomass dry. The cuttings can be dried in an oven at 110°C.) It is worth spending some time discussing with students exactly what they would do.

Questions 3 and 4:
The purpose of this part is to apply the criteria developed when answering Question 1.

Group work:
Put students in groups of two or three to identify the variables for questions 3 and 4 and how they would measure them. Allow the students a few minutes for each question. Students should make notes for each question so that they can report back in the plenary.

Plenary:
In a whole class discussion, clarify what variables are to be measured and suggestions for going about measuring them.

ANSWERS
Question 1: Is the height of plants different in different quadrats?
The criteria for judging answers are given below. The order of the answers is not clear as different answers address different criteria. Answers c, e and f include important criteria that should be considered.

Student answer	Good and bad points	Order 1=best
a. I looked at the plants in the two quadrats. Quadrat A has two big plants and two small ones. Quadrat B has one big plant and two small ones. Quadrat A has more big plants.	Bad: No measurements have been made. Bad: The conclusion is based on the biggest plants only. There has been no attempt to average. Bad: Size is not the same as height.	6
b. I measured plant 1 and plant 5 because these were the biggest in each quadrat. Plant 5 is 19mm tall and plant 1 is 13 mm tall. The plants in quadrat B are taller.	Good: Measurements have been made. Bad: The tallest plant may not be representative of a quadrat. More plants are needed. Unclear: Does height of plant mean the tallest leaf from each plant or is it an average of several leaves on the plant?	5
c. I measured the lengths of all the leaves on each plant in each quadrat. I worked out the average length of the leaves in each quadrat. In quadrat A the average length of leaves is 8.6 mm. In quadrat B the average length of the leaves is 8.6mm, so there is no difference.	Good: Measurements have been made. Good: An average has been worked out. Good: The average length of leaves is calculated based on the contribution of all the leaves. Bad: Height is not the same as length of leaves. Height means distance from the ground, so long leaves which are not vertical may not contribute much to the height of the plant.	3?
d. I measured the tallest leaf on each plant in each quadrat. In quadrat A the results were 13mm, 9mm, 6mm and 14mm. In quadrat B the results were 19mm, 6mm and 6mm. Quadrat B had the biggest plant but the three next tallest were all in quadrat A, so there are more tall plants in quadrat A.	Good: Measurements have been made. Bad: The results have not been averaged to make the comparison. Unclear: Does height of plant mean the tallest leaf from each plant or is it an average of several leaves on the plant?	4

Student answer	Good and bad points	Order 1=best
e. There are not enough plants shown to tell the difference. For example in quadrat B we do not know if plant 5 was unusually tall or plants 6 and 7 were unusually small. We need more plants to answer this question – at least 10 from each quadrat.	Good: This answer points out that the data are insufficient. Good: Ten readings seems an appropriate number given the spread of sizes seen in the two quadrats.	1?
f. I measured the two tallest leaves in each plant. I did not measure the length of the leaves, but measured straight up from the ground. The average height for quadrat A was 9.4mm and the average height for quadrat B was 9.7 mm, so the grass is taller in quadrat B.	Good: Measurements have been made. Good: An average has been worked out. Good: Height is an average of the two tallest blades of grass on each plant showing an awareness that the tallest blade may not be representative of the plant. Good: The answer recognises that height and length of leaf are different.	1?

Question 2: What makes grass grow quickly?

a. The answer to this question depends on how carefully the data has been collected, which we are not told.

b. Two approaches can be used to improve the reliability of the results:

i. Collect the data more carefully, e.g. make sure all the cuttings have been collected; cut the grass to exactly 2cm.

ii. Collect data over a longer time period e.g. weekly for four weeks.

Students are likely to choose (i). It is worth pointing out the limitations of this approach and point to (ii) as another way of improving reliability.

Question 3: Do dandelions in the shade have longer leaves than those in the light?

a. The variables are the amount of light and length of leaves.

b. A walk outside reveals that this question is difficult to answer in the field. You will see a variety of dandelion plants in different stages of development both in shady and light conditions. Young dandelions have smaller leaves than old ones, making it impossible to make a comparison unless you know the age of the plants. One way round this is to plant seeds in shady and light conditions and then compare plants of the same age. The considerations about what to measure are the same as for Question 1.

Question 4: How big are earthworms?

a. Size of earthworms can be interpreted as length or width or both. Alternatively size can be measured by weighing.

b. The worm is alive and must be handled carefully. Length can be measured using a ruler but this assumes the worm is straight. If it is not, placing a piece of string near the worm and matching it to the worm will allow students to straighten up the string and hence ensure the length of the worm.

Width can be measured using a ruler, or by placing a worm on paper and marking the worm's outline on the paper and then measuring the width on the paper. Alternatively, width could be measured using callipers, providing these are used with care so as to avoid injuring the worm.

Activity 1.1: Investigating the school field ecosystem

To an ecologist, there is a lot more to the school field than just some grass with a few birds walking about on it. There is a whole ecosystem out there, waiting to be explored!

In this activity you have an opportunity to select your own questions about life in the school field and to find the answers through your scientific enquiry.

Planning sheet for a school ecosystem enquiry

There are four parts to this enquiry

- Part 1: Planning
- Part 2: Obtaining evidence
- Part 3: Considering evidence
- Part 4: Evaluating

Use the following questions and prompts to help you plan each part of your enquiry.

Part 1: Planning

Think about the following:
- What is your research question?
- What will you observe or measure?
- How will you observe or measure? What apparatus will you need?
- How many observations or measurements will you make?

You will need to consider:
the range – when or where you will start and finish your readings,
the interval – the time or distance between readings,
repeat readings – whether you need to repeat readings, and if so, how many times.

Write down your research question and your plan.

Part 2: Obtaining evidence

How will you record your data?
Consider using tables, drawings or descriptions.

Activity 1.1: Investigating the school field ecosystem

Part 3: Considering evidence

Your evidence should help you answer your research question.

You may need to look for patterns in your data; for example by plotting graphs of measurements or by exploring the observations you made.

Describe how you analysed your data.
Have you collected enough data to allow you to answer your research question? If so, what is the answer?

Part 4: Evaluating

How reliable is your evidence?

To what extent are your conclusions supported by evidence?

Write down your evaluation of the quality of the evidence and how well it supports the conclusion.

ACTIVITY 1.1: INVESTIGATING THE SCHOOL FIELD ECOSYSTEM

Evaluation sheet (a) for a school ecosystem enquiry: advice

Using the evaluation sheet should allow you to ask critical questions about the write-up of an enquiry from another group and help them to improve it.

What to do

Read the enquiry given to you.
Use evaluation sheets b and c to write some critical questions or comments about how the group obtained their evidence and how reliable the evidence is.
Use the prompt boxes below to help you work out what you need to write.

How did the group obtain their evidence?

Do you understand exactly what was done? If not, ask some questions which will help you to find out what you need to know?

Can you suggest a better way of collecting the data?

How reliable is the evidence?

Is there enough evidence? Consider:

- **the range – when or where the readings start and finish,**
- **the interval – the time or distance between readings,**
- **repeat readings – did the group repeat any readings, and if so, how many times?**

Are the conclusions drawn supported by the evidence? Do you have any doubts about the conclusions? Why?

Choose one of your group to explain your critical questions and comments to the other group.

ACTIVITY 1.1: INVESTIGATING THE SCHOOL FIELD ECOSYSTEM

Evaluation sheet (b) for a school ecosystem enquiry: the evaluation (How did the group obtain their evidence?)

Enquiry title:

Enquiry group:

Evaluated by:

Our questions are:

1.

2.

3.

Our comments on the way the group obtained their evidence

ACTIVITY 1.1: INVESTIGATING THE SCHOOL FIELD ECOSYSTEM

Evaluation sheet (c) for a school ecosystem enquiry: the evaluation (How reliable was the evidence?)

Enquiry title:

Enquiry group:

Evaluated by:

Our comments about the amount of evidence

1. Range

2. Interval

3. Repeat readings

Our comment on how well the evidence supported the conclusions drawn by the group

ACTIVITY 2.1: THE SCHOOL FIELD ECOSYSTEM

Have you looked carefully at what lives in your school field? There is a complete ecosystem out there, teeming with life.

In this activity you will learn about some of the organisms that can be found in your school field.

You will find the following words in the passage **The School Field Ecosystem**.

angiosperm, annelid, biomass, ecology, ecosystem, environment, photosynthesis, quadrat, trampling

Read the passage and then match the scientific words in **bold** to their definitions in the table. If you need more information to match up the words you could use a scientific dictionary or search 'Encarta' on the internet at ***http://encarta.msn.com.***

The School Field Ecosystem

In **ecology** we study the relationship of plants and animals to their physical and biological environment. The school field is an **ecosystem**. It contains organisms that live together in the field. In the soil you can find **annelids**. A worm is an example of an annelid. Worms affect the quality of the soil and this affects how well certain plants grow in the soil. The dominant form of plant life is angiosperms and we find plenty of these in the school field. They are flowering plants such as grass and dandelions. How well **angiosperms** grow is affected by the **environment**. The amount of light received is an environmental factor that affects **photosynthesis** in green plants, and this affects the rate at which plants grow. Another environmental factor is the amount of moisture in the soil and this is different in different parts of the school field. Some areas of the school field are also subject to **trampling**. In well-trodden areas plants will grow differently and some species of plant may find it difficult to survive.

When studying the school field we can explore how some of these factors interact in the field ecosystem. A useful tool for this is a **quadrat**. This can be used to mark out specific areas of ground. For example, we could choose two areas on the school field that are quite different with respect to one of the environmental factors and then compare the two areas carefully. We might decide to look at how well grass grows in two different quadrats by comparing the **biomass** produced during a week.

Activity 2.1: The school field ecosystem

Scientific term	Definition
	All of the external factors affecting an organism. These factors may be other living organisms (biotic factors) or nonliving variables (abiotic factors), such as temperature, rainfall, day length, wind, ocean currents.
	Walking over plants. Grasses are adapted to withstand being trodden on.
	Abbreviation for biological mass, the amount of living material provided by a given area of the earth's surface.
	Flowering plants, the dominant form of plant life.
	Name for about 9,000 species of worm-like invertebrate animals with well-developed segmentation.
	Process by which green plants and certain other organisms use the energy of light to convert carbon dioxide and water into the simple sugar glucose.
	A piece of apparatus made from plastic or metal. It is used to identify a specific area of ground, usually 1 square metre, for ecological study.
	Organisms living in a particular environment, such as a forest or a coral reef, and the parts of the environment that affect them.
	The study of the relationship of plants and animals to their physical and biological environment.

ACTIVITY 2.2: WORMS

Earthworms are part of the school field ecosystem and they make a valuable contribution to the quality of the soil.

In this activity you will find out about the place of earthworms in the ecosystem – how worms affect the ecosystem and how they are affected by it.

Part A: Finding out about earthworms

Use the following internet sites to find three facts about earthworms.

http://www.naturegrid.org.uk/biodiversity/invert/earthworms.html
http://home.clara.net/xenotoca/earthworm.htm
http://www.wildlifetrust.org.uk/urbanwt/education/wildlifeeducationwebsite/worms.htm

Part B: Earthworms in the ecosystem

A group of students was on a school field studying earthworms when a gust of wind blew their notes away and jumbled them up.

1. Cut out cards A-L and sort out the notes under these headings: Feeding, Benefit to the Soil, Habitat
2. Write a paragraph about earthworms under each of the three headings.

Feeding

Benefit to the Soil

Habitat

Activity 2.2: Worms

Cards A-L for sorting into groups

Feeding | Benefit to the Soil | Habitat

A In the earthworm's gut, organic matter from the soil is broken down. It is then excreted (as wormcasts) which are used by micro-organisms in the soil.

B Earthworms are most numerous in the top 15cm of soil, they also are found in the subsoil.

C Earthworms live in almost all soil types except very acidic or very coarse soils (like sandy soils), bringing mineral rich soil from below to the surface.

D Each day earthworms produce nitrogen, phosphorus, potassium and many micro-nutrients in a form that all plants can use.

E Earthworms feed on partly decomposed organic material and ingest the soil.

F Not only do earthworms produce fertiliser (as wormcasts) but they spread it thoroughly within the top 30cm of soil.

G Earthworms will feed on roots or other parts of plants that have been decayed by other organisms, but they do not feed on healthy plants.

H Earthworms must have a moist environment in order to breathe. So, if the soil dries too much, the worms will move to another location.

I The organic matter that earthworms eat consists of decomposing plant material, animal parts, bacteria, fungi and nematodes.

J Most earthworms make their burrows at least a metre deep.

K The burrows that they make help to loosen the soil, which allows more oxygen into the soil. This helps the plants directly and improves conditions for some useful soil bacteria.

L The tunnelling of the earthworms provides an access to deeper soil levels for the numerous smaller organisms that contribute to the health of the soil.

ACTIVITY 2.3: PLANTS

Plants are part of the school field ecosystem. They are walked on, played on and mown. In this activity, you will find out about what the different parts of plants are and how they manage to survive.

In Part A you find out about the place of plants in the ecosystem and then in Parts B to E you find out about the different parts of grass and dandelions and how the plants manage to survive on a school field.

Part A: Finding out about plants

Use the following internet sites to find three facts about plants.

www.botanical-online.com/lasplantasangles.htm
http://www.enchantedlearning.com/subjects/plants/plant/

Part B: Grass - A tough plant

Read the passage about 'Grass'. Use highlighters or coloured pencils as indicated below.

- Find the **parts of the grass**. Highlight or underline these in RED.
- Find **what makes the grass survive in harsh conditions**. Highlight or underline these in BLUE.
- Find **what is needed for grass to grow**. Underline in BLACK.

ACTIVITY 2.3: PLANTS

Part B: Grass

There are many different grasses. Some are short and only grow to a few centimetres, whereas others like bamboo can grow to several meters. Grasses have the same basic structure. The stems are made of cellulose. Cellulose is a polymer made by molecules of sugar (glucose) reacting together. Bamboo has a hollow stem whilst maize has a softer 'pithy' stem. The main roots are usually fibrous: they look like lots of fibres. Secondary roots, called adventitious roots, start from the nodes (joints) of the stems.

Grass germinates from a seed, which has been dispersed by the wind. Germination requires water (to allow enzymes to go into solution), the correct temperature and oxygen (for respiration). After the plant has broken through the surface of the soil, light is also needed for photosynthesis to take place. Photosynthesis converts water and carbon dioxide into glucose and oxygen. The glucose is used to build the cells of the plant. Biological growth is best thought of as an increase in cells, although a plant will also increase in 'wet biomass' as it takes in water.

The leaf blade is usually long and narrow, with parallel veins, but the shape and size of leaf blades vary a lot. The leaf blade also has a growing area (called a meristem) near the point where it joins the stem. Growth occurs in this area rather than at the leaf tip. This is different from most plants. In most plants growth is at the leaf tip. This means that even if the upper end of a grass leaves are cut off, for example, when the school field is mown, the blades can continue to grow. The growing area, the meristem, is unaffected by cutting off the end of the leaves. This feature, together with the fact that grasses branch near the ground, enables grass to withstand a lot of rough treatment. Grasses are adapted to withstand burning, grazing, and trampling. Different species have been developed to be grown for football pitches, golf courses and, of course, the school field.

ACTIVITY 2.3: PLANTS

Part C: Dandelions

Read the information below and use it to label the diagram.

The dandelion

The dandelion is found commonly on school fields. It is easily recognised in the spring and summer by its bright yellow flowers and its "dandelion clock". The dandelion clock is made of small fruits, which are dispersed by the wind. Each fruit contains a seed. These seeds are effective at spreading this plant and it is often thought of as a weed. The leaves are quite broad and lobed. They lie close to the ground in a rosette. Beneath the leaves is a long tap-root. A plant's taproot is a strong, straight root that grows vertically down. It allows other roots to grow from it.

Lobed leaf

Main tap root

Dandelion clock

Fruit with seed

Rosette of leaves

Activity 2.3: Plants

Part D: Dandelions and grass

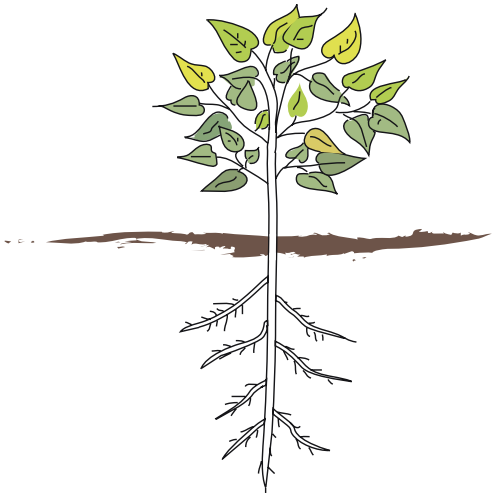
Read the information given in Parts B and C, and use it to complete the table.

Feature	Grass	Dandelion
Description of leaf		
Position of leaf		
Description of main root		
Description of stem		
Dispersal of seeds		

Part E: Surviving the mower

Here is a plant that has grown on the school field. Tomorrow the school field is due to be mown. Will the plant survive or not?

Write down two reasons why you think the plant might not survive.



Activity 3.1 Different kinds of Question - Different kinds of Enquiry

How big are earthworms? Are earthworms pretty? What kind of animal is an earthworm? Do earthworms eat grass? Is it cruel to investigate earthworms in a school laboratory? Scientific enquiries can be used to answer some of these questions, but which ones? What kinds of scientific enquiries can be used to answer each question?

In this activity you will look at a range of questions about life in the school field and decide what kind of enquiry could be used to answer each question.

You will need the sheet **'How can we find answers to questions?'** and the set of 'Question Cards'.

Work in a group. Read the 'Question cards'. This task is different from most lessons: **do not try to answer the questions on each card!**

1. For each question, decide which approach you would use to tackle it. Use the sheet **'How we can find answers'** as headings and place each question card under one of these headings.

2. Write some questions of your own on what you could ask about the school field. For each question decide how you could find the answer and place your question under the appropriate heading.

Be ready to share your ideas with the class and to explain why you put each question under its heading.

Activity 3.1 Different kinds of Question - Different kinds of Enquiry

How can we find answers to questions?

Fair testing

Do a fair test enquiry: Alter one factor and observe or measure the effect, while keeping the other factors thes same.
Example: What effect does water have on the rate of growth of grass?

Pattern-seeking (Surveys)

Collect data to see what factors are affecting a particular variable.
Example: What factors affect the numbers of greenfly found on plants?
Answering this might involve counting the number of greenflies in different places and keeping a note of a range of factors that might affect the numbers, such as the kind of plants they are on, the weather conditions, whether predators can be found and so on.

Identifying and classifying

Group the things in your collection or allocate your specimen to a group. Match the thing to something with a name.
Examples: Is this an annelid? What kind of animal is this? What different groups can you place earthworms into?

Exploring

Observe and keep a record over some time. You cannot affect any factors.
Example: How does a dandelion plant change as it grows?

Investigating models

Try out an explanation, see whether it works and makes sense.
Example: Collect evidence to test the following explanation: 'The number of lady birds is related to the number of greenflies because ladybirds feed on greenflies'.

Designing a system

Make something or invent a system to solve the problem.
Example: How can the rate of growth of grass be measured?

Opinion

This is related to personal feelings and can not be answered by scientific enquiry.
Example: Is it fun to study in the school field?

Activity 3.1 Different kinds of Question - Different kinds of Enquiry

Question 1 How big are earthworms?	Question 10 What do worms eat?
Question 2 Is the height of plants different in different quadrats?	Question 11 Do plants' leaves move during the day?
Question 3 Is the variety of plants different in different quadrats?	Question 12 What effect does trampling have on the plants in the school-field?
Question 4 How does mowing affect the number of dandelions growing in the school-field?	Question 13 Do dandelions in the shade have longer leaves than those in the light?
Question 5 Do worms prefer to be in wet, damp or dry conditions?	Question 14 How can the speed of worms be measured?
Question 6 How does a dandelion plant change as it grows?	Question 15 How can the rate of growth of grass be measured?
Question 7 Why is grass green?	Question 16. My question is:
Question 8 What makes grass grow quickly?	Question 17. My question is:
Question 9 Are worms nice?	Question 18. My question is:

ACTIVITY 3.2 WHAT TO OBSERVE? WHAT TO MEASURE? HOW TO MEASURE?

Measuring living organisms can be more difficult than measuring non-living things. For example, how much does a one-month-old child weigh?
The answer depends on which child you choose and even for the same child its weight will vary according whether it has just been fed. To add to your difficulties, children tend to move, making weighing accurately more difficult. We face similar difficulties in measuring living organisms on the school-field.

In this activity you will consider some of the problems involved in observing and measuring biological variables.

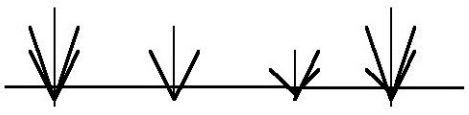
The following questions involve measuring living organisms:

Question 1: Is the height of plants different in different quadrats?
Question 2: What makes grass grow quickly?
Question 3: Do dandelions in the shade have longer leaves than those in the light?
Question 4: How big are earthworms?

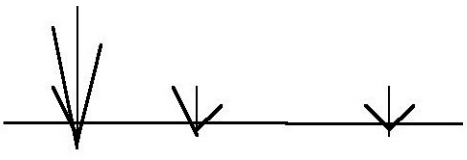
Question 1: Is the height of plants different in different quadrats?

In order to answer the question, we could compare the height of one kind of plant but what exactly would we measure? In any quadrat there are likely to be many plants and each of these has many leaves. The diagrams below represent plants. Look at the plants from quadrats A and B below. Four plants are shown from Quadrat A and three from Quadrat B.

Quadrat A



Quadrat B



Are the plants taller in quadrat A or in quadrat B?

ACTIVITY 3.2 WHAT TO OBSERVE? WHAT TO MEASURE? HOW TO MEASURE?

The table below gives some students' answers and their explanations of their answers. Discuss the students' answers. Pick out the good and bad points in the answers and decide which is the best answer, which is the next best, and so on.

Student answer	Good and bad points	Order 1 = best
a. I looked at the plants in the two quadrats. Quadrat A has two big plants and two small ones. Quadrat B has one big plant and two small ones. Quadrat A has more big plants.		
b. I measured plant 1 and plant 5 because these were the biggest in each quadrat. Plant 5 is 19mm tall and plant 1 is 13 mm tall. The plants in quadrat B are taller.		
c. I measured the lengths of all the leaves on each plant in each quadrat. I worked out the average length of the leaves in each quadrat. In quadrat A the average length of the leaves is 8.6 mm. In quadrat B the average length of the leaves is 8.6mm, so there is no difference.		
d. I measured the tallest leaf on each plant in each quadrat. In quadrat A the results were 13mm, 9mm, 6mm and 14mm. In quadrat B the results were 19mm, 6mm and 6mm. Quadrat B had the biggest plant but the three next tallest were all in quadrat A, so there are more tall plants in quadrat A.		
e. There are not enough plants shown to tell the difference. For example in quadrat B we do not know if plant 5 was unusually tall or plants 6 and 7 were unusually small. We need more plants to answer this question – at least 10 from each quadrat.		
f. I measured the two tallest leaves in each plant. I did not measure the length of the leaves, but measured straight up from the ground. The average height for quadrat A was 9.4mm and the average height for quadrat B was 9.7 mm, so the plants are taller in quadrat B.		

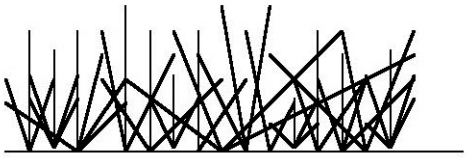
ACTIVITY 3.2 WHAT TO OBSERVE? WHAT TO MEASURE? HOW TO MEASURE?

Question 2: What makes grass grow quickly?

If you look at the school field you will probably find it very difficult to pick out individual plants, because the plants are all interwoven. To see how much grass has grown in a week, it is impossible to pick out individual plants. Have a look at quadrat C below:

Quadrat C at start

Quadrat D after one week



Has the grass grown in a week?

One way of measuring growth is to measure the increase in the biomass of the grass. This is what Aiden and Jack did to measure the increase in biomass:

They cut all the grass in quadrat C to a height of 2 cm at the beginning of the week. They wanted to compare this with quadrat D and so they did the same to quadrat D. They left the grass to grow for a week and cut the grass back to the same height and collected all the cuttings for weighing.

Here are the results:

	Quadrat C	Quadrat D
Increase in biomass after 1 week	190g	180g

Aiden said: 'The results show that the grass in quadrat C grew more quickly'.
Jack said: 'We can't tell the difference in the growth rate. The experiment is not very accurate and so our results might be out by 10 g'.

a. Who do you think is right?

b. What could be done to make the results more reliable?

ACTIVITY 3.2 WHAT TO OBSERVE? WHAT TO MEASURE? HOW TO MEASURE?

Now look at the other two questions.
In each case write down:
a. what you would need to measure to answer the question and
b. how you would measure it.

Question 3: Do dandelions in the shade have longer leaves than those in the light?

a.

b.

Question 4: How big are earthworms?

a.

b.