BUILDINGS

How does nature provide shelter?

AGE RANGE

14–16

DURATION

Preparation:
40 min.

Activity:
175 or 220 min. /
4 or 5 lessons

KEYWORDS

Building; sustainability; material; design; energy; water

SUMMARY

Shelter, warmth and protection are all functions of buildings. In this module, students search for similar functions in nature and investigate how to use this knowledge to create better and more sustainable buildings.

BIOMIMICRY PRINCIPLES

2 – Nature uses only the energy it needs
3 – Nature fits form to function
4 – Nature recycles everything
7 – Nature demands local expertise
9 – Nature taps the power of limits

LEARNING OBJECTIVES

- Students recognise that we can learn from nature to build better buildings.
- Students understand that nature can often provide solutions to human challenges.
- Students understand that all 'buildings' in nature are sustainable.

LEARNING OUTCOMES

- Students observe and investigate how nature creates structures.
- Students compare structures in nature with human buildings.
- Students apply biomimicry thinking to design a sustainable building.
- Students share ideas and learn from each other.

SUBJECT(S)

This learning module can be used flexibly within the curriculum to support key knowledge about Physics 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
Physics: KS4 Energy • calculating energy efficiency for any energy transfers. • renewable and non-renewable energy sources used on Earth, changes in how these are used. KS3 Energy changes and transfers • heating and thermal equilibrium: temperature difference between two objects leading to energy transfer from the hotter to the cooler one, through contact (conduction) or radiation; such transfers tending to reduce the temperature difference: use of insulators. Physical changes • conservation of material and of mass. Energy in matter • internal energy stored in materials. **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: **1b, 1d, 1e, 2b, 2g, 3b**. 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).
- Students are able to work in groups.
- Students become more familiar with professions and research topics that relate to nature-inspired sustainability and technological innovation, which can inform their choices in post-secondary education and careers.

SUMMARY OF THE ACTIVITIES

	Activity Name	Description	Method	Duration	Location
LESSONS 1–3: Introduction					
1	Buildings and shelters	Students discuss the functions of buildings and collect examples	• Discussion • Brainstorming	20	Indoor
2	How does it work in nature?	Students search for functions of buildings and shelters in nature	• Surveying • Group work	35	Outdoor
3	Let's build...a nest (optional)	Students research nests and then build one	• Research • Hands-on activity	45	Indoor/ outdoor
LESSONS 4–5: Planning an environmental and people friendly building					
4	Planning and designing	Students work in teams to apply biomimicry principles to building design	• Research	30 + at least 45 mins to develop ideas	Indoor/ outdoor
5	Sharing ideas and cooperative design	Student teams share their ideas, evaluate them and learn from each other	• Design activity • Group work	45	Indoor

BACKGROUND FOR TEACHERS

Biomimicry thinking in building design and construction is a developing science. In this module we introduce some initial ideas for inspiration, including examples of where this practice is already in use.

We spend a major part of our life in buildings. The energy, material and water usage connected with buildings is significant, and used for space heating, cooking, lighting and powering all our gadgets. Space and water heating are one of the key energy consumers in buildings, roughly equivalent to the energy consumed by transport (Department for Business, Energy and Industrial Strategy 2018).

Materials for building construction is mined and fabricated in factories. More than 35 billion tonnes of non-metallic minerals are extracted from the earth every year. This is a staggering quantity of resources, and likely to increase in the coming years as the global population continues to grow (https://theconversation.com/how-we-can-recycle-more-buildings-126563).

The average person in the UK uses 142 litres of drinking water every day. This is not only water which is drunk, it is also used for flushing the toilet, taking a shower, washing clothes and cleaning etc. Showers and toilet flushing are the two biggest water consumers.

Can it be different? How does nature provide shelter and remain sustainable? How does nature use and store water? What can we learn from nature about construction and creating biodegradable materials?

Biomimicry takes the interpretation of sustainability a step further. In order to maintain the earth in a state habitable for humans, we need to start designing products and processes which give back to nature. Living systems design are sustainable by being regenerative (Reed, 2007).

Regenerative design means that the building gives more back to the environment than it consumes: produces energy for the community, cleans more water than it uses, etc. (https://sevengroup.com/2017/09/08/regenerating-7group/) According to this approach, there is a wide range of opportunities through which we can improve our buildings. The result can be sustainable buildings which actually improve the health of their users and the environment.

Another aspect to consider in construction is biophilic design. This concept is used within the building industry to increase occupant connectivity to the natural environment through the use of direct nature, indirect nature, and space and place conditions (https://en.wikipedia.org/wiki/Biophilic_design). It is a relatively new direction in building design and construction, discovering that human beings need nature, and it is deeply written into our psyche. The word 'biophilia' was first used by Erich Fromm, a German psychoanalyst, believing that nature is necessary for the normal development of a human being and without it we become affected by 'nature deficit disorder.' Many of us feel much better in a building with nature in or around it. You can find more about this topic here: https://www.terrapinbrightgreen.com/reports/14-patterns/#nature-design-relationships .

For more websites and information about this topic see 'Literature, additional information' at the end of the module.

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.'

It is expected that students will already be familiar with the principles of biomimicry; if not see the introductory modules on the BioLearn website.

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.

LESSONS 1–2: Introduction

LOCATION
Indoor

1 | BUILDINGS AND SHELTERS

» DISCOVER

The purpose of this activity it to familiarise students with the wide range of functions (purposes) that buildings provide. This is important for when, later in the module, they research how inspiration from nature can improve these functions and make buildings more sustainable.

Discuss the following topics with students:

- Why do we need buildings?
- What purpose (or function) do they serve?
- Do these functions differ between buildings?

Summarise the results together and keep the list. Some examples of functions are:

- Regulate temperature/humidity/water.
- Protection from pests/insects.
- Physical/psychological well-being.
- Provide shelter.
- Prevent unwanted sounds (noise).
- Maintain strength (prevent building collapse).
- Produce energy.

ACTIVITY DETAILS

LOCATION
Outdoor

TOOLS AND MATERIALS

- student worksheet W2.1
- teacher worksheet T2.1
- the nine principles of biomimicry from student worksheet W5.1
- nature books (optional)
- internet access (optional)

PREPARATIONS

Outdoor activity.

Print W2.1 (one copy per group).

Print the nine principles of biomimicry from student worksheet W5.1 (one copy per group).

2| HOW DOES IT WORK IN NATURE?

» DISCOVER

The purpose of this activity is to recognise that in nature, similar functions to human buildings can be found (see list from Activity 1).

How does nature provide functions similar to those of buildings? Can nature help suggest how buildings can become more sustainable?

Working in groups, provide students with student worksheet W2.1. Ask them to search outside in nature for the listed functions. Also ask them to connect their findings with one or more of the biomimicry principles described in student worksheet W5.1. See Teacher notes T2.1 for suggested answers.

This activity is best done outside, even a small area with some shrubs or trees is sufficient, or it can be set as a homework task.

Once students have completed the worksheet, ask them to discuss the results and compare them with the list of functions for human buildings. Are there any similarities? Are there any ideas from nature which could be useful for improving human buildings? What strategies can we learn from nature?

ACTIVITY DETAILS

LOCATION
Indoor / Outdoor

TOOLS AND MATERIALS

- student worksheets W3.1 and W3.2
- nests (optional)
- internet access (optional)
- raw materials for the nest (if delivered inside)

PREPARATIONS

Outdoor activity.

Print student worksheet W3.1 and W3.2, one set per group.

3| LET'S BUILD...A NEST (OPTIONAL)

» DISCOVER

Nests appear to be very simple 'buildings' and easy to build. In this activity, students try to build a bird's nest which meets a set of functions.

List the functions and attributes of a nest with students e.g. soft, warm, durable, provide protection for eggs, nestlings and parents, etc. Some examples for functions and other characteristics of different nests are listed in student worksheet W3.1 and some pictures in W3.2. After the conversation, provide the list and pictures to students.

Provide groups of students with prepared nest building materials or time to gather them outside. Ask them to build a nest which delivers the functions they have listed. Once finished, they should test their design to see if it works. Students could use weights to test strength, a thermometer to compare internal and external air temperatures, etc. Ensure students record their results appropriately and think of improvements to their nests based on the results.

NOTE: Not only birds build nests, other types of animals such mammals, reptiles, amphibians, fish and insects also build nests.

LESSONS 4–5: Planning an environmental and people friendly building

LOCATION
Indoor / Outdoor

TOOLS AND MATERIALS

- student worksheets W4.1, W4.2, W4.3, W4.4, W4.5 and W4.6
- teacher pages T4.2, T4.3 and T4.4.
- internet connection

PREPARATIONS

Indoor/outdoor activity.

Copies of W4.1, W4.2, W4.3, W4.4, W4.5 and W4.6; one set per group.

RESOURCES

Websites used in the activity and additional resources see in T4.2 to T4.4.

4| PLANNING AND DESIGNING

» CREATE

How could a building be more environmental and person friendly? How could we use inspiration from nature to rethink buildings? In this activity, students apply the insights they have gained from nature to redesign a building using biomimicry principles.

Students can choose to redesign any building of their choice, for example a school, home, hospital/health centre, theatre, community centre, sport centre, store, factory, train/bus station, etc.

To make the task more relevant, the building (fictional or real) should be sited in the students own town or neighbourhood. This might entail specific, local, design requirements; remember that nature demands local expertise.

You could ask the whole class to work on the same building, with teams working on different elements/functions. Student worksheet W4.1 provides a list of suggested functions each student group could work on. Alternatively, teams can work on their own building independently selecting one or more functions to focus on.

As a starting point, suggest the following functions to select from:

- Maintain strength and form (support human activities; resist strong winds).
- Maintain a constant temperature (heating/cooling).
- Manage natural light.
- Store water/energy/heat/cool.
- Minimize water use.
- Encourage cooperation between (human) users.
- Maintain cleanliness.

For each function, students will also need to consider how they can be met in ways which are environmentally friendly and support the well-being of building users (think about the use of chemicals and toxins; what happens to waste?).

Students should present their ideas as a drawing/poster annotated to illustrate how they have used nature as an inspiration for their design(s), and which biomimicry principles have inspired them. Depending on time, students should have at least 45 minutes for this task, but it can be extended with homework; of course, the task could take place over several sessions depending on complexity and depth of detail. As part of Design & Technology scale models could be constructed.

Student worksheets W4.2 to W4.5 provide examples to inspire students. There are also many online resources including those listed at the end of the module. And of course, go outside and be inspired by how nature delivers these functions.

You can provide students with the evaluation wheel in student worksheet W5.1 to help them reflect on their design ideas and improve them.

Students might struggle to see beyond 'standard' responses to sustainability. To help them apply biomimicry thinking, ask them to:

1. *List the functions their building needs to provide, e.g. regulate temperature.*
2. *Explore examples from nature where the same functions are provided, e.g. a termite mound.*
3. *Investigate how nature provides this function (the strategy), e.g. through a network of tunnels which draw in cool air and expel warm air.*
4. *Think how this can be applied to their building. Do not worry if the solution seems impossible now, it is the idea that matters.*

Further resources are provided in teacher sheets T4.2 to T4.4.

ACTIVITY DETAILS

LOCATION
Indoor

TOOLS AND MATERIALS

Student worksheet W5.1

5| SHARING IDEAS AND COOPERATIVE DESIGN

» CREATE

Once groups have worked on their own building design, they present their findings to the whole class.

Depending on the approach you have taken in activity 4, this might be:

a. Students explaining how their function can be delivered in the selected class building; or
b. Students presenting the design for their self-selected building and specific functions they have incorporated.

Once presentations are over, discuss how each groups design can be integrated into a single building or community. What changes might each group make based on learning from each other? Can buildings 'cooperate' to form an urban ecosystem? (e.g. in how they deal with waste)

One good method for this activity is the World Café. One team member stays at their team table as host to present the plans. The other members go to different tables and listen to the other hosts and share ideas. After visiting all tables, the original team decides what to accept and what to refuse. They have to think continuously also about their original goal.

See: www.theworldcafe.com/key-concepts-resources/world-cafe-method/

To finish, ask students to evaluate their work using the biomimicry evaluation wheel in student worksheet W5.1. Where can improvements be made?

LITERATURE, ADDITIONAL INFORMATION

Regenerating thinking:
Bill Reed (2007): Shifting from 'sustainability' to regeneration www.tandfonline.com/doi/full/10.1080/09613210701475753
7group: https://sevengroup.com

Biomimicry in building designs:
https://www.thefifthestate.com.au/columns/spinifex/incorporating-biomimicry-into-building-design/
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7344704/

ACTIVITY DETAILS

Some examples:
http://www.bbc.com/earth/story/20150913-nine-incredible-buildings-inspired-by-nature
https://www.re-thinkingthefuture.com/fresh-perspectives/a952-10-stunning-examples-of-biomimicry-in-architecture/
https://paxscientific.com/
https://www.edenproject.com/eden-story/behind-the-scenes/architecture-at-eden

Searching for solutions:
https://toolbox.biomimicry.org/
https://asknature.org/

Teaching material:
https://www.learningwithnature.org/
Education Materials / Middle/High School Engineering Curriculum / 6. The Architectural genius of Nature's Materials (p.68); 7. Brainy Coral (p. 79)

See also the pictures and resources referred to on Teachers' pages.

T2.1 HOW DOES IT WORK IN NATURE?

Many of the examples exhibit several biomimicry principles, for example nature recycles everything, nature taps the power of limits, nature runs of solar income. The examples seen in the context of their ecosystem contribute to nature banks of diversity and nature rewards balance. You could include all these into the list in the final column.

Function	Human solution – example	How does nature fulfil/maintain this function? organism/part	solution	Nine biomimicry principles
Avoid rain	*roof*	*plant leaf*	*waterproof cells (cell walls)*	*3*
Prevent insects	screen, pesticides	Tansy *(Tanacetum vulgare)*	Strong aroma of leaves and flowers act as a repellent	1
Maintain stable temperature	Heating system and insulation	Termite mounds	Use natural convection of warm air to draw cool air inside the nest	1, 2
Prevent noise	Lining walls with absorbent materials	Lion	Large foot pads cushion the sound as they walk	3
Protect from extreme weather	Walls constructed from brick, concrete and steel	All animals and plants adapt to their environment	For example, cellulose in trees creates longitudinal strength and flexibility to absorb strong winds; Sea Urchin shape and interlocking plates distribute stress evenly reducing load	1, 3
Store energy	Batteries	Both animals and plants store energy but mainly short-term	Bees create honeycomb structures to store food	3
Provide protection	Bicycle helmets (impact); lunch box (prevent liquid entering)	Horse chestnut tree	Produces seeds with spiked seed pods including a soft skin to protect from predators and falling from the tree	1, 3
Deliver/transport/ store water	Pipes supply water to homes and remove dirty water	Both animals and plants store liquids but mainly short-term	Bromeliads capture water in a 'storage tank'	1, 3
Maintain shape/ form	Walls of buildings	Birds	Create nests to hold eggs and rear young	3

T4.2 PLANNING AND DESIGNING

Maintain strength and form (support human activities; resist strong winds)

Resources:

Texture of wood structure	Education Materials / Middle/High School Engineering Curriculum / 6. The architectural genius of nature's materials (p. 68.) from https://www.learningwithnature.org/
Spider web	https://en.wikipedia.org/wiki/Spider_silk
Coral reef	Education Materials / Middle/High School Engineering Curriculum / 7. Brainy Coral (p. 79) from https://www.learningwithnature.org/ More: Sustainable materials inspired by nature (coral-cement) https://www.seeker.com/10-materials-that-emulate-nature-photos-1765169159.html and http://forterausa.com/
Sea cucumber	Read more: https://www.newscientist.com/article/dn13420-floppy-when-wet-sea-cucumber-inspires-new-plastic/#ixzz6dZXdciws
Bone structure	Education Materials / Middle/High School Engineering Curriculum / 5. Enlightened by Bones (p. 61) from https://www.learningwithnature.org/
Bee honeycombs	https://asknature.org/strategy/honeycomb-structure-is-space-efficient-and-strong/

Built examples:

	Carapace building – Tenuta Castelbuono, Italy Picture: "The Carapace of Bevagna" by AHLN is licensed under CC BY 2.0
	Downland Gridshell Building, UK mimicking a bird nest Picture: "Inside the Gridshell" by Maniacalrobot is licensed under CC BY-NC-ND 2.0
	Pneumocell – Inflatable Resilient Structures: https://asknature.org/idea/pneumocell/ Picture: "Moblies Ö1 Atelier" by Ars Electronica is licensed under CC BY-NC-ND 2.0
	Eden project https://www.edenproject.com/eden-story/behind-the-scenes/how-we-built-the-core Picture: "Eden Project Panorama 6. Nikon D3200. DSC_0076-0079." by Robert.Pittman is licensed under CC BY-ND 2.0

For more ideas search https://www.seeker.com/10-materials-that-emulate-nature-photos-1765169159.html:

- Plants: green plastic (Novomer)
- Self-healing buildings – by the help of bacteria http://www.urban-biology.com/articlepagebiomim.html
- Self-cleaning facade paint – lotus leaf http://www.urban-biology.com/articlepagebiomim.html
- Self-repairing concrete: https://asknature.org/idea/self-repairing-concrete-2/

T4.3 PLANNING AND DESIGNING

Maintaining a constant temperature (heating/cooling)

For more ideas search https://asknature.org/

- Dye-sensitized solar energy: https://asknature.org/resource/dye-sensitized-solar-energy/
- Colonies maintain temperature and humidity: https://asknature.org/strategy/colonies-maintain-temperature-and-humidity/
- Arches provide structural support: https://asknature.org/strategy/arches-provide-structural-support/
- Leaf fan optimizes cooling and wind resistance: https://asknature.org/strategy/leaf-fan-optimizes-cooling-and-wind-resistance/

T4.4 PLANNING AND DESIGNING

Maintain cleanliness and remove pollutants

For more ideas search:

- Chaac-ha Water System Collector: https://asknature.org/idea/chaac-ha-water-system-collector/
- Biolytix water filter: https://asknature.org/idea/biolytix-water-filter/

Sources of images

W4.2 Maintain strength and form (support human activities; resist strong winds)

Texture of wood structure	S. Stier
Spider web	"Spide Web" by sbittinger is licensed under CC BY 2.0
Coral reef	"Panama Marine Life - Coral Reefs" by thinkpanama is licensed under CC BY-NC 2.0
Sea cucumber	"sea cucumber" by happy via is licensed under CC BY-NC-ND 2.0
Bone structure	"#bone cross section" by Duncan Creamer is licensed under CC BY-NC-ND 2.0
Bee honeycomb	"Honeycomb" by justus.thane is licensed under CC BY-NC-SA 2.0
Snail shell	"Snail shell" by blairwang is licensed under CC BY 2.0
Hornet nest	"Hornet Nest" by pellaea is licensed under CC BY 2.0
Nidus (nest) of Oak Leaf-rolling Weevil	"Nidus (nest) of Oak Leaf-rolling Weevil" by bob in swamp is licensed under CC BY 2.0
Chinese lantern plant	"Chinese lantern plant" by tamaki is licensed under CC BY-NC-ND 2.0
Pine cone	"Pine Cones - Scots Pine" by foxypar4 is licensed under CC BY 2.0
Tinder agaric	"zunder on the rocks" by simon_diet is licensed under CC BY-NC-SA 2.0

W4.3 Maintaining a constant temperature (heating/cooling)

Termite mounds	"Cathedral Termite Mound" by brewbooks is licensed under CC BY-SA 2.0
Eastgate Centre	"P1000957" by damien_farrell is marked with CC PDM 1.0
Sea sponge	"Sea Sponge" by dimsis is licensed under CC BY-SA 2.0
30 St Mary Axe (the Gherkin), London	"30 St Mary Axe / Gherkin" by Remko van Dokkum is licensed under CC BY 2.0
Penguin	This Photo by Unknown Author is licensed under CC BY-SA
Grass	"I see grass of green" by chriscom is licensed under CC BY-SA 2.0
Squirrel	"Squirrel eating an ice cream cone" by Kham Tran is licensed under CC BY 2.0
Feathers	"Feather" by gemsling is marked with CC0 1.0

W4.4 Maintain cleanliness and remove pollutants

Baleen whale mouth	"Baleen Whale Song" by flythebirdpath >>> is licensed under CC BY-NC 2.0
Earthworm	"Earthworm" by pfly is licensed under CC BY-SA 2.0
Desert rhubarb	https://commons.wikimedia.org/wiki/File:Rheum_palaestinum_2.JPG
Lotus leaves	This Photo by Unknown Author is licensed under CC BY-SA
Creek in a forest	E. Neumayer
Alhambra	E. Neumayer
Sempervivium	"sempervivium 2014Aug13_0612 hens and chicks houseleek live forever" by Dick Thompson Sandian is licensed under CC BY-NC-SA 2.0

Teasel	"TEASELS P1350226" by ianpreston is licensed under CC BY 2.0
Leaf	"Green leaf" by @Doug88888 is licensed under CC BY-NC-SA 2.0
Rotting apple	"A Rotting Apple" by oatsy40 is licensed under CC BY 2.0 dropp
Droppings	"Rabbit dropping" by nojhan is licensed under CC BY-SA 2.0
Seedlings	E. Neumayer

W4.5 Encourage cooperation between (human) users

Houseplants	https://www.pexels.com/da-dk/foto/have-hus-planter-kraftvaerker-3076899/
Natural light	https://pixabay.com/de/photos/b%C3%BCro-nat%C3%BCrliche-ansicht-gras-raum-4987577/
Green wall	https://www.pexels.com/da-dk/foto/arkitektdesign-byggeri-dagslys-glasvinduer-1188834/
Water surfaces in building	https://pixabay.com/ro/photos/singapore-aeroportul-changi-turisti-1383023/
Natural building inside	https://www.pexels.com/photo/creeping-plants-on-arched-inside-art-galery-3700245/
Playing with light	https://www.pexels.com/photo/walkway-with-arched-brick-wall-2133051/

W2.1 HOW DOES IT WORK IN NATURE?

Functions and solutions

Function	Human solution – example	How does nature fulfil/maintain this function? organism/part	solution	Nine biomimicry principles
Avoid rain	roof	plant leaf	waterproof cells (cell walls)	3
Prevent insects				
Maintain stable temperature				
Prevent noise				
Protect from extreme weather				
Store energy				
Provide protection				
Deliver/transport/store water				
Maintain shape/form				
Your ideas				

W3.1 LET'S BUILD... A NEST (OPTIONAL)

Bird nest functions and characteristics

FUNCTIONS	• protection – keeping eggs safe • provide strength – resist damage from strong wind/rain • communication – provide information for mate selection • regulate (control) temperature • protect from living threats – prevent microbes, parasites • regulate air flow/ventilation • prevent detection (camouflage) • breakdown after use (biodegradable)
MATERIALS – STRUCTURAL	• branches/twigs • stones/gravel • mud • tree trunk (cavity-nest) • soil • sedge/reeds/grass • water • man-made materials
MATERIALS – LINING	• feathers • grass • leaves • hair/fur • wood chips • man-made materials (e.g. cotton)
ARRANGEMENT	• solitary • community
CONSTRUCTION METHODS	• weaving • twisting • carving • digging (into soil)

W3.2 LET'S BUILD... A NEST (OPTIONAL)

Some nests and their functions

FINCH NEST

Function:
- protection –keeping eggs safe
- regulate (control) temperature
- protect from living threats – prevent microbes, parasites
- regulate air flow/ventilation

BOWER BIRD NEST (with natural and artificial elements)

Function:
- communication – provide information for mate selection

WEAVER NEST

Function:
- communication – provide information for mate selection
- protection – keeping eggs safe
- protect from living threats – prevent microbes, parasites
- regulate (control) temperature
- regulate air flow/ventilation

W4.1 PLANNING AND DESIGNING

Function groups

Each card provides questions to focus the attention of students.

Maintain strength and form (support human activities; resist strong winds)

Think about:

- How your building will keep its form/shape?
- How will it protect against extreme weather?
- What materials will support this?
- How does nature grow shapes and materials?

Maintain cleanliness and remove pollutants

Think about:

- How does nature separate materials?
- How does nature remove pollutants?
- How can energy use be minimised? How can it be produced?

Maintaining a constant temperature (heating/cooling)

Think about:

- What influences temperature (location of windows, wall types, lighting, appliances, etc.)?
- Ventilation – how air is moved around the building?
- How can natural processes influence temperature?

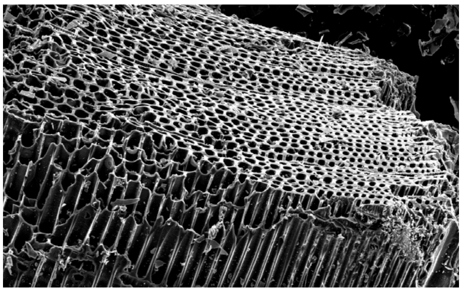
Encourage cooperation between (human) users

Think about:

- How to maximise movement?
- How to communicate information to users?
- Providing space to meet and gather
- Creating calm and harmony

W4.2 PLANNING AND DESIGNING

Maintain strength and form (support human activities; resist strong winds)



WOOD STRUCTURE

The structure of the growth rings creates a structure which is dense (strength) and flexible at the same time.

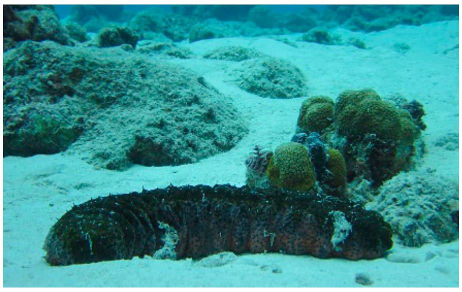
Wood is composed primarily of two materials: cellulose and lignin. Cellulose is like rope, very strong when pulled, not when compressed. Lignin is like cement, strong in compression but not in tension.

SPIDER WEB

Most spider web silks have exceptional mechanical properties. They exhibit a unique combination of high tensile strength and extensibility (ductility). This enables the silk fibre to absorb a large amount of energy before breaking. Comparing silk to other materials, weight for weight, spider silk is stronger than steel, but not as strong as Kevlar.

CORAL REEF

Corals make their building materials (mainly limestone) without mining by using carbon-dioxide (CO_2) and sea water. Limestone is the main component of cement; corals offer a less energy intensive way to make cement.



SEA CUCUMBER

Sea cucumbers' skin is usually supple, allowing them to slide through narrow spaces between rocks and corals. But when touched a defensive reaction makes their skin go rigid in seconds, thanks to enzymes that bind protein fibres together. A second set of enzymes can break those bonds to make the skin soft again.

BONE STRUCTURE

The structure of bones is designed for holding weight whilst minimising material. Also, bones can adapt to increased or reduced stress and loads. The Eiffel tower in Paris was designed by studying the trabecular and macro structure in a femur bone.

BEE HONEYCOMBS

"A hexagonal honeycomb is the way to fit the most area with the least perimeter." (Thomas Hales mathematician). Space-efficiency in not the only benefit of building with hexagons. Stacked together, hexagons fill spans in an offset arrangement with six short walls around each 'tube' giving structures a high compression strength.

Some more inspiring shapes and structures in nature; examples for biomimicry purposes can be found by searching online.

		
Snail shell	Hornet nest	Nidus (nest) of Oak Leaf-rolling Weevil
		
Chinese lantern plant	Pine cone	Tinder agaric

W4.3 PLANNING AND DESIGNING

Maintaining a constant temperature (heating/cooling)

Some inspiring solutions:

TERMITE MOUNDS

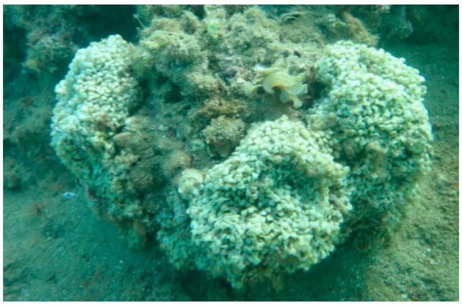
Termite mounds and the ventilation of the Eastgate Centre, Zimbabwe

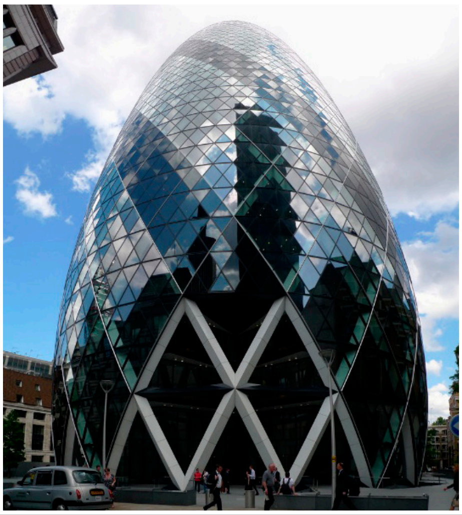
"The mounds act like an 'external lung,' harnessing the change in temperature as day becomes night to drive ventilation. Inside the hill is a large central chimney connected to a system of conduits located in the mound's thin, flutelike buttresses." (https://www.sciencemag.org/news/2015/08/how-termite-mounds-breathe)

"Architect Mick Pearce, one of the designers of the *Eastgate Centre*, was inspired by models of internal temperature regulation in termite mounds. At the time of the building's design, researchers had proposed that termite mounds maintained stable internal climates by having a physical structure that enables passive internal airflow. While subsequent research on termite mounds has altered our understanding of the function of mound structure, the Eastgate Centre still achieves a controlled internal climate with the help of cost-effective and energy-efficient mechanisms originally inspired by termite mounds." (https://asknature.org/idea/eastgate-centre/)

Further information from:

- https://materialslab.wordpress.com/2015/11/26/learning-from-termites/eastgate-zimbabwe-apartment-building/
- https://inhabitat.com/how-biomimicry-can-help-designers-and-architects-find-inspiration-to-solve-problems/





SEA SPONGE

30 St Mary Axe (the Gherkin), London – air ventilation system is similar to sea sponges and anemones.

"That air is distributed between the connected floors for the natural ventilation through pressure differentials. This mixed-mode ventilation system provides passive cooling and heating effects depending on the season. In the winter, the insulating effect keeps the building warm through passive solar energy. In the summer, external pressure differentials pull out the warmer air. In essence, the building breathes in and out via the flow of air through it. This air flow into and up through the building mimics the flow of water and nutrients through the Venus' flower basket sponge." (https://steemit.com/architecture/@snaves/biomimetic-architecture-the-gherkin)

Further information from:
http://www.miamiironside.com/blog/biomimetic-architecture

PENGUIN SHAPE

The penguin's body is adapted for swimming. Its body is fusiform (tapered at both ends) and streamlined.
https://seaworld.org/animals/all-about/penguins/physical-characteristics/

This shape can be used in aerodynamics of buildings, as illustrated in an industrial and office building in Hungary. The covers of the chimney are penguin shaped and help ventilate of the building.

https://energiadesign.hu/en/article/projects/hungarys-first-energy-positive-industrial-and-office-building-komlo-2012

MYCELIUM

Fungi mycelium can be mixed with a substrate and grown into packaging, and also has good insulation properties.

See more in "Natural economy module"

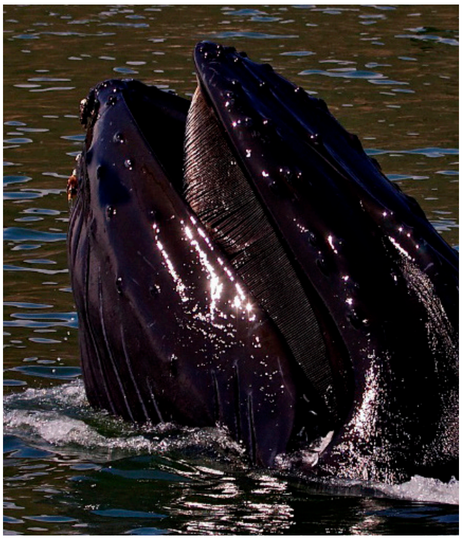
For further ideas of insulation in nature explore:

		
Grass	Fur: Grey squirrel *(Sciurus vulgaris)*	Feathers

W4.4 PLANNING AND DESIGNING

Maintain cleanliness and remove pollutants

Some inspiring solutions:



BALEEN WHALE MOUTH

The baleen whale has specialized structures that enable it to efficiently consume small organisms, especially tiny shrimp-like crustaceans called krill. Krill swarm in huge clouds in the ocean, where baleen whales scoop them up, water and all, and send them through a baleen filter-feeding system.
https://asknature.org/strategy/baleen-plates-filter-food/

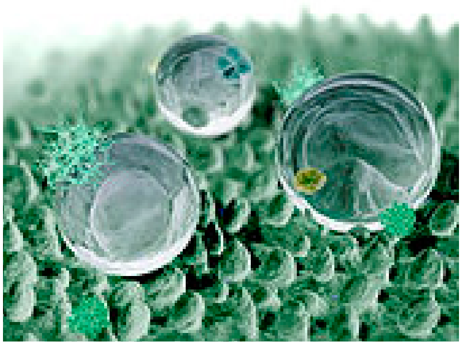
Baleen Filters water filters were developed based on the idea above. It is a highly efficient, non-pressurized, self-cleaning separation technology that offers reliable, trouble-free filtration to 25 microns without chemical assistance.
https://asknature.org/idea/baleen-filters-water-filters/

EARTHWORM

Earthworms can help in remove contaminants from wastewater. There are water cleaning systems using earthworms and beetles.

DESERT RHUBARB *(Rheum palaestinum)*

Leaves and roots maximize water collection. The desert rhubarb sets itself apart by having a sophisticated water collection system that transports and absorbs water deep in the ground. First, rain water collects on the surface of the rhubarb's leaves. The rhubarb has one to four meter long leaves with a series of successively wider, hydrophobic (water-repelling) grooves embedded into its sides. The grooves funnel rain water down the leaf similar to a system of rivers and creeks down a mountain.
https://asknature.org/strategy/leaves-and-root-maximize-water-collection/



LOTUS LEAVES

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 paints. (See also “Water, water every-where…” module.)

Some further inspiring ideas:

		
Sempervivum – water storage	Teasel – water retention	Leaf – water net
		
Rotting apple – all natural ‘products’ are biodegradable	Droppings – all natural ‘products’ are biodegradable	Seedlings on decaying wood show upcycling in nature

W4.5 PLANNING AND DESIGNING

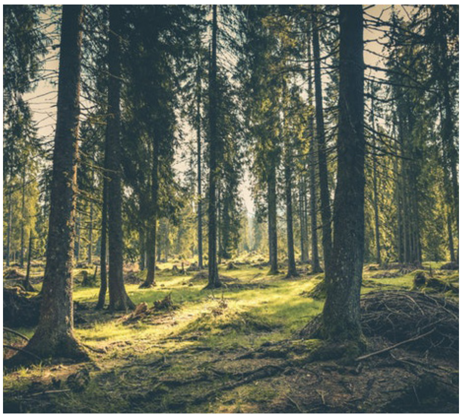
Encourage cooperation between (human) users

Some inspiring solutions:

BEE 'TALK'

Honeybees have a very clever way of communicating where flower patches are to the rest of the colony. They communicate this information by doing a dance involving waggle movements. The orientation of the dance conveys the direction of the flower patch. The length of the waggle movements indicates the distance to the flower patch.

Photo: "Honey Bee & Gray Nickerbean" by bob in swamp is licensed under CC BY 2.0



FOREST BATHING

Forest bathing, or Shinrin-Yoko as originally named in Japan, is the practice of spending time amongst trees. It has been demonstrated to create calming neuro-psychological effects by reducing the stress hormone cortisol and boosting the immune system.

Trees also release an organic compound called phytoncides. The scent released is associated with reduced adrenaline and decreased heart rate.

Photo by Rudolf Jakkel from Pexels

COLOURS – FLOWERING MEADOW, AUTUMN LEAVES

There are no two flowers of the same colour in a flowering meadow. In spite of the diversity the view is calming. The aim of the forms, colours and smells is to attract insects and this can also have a positive impact on human well-being.

Autumn is often thought of as the most colourful season. You can find brown, yellow and red leaves, and all of them are harmonised.

It seems to be wise to borrow colours from nature for our buildings.

Photo by Freddie Ramm from Pexels

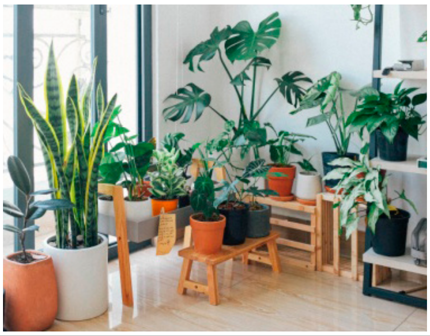
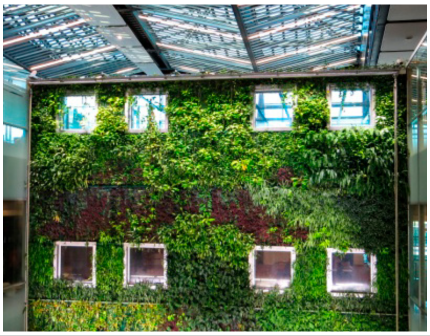
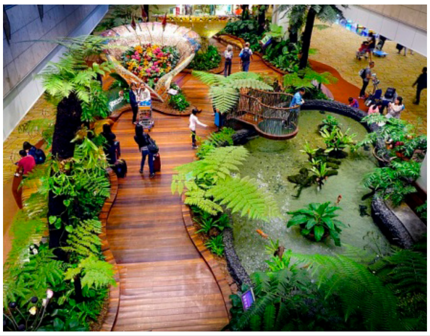
FLOCKING BIRDS

Starlings fly together in large numbers without crashing into each other. Starlings manage this by paying close attention to the speed and direction of the closest birds to them, seven to be exact. Even though there are thousands of birds, monitoring only the closest seven is enough to keep apart and safe. Sometimes too much information leads to worse decisions.

Image "Starling Murmuration Near Starved Rock State Park IL DDZ_0104" by NDomer73 is licensed under CC BY-NC-ND 2.0

Biophilic design: Wellbeing

Maintaining regular contact with nature has well researched health benefits. Of course, we are a part of nature, but we often surround ourselves with more concrete than trees. Biophilic design brings nature inside buildings to have a tangible effect on the occupant's well-being. It also mimics the shapes of nature within building design to create a more 'naturally feeling' building.

		
Houseplants	Natural light	Green wall
		
Water surfaces in building	Natural building	Playing with light

Think also about sounds, smells, space, light, air quality – anything what makes you to feel better!

W4.6 PLANNING AND DESIGNING

Assessing functions

Function – What do you want to do? HINT think about the functions your building needs to perform	**Ask Nature –** Where might you find this in nature? How does nature do this?	**Apply –** How can nature help you address your challenge? What can you borrow from nature, and how might it be applied in this context?
EXAMPLE: Regulate temperature	*Termite mounds maintain a stable temperature using a network of tunnels with draw in cool air and expel warm air*	*Convection – use rising warm air escaping through roof vents to draw in cool air from pipes below ground*

W5.1 EVALUATION OF THE BUILDING

Evaluation wheel

PRODUCT:. . . . .

DESIRED FUNCTION / CONCEPT: . . . .

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 the strongest? **Why is this the case?**

. . . .

Q3: Which areas are the weakest? **Why is this the case?**

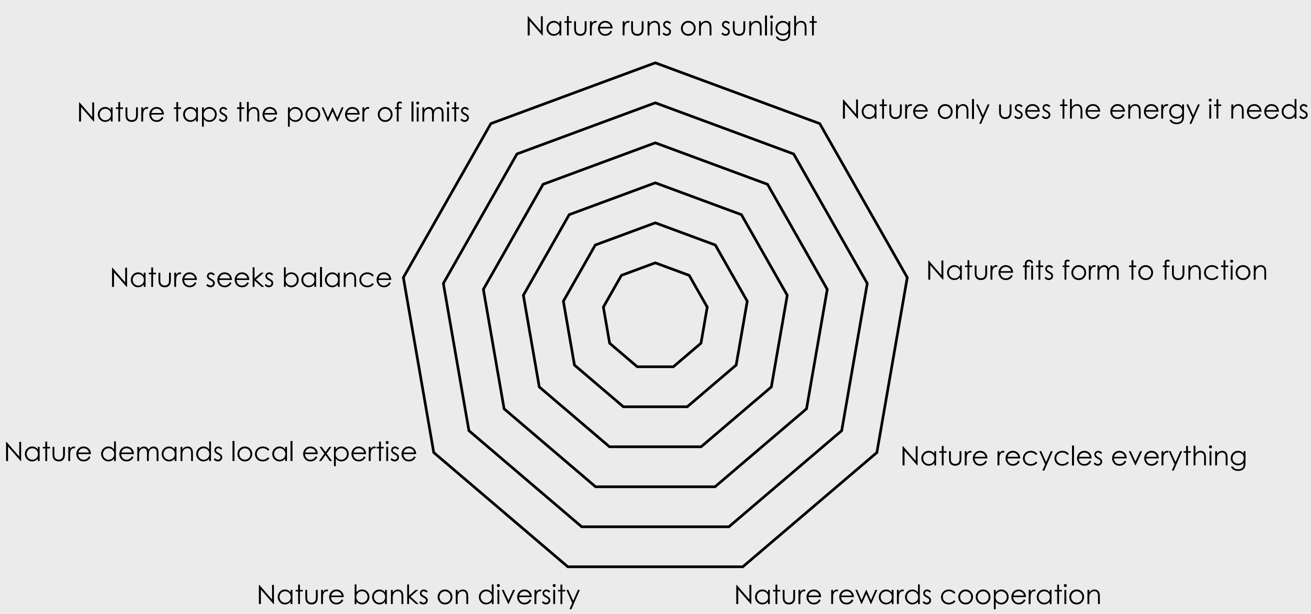
. . . .

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?

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.



The Nine Principles of Biomimicry

(Adapted from the work of Janine Benyus)

1. Nature runs on sunlight
Nature uses sunlight as the main source of energy. Organisms use heat and UV radiation from this never-ending source. So, we can say that nature is powered by sunshine. Humans use fossil fuels, these sources are not renewable, and burning them creates CO_2 which is one of the gases causing climate change. Why don't we do the same and prevent the climate crisis? A wise person would mimic nature and rely on renewable power.

2. Nature uses only the energy it needs
Nature takes only what it needs. So why do we not do the same? Our economy is focused on maximizing output and is a big energy consumer. We transport food around the world because that is economically cheaper. Only money seems to count in a lot of decisions, not our energy consumption and the impact this has on the natural world. How can we learn to optimize the performance of goods and services to sip energy rather than gulp it?

3. Nature fits form to function
A tree is rooted in the ground to draw water and nutrients from the soil; it spreads its branches and leaves wide to increase surface area and absorb the sunlight to produce energy and grow. Seeds are lightweight and some even come equipped with a sort of umbrella so they can float in the air. Nature creates designs for the function they provide, so should our buildings, transportation systems and schools.

4. Nature recycles everything
There is no 'away' to throw things. Everything produced in nature is biodegradable, there is no waste. There can still be abundance, look at all the blossom on a cherry tree, but that all serves a purpose and will be food and nutrients for others. Once the natural life of a pinecone has come and gone, it breaks down into essential elements that are repurposed into new life.

5. Nature rewards cooperation
We see competition in nature, but only when it's impossible to avoid; in general competition costs too much energy. On the other hand, very little in nature exists in isolation. Plants cooperate with pollinators to disperse seeds, and the pollinators feed on nectar. Ladybirds feed on aphids and help plants to stay healthy. Nature favours cooperation because it maintains the health of the whole system.

6. Nature banks on diversity
Diversity is one of nature's best insurance policies. When one food source is unavailable, others can be found. Plants use several different strategies to spread seed or defend against predators. We know that species with limited genetic diversity have more difficulty adapting to environmental change, and that ecosystems rich with diversity are more stable.

7. Nature demands local expertise
Nature's systems are inherently local. Certain species thrive under specific conditions; local and regional weather patterns matter, as do other conditions such as soil, air quality and water temperature. Relationships are created locally and local resources are used. Of course, some birds travel long distances but have you seen them take their food with them?

8. Nature seeks balance
Ecosystems will always try to keep in balance. More mice? Then you will see more owls to feed on the mice and keep the population in balance. Forest fires are a great example of a natural phenomenon that renews and refreshes, reducing excessive growth and allowing for regeneration. Every natural system has a tipping point, a carrying capacity or a state of disequilibrium that triggers a change to a different state.

9. Nature taps the power of limits
Unlimited growth on a finite earth is not a good idea. All living things are governed by limitations; age, climate, population density and many other factors determine how species and systems develop. Nature has found ingenious ways to work within these limits to be as productive as possible over the long run.

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