

Murderous Plants

Investigating adaptation and
competition
in carnivorous
plants



Teacher's Pack



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Specification links

OCR A-Level Biology

Biodiversity:

- Biodiversity refers to the variety and complexity of life. It is an important indicator in the study of habitats. Maintaining biodiversity is important for many reasons. Actions to maintain biodiversity must be taken at local, national and global levels.

Evolution and Classification:

- Evolution has generated a very wide variety of organisms. The fact that all organisms share a common ancestry allows them to be classified. Classification is an attempt to impose a hierarchy on the complex and dynamic variety of life on Earth. Classification systems have changed and will continue to change as our knowledge of the biology of organisms develops.

Populations and sustainability:

- There are many factors that determine the size of a population. For economic, social and ethical reasons ecosystems may need to be carefully managed. To support an increasing human population, we need to use biological resources in a sustainable way.

AQA AS and A-level biology

Section 3.4 Genetic information, variation and relationships between organisms

- Biodiversity is reflected in the vast number of species of organisms, in the variation of individual characteristics within a single species and in the variation of cell types within a single multicellular organism.

Section 3.7: Genetics, Populations and Ecosystems

- The theory of evolution underpins modern Biology. All new species arise from an existing species. This results in different species sharing a common ancestry, as represented in phylogenetic classification.
- Populations of different species live in communities. Competition occurs within and between these populations for the means of survival. Within a single community, one population is affected by other populations, the biotic factors, in its environment. Populations within communities are also affected by, and in turn affect, the abiotic (physicochemical) factors in an ecosystem.

Edexcel AS Unit 2: Development, Plants and the Environment

Topic 3: Classification and Biodiversity

- The evidence used in the development of models for the classification of organisms. It also considers the limitations of these models. The topic includes the principles underlying natural selection and how this can lead to speciation.

Topic 10: Ecosystems

- Interactions between the organisms and the environment within an ecosystem.
- How biotic and abiotic factors are involved in the development of ecosystems over time.
- Human influences on ecosystems and the need for conservation.

WJEC AS Unit 2: Biodiversity and the Physiology of Body Systems

Section 1: All organisms are related through their evolutionary history.

- Biodiversity has been generated through natural selection.

Section 4: Adaptations for nutrition.

WJEC AS Unit 4: Energy, Homeostasis and the Environment

Section 1: All organisms are related through their evolutionary history.

- Biodiversity has been generated through natural selection.

Section 5: Population Size and Ecosystems.

Section 6: Human Impact on the Environment.

SQA Higher Unit 2: DNA and the Genome

- Evolution.

SQA Higher Unit 3: Sustainability and Interdependence

- Plant growth and productivity
- Mass extinction and biodiversity
- Threats to biodiversity.

Darwin-Inspired Learning

1. Encourages a sense of place and direct engagement with the natural world using local environments and the environment of Down House and other places Darwin worked.
2. Has a pedagogy of enquiry which places importance in:
 - Active learning - seeking out experiences and questions, solving problems and dialogue between teachers and pupils and between learners.
 - Teaching that facilitates imagination and thoughtful hands-on inquiry as well as the delivery of high quality engaging content.
 - Teaching that engages critical, creative thinking about how we know and how scientists work.
3. Encourages interdisciplinary studies, with Darwin as the context, between science, literature, writing and expression, history, religious studies, geography, horticulture, dance and drama, design and technology, numeracy, music and art.

How to use this pack

There are three lessons in this module. Each lesson is laid out in the suggested order of teaching.

Depending on when in the A Level course this module is used, more explanation of terms may be required as some elements use knowledge gained in other units of the specifications.

At the start of each lesson there is a timing guide. However, you may want to allow more or less time depending on what you would particularly like to focus on with your students. Although you can choose to miss certain activities, we recommend working through all of them to provide students with a broader understanding of the topic.

In the teacher's pack, the answers to the activities have been provided in green. Please bear this in mind if you choose to print this pack in black and white.

Powerpoint slide numbers are given at the start of the text they refer to.

The module is complemented by videos of Darwin Inspired Scientists which provide a case study of how scientists work today and the relevance of Darwin to their work and current research.

A video showing an example of a pitcher plant dissection is available at www.bit.ly/PitcherDissection.



Some of the activities in this pack are practical-based, requiring the use of practical equipment, these are highlighted with a microscope symbol.

Darwin Inspired Scientists:

Video interviews with a contemporary scientist www.bit.ly/DarwinsDrosera and www.bit.ly/CarnPlants.

Further sources of information:

Two good introductions to this fascinating subject are the books *The Curious World of Carnivorous Plants: A Comprehensive Guide to Their Biology and Cultivation* by Wilhelm Barthlott, Stefan Porembski, Rudiger Seine and Inge Theisen and *The Savage Garden, Revised: Cultivating Carnivorous Plants* by Peter D'Amato.

A more detailed paper, grounded in Darwin's original work, is Ellison, A. M. and Gotelli, N. J. (2009). Energetics and the evolution of carnivorous plants—Darwin's 'most wonderful plants in the world'. *Journal of Experimental Botany*, 60(1): 19–42. www.bit.ly/EllisonGotelli.

A short clip of a Venus flytrap catching an insect

www.bit.ly/FlytrapVideo.

The IUCN (International Union for Conservation of Nature) Red List of Threatened Species

www.iucnredlist.org.

The International Carnivorous Plant Society: Conservation Policies and Statements

www.bit.ly/ICPSConservation.

The letters sent between Mary Treat and Charles Darwin concerning carnivorous plants can be viewed online

www.bit.ly/TreatLetters.

The Science and Plants For Schools website also has information on using sundew and Venus flytrap

www.saps.org.uk.

Module overview

Learning objectives and outcomes

Students will:

- Develop an understanding of adaptation and competition in the context of carnivorous plants.
- Use carnivorous plants and their habitats as stepping stones for exploring broader ecological concepts including the structure of an ecosystem, predator-prey relationships.
- Consider biodiversity conservation in a plant-based context.
- Gain an appreciation of the 19th century botanical studies of Charles Darwin and Mary Treat, in relation to modern scientific practice.

Introduction to unit

This unit, inspired by the work of Charles Darwin and his American correspondent Mary Treat, considers adaptation and competition in the context of carnivorous plants.

It also uses carnivorous plants and their habitats as a stepping-stone for exploring broader ecological concepts, in particular the structure of an ecosystem and predator-prey relationships. Students will experience Darwin inspired activities with living specimens through inquiry-based learning.

Contemporary scientists, such as Aaron Ellison at Harvard University, continue to research these enigmatic plants and their extraordinary forms and behaviour. By experiencing this learning module, formed of three lessons, students will engage with late Victorian botanical science in relation to how modern science works, and consider the continuing role of evidence, theory building and peer-review.

This unit uses carnivorous plants to:

- Apply the concept of adaptation.
- Explore ecological concepts specifically: ecosystem, species survival, competition, predator-prey relationships, mutualism, trophic levels, plant nutrition, keystone species.
- Transfer understanding of ecosystems from macro- to micro- contexts.
- Consider genetic and ecological investigative methods.
- Use laboratory based investigations to further understanding of specific adaptations.
- Compare 19th and 21st century scientific methods.
- Explore contemporary conservation issues.

Keywords

adaptation, mineral-poor, species, wetland habitats, carnivory, trapping mechanisms, competition, observation, investigation, evolution, ecology, trophic level, ecosystem, evidence, abiotic, physiological, anatomical, behavioural, predator, prey, genetics, keystone species, food webs, models, digestive enzymes, conservation, biodiversity

Darwin's questions and big ideas

- Does the nutrition of carnivorous plants make them disguised animals?
- Can plants perceive and exhibit behaviours?
- Do carnivorous plants have a common ancestor?

Darwin's *Drosera*

Charles Darwin first came across *Drosera rotundifolia* while walking in Sussex and was curious as to why there was such 'prodigious slaughter' of insects on its leaves. Darwin and his American correspondent Mary Treat (1830-1923), became fascinated by plant nutrition in relation to these carnivorous plants - both scientists researched a range of plants exhibiting different trapping mechanisms. Their studies were conducted through observation in the field and experimentation in their homes and gardens. Darwin published his ground-breaking study on *Insectivorous Plants* in 1875. He was particularly interested in the concept of a plant exhibiting animal-like behaviours.

Darwin's ways of working

- Raising and solving problems through observation, questioning, reflection and argument.
- Using creative thought to generate ideas to explain observations.
- Close observation of the natural world as it changes through time.
- Collecting written records of evidence and ideas in themed notebooks.
- Reflection on evidence and ideas and building of theories.
- Investigating using experimentation usually making all his own equipment from everyday materials.
- Collaboration with others through letters and face-to-face to make sense of data and find new avenues for investigation.

Scientific questions

This unit addresses the following questions:

- Why do carnivorous plants lure and trap insects?
- How do carnivorous plants digest their prey?
- What are the ways in which carnivorous plants have modified their leaf structures?
- How effective are these modifications?
- In which habitats do these plants occur and why?
- Does carnivory offer these plants a competitive advantage?
- Can the pitchers of *Sarracenia* plants be used to model larger ecosystems?
- What evidence have modern scientists used to consider if carnivorous plants have a common 'sticky-trapped' ancestor?
- Why was Darwin interested in carnivorous plants?
- If Charles Darwin and Mary Treat had access to time-lapse photography how do you think it would have impacted on their science?

Background information on carnivorous plants

Carnivorous plants are found in habitats where the soil is low in nutrients and/or acidic. This includes scrub-land with sandy soils and boggy areas.

This module considers three genera of carnivorous plants (although there are others): *Dionaea* (Venus flytraps), *Sarracenia* (pitcher plants) and *Drosera* (sundews).

The Venus flytrap has hinged leaves that snap shut when trigger hairs are touched and is, therefore, described as an 'active' trap. As the traps can only close a certain number of times before becoming inactive, the plant has adapted mechanisms so the leaves will only shut when there is a high likelihood that an insect is contained within the hinged leaf structure. The traps will only close if two or more of the trigger hairs are touched, or if the same hair is touched twice, within 20 seconds. Touching the 'teeth' or base of the trap has no effect. Rain or gusts of air also have no effect.



© Mair Shepherd



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The leaves of the pitcher plant are folded to create a type of pitfall trap, so it is described as a 'passive' trap. At the bottom of the trap is a pool of digestive enzymes. Insects are attracted to the plant by visual lures and also nectar. The plant produces nectar around the rim of the plant and also underneath the 'lid'. This nectar contains a mild narcotic. The internal structure of the pitcher trap includes slippery, waxy sides near the top and downward pointing hairs near the bottom. This makes it difficult for an insect to escape once in the trap. The pool of liquid at the bottom of the trap then digests the insects soft tissues. Pitcher plant traps contain complex mutualistic communities in which a range of insects, and micro-organisms, feed on chitinous and non-chitinous materials. Recent research papers, such as that by Ellison and Gotelli, (2009), suggest that categorisation of trap-types into 'passive' and 'active' needs to be 'rethought', and 'renewed attention' focused on the activity of traps such as *Sarracenia*, currently considered 'passive'.

The sundew has leaves with stalked glands which are tipped with a sweet, sticky substance (mucilage) which attracts insects. The insect becomes stuck to this substance and so sundews are often described as flypaper traps. As the insect struggles, the tentacles nearby bend over the insect and in many species the leaf will fold over the insect to aid external digestion. This ability means the sundews are described as 'active' traps. The insect becomes smothered in mucilage and dies of suffocation. The stalked glands and pores on the leaves produce digestive juices. These juices increase in production once an insect is caught. Although the sundew is an active trap, its action is slow when compared to the Venus flytrap and movement can only be seen if recorded using time-lapse photography.



© Leonie Berwick

Research has shown that the habit of carnivory in plants has evolved independently in many plant lineages, for example in pitfall-type plants and flypaper-type plants, therefore showing convergent evolution. However, the snap trap plants evolved only once.

Keeping carnivorous plants in the classroom

Carnivorous plant specimens for U.K. classrooms can be obtained from South-West Carnivorous Plants www.littleshopofhorrors.co.uk or Hampshire Carnivorous Plants www.hantsflytrap.com. Both nurseries are specialists - growing their own plants rather than using specimens collected in the wild. Their websites offer practical advice to keep your plants healthy. Using rainwater and keeping plants in a well-lit area is crucial.

Lesson 1: Plant nutrition and adaptation

Overview and lesson plan

This lesson will use the context of Darwin's work on *Drosera* to explore adaptation.

Students will explore the concept of adaptation using their prior knowledge of photosynthesis and plant nutrition. Students will evaluate Victorian and contemporary scientific theories regarding carnivorous plants.

Activity	Timing	Description and Pedagogical Approach
Lesson starter	5 mins	Individual student reflection Concept Cartoon (Slide 2). Students reflect on plant nutrition using prior knowledge of photosynthesis.
	15 mins	Small group discussion: reasoning, assessing and evaluating ideas Students consider three types of adaptation (anatomical, physiological and behavioural) to the environment. Students discuss the challenges for a plant living in mineral-poor environments and how they may have adapted to survive.
Activity: Group One	15 mins	Teacher-led opener: reasoning, assessing and evaluating evidence Students observe Venus flytrap plants and evaluate Darwin's hypothesis regarding size of prey in Venus flytraps (Slide 7).
Activity: Group Two	15 mins	Small group discussion: reasoning, assessing and evaluating evidence Students observe pitcher plants and evaluate contemporary evidence for use of pitcher plants as models for larger ecosystems (Slide 8).
Plenary	15 mins	Individual activity: self-evaluation of learning Students consider the various themes covered in the lesson and share one thing they have learnt in relation to one of the themes.

Lesson starter part 1

- (Slide 2) Students are shown the concept cartoon at the start of the lesson.
- Ask students to write down key processes in plant nutrition on post-it notes and group these notes on a classroom wall for reference.

Lesson starter part 2

- In small groups of approximately four, students are asked to discuss the concept of adaptation to the environment for five minutes. Use the following categories in relation to a range of plants and animals that you have selected, including carnivorous plants:
 - Anatomical adaptations
 - Physiological adaptations
 - Behavioural adaptations
- (Slide 3) Students are shown the quote on carnivory in plants.
- Ask them to consider, for another five minutes, the challenges of being a plant living in a mineral-poor, temperate wetland and what adaptations might be beneficial in such environments.
- Allow five minutes for groups to feedback key points of their discussions to the class.

Carnivory in plants

Carnivorous plants have adapted to mineral-poor environments (often through leaf modification) by developing the ability to lure and trap flies and other insects. The habitats of carnivorous plants are generally open areas with moist, low nutrient soils. This includes scrubland with sandy soils and boggy areas. The plants use the insects' bodies as replacements for the missing minerals, in particular nitrogen. Carnivorous plants exhibit a variety of trapping mechanisms in order to catch insects.

In this module, we are considering three types of carnivorous plant although there are others. The genera considered in this module represent three types of trapping mechanism:

(Slide 4) Genus: *Sarracenia* (pitcher plant). These are described as 'pitfall-type' traps; where the insect prey 'falls' into the pitcher which contains digestive liquid. The insect then either drowns or dies of exhaustion, which is followed by digestion of the soft tissues.

(Slide 5) Genus: *Dionaea* (Venus flytrap). These are described as 'snap-traps' or 'spring traps'; where the two leaf lobes close quickly trapping the insect and then covering their bodies with digestive acids and enzymes.

(Slide 6) Genus: *Drosera* (sundew). These are described as 'flypaper' type traps; where the insect prey gets stuck on the sticky substance (mucilage) produced by the plant's tentacles. The insect is then digested externally.

Carnivorous plant science today

Research has shown that within the pitcher-shaped traps of *Sarracenia* there exists a tiny ecosystem where organisms, such as fly larvae, have created an intricate food web.

Fly larvae are the top-level predator in the pitcher, the analogues of terrestrial tigers or wolves. They're what ecologists call a 'keystone' species, who control the abundance of every other species, but require a habitat of sufficient size to support those other creatures.

(Slide 7) Robert Holt, from the University of Florida, is one of the scientists studying this. He says that "some ecosystem processes might be scale-dependent, emerging only at certain absolute sizes." But he thinks other pitcher plant processes — predator-prey interactions, mutually beneficial species, the effects of disturbance — are found across ecosystems. "Everything that happens in a pitcher plant happens at a larger scale," said Holt. "There's a tremendous amount of information in there."

Extracts taken from Keim, B. (2009) In the Bowels of Carnivorous Plants, a Tiny Model of the World. *Wired* [online] www.bit.ly/PlantModels.

Activity

Divide your students into two groups. Students spend 15 minutes on each part of the activity before changing round.

Group One

(Slide 8) Show students the quote by Charles Darwin.

Teacher-led discussion:

- Ask students to consider what type of adaptation has occurred to enable Venus flytrap to capture insects, how the digestion process might take place and if Darwin's hypothesis concerning the energetic expenditure between the capture of small and large insects might be correct.

Student to student discussion:

- Ask students to use observation and peer-to-peer collaboration to note down whether they support Darwin's claims, what evidence they consider to be important for his argument, if they agree and why. Finally, ask them to discuss if Darwin's analogy of a fishing net to describe the trapping mechanism is still a useful one, if not what would be more appropriate

Group Two

(Slide 9) Show students the summary from contemporary scientists exploring the complex relationships between organisms living in the traps of *Sarracenia*. (The full article is available at www.bit.ly/PlantModels).

Teacher-led discussion:

- Ask students to consider:
 - The characteristics of islands and lakes and how these might be applied to the internal world of a *Sarracenia* plant.
 - What organisms might survive there?
 - What kinds of trophic levels might exist?
- Ask students to note down their ideas and the types of investigations they might conduct to collect evidence about these micro-ecosystems.

Student to student discussion:

- Ask your students to discuss how these 'modest-scale islands' offer models for larger ecosystems and the challenges that disruptions, such as the removal of a top predator or the introduction of a non-endemic species, might have in a lake or island ecosystem.

Plenary

Each student shares a key personal learning point with the class in relation to one of the following:

- Adaptation to environment.
- Commonalities and differences between 19th and 21st century approaches to biological science.
- The limitations of using micro-models of macro-ecosystems.

Extension Activity (A2 Level)

Students could be asked to map out ideas for an investigation to test Darwin's hypothesis of scale. Key data on page 32 in Ellison and Gotelli's (2009) paper could be used to structure their thinking. This paper is available online at: www.bit.ly/EllisonGotelli.

Lesson 2: Following in Darwin and Treat's footsteps: Investigating carnivorous plants

Overview and lesson plan

This lesson will use the context of Darwin's work on *Drosera* and that of his contemporaries to explore scientific method.

Students are asked to use their observation skills to investigate various carnivorous plant species, as Charles Darwin and Mary Treat might have done.

Activity	Timing	Description and Pedagogical Approach
Lesson starter	10 mins	Class discussion led by teacher Students consider Victorian carnivorous plant science.
Activity 1 [Worksheet]	35 mins	Inquiry-based learning: observation, reasoning, assessing and evaluating evidence Students observe plants from the following species: <i>Dionaea</i> (Venus flytrap), <i>Drosera</i> (sundew), <i>Sarracenia</i> (pitcher plant).
Activity 2 [Worksheet]		Inquiry-based learning: observation, reasoning, assessing and evaluating evidence Students dissect plants from the following species: <i>Dionaea</i> (Venus flytrap), <i>Drosera</i> (sundew), <i>Sarracenia</i> (pitcher plant).
Plenary	15 mins	Whole class reflection Students share questions that emerged during their practical investigations. Students consider how Darwin might have approached these questions and how modern scientists might approach them.

Introduction to lesson starter

(Slide 2) Charles Darwin first came across *Drosera rotundifolia* while walking in Sussex and was curious as to why there was such 'prodigious slaughter' of insects on its leaves.

You may want to show students the video 'Darwin's beloved *Drosera*': www.bit.ly/BelovedDrosera.

(Slide 3) Darwin and his American correspondent Mary Treat (1830-1923), became fascinated by plant nutrition in relation to these carnivorous plants - both scientists researched a range of plants exhibiting different trapping mechanisms.

(Slide 4) Their studies were conducted through observation in the field and experimentation in their homes and gardens. For Darwin and Treat, observations and simple experiments, using living specimens over lengthy periods of time, coupled with detailed notes and sketches, were their principal research methods. Both scientists shared personal letters concerning their experiments, ideas and findings with other scientists around the world. Indeed for Mary Treat, as a 19th century female scientist, this was one of the few channels of frank scientific debate open to her.

You may want to show students the video 'Darwin's greenhouse': www.bit.ly/DarwinsGreenhouse.

Darwin was so fascinated by *Drosera* that he spent 285 pages of his ground-breaking study on *Insectivorous Plants* (1875) describing his own experiments on it. (Slide 5) He was particularly interested in the idea that a plant should exhibit animal-like behaviours.

“The fact that a plant should secrete, when properly excited, a fluid containing an acid and ferment, closely analogous to the digestive fluid of an animal, was certainly a remarkable discovery.”

Charles Darwin,
From *Autobiographies* (Eds. Neve and Messenger), 2002

At one point in his investigations he was said to exclaim:

“By Jove I sometimes think *Drosera* is a disguised animal.”

Charles Darwin, [in a letter to the botanist Joseph Hooker], December 1860

He was so passionate about this plant he called it ‘My beloved *Drosera*’.

Mary Treat wrote detailed essays on carnivorous plants in magazines and in her book *Home Studies in Nature* (1885). (Slide 6) Like Darwin, she appeared to cross the boundaries between animal and plant with her description of bladderwort (*Utricularia*) ‘digestion’.

“These little bladders are in truth like so many stomachs, digesting and assimilating animal food.”

Mary Treat, *Plants that Eat Animals*, in: *American Naturalist*, 1875

Bladderwort is another genus of carnivorous plant and Treat’s work on the sensitivity of the hairs surrounding bladderwort traps and their involvement in creating a ‘partial vacuum’ was not corroborated until some thirty years after publication of her observations.

Lesson starter

Ask students to imagine how Darwin’s first encounter with *Drosera* might have impacted on his thoughts about plants in relation to animals. Invite them to share their thoughts on how Darwin might have felt at this moment.

Darwin’s ideas and big questions

(Slide 7) Darwin presented the idea of homology - that is the similarity of traits resulting from shared ancestry - in *Origin of Species* and stated its importance in understanding evolutionary relationships. Essentially, homology is the existence of shared ancestry between a pair of structures, or genes, in different species.

(Slide 8) Darwin’s interest in carnivorous plants led him to develop his ‘big questions’ which he would attempt to answer through his experiments and observations.

Activity 1: Observation with a hand lens



Equipment

Hand lenses

Plant Specimens

- Genus: *Dionaea* (Venus flytrap)
- Genus: *Drosera* (sundew)
- Genus: *Sarracenia* (pitcher plant)

Instructions

- Ask students to examine each plant in turn using hand lenses to make close observations.
- The questions provide a framework for student enquiry, but you may encourage students to build their own questions from these beginnings.

Activity 1: Observation with a hand lens - ANSWERS

Examine each plant in turn and then answer the following questions.

- What evidence is there that these plants *are* carnivorous?

Students may come up with any of the following (other suggestions not listed here may also be valid):

Dead insects can be seen on plant.

The leaf structure has a purpose other than photosynthesis.

The leaves have some features that might suggest they could act as traps to visiting insects e.g. sticky, tubes with smooth surfaces difficult to climb out of, leaves that close to be like a cage.

- How do you think each plant traps its prey? What are the main features of the trapping mechanism?

Students may come up with any of the following (other suggestions not listed here may also be valid):

<i>Dionaea</i> (Venus flytrap)	<i>Drosera</i> (sundew)	<i>Sarracenia</i> (pitcher plant)
Active trap. Trigger hairs. Insect brushes hairs causing trap to snap shut. 'Teeth' on trap edge prevent large insects escaping. Trap able to re-set itself.	Semi-active trap. Insect lands on leaf and gets stuck to sticky fluid on tentacles. Movement of insect causes plant to produce more adhesive and digestive fluid. Leaf curls up around insect and it is absorbed.	Passive trap. Insect is attracted by nectar and red veins. Insect starts to go down inside the leaf to get nectar, slips and falls into the fluid. Downward-pointing hairs prevent escape.

- Describe the similarities and differences between the species.

Students may come up with any of the following (other suggestions not listed here may also be valid):

Venus flytrap and pitcher plant have smooth leaf surfaces whilst sundew has hairs.

Leaves on Venus flytrap and pitcher plant are much larger than sundew leaves.

Venus flytrap and sundew have leaves that can move in response to touch .

Sundew secretes a sticky substance.

Pitcher plant leaves form a vessel/cup/tube with liquid at the bottom.

Venus flytrap leaves have teeth like structures along the edge.

- Can you suggest why these plants are not seen growing in high nutrient habitats?

In high nutrient habitats, other plants that are adapted to gain nutrients directly from the soil will outcompete them. The carnivorous plant lifestyle is not very efficient in terms of energy conversion but provides a competitive advantage in low nutrient habitats as these plants are able to source nutrients by trapping and digesting insects.

Activity 2: Dissection



Equipment

Dissecting scissors
Scalpels
Microscopes
Ceramic tiles

Plant Specimens

- Genus: *Dionaea* (Venus flytrap)
- Genus: *Drosera* (sundew)
- Genus: *Sarracenia* (pitcher plant)

Health and Safety

Remind students to take care when using dissecting scissors and scalpels.

Instructions

Ask students to carefully cut a trapping leaf from each plant using dissecting scissors and examine in detail, using the information on the worksheet to guide their investigation. (You may want to show students the video of a *Sarracenia* dissection: www.bit.ly/PitcherDissection).

Activity 2: Dissection - ANSWERS

Using dissecting scissors carefully cut a trapping leaf from each plant and examine in detail.

- On a ceramic tile use a scalpel to take a small piece from the end of the *Drosera* leaf and mount on a glass microscope slide. Using a x10 objective lens (or lower if available), describe the features of the leaf you can see. Can you explain what the role of the feature(s) might be?

Students may come up with any of the following (other suggestions not listed here may also be valid):

Stalks/hairs with shiny droplets on the end – sweet sticky substance which attracts insect and once insect touches substance it becomes stuck.

Pores secreting liquid – digestive enzymes contained within liquid to digest prey.

- Using dissecting scissors open up the *Sarracenia* 'pitcher' by cutting from the top to the base of the leaf. Note the contents and any features of the interior. What do you find? Does the trap contain a particular type of insect? Can you suggest why these particular insects might want to visit the plant?

Students may come up with any of the following (other suggestions not listed here may also be valid):

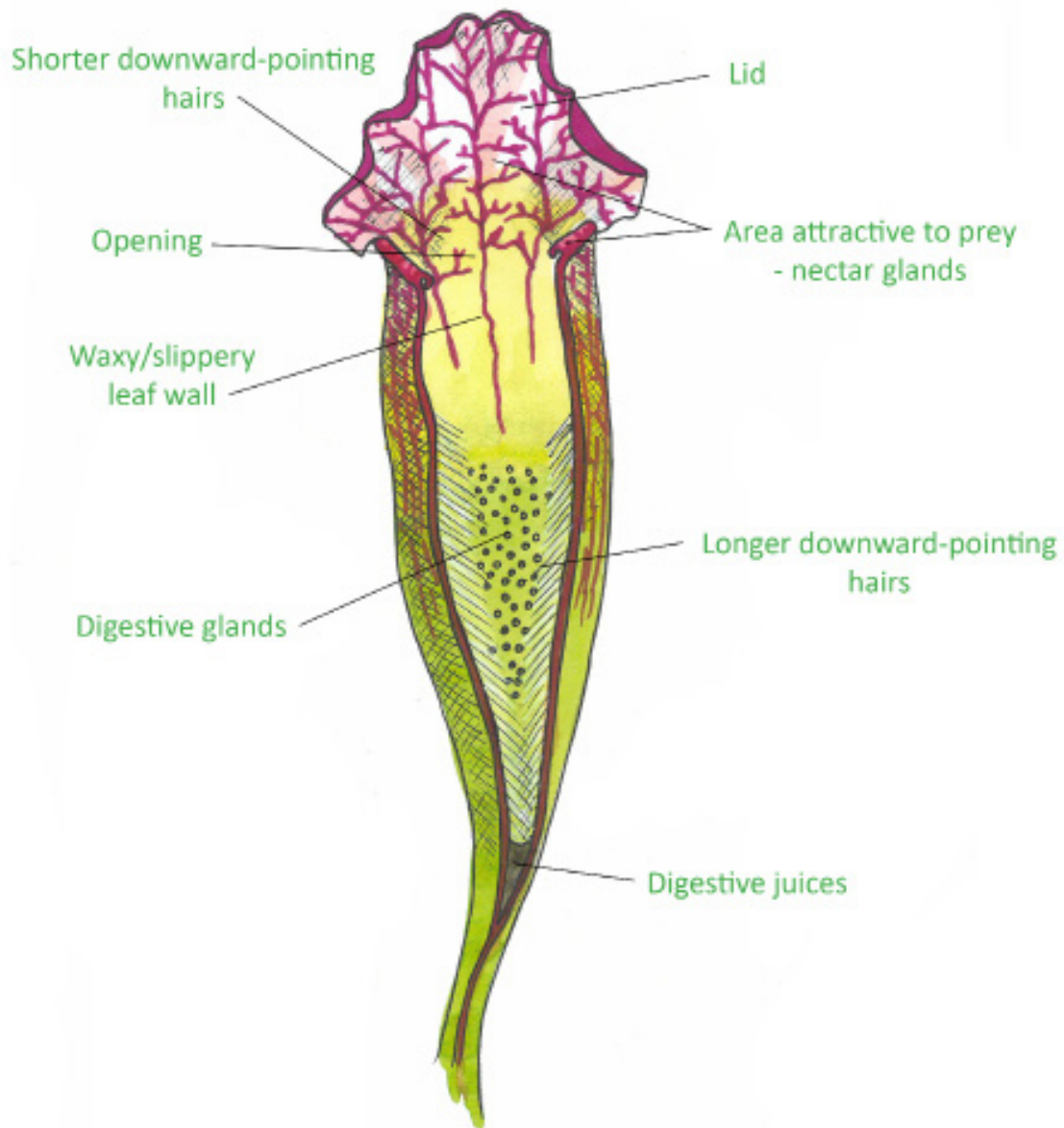
Insects, other invertebrates.

Pollinators (bees, butterflies) insects attracted by smell and colour (flowers).

Flies – insects attracted by smell (decay).

- Draw an annotated cross-section of the pitcher plant showing the features that help it trap and digest its prey.

Students may include any of the following detail:



Original drawing © Helen Cowdy

- On a ceramic tile use a scalpel to take a small piece (a square measuring 2cm by 2cm should be sufficient) from both the bottom and top of the pitcher-shaped trap. Mount each on a glass microscope slide. Can you distinguish any features using a x10 objective lens (or lower if available). How might these modified leaf features help the plant trap and digest prey?

Students may come up with any of the following (other suggestions not listed here may also be valid):

BOTTOM: Downward pointing hairs on the surface – could stop insects climbing up to get out.

TOP: Very smooth surface – could cause insects to slip into the fluid in the bottom of the pitcher.

- Make close observations of the Venus flytrap trapping leaf. Do you think it is most closely related to *Drosera* or *Sarracenia*? Give your reasons.

It is most closely related to *Drosera* as they both have active mechanisms for trapping - they move in response to touch.

Carnivorous plant science today

Darwin's book *Insectivorous Plants* (1875) continues to inspire the work of modern scientists, and Aaron Ellison, a carnivorous plant scientist at Harvard University, USA, considers bladderwort traps (which Mary Treat studied) an under-explored area of research (see Ellison and Gotelli, 2009).

Modern scientists, due in part to technological change and an increased understanding of genetics and ecology, can examine questions beyond the reach of these 19th century pioneers. But without Darwin and Treat we would know much less about the diverse forms and functions of carnivorous plants and their extraordinary adaptations to mineral-poor environments.

Using the science of genetics contemporary scientists can build a picture of the relationships between carnivorous plant families and their evolutionary origins. Their work, for example, has explored the idea of a common sticky-trapped ancestor for carnivorous plants.

(Slide 9) Mark Chase and colleagues at Kew and the Natural History Museum (Chase et al, 2009), have stated that "Flypaper traps are by far the most numerous, and it is easiest to consider a flypaper trap as the logical antecedent for the development of more specialised traps."

(Slide 10) They, and other teams around the world continue to examine evidence for and against 'the six lineages of carnivore' argument, which is what current evidence suggests.

(Slide 11) The aim is to build a phylogenetic tree for 'true carnivores'. The name given to plants that exhibit a) a means of attracting insects to their traps, b) capture of prey, and c) digestion.

(Note - This is not the only way to classify plant carnivory and Barry Rice (2011) gives further suggestions for definitions.)

Plenary

- o Ask students to share any questions that emerged from their practical investigations. Record these on the whiteboard.
- o Invite students to consider how Darwin might have approached these questions and how scientists might approach them now.

Extension activity - How Science Works

Students can conduct individual research projects on contemporary carnivorous plant scientists (see the 'Carnivorous plant science today' sections of each lesson for example case studies).

Lesson 3: Conserving carnivorous plants in a changing landscape

Overview and lesson plan

This lesson will use the context of carnivorous plants to consider the issues involved when conserving habitats.

Students will consider the challenges involved when developing a conservation plan, using carnivorous plants and their habitats as a case study.

Activity	Timing	Description and Pedagogical Approach
Lesson starter	15 mins	Group activity: discussion, problem solving, questioning, evaluating evidence Students discuss the issues facing carnivorous plant conservation. Working in small groups, students use the prompt cards provided to prioritise the actions they would take to protect carnivorous plant communities.
Activity	30 mins	Small group discussion: reasoning and argumentation Students discuss and prepare a conservation case. A spokesperson from each group presents their case to the class. Students vote on the case they think would be most effective. After voting has taken place, students verbally present their reasons for voting as they did.
Plenary	15 mins	Group activity: discussion, reasoning, analytical thinking, evaluating evidence Students reflect on the process of developing and voting on a conservation case.

Introduction to lesson starter

(Slide 2) Carnivorous plant genera vary greatly in their level of endemism. Some, such as the Venus flytrap (*Dionaea muscipula*) and the Californian Darlingtonia (*Darlingtonia californica*), are highly endemic whereas others, such as the Common Sundew ('Darwin's Beloved' *Drosera rotundifolia*), have a wide-ranging distribution, but nevertheless are threatened by human activity.

Many communities of carnivorous plants are threatened by changing land use, drainage of wetlands, collectors taking wild specimens and climate change.

(Slide 3) Darwin's 'beloved *Drosera*' has not been seen growing on Keston Common since 1986 due to land management practices.

(Slide 4) However, the sphagnum moss remains, and it is hoped that recent conservation actions will create appropriate conditions for any viable seed left in the mire.

You may want to show students the video 'How should Keston be managed for *Drosera* to return?': www.bit.ly/KestonManage.

Lesson starter

- Working in small groups, ask students to consider the issues facing carnivorous plant conservation.
- Provide each group with a set of conservation prompt cards (cards to cut out can be found at the end of this pack).
- (Slide 5) Ask the groups to use the prompt cards provided to prioritise the actions they would take to protect carnivorous plant communities.

Biodiversity and conservation

The Venus flytrap, a plant Darwin considered ‘most wonderful’, is listed in the IUCN Red Data lists www.iucnredlist.org/apps/redlist/details/39636/0. Due to its high level of endemism and attraction to humans this plant is now considered a vulnerable species, and continued survival in the wild is uncertain. Poaching for plant sales is rife and conservation protection includes marking wild populations with ultra violet light markers to help detect thefts.

It was common for Darwin to remove specimens of *Drosera rotundifolia* for his greenhouse studies. If all contemporary scientists removed specimens for study, it could add to the issues surrounding species conservation. You may want to show students the video ‘Should scientists remove plants like *Drosera* from their habitats to study them?’: www.bit.ly/DroseraRemoval.

Activity

- Ask students (still in their original groups) to focus on their top priority from their starter activity. Each group is then given time to prepare a conservation case. Once cases are prepared a spokesperson from each group presents each group’s case to their class.
- At the end of the group presentations each individual student is asked to vote on the conservation case they think would be most effective in protecting carnivorous plant communities. Once voting has taken place, and the results are announced, ask students (volunteers) to present, verbally, their reasons for voting as they did.

Carnivorous plant science today

Recent research has highlighted previously unknown interactions between carnivorous plants and other species in their habitats. These discoveries further highlight the potential importance of carnivorous plant conservation - as their removal from an ecosystem may have consequences that are currently unknown.

Jennings *et al.* (2010) have discovered that, as well as luring and trapping insects, in some habitats carnivorous plants are in competition with certain spiders present for the same prey.

(Slide 6) Jason Rohr, an ecologist at the University of South Florida, who worked on this study, notes that “Overall, this contradicts a long-held assumption that competition for food mostly occurs among closely related taxa, or categories of organisms.”

Other recent discoveries in carnivorous plant ecology concern mutualistic relationships between *Nepenthes* plants (a type of pitcher plant known as monkey cups) utilising the nitrogen content of the faecal matter of specific animal species they have attracted by providing them with something in return.

(Slide 7) Clarke *et al.* (2010) describe how three species of *Nepenthes* pitcher plants from Borneo engage in a mutualistic interaction with mountain tree shrews, the basis of which is the exchange of nutritional resources. The plants produce modified “toilet pitchers” that produce copious amounts of exudates, which serve as a food source for tree shrews. These exudates are only accessible when the tree shrew positions

its hindquarters over the pitcher orifice. Tree shrews mark valuable resources with faeces and therefore regularly defecate into the pitchers when they visit them to feed. This provides a valuable source of nitrogen for these *Nepenthes* species.

Clarke suggests further research is required to further understand this mutualism. This includes investigating the seasonal variation in exudate production rates by the plants, the behavioral ecology of visiting tree shrews and the mechanism by which the plants signal to tree shrews that their pitchers represent a food source.

Plenary

Using a mind-map on the whiteboard ask your students to reflect on the process of developing and voting on a conservation case. Encourage them to voice their views on the challenges of such a process both for scientists and citizens.

Extension activity

Students could also discuss whether the statement ‘Plants grow, while animals behave’ (Kinchin, 1999) still holds true or indeed if we have reached a stage in biological science where ‘Terms such as “perception” and “behaviour” are becoming more common descriptors of plant movement and imply a form of plant intelligence’ (Chase et al, 2009). Plants exhibiting behaviours is a concept Darwin foresaw as his studies into insectivorous plants deepened.

Using data from the National Biodiversity Network Gateway <http://data.nbn.org.uk/> students could model the distribution of two British *Drosera* - *Drosera anglica* and *Drosera rotundifolia* and consider current and future pressures, such as climate change, invasive species and urban expansion, on their distribution.

Extension activity: field trips

Students could go on a field trip to Down House or Keston Bog or a visit to a botanic garden with a carnivorous plant collection e.g. Chelsea Physic Garden or Royal Botanic Gardens at Kew. Students with local access to national parks containing carnivorous plants could examine such plants *in-situ* (the summer is the best time to see these plants in their natural habitat).

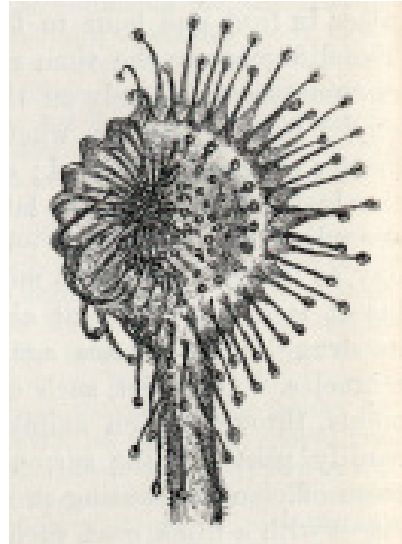
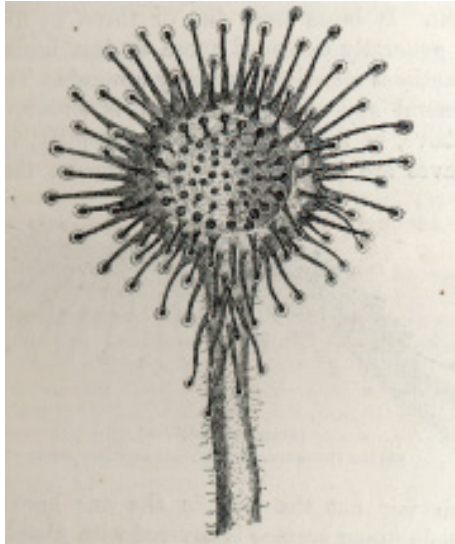
These external visits could form the basis of further student investigations for example:

- Recent habitat pressures at Keston Bog and the impact on the *Drosera* population. Changes in the conservation management plan to improve germination viability for any potential *Drosera* seed bank.
- Ways of displaying carnivorous plants in botanic gardens to communicate adaptation to environment and the issues of human impact such as land drainage and unregulated specimen collection in their natural habitats.

Exam-style question

- 1 Adaptation is the process where an organism becomes more suited to its environment by developing traits that will enable it to survive.

The diagram below shows *Drosera rotundifolia*, a species of plant that is found in nitrogen-poor, waterlogged soils. This plant is carnivorous and obtains nitrogen from insects.



Diagrams: *Drosera rotundifolia* detail, Darwin 1875

- 1 (a) Suggest **two** features of *Drosera rotundifolia* that make it well-adapted to survive in nitrogen-poor soils. Explain how each feature helps it to survive.

[4 marks]

- i. **Tentacles.** These entrap insects and exude digestive enzymes to digest soft tissues of insect's body as a source of nitrogen
- ii. **Sticky droplets.** These suffocate the insects.

- 1 (b) Discuss the ways in which pitcher plant traps, such as *Sarracenia*, can be used to model larger ecosystems such as lakes. What are the limitations of this approach to ecological modelling?

[2 marks]

Pitcher plant traps can contain complex food webs of 5 trophic layers thus mirroring the structure of larger ecosystems such as lakes. Although similar in structure, differences in scale and complexity can add additional factors into the lake ecosystem not present in the *Sarracenia*. Furthermore, human leisure activity may create additional impacts in the lake ecosystem.

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Appendix: Lesson 3 Starter Activity: Prompt Cards

Cut out the prompt cards below and give a set to each group of students.

Creating Protected Areas	Passing New Laws	Developing an Education Programme
Reducing Climate Change	Changing Land Management Practices	Collecting Seed and Growing Plants Off-site <i>[Ex-Situ]</i>

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