DARWIN INSPIRED LEARNING

Enquire with Darwin

KS3

Module 1: Darwin's Bees

Lesson plan

Small links in the chain of evolution

Many religious people at the time said that the perfect hexagonal cells of the honeybee comb must result from divine force and that the bees were 'heaven guided'. Darwin knew that to convince others of evolution through natural selection he had to show that social bee behaviour was a result of inherited instincts and that comb building had evolved in small steps over long stretches of time.

Charles Darwin kept honeybees aided by the Vicar of St Mary's church in Downe village, who lent him a hive and helped him to manage it. The glass-sided observation hive they made enabled Darwin to watch bee behaviour and to experiment. He met other beekeepers to share knowledge, and exchanged many letters with experts and friends across the world. He also developed a deep interest in bumblebees, wasps and the combs they built.

Continuing research on comb building has confirmed Darwin's work and his big idea that bees' instincts to build wax into spheres at set distances, producing hexagonal cells with interlocking bases for strength and capacity, is an extremely efficient use of wax.

Above: Honeybees in a hive.
Below: Hexagonal cells.

Quotation

'Thus I believe that most wonderful of all known instincts that of the hive bee can be explained by natural selection…that individual swarm which thus made the best cells with least labour, and least waste of honey in the secretion of wax, having succeeded best, and having transmitted their newly acquired economical instincts to new swarms, which in their turn will have had the best chance of succeeding in the struggle for existence.'

Charles Darwin, *On the Origin of Species,* 1859.

Lesson outcomes

- Consolidating understanding about the life history, body plan and classification of the honeybee as an example of an animal, arthropod, and insect.
- Watching honeybees to gather evidence about their behaviour.
- Following Darwin's reasoning, collecting evidence and building an argument for the hexagonal cells being the result of instinctive bee behaviour as they act together.
- Considering the threats to and benefits from bees in the environment.

Worker honeybee.

Curriculum links

- Developing most aspects of practical and enquiry skills, especially the critical use of evidence.
- Bee classification, behaviour, life cycle and significance in the environment.

Key words

Comb building, hexagonal cells, rhombic dodecahedrons, spheres, observation hive, social insects, abdomen, drones, workers, queen, eggs, larvae, swarm, pollen, nectar, waggle dance, arthropods.

Resources

Darwin notebooks, some pieces of drawn comb and foundation, some beeswax, beakers, drinking straws and empty CD covers, drawing compasses, rulers, scissors, glue, bubble mixture (see Notes for teachers page 10).

Lesson sequence

Pre-visit lesson

Starter activity

Start by sharing experiences and knowledge of honeybees. Possible ways:

- Know, want to know, learnt (KWL) chart (see Resource materials page 14 and PowerPoint slide 26). Encourage students to think widely what they know about honeybees. Clues: classification, body structure, usefulness, habitat, inside the hive, flowers. Then put in what they want to know. Keep the chart to complete at the end.
- Make true or false statements or ask some questions about honeybees (see Notes for teachers page 08). Students write down the answers and decide on a 1-5 scale how sure they are that the answer is right. When they feedback ask them to explain their thinking.
- In small groups, use the conflicting concepts mind map, How do honeybees build comb? (see Resource materials page 15 and slide 27). Not all of the statements are true. Using their Darwin notebooks, students make a note of which statements they think are true. Discuss which idea Darwin might have found most interesting, most important, and why (see Notes for teachers page 9).

Above: Landing platform of a hive.

Below: Worker honeybee collecting nectar. See the pollen on the hind leg.

Pre-visit lesson

Main activity

Darwin's big idea

Honeybees build their hexagonal comb by acting on an inherited instinct built up over millions of years of evolution as individuals inherited slight, favourable modifications.

A Circus of activities (numbered 1-7) show Darwin's ways of working and the kind of evidence he collected to make an argument to support his big idea. Students should take notes on each activity and answer associated questions before moving on.

1. Fossil bees and comb

PowerPoint slides 2-4 use recent research into fossil bees and comb to support understanding of how cylindrical cells become hexagonal.

2. Arguments regarding the evolution of the comb

Slides 5-7 include videos of comb to explore and discover the flat surfaces, angles and how the two plates join.

3. A theory of how bees might make a hexagonal comb

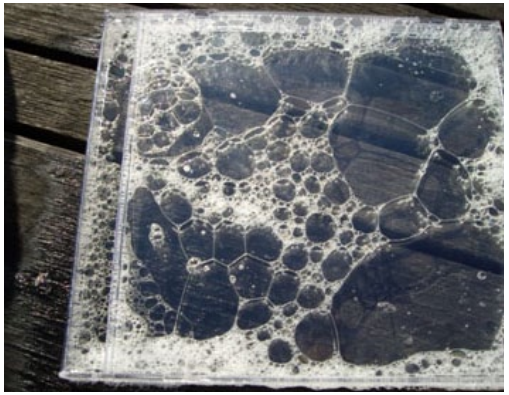
Slides 8-10 give more insight into how a hexagonal cell might form. There is an excerpt from the correspondence between Darwin and Mr Waterhouse, and Darwin's notes on making hexagons from circles are illustrated. Students can make their own models to help them understand the process.

4. Looking closely at the construction of a double layer of comb

Slides 11-14 encourage observation as students answer the questions posed and make a model of a cell.

5. A model of a whole comb using bubbles

Slides 15-17 encourage model comb building by making rafts of bubbles, and explores surface area: volume ratio.



Above: Hexagonal cells in a hive.

Below: Hexagonal cells forming in soap bubbles.

Pre-visit lesson

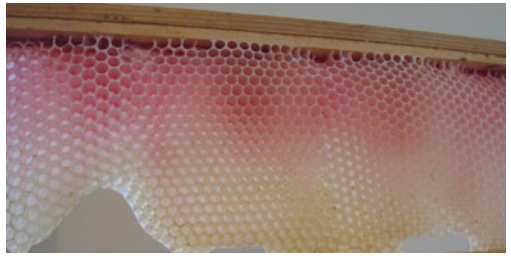
6. Experiments with blocks of wax

Slides 18 - 20 have photos of Darwin's experiment with bees and their excavation of blocks of wax (the pale brown wax under the combs).

7. Experiments with red wax in the hives

He carried out this experiment when he was studying bee evolution, how honeybees evolved alongside plants and how adaptations might have been selected. Slides 21 and 22 show recently repeated Darwin experiments with coloured wax.

Slides 23-25 show how the garden visit is related to this study and could be used as an introduction to observations linked to Darwin's experiments.



Experiments with red wax in a hive.

Plenary

The class draws on the evidence collected from the circus. In pairs or small groups, students construct their own argument from this evidence to support Darwin's big idea. Pay close attention to reasoning and knowledge. Vote on who makes the most convincing presentation.

Extension activities

Differentiation:

Read Cell making instinct of the hive bee in Chapter V11 Instincts, *On the Origin of Species*, 1859 (see websites) Is his argument as good as yours?

- Find out more about the roles that the worker bees play at different ages.
- Make models out of warm beeswax and experience its malleability.
- Find out about the most recent concern: bee deaths due to colony collapse disorder.

Visit

Visit a park, local nature reserve or, if possible, Down House. Students get very excited by seeing real bees at work. It makes a lasting impression. If possible visit an observation hive where small groups can each identify the shape of the comb, the queen, workers (doing different tasks at different ages), the drones and the eggs, developing larvae and capped cells, hatching brood cells, the pollen stores and nectar. A lot of questions will arise from this experience and can be the basis of further work. If this is not possible, view an online video of bees in a hive (see websites).

In a garden, count the numbers of honey and other bees on different flowers and note the flower colour. Group the data and decide which flower colour bees prefer at this place and time.

Watch the bees foraging. What are they collecting and why? Try to follow one bee and count how many flowers it visits before it flies off. Group the data and decide how many flowers of each kind all the bees observed visited.

Watch how bees get to the nectar of deep flowers. What do they do on flowers which are flatter? On which of these two kinds do they spend the least time? Watch carefully to see the pollen on the legs of the bees. Ask students to think of questions relating to bees. For instance, how do bees know where to find nectar and pollen? Record any observations in a Darwin notebook. Digital images will also be useful. Digital images of bees on flowers can be helpful in recognising bees and bee body parts.

Above: Honeybee worker on *Hebe*.

Middle: Honeybee on marjoram. You can see the mouthparts in the flower.

Below: Bumblebee on knapweed. You can see the two pollen sacs on its legs.

Post-visit lesson

Main activity

If used, complete the KWL chart by adding what the students now know about bees.

Display both the data collected graphically and the digital images. Draw conclusions from the visit regarding bee behaviour. Make a collection of questions students have raised and group them. A local beekeeper might visit to answer these questions.

Plenary

Play the game of connectives to get everyone synthesising their new understanding.

Assessment of progression

AF1, AF2, AF3, AF4, AF5:

Apart from the requirements for the Key stage, assessment might include the Darwin Inspired learning developmental summary (see KS3 Introduction).

Notes for teachers

Pre-visit lesson

Examples of starter questions about honeybees

The queen bee lays all the eggs, fertilised eggs turn into male drone bees.
(no, they are unfertilised)

There are no male bees in the hive in winter.
(correct, they are thrown out in autumn)

Worker bees use the sun as a compass to guide them to nectar in flowers.
(correct)

What group of invertebrates do bees belong to?
(arthropods with jointed legs/ insects)

How many bees are there in a beehive in summer?
(20,000-80,000 workers)

Why do bees swarm?
(colony too big, queen old, new queen hatching)

What is comb made of?
(from wax secreted by worker bees from abdomen)

What is pollen?
(male part of the flower)

How do bees make honey?
(by collecting nectar, mixing with enzymes in stomach, evaporating water in hive and storing in capped cells)

Honeybee queen is attended by worker bees.

Pre-visit lesson

To experience putting together a persuasive argument for the honeybees acting on instinct as Darwin did, this lesson is presented as a circus of activities, but could be organised in other ways. It is important for students to think critically so that they appreciate how Darwin made his argument. This was a key argument in countering the 'great designer' argument current at the time amongst religious people. Today we respect the varied religious cultures represented in a class yet we must present firmly scientific evidence and its conclusions. Science asks questions that require investigation. Religious questions tend to look for ultimate causes and spiritual reasoning. Scientists can be both religious and scientific, seeing the two areas of human experience as complimentary.

Confilcting concepts mind map

The picture replicates one of Darwin's experiments with honeybees working at the red wax inserted at the top. The colour is diffused as bees are adding and taking away at the working edge. The lower picture is of a worker bee showing the underside of the abdomen. The 10-12-day-old worker extrudes the wax as flakes between scales under its abdomen. These flakes are passed to the mouth, chewed and used to build comb.

Darwin was interested in comb building because of the prevailing view of many religious people expressed by Mr Cotton 1842 when writing for beekeepers: *'Look at the cut of the Honey-Bee's comb; each cell is a perfect pattern of neatness, beauty, and skill; it serves most admirably as a nursery for the young Bees, and afterwards for a honey-pot, in which they may store their food for the winter. THERE ARE NO BUILDERS SO CLEVER AS THE HEAVEN-GUIDED BEES.'* Darwin knew that in his book *On the Origin of Species* he needed to explain evolution through natural selection well enough to be accepted, and this meant providing proof. Each comb building experiment provided one element of this proof.

Above: The red wax experiment.

Below: Underside of worker honeybee.

Pre-visit lesson

Circus of activities

The PowerPoint has 7 activities which each take 5-10 minutes. Each activity is a link in a chain of reasoning that helped Darwin to understand evolutionary processes and their timescale.

Bubble Recipe

- ½ cup of washing-up liquid
- 5 cups water (soft water is best – but use distilled or bottled water if water is very hard)
- 2 tablespoons glycerine (from a pharmacy or supermarket) or corn syrup (not golden syrup).
- Mix the ingredients very carefully so that you don't make it too bubbly. Pour into storage containers and leave overnight to blend.

Above: Worker honeybees in a hive.
Below: Worker bee.

Plenary

The aim of this plenary is to gather the different sorts of evidence Darwin used. Students list the sorts of evidence Darwin collected and used including experimental evidence from wax blocks; observational evidence from samples of comb; phylogenetic evidence from fossils and existing species; modelling evidence from geometry and bubble experiments; theories and data from friends and fellow beekeepers.

Visit

Risk assessment for the visit should include assessment of the risk associated with bee stings. Students with allergies should have notified the school and the teacher should be informed. Carry prescribed antidote and pump for removing stings if required. First aid: include common medication for stings.

Have a laminated diagram of the mouthparts of a bee and discuss what happens to the nectar on the way back to the hive and inside the hive (see PowerPoint slides 24 and 25). Careful observation will show individual bees visiting the same type and colour of flower to collect nectar or pollen. Students should be able to observe the bees using their mouthparts as a tube to draw up nectar and scraping the pollen into the pollen baskets on the hind legs. They should be able to observe that individual bees are collecting different coloured pollen.

Honeybee mouthparts

Post-visit plenary

Draw all the evidence together from the Circus activities and the visit, to summarise Darwin's work on the development of comb structure.

Connectives

Have a list of places, objects, people and ideas connected with Darwin written on a big sheet or whiteboard.

Examples: Charles Darwin, Down House, honeybees, species, survival of the fittest, *Origin of Species*, wax, garden, beekeeper, comb building, hexagonal cells, rhombic dodecahedrons, spheres, observation hive, instinct, drones, workers, queen, eggs, larvae, swarm, pollen, nectar, waggle dance, angle, arthropods, insects, flowers.

Add the connectives - but, some, and, then, because, if, when, for, in which, such as, therefore, however, from…

In pairs, students use connectives to link two items and feedback to the class. They can make as many sentences as they can after that. Make sure the statements made show developing understanding. Write down the sentences to assist with assessment of progression.

Worker honeybee collecting pollen. You can see the pollen sacs on the legs.

Assessment of progression

Students should progress not only in their understanding of bees but also in their use of Darwin Inspired learning. See KS3 Introduction for the development summary.

Website links, videos, Interactives, references

Bee videos

Honeybees: www.arkive.org/honey-bee/apis-mellifera/video-03.html

Waggle dance: www.bbc.co.uk/nature/life/European_honey_bee

Amazing honeybee facts: news.bbc.co.uk/1/hi/sci/tech/7925218.stm

Bumblebee nest: www.youtube.com/watch?v=LqreQmaJpmg&feature=endscreen&NR=1

Melopina: (a bee that is unlike the honey-bee in the way it makes its comb) www.youtube.com/watch?v=JWOTczp0BiA&feature=related

www.arkive.org/honey-bee/apis-mellifera/video-03.html and http://www.bbc.co.uk/nature/life/European_honey_bee and http://news.bbc.co.uk/1/hi/sci/tech/7925218.stm

---

Honeybees, their origins, evolution and diversity: www.bibba.com/origins_milner.php

British Beekeepers Association: www.bbka.org.uk/learn/general_information/biology__interesting_facts

Darwin-online: *On the Origin of Species*, 1859, Chapter VII, Instinct:
darwin-online.org.uk/content/frameset?viewtype=text&itemID=F391&pageseq=1

Darwin-online also has all Darwin's publications in a searchable database: http://darwin-online.org.uk/

Darwin Correspondence Project: The evolution of honeycomb:
www.darwinproject.ac.uk/the-evolution-of-honey-com

BBC oldest bee fossil known: http://news.bbc.co.uk/1/hi/sci/tech/6084974.stm

---

References

Sheperdson, D. (2002) Bugs butterflies and spiders: children's understandings about insects. *International Journal of Science Education* 24 (6) 627-645.

Wenzel, J.W. (1990) A social wasp nest from the cretaceous period, Utah, USA, and its bio-geographical significance, *Psyche* 97 21-29.

Williams, J. (2009) *Darwin's bees.* Upminster: Central Association of Bee-keepers.

Resource materials

Know, want to know, learnt (KWL) chart

Know	Want to know	Learnt

Resource materials

Conflicting concepts mind map

How do honey bees build comb? What do you think?

Bees must make the cells strong but use just enough wax in the process

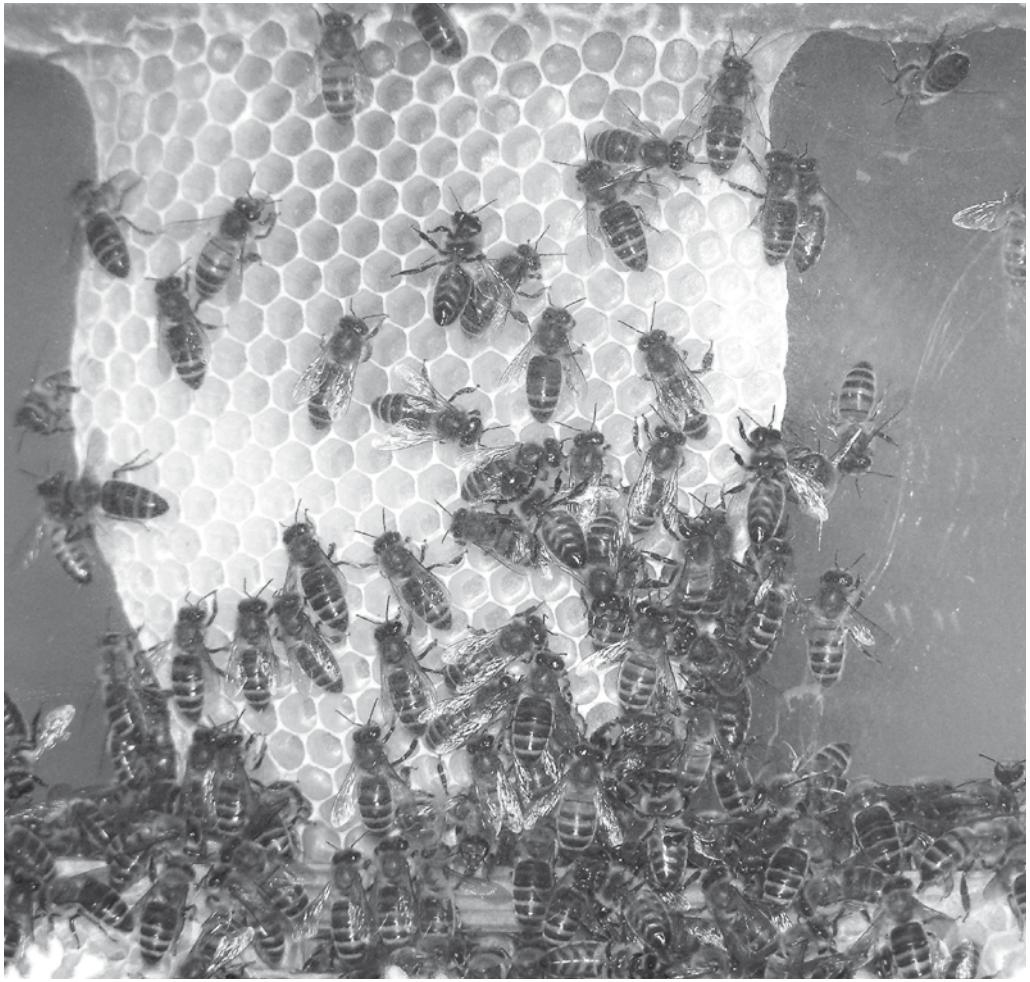
Cells of honey comb are stong and made of wax. Small flakes of wax under the abdomen are chewed and used to build comb.

Underside of a worker honeybee. ▲

The wax gland will only secrete wax if bees cluster together to raise the temperature. Bees are social insects and work together.

Cells are where the larvae are reared. Cells are used later to store honey i.e. food for winter.

Bees never begin one cell at a time, always several; they can judge distance and angles.



Bees must be '*heaven guided*' to make perfect 3D hexagonal cells.

Making wax takes a lot of effort. About 7KG of honey is needed for bees to make 1KG of wax.

One honeybee will make just half a teaspoon of honey in it's lifetime.

Bees work from wax at the top of the comb and add downwards.

A 3D hexagonal cell cannot have started out as a cylindrical cell.

Bees build 3D hexagonal comb cells back to back to provide 2 plates of cells locked together.

Bees work from wax at the bottom of the frame and add upwards.

CHARLES DARWIN TRUST

Acknowledgements

This resource has been produced by The Charles Darwin Trust

Series editor Dr Susan Johnson
Author Dr Carolyn Boulter
Editor Karen Goldie-Morrison
Design SPY Studio

Photographs taken at Down House are with thanks to English Heritage which owns and opens the House to the public.

Thank you to our current funders who are supporting Darwin Inspired learning and have made *Enquire with Darwin* possible: the Evolution Education Trust, the Foyle Foundation, the Garfield Weston Foundation, the JJ Charitable Trust and the Mark Leonard Trust, The Mercers' Company, and a number of individual donors.

Picture Credits

Front page John Williams
Page 1 above Waugsberg/Wikimedia
Pages 1 below, 2 , 4 above, 10 below Makro Freak/Wikimedia
Page 3 above Zonki/Wikimedia
Page 3 below Frank Mikley/Wikimedia
Page 4 below Dr Carolyn Boulter
Pages 5, 6 Dr Susan Johnson
Page 8 Waugsberg/Wikimedia
Page 9 above John Williams
Page 9 below Andre Karwath/Wikimedia
Page 10 above Waugsberg/Wikimedia
Page 10 below Makro Freak/Wikimedia
Page 11 Siga Wikimedia commons
Page 12 Pollinator/Wikimedia
Page 15 centre John Williams
Page 15 left top Andre Karwath/Wikimedia