WATER WATER EVERYWHERE... BUT NOT A DROP TO DRINK

How does nature store water?

AGE RANGE

13–15

DURATION

Activity:

160 minutes / 3½ lessons

KEYWORDS

Plastic; bottle; biodegradable; natural functions

SUMMARY

In this module students explore how nature has a range of different abilities we can learn from. Students use the abilities of nature to inspire ways to address the challenge of plastic bottle pollution. By the end of the module, students will have created their own solutions to the challenge of plastic bottle pollution.

BIOMIMICRY PRINCIPLES

3 – Nature fits form to function
4 – Nature recycles everything
7 – Nature demands local expertise

LEARNING OBJECTIVES

- Students understand why plastic bottles are a part of their lives and the function(s) they provide.
- Students know and are able to apply biomimicry principles to solving a problem.
- Students realize that nature offers solutions for a sustainable future.
- Students can differentiate between different solutions and their ethical value to society.

LEARNING OUTCOMES

- Students ask questions and research answers.
- Students investigate an issue of concern (use of single use plastic bottles).
- Students apply analogical thinking to finding solutions using nature as inspiration.
- Students create designs for solutions.
- Students discuss, debate and evaluate the sustainability of their solutions.

SUBJECT(S)

This learning module can be used flexibly within the curriculum to support key knowledge about Biology, Chemistry and Design Engineering & Technology, and develop working scientifically competences. The learning links with the Sustainable Development Goals and provides a broader context for student learning. It is suitable for adapting as a STEM activity or Eco Club.

Programme of Study Reference	Working Scientifically
Biology: KS4 Ecosystems • how materials cycle through abiotic and biotic components of ecosystems • the role of microorganisms (decomposers) in the cycling of materials through an ecosystem • organisms are interdependent and are adapted to their environment • the importance of biodiversity • positive and negative human interactions with ecosystems. KS3 Material cycles and energy Photosynthesis • the dependence of almost all life on Earth on the ability of photosynthetic organisms, such as plants and algae, to use sunlight in photosynthesis to build organic molecules that are an essential energy store and to maintain levels of oxygen and carbon dioxide in the atmosphere. Interactions and interdependencies; Relationships in an ecosystem • the interdependence of organisms in an ecosystem, including food webs and insect pollinated crops • how organisms affect, and are affected by, their environment, including the accumulation of toxic materials. **Chemistry:** KS4 Chemical and allied industries • life cycle assessment and recycling to assess environmental impacts associated with all the stages of a product's life • the viability of recycling of certain materials • carbon compounds, both as fuels and feedstock, and the competing demands for limited resources **Design, Technology and Engineering:** KS4 • Technical principles (links with most areas). • Design and making principles (links with most areas). KS3 • Design, Make, Evaluate (links with most areas).	Students successfully completing this module will have had the opportunity to access these statements: **2a, 2c, 2e, 3b, 3c, 3d, 3f**. See Annex 1 for full statements.

BIOLEARN COMPETENCES

- Students are able to abstract principles of sustainability from the way the natural world functions.
- Students are able to identify functional design in nature, develop greater awareness and appreciation for design excellence in nature, and appreciate how nature works as a system which is elegant and deeply interconnected.
- Students are able to identify important needs and opportunities that can be addressed through design innovation for products, processes and systems.
- Students are able to use analogical creativity to innovate, using biological models to inspire solutions to design challenges.
- Students are able to assess the consequences of applying biomimicry solutions (values).

SUMMARY OF THE ACTIVITIES

	Activity Name	Description	Method	Duration	Location
1	So... how does nature work?	Students understand how nature works as a sustainable system	• Hands-on activity • Group discussion	45	Outdoor
2	What has nature ever done for me?	Students discover how nature offers solutions to human challenges, and that this process is called biomimicry	• Card sort • Group discussion	25	Indoor
3	Nature's bottle	Students create a design for a water bottle based on biomimicry principles	• Research • Design activity • Student presentation	2 × 45	Indoor

BACKGROUND FOR TEACHERS

Plastic water bottles are a universal part of most people's lives. Until recently we thought very little about them, just another part of the consumer economy. Recent news and nature documentaries have changed that. Governments and business are being exhorted to take action, and some are. What does a biomimicry approach to plastic water bottles look like?

Just 43% of the 13bn plastic bottles sold each year in the UK are recycled, and 700,000 become litter each day (57% of PET bottles are recycled in Europe as a whole). Pressure is growing on the government, retailers and consumers to increase rates of plastic bottle recycling and so reduce marine pollution.

It is expected that students will already be familiar with the principles of biomimicry; if not see the introductory module to biomimicry.

During the lessons, students will become familiar with the terms function and strategy. It is important to be clear about these terms and we offer the following definitions:

Functions: In biomimicry a function refers to an organism's adaptations which help it survive. For example, the purpose of bear fur is to keep warm, in technical terms its function is to conserve heat (insulation). A leaf is made to biodegrade, so one function of a leaf is to 'break down' after use. Human products also have functions; a kettle has the functions to both contain water and heat water (modify its physical state). In brief, a function is 'what it does.'

Strategy: Organisms meet functional needs through biological strategies. This is a characteristic, mechanism or process which performs the function for them. In the bear example, fur is the strategy for delivering insulation. In a kettle, electrical energy is transferred into physical heat which modifies the temperature of water. In brief, a strategy is 'how it does it.'

Health and Safety

Appropriate consideration needs to be given to health and safety when working outdoors, but this should not prohibit regular use of the outdoor learning environment.

For guidance on using the outdoor learning environment review the Council for Learning Outside the Classroom suggestions on Plan and Deliver. CLEAPSS also provides guidance for members. We recommend you read and act on L196 – Managing Risk Assessment in Science. Finally, check your school policy on learning outside the classroom.

The Institute for Outdoor Learning provides a good overview into the risks and benefits of outdoor learning here. They also offer specific guidance and advice for schools here.

ACTIVITY DETAILS

LOCATION
Outdoor

TOOLS AND MATERIALS

Student worksheet: W1.1

PREPARATIONS

Prepare cut up copies of W1.1

1 | SO... HOW DOES NATURE WORK?

» DISCOVER

This activity introduces students to a range of different functions nature provides, and helps them to start viewing nature as a potential source of solutions to human challenges. In the activity, students identify a range of functions nature delivers.

This activity takes place outside, ideally in an area where there is some natural vegetation and larger shrubs/trees.

a) Cut up the functions (abilities) in W1.1 ready to distribute to students.
b) Explain to students that in this activity they will be exploring how nature provides/delivers different functions (i.e. how nature does certain things; has certain capabilities), and that you will be providing them each with different functions to identify and explore. For example, trees exhibit the function of 'protection' through their bark which prevents attack from insects.
c) Ask students to work in groups of 2–3. Provide each group with 3–4 different functions and ask them to see if they can find examples of how nature exhibits these functions. Provide 10–20 minutes for this task.
d) After the allotted time is up, re-convene and walk through your working area asking students to explain the functions they have identified and state their reasons.
e) As students share their findings you can ask questions to clarify more:
    - How did you identify this function?
    - Can nature provide the same function in different ways?
    - How does the function benefit this species?
    - Do organisms in nature just provide a single function or many?
    - What value do you think it has for nature?
    - Is this how you are used to seeing nature? How is it different to how you are used to seeing nature?
    - What can we learn from how nature exhibits functions?

You could choose to carry out this activity as a homework task, asking students to take photographs of the functions they find to share later.

By the end of this activity students will have experienced how nature delivers a range of different functions which enable it to work as a system and sustain itself.

ACTIVITY DETAILS

LOCATION
Indoor

TOOLS AND MATERIALS

Student worksheet: W2.1

PREPARATIONS

Prepare cut up copies of W2.1

2| WHAT HAS NATURE EVER DONE FOR ME?

» DISCOVER

This quick card sort activity introduces students to different ways biomimicry has helped solve human challenges. Students attempt to match up the natural thing (species or process) with the biomimicry inspired human design, e.g. Namib beetle and water collection device. This activity provides affirmation that biomimicry can help us find solutions to significant issues.

See W2.1 for images and functions. The accompanying PowerPoint (Biomimicry Card Sort) will guide you through the activity and the table below describes each pairing. The table below provides more details about each example to explain with your students.

Once students have matched the natural thing (species or process) with the biomimicry inspired human design, they are invited to think about what strategy from nature is being emulated to solve the human challenge. You can either ask students to think about this unaided or guide them through the presentation provided.

Finish by offering the following definition of biomimicry for students:

"Biomimicry is the design and production of materials, structures, and systems that are modelled on biological entities and processes."

By the end of this activity students will have raised awareness on the opportunities biomimicry offers.

ACTIVITY DETAILS

Inspiration from nature	Human invention	Function	Strategy
Namib beetle	Fog catcher	Harvest water	Bumps and grooves on the surface of the Namib beetle allow water to condense from moist air. A combination of hydrophilic (water attracting) and hydrophobic (water repelling) areas increase this function and channel water to where the beetle can drink it. This is being mimicked to harvest water from fog for human consumption.
Lotus	Self-cleaning paint	Cleaning	Lotus leaves stay clean without detergents. The plants cuticle is extremely water repellent. This is accomplished through microscopic bumps on their leaf surface. This reduces the stickiness of water droplets to the surface so they run off easily and take dirt away at the same time. This is being mimicked in self-cleaning panes of glass.
Ivy	Dye sensitized solar cells	Energy generation	Ivy grows vertically to avoid competing for sunlight and nutrients with ground plants and paint. Solar panels often take up a lot of space. A company has designed solar cells to use building walls like ivy to utilize space. The Solar Ivy System is customizable to any wall space. It uses both wind and solar to generate energy, and is built using recycled materials where possible.
Humpback whale	More efficient turbine blades	Drag reduction	The tubercles (bumps) on the flippers of humpback whales allow them to 'grip' water and turn tightly when catching food. Wind tunnel tests demonstrate that this design provides a 32% reduction in drag (resistance). This is being mimicked to create more efficient wind turbines.
Termite mounds	Passive cooling/ heating	Temperature control	Termites build thin tunnels at the edge of their mound. These warm up during the day and as the heat rises to escape it draws cooler air up through the central column of the mound. The process reverses at night. The Eastgate Centre in Harare mimics this process. Warm winds pass through the porous concrete walls of the centre, cooling them before they enter the interior of the centre.
Ants	Efficient delivery system	Route finding	Ants lay down scent trails to mark where they have been. When an ant finds food, it takes this back to the nest. As more ants locate the food source a stronger scent trail develops 'telling' other ants where the best food source is. Virtual ants are programmed to explore paths between a set of destinations. The quicker the ants achieve the task the stronger their virtual trail becomes. The ants work randomly at first, but as quicker (less distance) routes emerge they coalesce around the fastest route.

ACTIVITY DETAILS

LOCATION
Indoor

TOOLS AND MATERIALS

Student worksheet:
W3.1, W3.2

3| NATURE'S BOTTLE

» CREATE

The purpose of this activity is for students to identify how to address the challenge of waste created by single use plastic bottles. It challenges students to think about how nature builds materials and deals with them when finished.

By the end of the activity students should have produced a design for a new type of bottle. This could raise other questions such as: why use bottles at all, how is water purified, are there better ways to transport water? These are all good and worth investigating.

Provide students with worksheet W3.1 which gives details of their challenge. The biomimicry evaluation wheel (see W3.2) can be used to help students reflect on their ideas and focus on the biomimicry principles; it is best used as a reflection tool once students have their initial ideas, and then again at the end of the process.

To help students address their challenge, you could invite them to spend some time outside searching for examples from nature; for each function they can seek an example of how nature delivers this function (see 1. "So... how does nature work?" above). Then, they can research ideas online.

Here are some examples to inspire.

Construct Materials: The Interall Group uses waste from human consumption to make useful products. Black corals produce a material called chitin which could be used as a biodegradable material for packaging.

Disposing of Materials: Fungi can digest plastic waste. To date over 50 fungi species have been identified that might help tackle plastic pollution. And bacteria are getting in on the act as well, but will it work?

Collecting Water: GENAQ is a company collecting water through condensation of water vapour. Here is someone trying this in a small scale. And another one.

By the end of this activity students will have discovered how nature offers potential solutions to creating plastic water bottles which ameliorate the issues they have identified. To help students, remind them to:

- Write a clear research question.
- Describe the functions their design must fulfil.
- Consider which of the biomimicry principles need to apply to their design.
- Think about which solutions from nature they can mimic in their design.

EXTENSION(S)

The module focuses on redesigning plastic bottles. Students may wish to take this in different directions, for example, replacing plastic bottles with free drinking water stations. This would lead to a more systemic approach to biomimicry rather than a product re-design. It is also possible to explore the chemistry of bio-based plastics and synthesize them. This is not explored in this module but can be followed up with the links below:

- https://edu.rsc.org/resources/making-plastic-from-potato-starch/1741.article
- https://bloom-bioeconomy.eu/schoolnetwork/schoolbox/
- https://www.stem.org.uk/resources/elibrary/resource/29481/bioplastics

For a useful lesson on the challenge of plastic on a global scale see:

- https://www.stem.org.uk/resources/elibrary/resource/35961/plastic-challenge

WEBSITES

Relevant links are provided within the activities.

W1.1 SO... HOW DOES NATURE WORK?

Natural functions/abilities

Select from:

Attach	Dynamic design	Move 'fluids' (air, water, etc.)
Balance	Enduring sources of energy	Optimize (e.g. strength and material, information and time)
Bottom-up manufacturing	Flexibility	Orient
Buffer (e.g. from impact)	Grind	Pack into a small space
Collect (e.g. water, sunlight)	Grip	Power without pollution (i.e. clean sources of energy)
Collect raw materials (i.e. without mining)	Heat up	Protect
Communicate	Hold onto	Raw materials without mining (i.e. from the air, from groundwater)
Connect	Insulate	Recycle
Cool down	Information instead of material	Resilience
Cooperate	Life-friendly chemistry (i.e. chemistry that is safe for living tissues)	Restorative
Coordinate	Manage	Stabilize
Create color	Manage interactions	Stabilize soil
Create conditions conducive to life	Manufacture at ambient temperatures	Stick together
Create Flow	Maximize (e.g. resources)	Store
Decompose	Minimize (e.g. weight)	Streamline
Detect	Move	Strength
		Withstand wind

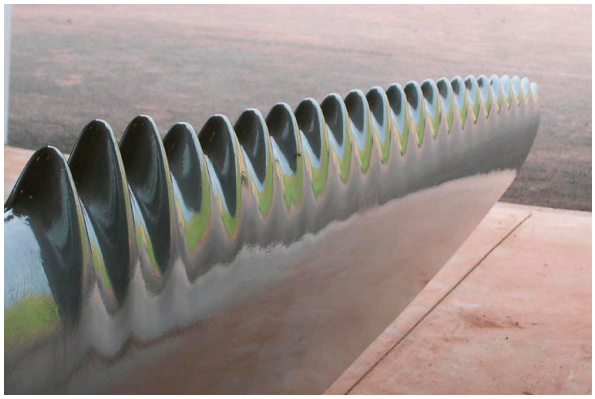
W2.1 WHAT HAS NATURE EVER DONE FOR ME?

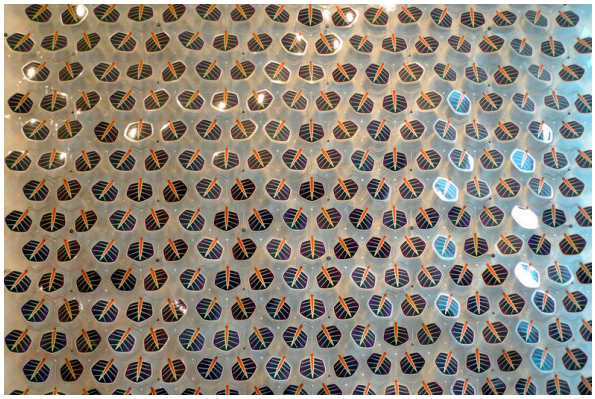
Biomimicry card sort

Use the accompanying PowerPoint with this activity, which also includes the answers.

Inspiration from nature

Human invention





W3.1 NATURE'S BOTTLE

Student challenge

RESEARCH QUESTION:

PLASTIC BOTTLES

At present just 43% of the 13bn plastic bottles sold each year in the UK are recycled, and 700,000 become litter each day (57% of PET bottles are recycled in Europe as a whole). Pressure is growing on the government, retailers and consumers to increase rates of plastic bottle recycling and so reduce marine pollution.

In the past 100 years humans have produced a lot of plastic. It's cheap, strong, light and versatile. So, it's not surprising we're using mountains of the stuff. But plastic production contributes to climate change (4–8% of annual global oil production is used in creating plastic; mining and refining oil releases carbon into the atmosphere), and the waste harms the environment, polluting our waterways and threatening our wildlife. Plastic hangs around in the environment for at least hundreds of years. It doesn't disappear, it just breaks down into tiny pieces that continue to pollute our lives.

Avoiding it is more difficult than it sounds. It's in so many of the everyday things we buy. In a lot of cases it's hidden from plain sight, lurking in everything from teabags and beer caps, to clothes and cosmetics.

CHALLENGE:

What can we learn from nature about how it builds materials and deals with waste?

To help you, think about 'how nature does it' for example:

- How does nature construct materials?
- How does nature dispose of materials?
- How does nature contain liquids?

Starting points:

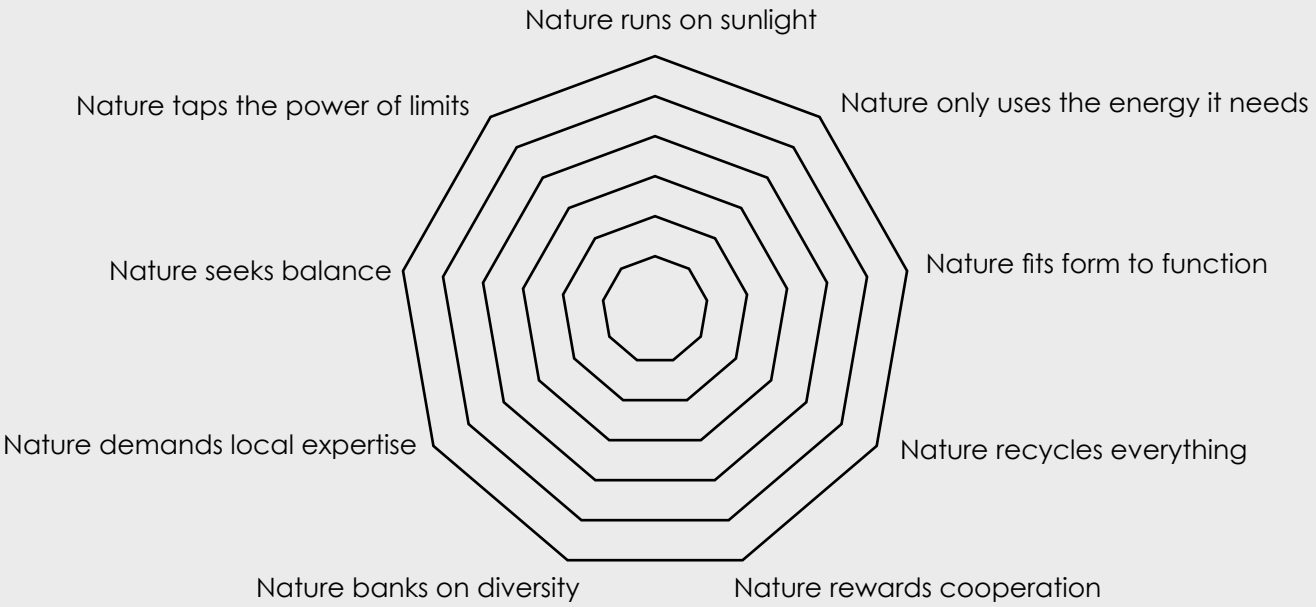
- What material will your bottle be made from?
- How will you deal with the bottle after use?
- Is redesigning the bottle the best solution? Nature taps the power of limits... is your product really needed? Are there other solutions to providing water on the move?

Review your ideas against the biomimicry evaluation wheel (see W3.2). How many of the nine principles can you include?

W3.2 NATURE'S BOTTLE

Biomimicry evaluation wheel

TASK: Use the diagram below to plot how your product achieves in relation to each biomimicry principle of design. Use this to consider the strengths and weaknesses of your design.



Q1: Based on the nine principles of biomimicry, this is close to how nature would design this product/project.

STRONGLY AGREE	AGREE	NEITHER AGREE NOR DISAGREE	DISAGREE	STRONGLY DISAGREE

Q2: Looking at your design and comparing it to the nine principles of biomimicry, which areas are it strongest?

. . . . . .

Q3: Which areas are it weakest?

. . . . . .

Q4: Think of one practical way you can improve your design.

. . . . . .

Improving your design
Consider how you might use the nine principles of biomimicry described overleaf to improve your design. How might nature go about designing the product or function you are trying to produce?

ANNEX 1

Key Stage 4 Working Scientifically Statements

Through the content across all three disciplines, students should be taught so that they develop understanding and first-hand experience of:

1. THE DEVELOPMENT OF SCIENTIFIC THINKING	a. the ways in which scientific methods and theories develop over time b. using a variety of concepts and models to develop scientific explanations and understanding c. appreciating the power and limitations of science and considering ethical issues which may arise d. explaining everyday and technological applications of science; evaluating associated personal, social, economic and environmental implications; and making decisions based on the evaluation of evidence and arguments e. evaluating risks both in practical science and the wider societal context, including perception of risk f. recognising the importance of peer review of results and of communication of results to a range of audiences
2. EXPERIMENTAL SKILLS AND STRATEGIES	a. using scientific theories and explanations to develop hypotheses b. planning experiments to make observations, test hypotheses or explore phenomena c. applying a knowledge of a range of techniques, apparatus, and materials to select those appropriate both for fieldwork and for experiments d. carrying out experiments appropriately, having due regard to the correct manipulation of apparatus, the accuracy of measurements and health and safety considerations e. recognising when to apply a knowledge of sampling techniques to ensure any samples collected are representative f. making and recording observations and measurements using a range of apparatus and methods g. evaluating methods and suggesting possible improvements and further investigations
3. ANALYSIS AND EVALUATION	a. applying the cycle of collecting, presenting and analysing data, including: i. presenting observations and other data using appropriate methods ii. translating data from one form to another iii. carrying out and representing mathematical and statistical analysis iv. representing distributions of results and making estimations of uncertainty v. interpreting observations and other data, including identifying patterns and trends, making inferences and drawing conclusions vi. presenting reasoned explanations, including relating data to hypotheses vii. being objective, evaluating data in terms of accuracy, precision, repeatability and reproducibility and identifying potential sources of random and systematic error b. communicating the scientific rationale for investigations, including the methods used, the findings and reasoned conclusions, using paper-based and electronic reports and presentations

4. VOCABULARY, UNITS, SYMBOLS AND NOMENCLATURE	a. developing their use of scientific vocabulary and nomenclature b. recognising the importance of scientific quantities and understanding how they are determined c. using SI units and IUPAC chemical nomenclature unless inappropriate d. using prefixes and powers of ten for orders of magnitude (e.g. tera, giga, mega, kilo, centi, milli, micro and nano) e. interconverting units f. using an appropriate number of significant figures in calculations