Biomimicry Design for Sustainability Skills in VET

KA220-VET-00620D4B

KA220-VET - Cooperation Partnerships in Vocational Education and Training

WP3 Training modules on Biomimicry Process Design

D3.3 Biomimicry training modules

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1. Introduction

Project Let’s Mimic has developed innovative training modules designed to enhance the sustainability skills of Vocational Education and Training (VET) learners. These modules support the uptake of the biomimicry design process by guiding the six core steps of the biomimicry methodology: DEFINE, BIOLOGIZE, DISCOVER, ABSTRACT, EMULATE, and EVALUATE. Each module is crafted to provide a structured and practical learning experience.

The training modules on Biomimicry Process Design aim to introduce VET learners aged 14-16 to the innovative field of biomimicry. Biomimicry involves learning from and mimicking nature's strategies to solve human challenges sustainably. These modules aim to provide a comprehensive framework for students to explore and apply biomimicry principles. The development of these modules is guided by the framework defined within WP2, ensuring a cohesive and effective learning experience.

The primary purpose of these training modules is to promote sustainability skills among VET learners. By engaging with the biomimicry design process, students will develop a deeper understanding of how nature-inspired solutions can address environmental and societal challenges. The modules aim to foster critical thinking, creativity, and problem-solving skills, which are essential skills of the 21st century. Additionally, the modules support Project-Based Learning (PBL), encouraging students to work on real-world projects that apply biomimicry principles.

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2. Purpose and relevance

The training modules are meticulously designed to achieve specific objectives that enhance the sustainability skills of Vocational Education and Training (VET) learners. These modules are structured based on the six steps of the biomimicry design process: DEFINE, BIOLOGISE, DISCOVER, ABSTRACT, EMULATE, and EVALUATE. Each step is integrated into the learning experience to ensure a comprehensive understanding and practical application of biomimicry principles.

The training modules aim to achieve the following objectives:

- **Understanding biomimicry:** To provide learners with a foundational knowledge of biomimicry and its significance in promoting sustainability.
- **Exploring nature's strategies:** To enable students to investigate and analyse various natural strategies and their applications in design and technology.
- **Applying biomimicry principles:** To guide learners through the six steps of the biomimicry design process, facilitating hands-on experience and practical application.
- **Enhancing 21st-century skills:** To develop critical thinking, creativity, collaboration, and communication skills through PBL and biomimicry projects.
- **Promoting environmental awareness:** To raise awareness about environmental issues and the importance of sustainable solutions inspired by nature.

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3. Description of the training modules

3.1. TM01 Stylish and efficient ceiling fan inspired by the aerodynamics of the Sycamore tree seeds

This example presents the design of a ceiling fan that combines both aesthetic appeal and high efficiency, while drawing inspiration from nature, more specifically from the unique aerodynamic properties of Sycamore tree seeds.

This training module comprises a total of 30 tasks assigned to students, divided into the six steps of biomimicry as follows: 12 tasks for Step 1 - Define the Challenge, 6 tasks for Step 2 – BIOLOGISE, 2 functions for Step 3 – DISCOVER, 4 tasks for Step 4 – ABSTRACT, 4 tasks for Step 5 – EMULATE, and 2 tasks for Step 6 – EVALUATE.

The resources provided by the professors for this training module include 4 documents, 6 H5Ps, and 1 video.

3.2. TM02 Shark skin swimsuit to reduce drag

This example is of a nature-inspired swimsuit that reduces drag and allows swimmers to achieve faster speeds with minimal effort, more specifically, a swimsuit inspired by shark skin.

This training module contains a total of 28 tasks assigned to students, divided into the 6 steps of biomimicry as follows: 12 tasks for Step 1 - Define the Challenge, 4 tasks for Step 2 – BIOLOGISE, 2 tasks for Step 3 – DISCOVER, 4 tasks for Step 4 – ABSTRACT, 4 tasks for Step 5 – EMULATE, and 2 tasks for Step 6 – EVALUATE.

The resources given by the professors for this training module are: 1 document and 14 H5Ps.

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3.3. TM03 Efficient water harvesting in arid environments inspired by the beetles that drink water from air

This example presents the design of a scalable system that can harvest and store water in arid environments, drawing inspiration from nature, specifically the Namib Desert beetle.

This training module contains a total of 30 tasks assigned to students, divided into the 6 steps of biomimicry as follows: 12 tasks for Step 1 - Define the Challenge, 6 tasks for Step 2 – BIOLOGIZE, 2 tasks for Step 3 – DISCOVER, 4 tasks for Step 4 – ABSTRACT, 4 tasks for Step 5 – EMULATE, and 2 tasks for Step 6 – EVALUATE.

The resources provided by the professors for this training module include: 3 documents, 5 H5Ps, and 1 video.

3.4. TM04 Reflecting road studs inspired by the Cat eyes glow in the dark

This example presents reflecting road studs that combine both aesthetic appeal and high efficiency, while drawing inspiration from nature, more specifically from the unique properties of cat eyes that glow in the dark.

This training module contains a total of 27 tasks assigned to students, divided into the 6 steps of biomimicry as follows: 10 tasks for Step 1 - Define the Challenge, 5 for tasks Step 2 – BIOLOGISE, 2 for tasks Step 3 – DISCOVER, 4 tasks for Step 4 – ABSTRACT, 4 tasks for Step 5 – EMULATE, and 2 tasks for Step 6 – EVALUATE.

The resources provided by the professors for this training module include: 3 documents, 6 H5Ps, and 1 video.

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3.5. TM05 Multi-functional biodegradable shoes inspired by the biodegradability of algal organic matter

This example describes the design of shoes that combine both aesthetic appeal and sustainability, while drawing inspiration from nature, more specifically from the biodegradable properties of Algae.

This training module contains a total of 27 tasks assigned to students, divided into the 6 steps of biomimicry as follows: 10 tasks for Step 1 - DEFINE the challenge, 5 tasks for Step 2 – BIOLOGISE, 2 tasks for Step 3 – DISCOVER, 4 tasks for Step 4 – ABSTRACT, 4 tasks for Step 5 – EMULATE, and tasks 2 for Step 6 – EVALUATE.

The resources provided by the professors for this training module include: 3 documents, 6 H5Ps, and 1 video.

3.6. TM06 The termite mounds' tunnels and building design for efficient cooling and ventilation

This example outlines the design of a building ventilation system that combines efficiency and sustainability, drawing inspiration from nature, specifically from the unique cooling and ventilation properties of termite mounds.

This training module contains a total of 26 tasks assigned to students, divided into the 6 steps of biomimicry as follows: 8 tasks for Step 1 - DEFINE the Challenge, 6 tasks for Step 2 – BIOLOGISE, 2 tasks for Step 3 – DISCOVER, 4 tasks for Step 4 – ABSTRACT, 4 tasks for Step 5 – EMULATE, and 2 tasks for Step 6 – EVALUATE.

The resources provided by the professors for this training module include: 1 document, 6 H5Ps, and 1 video.

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3.7. TM07 Design a subway or railway network less prone to disruption inspired by the adaptive behaviour of slime mould

This example introduces the design of a railway or subway network that combines cost efficiency, decentralisation, resilience and scalability, while drawing inspiration from nature, more specifically from the unique way Slime Mould creates pathways when foraging for food.

This training module contains a total of 27 tasks assigned to students, divided into the 6 steps of biomimicry as follows: 10 tasks for Step 1 - DEFINE the Challenge, 5 tasks for Step 2 – BIOLOGISE, 2 tasks for Step 3 – DISCOVER, 4 tasks for Step 4 – ABSTRACT, 4 tasks for Step 5 – EMULATE, and tasks 2 for Step 6 – EVALUATE.

The resources provided by the professors for this training module include: 2 documents, 6 H5Ps, and 1 video.

3.8. TM08 High-speed and quieter passenger trains inspired by the kingfisher, the owl and the penguin

This example presents the design principles of a high-speed train that combines high speed and reduced noise pollution, specifically the "tunnel boom", with energy efficiency, drawing inspiration from nature. More specifically, this is inspired by the silent flight of owls, the streamlined bodies of Adélie Penguins, and the head and beak of the Kingfisher.

This training module contains a total of 27 tasks assigned to students, divided into the 6 steps of biomimicry as follows: 10 tasks for Step 1 - DEFINE the Challenge, 5 tasks for Step 2 – BIOLOGISE, 2 tasks for Step 3 – DISCOVER, 4 tasks for Step 4 – ABSTRACT, 4 tasks for Step 5 – EMULATE, and 2 tasks for Step 6 – EVALUATE.

The resources provided by the professors for this training module include 5 documents, 12 H5Ps, and 3 videos.

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3.9. TM09 Safe, waterless and portable toilets

This example presents the design of a portable toilet that combines both aesthetic appeal and high efficiency, drawing inspiration from nature, specifically from the unique ability of plants to undergo evapotranspiration.

This training module contains a total of 27 tasks assigned to students, divided into the 6 steps of biomimicry as follows: 10 tasks for Step 1 - DEFINE the Challenge, 6 tasks for Step 2 – BIOLOGISE, 2 tasks for Step 3 – DISCOVER, 4 tasks for Step 4 – ABSTRACT, 3 tasks for Step 5 – EMULATE, and 2 tasks for Step 6 – EVALUATE.

The resources provided by the professors for this training module include: 2 documents, 5 H5Ps, and 1 video.

3.10. TM10 Eco-friendly urban noise reduction inspired by nature

This example is about creating passive, eco-friendly solutions to reduce noise pollution in cities, while being inspired by nature, more specifically by forests that dampen the sounds by layered vegetation and by beings like owls that possess soft feathers to minimise sound during flight.

This training module contains a total of 30 tasks assigned to students, divided into the 6 steps of biomimicry as follows: 12 tasks for Step 1 - DEFINE the Challenge, 6 tasks for Step 2 – BIOLOGISE, 2 tasks for Step 3 – DISCOVER, 4 tasks for Step 4 – ABSTRACT, 4 tasks for Step 5 – EMULATE, and 2 tasks for Step 6 – EVALUATE.

The resources provided by the professors for this training module include: 3 documents, 6 H5Ps, and 1 video.

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4. Conclusions

Project Let's Mimic represents a forward-thinking initiative aimed at equipping VET learners with essential sustainability skills through the innovative lens of biomimicry. By integrating the six-step biomimicry design process — DEFINE, BIOLOGIZE, DISCOVER, ABSTRACT, EMULATE, and EVALUATE — into structured training modules, the project fosters a hands-on, inquiry-based learning environment.

These modules not only introduce learners aged 14–16 to nature-inspired problem-solving but also cultivate critical 21st-century competencies such as creativity, collaboration, and environmental awareness. Each module exemplifies how biological strategies can inform sustainable technological solutions. Grounded in a cohesive pedagogical framework, the Let's Mimic modules empower students to engage with real-world challenges, promoting a deeper understanding of sustainability and the transformative potential of biomimicry in shaping a more resilient future.

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Annex

TM 01 Stylish and efficient ceiling fan inspired by the aerodynamics of the Sycamore tree seeds.

BIOMIMICRY DESIGN	Description
Step 1 – Define the challenge	**INFO** Clearly express the desired impact of your design on the world, along with the specific criteria and limitations that will measure its success. In the context of biomimicry, the "Define" step involves two main tasks: ● **Describe the challenge:** This means understanding what your design needs to accomplish, for whom, and in what context. ● **Criteria and constraints:** These are the standards and limitations that will help you evaluate whether you will be successful. Criteria might include factors like cost-effectiveness, durability, and environmental friendliness. Constraints could be things like budget limits, material availability, or regulatory requirements.
	TASKS **Task 1** Define the challenge as a question. **Task 2** Define the exploratory questions. **Task 3** Define the primary goal. **Task 4** Define the design needs. **Task 5** Define the target audience.

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Task 6

Define the context and the locations or settings for the implementation.

Task 7

Identify the opportunities and/or constraints that may impact achieving a successful outcome.

Task 8

Identify the connections to other solutions or challenges.

Task 9

Identify the favourable circumstances, initiatives or legislation.

Task 10

Identify the limitations or risks.

Task 11

Identify the cost.

Task 12

State your conclusions for the Define step.

RESOURCES PROVIDED BY TEACHERS TO STUDENTS

[Resource 1 - H5P Course presentation/Interactive Book]

[Define the challenge]

Challenge

The challenge given is to design a ceiling fan that combines both aesthetic appeal and high efficiency, drawing inspiration from the unique aerodynamic properties of Sycamore tree seeds.

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	Key concepts to follow ● **Aerodynamic efficiency:** Utilise the principles observed in Sycamore tree seeds to enhance the fan's airflow and energy efficiency. ● **Elegance:** Ensure the design is visually appealing and integrates seamlessly into modern interior spaces. ● **Functionality:** The fan should be easy to install, operate quietly, and provide effective cooling.
	STUDENT ASSIGNMENTS [Collaborative space] [Take your notes] **Task 1: Challenge as a question** How can we design an efficient ceiling fan that reduces energy consumption and has a lower environmental impact? **Task 2: Exploratory questions** How does the blade design contribute to lower operating speeds and reduced turbulence? What are the unique structural features of sycamore seeds that enable them to disperse effectively? **Task 3: Primary goal** The primary objective is to design ceiling fans that operate at low speeds while providing high airflow with minimal turbulence and noise, thereby offering a more efficient and cost-effective solution for both residential and commercial settings. **Task 4: Design needs** The design needs to address the inefficiencies and drawbacks of conventional ceiling fans, which typically require high operating speeds to achieve adequate airflow. These high speeds create significant turbulence and wind noise, leading to a less comfortable environment. Furthermore, conventional fans often utilise multiple blades, which increases material costs and energy consumption.

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	Task 5: Target audience ● **Homeowners and residents:** The primary users of the fan in residential settings, who will benefit from enhanced energy efficiency, quieter operation, and improved air circulation. ● **Environmental advocates:** This group would be interested in how the design reduces energy consumption, lowers carbon footprints and promotes sustainability. ● **Energy efficiency organisations:** Agencies promoting energy conservation may evaluate and endorse the fan design if it demonstrates clear benefits in reducing electricity usage. ● **Consumers in developing regions:** In regions with limited access to reliable electricity, an energy-efficient fan could have a significant positive impact, improving living conditions and reducing reliance on costly or scarce electricity. **Task 6: Context and locations** **Context** The design can be implemented in residential homes, offices, commercial buildings, buildings in tropical and hot climates, eco-homes, green buildings, sustainable architectural projects, public buildings, and institutions. **Locations or settings for implementation:** ● **Residential homes:** The design would primarily be used in homes, where energy efficiency and comfort are key. It would appeal to both urban and suburban households. ● **Offices and commercial buildings:** Energy-efficient and aesthetically pleasing fans would be ideal for modern offices or retail spaces, where cost-saving and design are both important factors. ● **Tropical and hot climates:** Areas where ceiling fans are heavily relied upon, such as regions in Southeast Asia, Latin America, and Africa, would benefit greatly from a design that circulates air more efficiently with less energy consumption. ● **Sustainable or eco-friendly developments:** The fan could be implemented in eco-homes, green buildings, or sustainable architectural projects aiming to reduce environmental impact. ● **Public buildings and institutions:** Schools, hospitals, and government buildings may incorporate these fans for their

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energy savings, especially in regions where energy conservation is a priority.

By identifying these groups and settings, it's clear that this sycamore seed-inspired ceiling fan design has a broad range of applications, from individual households to large-scale commercial and institutional projects, with a particular focus on energy efficiency and sustainability.

Task 7: Opportunities and constraints

Opportunities	Constraints
Growing demand for energy efficiency	High R&D and manufacturing costs
Green building certifications (LEED)	Competitive market saturation
Government energy-saving incentives	Consumer hesitation with new designs
Rising energy prices (cost-saving appeal)	Complex supply chain for eco-materials
Eco-conscious consumer base	Compliance with regional regulations
Integration with smart home systems	Difficulty in scaling manufacturing

Task 8: Connections to other solutions or challenges

- Energy efficiency and smart home integration
- Sustainability and eco-friendly design
- Climate change and indoor air quality

Task 9: Favourable circumstances, initiatives or legislation

- Government incentives for energy efficiency and green technologies.
- Legislation pushing for carbon reduction and sustainable building practices.
- Growing consumer demand for eco-friendly and smart home products.

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- International agreements and corporate ESG goals promoting sustainability.
- Circular economy initiatives and waste reduction regulations that support the use of sustainable materials.

Task 10: Limitations or risks

- Performance vs. aesthetics.
- Material durability.
- Market adoption and consumer behaviour.
- Consumer resistance to new technology.

Task 11: Cost

- Mid-range Fan: A sycamore seed-inspired fan designed for energy efficiency but manufactured with standard materials might cost around $150 - $300, similar to other high-quality ceiling fans.
- Premium fan: If positioned as a designer or luxury product using premium materials like carbon fibre or incorporating smart technology, the price could rise to $500 - $1,000 or more.
- Eco-friendly/smart options: Models designed for energy conservation and featuring smart controls could fall in the $300 - $600 range, balancing technology and eco-friendly features.

Task 12: Conclusions

The sycamore seed-inspired ceiling fan presents significant opportunities in terms of energy efficiency, sustainability, and market demand for eco-friendly products. However, constraints such as high development costs, market competition, and potential consumer hesitation need to be carefully managed. The success of the fan will depend on effectively balancing these factors, ensuring cost-effectiveness, and strategically positioning the product in the market through education, innovation, and partnerships with sustainability-focused initiatives.

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BIOMIMICRY DESIGN	Description
Step 2 – Biologize	**INFO** Analyse the essential functions and context your design solution must address. Reframe them in biological terms, so that you can "ask nature" for advice. In the context of biomimicry, the "Biologize" step involves the following tasks: ● **Identify biological models:** Research and identify organisms, ecosystems, or natural processes that exhibit the desired functions or characteristics you want to emulate in your design. ● **Understand biological principles:** Dive deep into understanding the underlying principles and mechanisms that make these biological models effective. This involves studying the anatomy, physiology, and behaviours of the organisms or systems you're interested in. ● **Translate biological strategies and consider opposite functions:** Translate the biological strategies into design principles that can be applied to your project. This means figuring out different natural processes that can be mimicked or adapted in a practical context.
	TASKS **Task 1** Read about the Sycamore seed and solve the quiz. **Task 2** What did you observe in the video presented? Write your observation using the concepts you discovered in the resources provided. **Task 3** State your challenge from the natural point of view. Ask yourself how nature can address this issue. **Task 4** Identify key functions applicable to nature's contexts.

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Task 5

Consider the opposite function and try to rephrase the question that describes the challenge from a natural perspective.

Task 6

You are given three natural models: termite mounds, cactus spines or animal nostrils. Pick up a natural model, and explain in a note how airflow is restricted or managed.

RESOURCES PROVIDED BY TEACHERS TO STUDENTS

[Resource 1 – Interactive Book]

[Let’s discover Sycamore seeds]

Context

In nature, the shape of the sycamore seed’s wings allows it to glide through the air, creating a spiral motion.

Sycamore seeds, also known as samaras, have a fascinating design that allows them to glide through the air with minimal energy expenditure. Their wings create a spiral motion, which helps them stay aloft longer and travel further from the parent tree. This mechanism is a brilliant example of nature solving the challenge of creating substantial airflow with minimal power.

How do Sycamore seeds glide and spin?

- **Wing design:** The wings of sycamore seeds are broad and papery, catching the air as they fall. The seed itself is heavier than the wing, creating a balance that allows the seed to orient itself and start spinning.
- **Autorotation:** As the seed falls, the broad wing slows down due to air resistance, causing the seed to tilt. This tilt generates a spiral motion, similar to a helicopter blade, which slows the descent and allows the seed to be carried further by the wind.
- **Aerodynamics:** The spinning motion creates a vortex that increases lift, enabling the seed to remain airborne for a more extended period. This principle is similar to those used by insects, bats, and hummingbirds.

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Fun facts about sycamore seeds and their fascinating flight

- **Natural helicopters:** Sycamore seeds are often called "nature's helicopters" because of their spinning motion, which is similar to the blades of a helicopter.
- **Efficient travel:** The design of sycamore seeds allows them to travel up to 100 meters away from the parent tree, helping the tree spread its offspring over a wide area.
- **Vortex creation:** The spinning motion of the seeds creates tiny vortices in the air, which help to keep them aloft longer. This principle is also used in the design of aircraft wings.
- **Inspiration for technology:** The autorotation mechanism of sycamore seeds has inspired engineers in designing more efficient wind turbines and drones.
- **Seasonal show:** In autumn, sycamore trees release thousands of seeds, creating a mesmerising display of spinning seeds falling to the ground.

[Resource 2 – H5P Flash cards]

[Did you know]

Did you know that sycamore seeds are designed to be dispersed with a relatively uniform airflow?

How?

Their wing-like structure, known as a samara, allows them to catch the wind and spin as they fall, creating a stable and controlled descent. This spinning motion, or autorotation, helps to distribute the seeds evenly over a wide area, ensuring that they do not all land in the same place and reducing competition among seedlings.

[Resource 3 – H5P Find multiple hotspots]

[I spy with my little eye]

Instructions

Let's take a look at what you have discovered until now. Can you identify in the interactive activity below what a Sycamore seed looks like?

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[Image to be used]

[Resource 4 – Link to video]

[Let's watch]

Take a look at this video, which captures the slow motion of sycamore seeds

https://youtu.be/SdOOpT1ZrN0?si=dst9G30XJlDMATES

[Resource 5 - Sycamore seeds vs airflow restriction]

[Document]

Nature has some fascinating ways of restricting or blocking airflow, and while sycamore seeds are primarily designed for efficient air circulation and dispersal, we can draw some interesting parallels:

Sycamore seeds are designed to maximize their dispersal by catching the wind and spinning. However, their structure can also provide insights into how airflow can be managed or restricted, such as:

1. Wing shape and orientation

- The wing-like structure of sycamore seeds creates a controlled descent by generating lift and drag. By adjusting the angle and shape of the wings, the seeds can manage the airflow around them, slowing their fall and ensuring they travel further.
- This principle can be applied to design structures that control airflow by altering angles and shapes to either enhance or restrict air movement.

2. Surface texture

- The surface of sycamore seed wings can influence how air flows over them. A rough or textured surface can create

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turbulence, which can slow down the airflow and reduce the speed of descent.

- Similarly, surfaces with specific textures can be designed to create turbulence and restrict airflow in various applications, such as in ventilation systems or aerodynamic designs.

STUDENT ASSIGNMENT

[Collaborative space]

[Take your notes]

Task 1

Students access the interactive activity and click on the correct image. The platform will inform students about their answers (correct or incorrect) and provide a personalised message.

Task 2

In the video, I can see that the sycamore seed's broad, papery wing catches the air as it falls. The heavier seed at the base creates a balance, allowing the seed to orient itself and begin spinning. This design helps the seed glide smoothly through the air.

Task 3

How can nature solve the challenge with less power to create a substantial airflow?

Task 4

Summary of key functions applicable to nature's contexts:

- Efficient air circulation: Fish fins, whale flippers
- Silent operation: Owl wings, shark skin
- Durability and lightweight design: Spider silk, bird bone structure
- Heat regulation: Termite mounds, elephant ears
- Adaptability and flexibility: Plant leaves (tropism), penguin thermoregulation
- Sustainability and eco-friendly materials: Bamboo, mollusk shells

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	- Dispersed, uniform airflow: Schooling fish, beehive airflow regulation By understanding how organisms have adapted to solve similar problems in nature, these key functions can inspire innovative solutions that enhance the performance, sustainability, and appeal of the sycamore seed-inspired ceiling fan. **Task 5** How can nature restrict or block airflow? **Task 6** **Termite mounds:** **Structure and design:** Termite mounds are built with a complex network of tunnels and vents. These structures are designed to regulate temperature and humidity inside the mound, which is crucial for the survival of the termite colony. **Airflow management:** The mounds have a system of ventilation shafts that allow hot air to rise and escape from the top, while cooler air is drawn in from the bottom. This creates a natural convection current, helping to maintain a stable internal environment. **Efficiency:** The design of the termite mound ensures that fresh air circulates throughout the structure, removing carbon dioxide and bringing in oxygen. This efficient airflow management allows termites to thrive even in harsh climates.

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BIOMIMICRY DESIGN	Description
Step 3 – Discover	**INFO** Look for natural models (organisms and ecosystems) that require the same functions and context as your design solution. Identify the strategies used that support their survival and success. In the context of biomimicry, the “Discover” step involves the following tasks: ● **Explore nature:** Spend time discovering natural models to study various ecosystems and organisms. ● **Identify functions:** Look for specific functions or strategies in nature that can solve the design challenge you're facing. ● **Gather information:** Collect detailed information about biological models that exhibit the desired functions, including scientific research, case studies, and firsthand observations.
	TASKS **Task 1** Search for other natural models that match the same functions as the Sycamore seeds and apply some context to your design solution. **Task 2** Identify experts and communities in the field of biomimicry.
	RESOURCES PROVIDED BY TEACHERS TO STUDENTS [Resource 1 – Course presentation] [Functions of Sycamore seeds] The sycamore seed, also known as a samara, is a marvel of natural engineering. Its wing-like structure is designed to maximise aerodynamic efficiency. When these seeds fall from the tree, they spin rapidly, creating lift and allowing them to glide through the air. This spinning motion helps the seeds travel further from the parent tree, increasing the chances of finding a suitable place to germinate. **Detailed functions of sycamore seeds** **1. Efficient air circulation**

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- **Aerodynamic design:** The unique shape of the sycamore seed's wing allows it to catch the wind effectively. This design minimises the energy required to stay airborne, enabling the seed to travel long distances.
- **Energy conservation:** By using minimal energy to move through the air, the seed can cover a larger area, which is crucial for the species' dispersal.

2. Silent operation

- **Quiet movement:** The sycamore seed's descent is almost silent, thanks to its smooth, aerodynamic shape, which reduces turbulence and noise as it spins and glides.
- **Stealthy dispersal:** The quiet operation ensures that the seeds can disperse without attracting the attention of potential predators, thereby increasing their chances of survival.

Additional insights

- **Environmental adaptation:** The ability to glide long distances enables sycamore seeds to adapt to diverse environments. They can find new areas with optimal conditions for growth, such as adequate sunlight, soil nutrients, and moisture.
- **Biodiversity contribution:** By spreading out over a wide area, sycamore seeds contribute to the biodiversity of their ecosystem. They help maintain genetic diversity within the species and support the health of the forest.

STUDENTS ASSIGNMENTS

[Collaborative space]

[Take your notes]

Task 1

Natural models:

- **Dragonfly wings:** Dragonflies possess highly efficient wings that generate lift and propulsion with minimal energy, enabling them to fly rapidly and agilely.
- **Bat wings:** Bats use a flexible wing membrane that adapts its shape for efficient, controlled flight, optimising airflow around their wings for manoeuvrability.

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- **Owl wings:** Owls have specialised wing feathers with serrated edges that reduce turbulence and noise, enabling nearly silent flight.
- **Beetle wings:** Some beetles, such as the titan beetle, have wing structures that reduce noise during flight due to their unique wing texture.
- **Hummingbird feathers:** Hummingbirds use specialised feathers to minimise noise while hovering and rapidly moving.

Task 2

Experts

1. University and research institutions, for example

- **University of California, Berkeley:** Science, Policy & Management, and Mechanical Engineering departments.
- **Harvard University:** The Wyss Institute for Biologically Inspired Engineering often conducts research related to biomimicry.

2. Specific experts, for example

- **Janine Benyus:** A biologist and author of Biomimicry: Innovation Inspired by Nature.
- **Daniel Pauly:** Marine biologist known for his work on fishery biology and ecosystem modelling.
- **Mark Miodownik:** Professor of Materials and Society at University College London with expertise in material science inspired by natural structures.

3. Professional associations, for example:

- **Biomimicry Institute:** Experts involved in biomimicry and its applications. Look for key figures, such as Beth R. R., from the institute.
- **American Society of Mechanical Engineers (ASME):** Mechanical engineers specialising in aerodynamics and material science.
- **Society for Conservation Biology:** Experts in conservation and ecology who can offer insights on environmental impacts and applications.

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4. Specialised journals and publications:

- **Journal of Experimental Biology:** Features articles on the biomechanics of animals and how their adaptations can inspire technology.
- **Nature and Science:** Leading journals with research on biomimicry, natural systems, and innovations inspired by nature.

Communities:

1. Online forums and social media

- **Reddit:** Subreddits like r/biomimicry, r/biology, and r/nature can be great for informal discussions and networking.
- **LinkedIn groups:** Join groups like "Biomimicry Network" or "Biomimicry and Design" to connect with professionals and enthusiasts.

2. Conferences and workshops

- **Biomimicry Global Design Challenge:** Attend events related to the competition to meet innovators and researchers in biomimicry.
- **International conference on biomimetic and biohybrid Systems:** A gathering of researchers working on bio-inspired systems and technologies.
- **Ecological Society of America (ESA) Annual Meeting:** Offers sessions and networking opportunities with ecologists and biologists.

3. Academic and professional societies

- **Biomimicry Institute:** Engage with the institute's community through workshops, webinars, and networking events.
- **International Society for Bioclimatic Architecture (ISBA):** Connect with professionals focused on integrating biological and climatic principles into building design.
- **American Institute of Architects (AIA):** Join AIA's special interest groups related to sustainable and biomimetic design.

4. Local naturalist groups

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	● **Local nature centres and botanical gardens:** The gardens often have naturalists and biologists who can offer practical insights and local expertise. ● **Audubon society chapters:** Engage with local chapters for connections with naturalists focused on bird behaviour and habitat studies. **5. Online communities and platforms** ● **ResearchGate:** A platform where researchers share their publications and can connect with experts in their field. ● **Academia.edu:** Another platform for finding and connecting with academics working on relevant topics.

BIOMIMICRY DESIGN	Description
Step 4 – Abstract	**INFO** Carefully study the essential features or mechanisms that make the biological strategies successful. Restate them in non-biological terms, referring to them as "design strategies." In the context of biomimicry, the "Abstract" step involves the following tasks: ● **Extract principles:** Identify and extract the underlying principles and strategies from the biological model you have studied. This means understanding the core functions and mechanisms that make these natural solutions effective. ● **Generalise concepts:** Generalise these biological principles so they can be applied to a wide range of design challenges. This involves translating specific biological strategies into broader design concepts that are not tied to a particular organism or ecosystem. ● **Create analogies:** Develop analogies that link the biological principles to human design challenges. These analogies help bridge the gap between nature and technology, making it easier to apply natural strategies to human-made systems.
	TASKS **Task 1** From the core function presented, summarise the key elements of the biological strategy of the Sycamore seed by defining the function and identifying relevant keywords.

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Task 2

Create a diagram or drawing, and/or find images of Sycamore seeds that can inform the design.

Task 3

Translate lessons from nature into design strategies. Rewrite the strategy without using biological terms and connect it to the functions and the context from a human perspective.

Task 4

Create a diagram or drawing, and/or find images of the design of your solution.

RESOURCES PROVIDED BY TEACHERS TO STUDENTS

[Resource 1 – Core functions of Sycamore seeds]

[H5P Flashcards]

Core functions

- **Efficient air circulation:** Achieves smooth and efficient air movement with minimal energy and less noise
- **Autorotation:** Enables the seedpod to stay in the air for longer and travel greater distances.
- **Curved shape:** Facilitates the autorotation of the seedpod.
- **Weight and wing length balance:** Ensures smooth autorotation during free fall.

STUDENT ASSIGNMENTS

[Collaborative space]

[Take your notes]

Task 1

- **Efficient air circulation**
- **Keywords**: Aerodynamics, Lift, Glide, Efficiency

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- **Description:** Sycamore seeds are designed to maximise air circulation through their aerodynamic shape. The wing-like structure (samara) allows them to catch the wind and travel long distances, ensuring efficient dispersal.

1. **Autorotation**
    - **Keywords:** Spinning, Stability, Slow Descent
    - **Description:** Sycamore seeds exhibit autorotation, which means they spin as they fall. This spinning motion stabilizes the seed and slows its descent, allowing it to be carried further by the wind. The autorotation is achieved due to the uneven mass distribution and the aerodynamic shape of the seed.

2. **Curved shape:**
    - **Keywords:** Aerodynamic, Lift, Glide
    - **Description:** The curved shape of sycamore seeds enhances their aerodynamic properties. This curvature helps generate lift and allows the seeds to glide smoothly through the air. The shape ensures that the seeds can travel longer distances and disperse more effectively.

3. **Weight and wing length balance:**
    - **Keywords:** Center of Mass, Center of Pressure, Balance.
    - **Description:** The balance between the weight of the seed and the length of its wing is crucial for its flight. The seed's heavier end (seed head) and the broad, lightweight wing create a balance that facilitates autorotation and stable descent. This balance ensures that the seed can maintain its spinning motion and travel efficiently.

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Task 2: Image of a Sycamore seed

Copyright @Adobe Stock

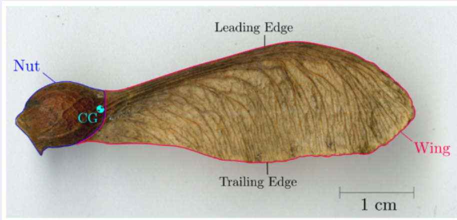

Photo of Sycamore seed (Acer pseudoplatanus) of the Maple genus, with a breakdown of the structure. CG is the location of centre of gravity of the whole seed. (Copyright @ Sectional Leading Edge Vortex Lift and Drag Coefficients of Autorotating Samaras, ResearchGate)

Task 3

- **Efficient air circulation:** Design the fan blades to create smooth, effortless airflow. The blades should be shaped to move air effectively while using minimal energy, ensuring a high-performance cooling effect.
- **Ensure quiet operation:** Incorporate features that minimise noise during operation. Design the fan blades and motor in a way that reduces vibrations and sound, creating a calm and pleasant environment.
- **Weight and wing length balance:** Use materials that are both strong and lightweight. This ensures the fan is durable and easy to handle, yet sturdy enough to withstand regular use.
- **Regulate temperature efficiently:** Integrate design elements that help manage and maintain a comfortable temperature. This might involve optimising airflow patterns to enhance cooling and improve overall temperature control.

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	Task 4: Image of a fan  Photo of Sycamore fan produced by Sycamore Technology Company (Copyright: https://www.sycamorefan.com)

BIOMIMICRY DESIGN	Description
Step 5 – Emulate	**INFO** In the context of biomimicry, the “Emulate” step involves the following tasks: ● **Apply biological principles:** Implement the biological strategies and principles you have abstracted into your design. This involves applying the insights gained from nature directly to create innovative solutions. ● **Prototype development:** Develop prototypes that incorporate the biomimetic principles. This involves creating models or samples that demonstrate how the natural strategies can be used in practical applications. ● **Integration:** Integrate the biomimetic design into the final product or system, ensuring that natural strategies are seamlessly incorporated and that the design meets all necessary criteria and constraints.
	TASKS **Task 1** Do the practical example and note your findings. **Task 2**

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	Identify as many ideas as possible for the design of your solution. **Task 3** Organise your ideas into categories that include features, context, and constraints. **Task 4** Select the design concept (ideas) that best fit your solution.
	RESOURCES PROVIDED BY TEACHERS TO STUDENTS [Resource 1 – Look into] [H5P Course presentation] When designing a ceiling fan inspired by the aerodynamics of Sycamore tree seeds, consider the following essential features to guide your ideas: ● **Maximise airflow with minimal energy:** Utilise the natural efficiency of Sycamore seeds, which spin and glide effortlessly through the air. Your design should aim to replicate this efficiency, ensuring that the fan moves a large volume of air while consuming as little energy as possible. ● **Noise reduction:** Sycamore seeds fall silently, demonstrating a natural form of noise reduction. Incorporate design elements that minimise operational noise, creating a quiet and comfortable environment. ● **Material optimisation:** Just as Sycamore seeds are lightweight yet durable, your fan design should use materials that provide strength without unnecessary weight. This optimisation will enhance performance and reduce energy consumption. ● **Sustainable materials:** Nature is inherently sustainable. Choose eco-friendly and sustainable materials for your fan design, ensuring that the production and disposal processes have minimal environmental impact. [Resource 2 - Flying Helicopter Seeds Experiment] [Document] **Flying helicopter seeds experiment**

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Materials

Paper, paper clip or hair clip, scissors.

Instructions

Cut out a rectangle from paper, cut down the dotted lines, and attach the two ends with a paper clip. Hold the spinner as high as you can and drop it. Watch as it spins to the ground just like a sycamore seed.

Investigation ideas:

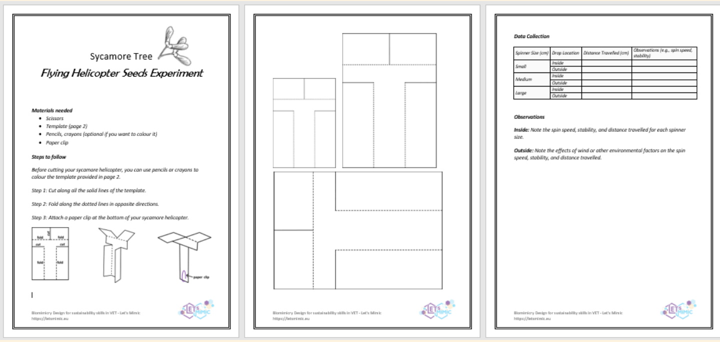
1. Size variation

- Create spinners of different sizes.
- Drop each spinner from the same height.
- Measure and record the distance each spinner travels

2. Environmental conditions

- Drop the spinners inside and outside.
- Observe and record any differences in their descent due to wind or other environmental factors (you can use a fan on the inside).

Template:


Sycamore Tree

Flying Helicopter Seeds Experiment

Materials needed

- *Scissors*
- *Template (page 2)*
- *Pencils, crayons (optional if you want to colour it)*
- *Paper clip*

Steps to follow

Before cutting your sycamore helicopter, you can use pencils or crayons to colour the template provided in page 2.

Step 1: Cut along all the solid lines of the template.

Step 2: Fold along the dotted lines in opposite directions.

Step 3: Attach a paper clip at the bottom of your sycamore helicopter.

Biomimicry Design for sustainability skills in VET - Let's Mimic
https://letsmimic.eu

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https://letsmimic.eu

Data Collection

Spinner Size (cm)	*Drop Location*	*Distance Travelled (cm)*	*Observations (e.g., spin speed, stability)*
Small	*Inside*		
	Outside		
Medium	*Inside*		
	Outside		
Large	*Inside*		
	Outside		

Observations

Inside: *Note the spin speed, stability, and distance travelled for each spinner size.*

Outside: *Note the effects of wind or other environmental factors on the spin speed, stability, and distance travelled.*

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STUDENT ASSIGNMENT

[Collaborative space]

[Take your notes]

Task 1

Students record their findings in the provided record sheet.

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Task 2

Ideas

- Curved and lightweight blades that mimic the shape of Sycamore seeds.
- High-efficiency motor.
- Multiple speed settings.
- Brushless DC motors.
- Materials that absorb sound.
- Carbon fibre or aluminium for the blades.
- Recycled or sustainable source of materials.
- LED lighting.

Task 3

Maximise airflow with minimal energy

- **Blade design:** Use curved, lightweight blades that mimic the shape of Sycamore seeds to enhance airflow efficiency.
- **Motor efficiency:** Integrate a high-efficiency motor that consumes less power while maintaining optimal performance.
- **Variable speed settings:** Implement multiple speed settings to adjust airflow based on room size and user preference.

Task 4

Noise reduction

- **Silent motor technology:** Use brushless DC motors known for their quiet operation.
- **Blade material:** Choose materials that absorb sound, such as composite materials or specially treated wood.
- **Aerodynamic blade shape:** Design blades with an aerodynamic profile to reduce turbulence and noise.

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Task 5

Material optimisation

- **Lightweight materials:** Utilise materials such as carbon fibre or aluminium for the blades to reduce weight without compromising strength.
- **Durable construction:** Ensure the fan components are durable to withstand long-term use while maintaining a lightweight design.
- **Energy-efficient components:** Select components that contribute to overall energy efficiency, such as LED lighting integrated into the fan.

Sustainable Materials

- **Eco-friendly materials:** Use recycled or sustainably sourced materials for the fan blades and housing.
- **Biodegradable components:** Incorporate biodegradable materials where possible to minimise environmental impact.
- **Energy-efficient manufacturing:** Adopt manufacturing processes that reduce energy consumption and waste.

Context

- **Residential use:** The fan should be suitable for various home environments, including living rooms, bedrooms, and offices.

Constraints

- **Budget**: Cost considerations for materials and production processes need to be balanced with the desired features and functionality.

Task 6

Curved and lightweight blades that mimic the shape of Sycamore seeds to enhance airflow efficiency with a high-efficiency motor, made of eco-friendly materials.

Inspiration drawn from the experiment:

- **Blade design:** Just like the paper spinner, fan blades should be designed to mimic the aerodynamic efficiency of Sycamore seeds.

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	● **Motor efficiency:** The spinner's effortless glide can inspire the use of high-efficiency motors in the fan. ● **Eco-friendly materials:** The use of paper in the spinner can inspire the choice of recycled or sustainably sourced materials for the fan

BIOMIMICRY DESIGN	Description
Step 6 – Evaluate	**INFO** In the context of biomimicry, the "Evaluate" step involves the following tasks: ● **Assess performance:** Evaluate the performance of your biomimetic design against the criteria and constraints defined earlier. This involves testing the design to see how well it meets the desired impact and functional requirements. ● **Compare with biological models:** Compare the effectiveness of your design with the biological models that inspired it, and determine whether the design successfully emulates natural strategies and achieves similar results. ● **Gather feedback:** Collect feedback from users, stakeholders, and experts to understand how well the design performs in real-world conditions. This feedback is crucial for identifying areas of improvement. ● **Analyse data:** Analyse the data collected during testing and feedback to identify strengths and weaknesses in the design. Look for patterns and insights that can inform further refinements. ● **Iterate and improve:** Based on the evaluation, make necessary adjustments and improvements to the design. This iterative process ensures that the final product is optimised for performance and sustainability.
	TASKS **Task 1** Evaluate the design concept about its alignment with the design challenge's criteria and constraints, as well as its compatibility with Earth's systems. Assess the feasibility of both the technical and business models.

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Task 2

Revise and revisit previous steps as necessary to generate a viable solution.

STUDENT ASSIGNMENTS

[Collaborative space]

[Take your notes]

Task 1

The design concepts for the Sycamore seed-inspired ceiling fan align well with the challenge's criteria, offering efficient air movement, quiet operation, strength, adaptability, and environmental sustainability.

Such a design can be compatible with Earth's systems by promoting energy efficiency and reducing waste. The technical and business models are feasible, although considerations for cost and market education will be necessary for successful implementation. The innovative features and eco-friendly design position the fan favourably in a growing market for sustainable home products.

Task 2

By revising and refining each design concept, the ceiling fan can be better aligned with the design challenge criteria, ensuring efficient air movement, silent operation, and adaptability while leveraging eco-friendly materials. The revised approach addresses technical and business feasibility, with a focus on sustainability and consumer demand. The final design will incorporate advanced features and environmentally conscious practices, positioning it as a competitive and innovative product in the market.

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TM 02 Shark skin swimsuit to reduce drag

BIOMIMICRY DESIGN	Description
Step 1 – Define the challenge	**INFO** Clearly express the desired impact of your design on the world, along with the specific criteria and limitations that will measure its success. In the context of biomimicry, the "Define" step involves two main tasks: ● **Describe the challenge:** This means you need to understand what your design needs to do, for whom, and in what context. ● **Criteria and constraints:** These are the standards and limitations that will help you evaluate whether you will be successful. Criteria might include factors like cost-effectiveness, durability, and environmental friendliness. Constraints could be things like budget limits, material availability, or regulatory requirements.
	TASKS **Task 1** Define the challenge as a question. **Task 2** Define the exploratory questions. **Task 3** Define the main goal. **Task 4** Define the design needs. **Task 5** Define the target audience. **Task 6**

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Define the context and the locations or settings for the implementation.

Task 7

Identify the opportunities and/or constraints that may impact achieving a successful outcome.

Task 8

Identify the connections to other solutions or challenges.

Task 9

Identify the favourable circumstances, initiatives or legislation.

Task 10

Identify the limitations or risks.

Task 11

Identify the cost.

Task 12

State your conclusions for the Define step.

RESOURCES PROVIDED BY TEACHERS TO STUDENTS

[Resource 1 - H5P Course presentation/Interactive Book]

[Define the challenge]

Challenge

This invention is essential to address the need for a suit that minimises drag and allows swimmers to achieve faster speeds with less effort. The target audience would include competitive swimmers at all levels, from aspiring athletes to Olympic champions, who are looking for any legal, performance-enhancing advantage.

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Key concepts to follow

- Drag Reduction: Focus on minimizing water resistance through materials, design, and fit.
- Performance Enhancement: Ensure the suit actively improves swimmer speed and efficiency within legal limits.
- Advanced Material Technology: Utilise innovative, hydrodynamic, lightweight, and flexible fabrics.

STUDENT ASSIGNMENTS

[Collaborative space]

[Take your notes]

Task 1: Challenge as a question

How can we design a swimsuit that reduces drag and enhances the swimmer's speed in the water?

Task 2: Exploratory questions

How can the design and material composition of the suit be optimised to reduce drag without compromising flexibility, comfort, or compliance with competitive swimming regulations?
What innovative technologies or biomimetic inspirations (e.g., shark skin, dolphin skin) can be integrated into the suit to enhance swimmer performance in real-world competition conditions significantly?

Task 3: Primary goal

To create a high-performance swimsuit that legally minimises drag, enhances speed, and maximises efficiency for competitive swimmers, giving them a measurable advantage in races without sacrificing comfort or mobility.

Task 4: Design needs

To meet the demands of competitive swimming, the suit must be designed for maximum hydrodynamic efficiency, minimizing drag while maintaining complete freedom of movement. It should feature lightweight, durable, and water-repellent materials that fit like a second skin, with strategic compression to support muscles and reduce fatigue. Seamless or bonded construction will further enhance

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	speed by eliminating unnecessary resistance. The suit must comply with all official regulations, ensuring it is race-legal while offering quick drying, thermal regulation, and a sleek, confidence-boosting appearance. Finally, ease of donning and removal must be considered to support the athlete's overall performance and convenience. **Task 5: Target audience** ● Competitive swimmers at all levels, from junior athletes to elite professionals. ● Olympic and international-level swimmers seeking legal performance advantages. ● Collegiate and university swim teams looking for high-performance gear. ● Swim coaches and trainers who recommend gear to their athletes. ● Swimming clubs and academies focused on competitive training. ● National swimming federations that equip their teams for major competitions. **Task 6: Context and locations** **Context** ● This invention is crucial in addressing the need for a suit that minimises drag and enables swimmers to achieve faster speeds with less effort. The target audience includes competitive swimmers at all levels, from aspiring athletes to Olympic champions, who are seeking any legal, performance-enhancing advantage. **Locations or settings for implementation** ● Professional swim competitions (e.g., Olympic Games, World Championships, Continental Championships like Pan Pacific or European Championships) ● National and regional swim meets ● University and collegiate swimming events (e.g., NCAA Championships) ● Swimming academies and elite training centres ● Local swim clubs and federations

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- Specialised sports stores (both physical and online) catering to competitive swimming gear
- Warm-weather and indoor aquatic training facilities (training camps in countries like Australia, the USA, Japan, and European centres)

The suit is designed for competitive swimming environments where performance gains through technological advancements are crucial. It will be used in high-stakes settings where every fraction of a second matters, such as swim meets, qualifiers, championships, and the Olympics.

Task 7

Opportunities and constraints

Opportunities	Constraints
Natural insights	Regulatory restrictions
Competitive demand	Cost and complexity of manufacturing
Fabrication techniques	Comfort and durability in balance
Eco-conscious consumer base	Water resistance and lightweight design

Task 8: Connections to other solutions or challenges

- Connection to high-tech athletic wear in other sports.
- Challenge of balancing performance and sustainability.
- Connection to regulations in competitive sports.

Task 9: Favourable circumstances, initiatives or legislation

- **Increased investment in sports science:** Fuels research into advanced, high-performance materials.
- **Growing demand for sustainable products:** Drives the development of eco-friendly fabrics that also enhance performance.
- **Collaborations between sports companies and academic institutions:** Allow for joint design efforts and real-world athlete testing to ensure comfort and speed.

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	● **Fair competition and clear material regulations:** Provide boundaries that encourage safe innovation, guiding designers to focus on legal, performance-enhancing materials. **Task 10: Limitations or risks** ● Regulatory restrictions. ● Material durability vs. performance. ● Cost and accessibility. ● Over-reliance on technology. **Task 11: Cost** **Estimated cost range** ● Basic Competitive Swimsuits: $50 - $150. ● High-Performance Suits (without tech enhancements): $150 - $350. ● Top-Tier Advanced Suits (with cutting-edge materials and designs): $350 - $600+ (some specialised Olympic-level suits can even exceed this). **Task 12: Conclusions** The overall conclusion for the development of a speedier swimsuit is that it represents a significant opportunity to enhance performance for competitive swimmers while meeting the growing demand for sustainable, high-performance athletic wear. By leveraging cutting-edge materials, strategic collaborations between sports companies and academic institutions, and ensuring regulatory compliance, the suit can offer swimmers a competitive edge in races without compromising comfort or legal standards. However, challenges such as material durability, cost considerations, and potential over-reliance on technology must be carefully managed to ensure the suit is both practical and accessible to athletes at all levels. With the right balance of innovation, research, and practical design, this swimsuit can significantly contribute to advancing the sport of swimming while providing long-term value to athletes and the competitive swimming community.

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BIOMIMICRY DESIGN	Description
Step 2 – Biologize	**INFO** Analyse the essential functions and context your design solution must address. Reframe them in biological terms, so that you can “ask nature” for advice. In the context of biomimicry, the “Biologize” step involves the following tasks: ● **Identify biological models:** Research and identify organisms, ecosystems, or natural processes that exhibit the desired functions or characteristics you want to emulate in your design. ● **Understand biological principles:** Dive deep into understanding the underlying principles and mechanisms that make these biological models effective. This involves studying the anatomy, physiology, and behaviours of the organisms or systems you're interested in. ● **Translate biological strategies and consider opposite functions:** Translate the biological strategies into design principles that can be applied to your project. This involves identifying different natural processes that can be mimicked or adapted in a practical context.
	TASKS **Task 1** Read about the Sharkskin swimsuits and answer the multiple-choice questions. **Task 2** Answer a true or false question. **Task 3** What did you observe in the video presented? Select the correct options as the questions appear in the video. **Task 4** State your answer to the question provided.

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RESOURCES PROVIDED BY TEACHERS TO STUDENTS

[Resource 1 – H5P Interactive Book]

[Let's discover swimsuits like sharkskin!]

"Part 1: The teacher should show the students the following text to introduce them to the topic of sharkskin swimsuits"

The Sharkskin Swimsuit is a high-performance innovation designed to reduce hydrodynamic drag and enhance speed in competitive swimming. It mimics the microstructure of real shark skin, which is covered in tiny, tooth-like scales called dermal denticles. These structures channel water more efficiently along the body, reducing turbulence and allowing smoother movement through the water. The suit's fabric incorporates ribbed textures and is engineered to compress the muscles, improving blood circulation and reducing fatigue.

How does it reduce drag?

Shark skin is covered in microscopic, tooth-like scales called dermal denticles, which are aligned in the direction of water flow, as well as high-tech elastic materials. These reduce drag by:

- **Channelling water efficiently:** The grooves between the denticles direct water along the swimmer's body, minimising turbulence.
- **Preventing vortex formation:** The ridged pattern helps break up the water in a controlled way, reducing the low-pressure vortices (swirls of water) that typically cause drag.
- **Reduce muscle vibration:** Less vibration means less water resistance.
- **Streamline body shape:** A smoother, more hydrodynamic form reduces form drag, the resistance caused by the body's shape as it moves through water.

[Resource 2 – HP5 Multiple Choice]

[Fun facts about sharkskin swimsuits!]

1. What material is most effective for reducing drag in sharkskin swimsuits?

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	A) Cotton. B) Nylon. C) Polyurethane. ✅ D) Silk. 2. Which organization helped test the suit's drag-reducing surface design? A) Red Bull. B) National Geographic. C) NASA. ✅ D) Google. 3. How long does it typically take elite swimmers to put on a sharkskin suit? A) 5–10 minutes. B) 10–15 minutes. C) 20–30 minutes. ✅ D) Over an hour. [Resource 3 – H5P True/False Question] [True or False] Sharkskin swimsuits are designed to absorb water, keeping swimmers cool. False – They are made from hydrophobic materials to repel water and reduce drag. [Resource 4 – H5P Interactive Video] [Let's watch and answer]

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Take a look at this video, which captures the benefits of the swimsuits, and answer the questions: “How Sharkskin Is Keeping Us Healthy and Speedy”

https://www.youtube.com/watch?v=YjeVRoDmXFs

Questions:

1. How far can sharks swim? (33 mph; 39 mph; 43 mph) - 28 seconds.
2. What are eddies in the context of fluid dynamics? (Sudden drops in water temperature during evaporation; Large underwater currents caused by seismic activity; Turbulent swirls or circular currents of slower-moving water; Waves formed by strong winds on the ocean surface) - 1 min 32 seconds.
3. How many records were broken by swimmers wearing Speedo’s Fastskin swimsuits? (13; 15; 12) - 2 mins 40 seconds
4. How do denticles help sharks avoid parasites and organisms like barnacles from attaching to their skin? (By secreting chemicals that repel marine life; By constantly shedding their skin; By creating a rough, uneven surface that resists attachment; By producing mucus that washes parasites away) - 4 mins and 23 seconds.

[Resource 5 - From Shark Skin to Speed]

[Document]

Sharks inspire a feeling of awe in many people, partly due to their natural speed and representation of power. Through modern biomimicry, scientists have been able to imitate shark skin and design speed-enhancing technologies to benefit transportation, medicine, and apparel design. The science behind shark skin speed is pretty simple:

- When an object is moving underwater, water flowing at the surface of the object moves more slowly than water moving away from that object.
- On smooth surfaces, the contrast in water speed surrounding the object causes the fast-moving water to break up into numerous turbulent vortices, which slows down the overall speed of an object moving underwater.
- Each dermal denticle has microscopic grooves running along it longitudinally, in alignment with water flow when

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	the shark swims forward. These grooves speed up slower water by pulling faster water around the shark onto its skin and mixing it with the slower water, thereby increasing the average speed of water on the shark's skin. ● Similarly, surfaces with specific textures can be designed to create turbulence and restrict airflow in various applications, such as in ventilation systems or aerodynamic designs. ● Denticles also channel the flow of water, breaking up sheets of water travelling over a shark's skin into smaller, less turbulent vortices. Ultimately, the dermal denticles on shark skin average out the speed of water surrounding it, causing less turbulence, so that the shark can glide through water at a greater overall speed https://illumin.usc.edu/from-shark-skin-to-speed/
	STUDENT ASSIGNMENT **Task 1** Students access the interactive activity and click on the correct answer. **Task 2** Students answer true or false questions. **Task 3** Students select the correct options as the questions appear in the video. **Task 4** How can we design a swimsuit that is resistant to drag and enhances the swimmer's speed in the water?

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<table>
<tr><th>BIOMIMICRY DESIGN</th><th>Description</th></tr>
<tr><td rowspan="3">Step 3 – Discover</td><td>
INFO

Look for natural models (organisms and ecosystems) that require the same functions and context as your design solution. Identify the strategies used that support their survival and success.

In the context of biomimicry, the “Discover” step involves the following tasks:

Explore nature: Spend time discovering natural models to study various ecosystems and organisms.
Identify functions: Look for specific functions or strategies in nature that can solve the design challenge you're facing.
Gather information: Collect detailed information about biological models that exhibit the desired functions, including scientific research, case studies, and firsthand observations.

</td></tr>
<tr><td>
TASKS

Task 1

Match the correct biomimetic function to its description and keywords.

Task 2

Identify experts and communities in the Biomimicry area.
</td></tr>
<tr><td>
RESOURCES PROVIDED BY TEACHERS TO STUDENTS

[Resource 1 – H5P Drag Text]
[Matching Challenge - What’s it for?]

Sharkskin is the unique, textured surface of a shark’s body, made up of tiny, tooth-like structures called dermal denticles. These hard, V-shaped scales resemble miniature teeth and are aligned in the direction of water flow to reduce turbulence and drag.

<table>
<tr><th>Term</th><th>Match to</th></tr>
</table>
</td></tr>
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Dermal Denticles	Drag Reduction
Hydrophobic Material	Water Repellency
Compression Zones	Muscle Support

It is possible to create a swimsuit design that successfully meets the demand of competitive swimming by recognising these essential roles and situations in nature. In addition to improving athletic performance, the emphasis on lowering drag through biomimicry promotes material science innovation.

[Resource 3 - HP5 Dialogue Cards]

[Expert Sources & Research Communities]

Front = “Expert Role” or “Community”; Back = Description and relevance.

Card Front: “Marine Biologists”

Back: “Experts in aquatic animal motion; explain how species reduce drag in water.”

Card Front: “Biomimicry Global Design Challenge”

Back: “An innovation event to explore nature-inspired engineering solutions.”

Card Front: “Fluid Dynamics Specialists”

Back: The American Institute of Aeronautics and Astronautics (AIAA) can provide valuable insights into how different textures and structures impact fluid flow.

Card Front: “Aquatic Research Facilities and Marine Labs”

Back: Laboratories such as the Scripps Institution of Oceanography or the Woods Hole Oceanographic Institution conduct research on marine animal locomotion and water dynamics.

STUDENTS ASSIGNMENTS

Task 1

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	Students must match the correct biomimetic function to its description and keywords. **Task 2** Students must format the list of experts and communities as interactive dialogue cards.

BIOMIMICRY DESIGN	Description
Step 4 – Abstract	**INFO** Carefully study the essential features or mechanisms that make the biological strategies successful. Restate them in non-biological terms, referring to them as “design strategies.” In the context of biomimicry, the “Abstract” step involves the following tasks: ● **Extract principles:** Identify and extract the underlying principles and strategies from the biological model you have studied. This means understanding the core functions and mechanisms that make these natural solutions effective. ● **Generalise concepts:** Generalise these biological principles so they can be applied to a wide range of design challenges. This involves translating specific biological strategies into broader design concepts that are not tied to a particular organism or ecosystem. ● **Create analogies:** Develop analogies that link the biological principles to human design challenges. These analogies help bridge the gap between nature and technology, making it easier to apply natural strategies to human-made systems.
	TASKS **Task 1** From the core function presented, summarise the key elements of the biological strategy of the Sharkskin Swimsuit by defining the function and identifying relevant keywords. **Task 2** Create a diagram or drawing, and/or find images of Sharkskin Swimsuits that can inform the design.

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Task 3

Translate lessons from nature into design strategies. Rewrite the strategy without using biological terms and connect it to the functions and the context from a human perspective.

Task 4

Write the correct answers in the blank spaces.

RESOURCES PROVIDED BY TEACHERS TO STUDENTS

[Resource 1 – Core functions of Sharkskin Swimsuit]

[H5P Accordion]

Core functions

- **Drag reduction:** Reduces friction and turbulence as water flows over the shark's body.
- **Surface protection / Durability:** The tough dermal denticles provide a protective, armour-like barrier.
- **Self-cleaning surface:** The texture and hydrophobic nature of sharkskin cause water and dirt to bead up and roll off.
- **Temperature and pressure adaptability:** Though not directly regulating temperature, sharkskin supports optimal movement at varying depths and pressures.

STUDENT ASSIGNMENTS

Task 1

Students must summarise the key elements of the biological strategy of the Sharkskin Swimsuit by defining the function and identifying relevant keywords.

[H5P Activity Type: Image Hotspots]

[Apply What You've Learned – Biomimetic Design Thinking]

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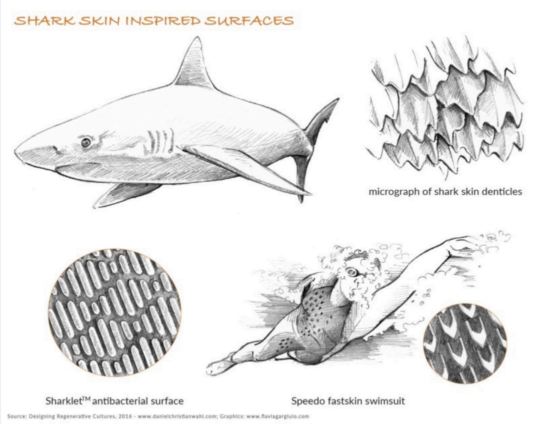
Task 2: Image of a Sharkskin Swimsuit

Speedo’s Fastskin line (Copyright @ Speedo LZR)

- **Hotspot 1:** This technology, developed from a coating that was originally used to protect satellites, provides durability so you can swim with the fastest, race after race.
- **Hotspot 2:** This surface mimics sharkskin to reduce water turbulence.



Engineering in Sports: Biomimetic Suits to Enhance the Swimming Experience (Copyright @ Flavia Gargiulo)

- **Hotspot 1:** As we know, this aqua predator has a significantly higher swim speed, even though its surface appears to be the same as any other fish. However, upon microscopic analysis, it

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was observed that the sharkskin had millions of small micro-sized structures called “denticles”.

- **Hotspot 2:** Compression zones reduce muscle vibration and delay fatigue.

Task 3

[H5P Activity Type: Drag and Drop]

[Apply the Concepts]

Players must drag the correct material/texture feature to each area. Examples:

- Smooth hydrophobic surface ⟶ Minimise drag.
- Textured layered surface ⟶ Reinforce durability.
- Nano-coated surface ⟶ Repels dirt and stains.

Task 4

[H5P Activity Type: Fill in the Blanks]

[Sharkskin Swimsuit Technology]

The swimsuit’s surface reduces water friction and boosts speed through a feature called [Drag Reduction].

To maintain its shape and provide muscle support under pressure, the suit utilises [Surface Protection].

Mimicking water-repellent surfaces like sharkskin, the suit dries quickly and reduces weight through its self-cleaning surface.

By staying snug in various conditions, the suit demonstrates its adaptability to temperature and pressure.

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BIOMIMICRY DESIGN	Description
Step 5 – Emulate	**INFO** In the context of biomimicry, the “Emulate” step involves the following tasks: ● **Apply biological principles:** Implement the biological strategies and principles you have abstracted into your design. This involves applying the insights gained from nature directly to create innovative solutions. ● **Prototype development:** Develop prototypes that incorporate the biomimetic principles. This involves creating models or samples that demonstrate how the natural strategies can be used in practical applications. ● **Integration:** Integrate the biomimetic design into the final product or system, ensuring that natural strategies are seamlessly incorporated and that the design meets all necessary criteria and constraints.
	TASKS **Task 1** Do the practical example and note your findings. **Task 2** Identify as many ideas as possible for designing your solution. **Task 3** Organise your ideas into categories that include features, context, and constraints. **Task 4** Select the design concept (ideas) that best fit your solution. **RESOURCES PROVIDED BY TEACHERS TO STUDENTS** [Resource 1 – HP5 Interactive Book] [Learn the Features]

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	The primary benefits of this product include improved swimming speed, reduced water resistance, and a flexible and comfortable fit. These components will be combined to create a lightweight, performance-enhancing swimsuit that enhances durability, reduces drag, and permits unhindered movement, all of which will increase swimming efficiency and endurance.
	Introduce 5 key features of sharkskin swimsuits: ● **Textured surface:** Like sharkskin, it helps water glide off smoothly. ● **3D panels or silicone zones:** Give muscles support and shape the body. ● **Hydrophobic coating:** Makes water slide off, not soak in. ● **Seamless design:** No stitches means no rubbing or slowing down. ● **Compression zones:** Helps reduce muscle fatigue and boost endurance. [Resource 2 - HP5 Drag the Words] [Design Time!] Drag each word into the correct blank to show where each design feature belongs. This swimsuit uses a [Hydrophobic Coating] across the entire surface to reduce drag. [Compression Zones] are located in the legs and core to support muscles and improve circulation. The [Seamless design] is applied to seams and joints to reduce resistance and enhance comfort.
	STUDENTS ASSIGNMENT [Resource 3 - HP5 Multiple Choice] [Sharkskin Suit vs. FINA-Legal Suit] **Task 1**

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	Students must answer the multiple-choice questions correctly. 1. Which suit was banned after the 2008 Olympics for giving swimmers an unfair advantage? A) Standard FINA-legal suit. B) Cotton training suit. C) Sharkskin suit. ✅ D) Wetsuit. 2. What is the primary material used in modern FINA-approved suits? A) Polyurethane. B) Textile-based fabric. ✅ C) Rubber. D) Sharkskin. 3. Which suit is allowed in official competitions today? A) FINA-legal suit. ✅ B) Sharkskin suit. C) Full-body polyurethane suit. D) NASA test suit. 4. How much of the body can a FINA-legal suit cover for men? A) Full-body. B) Shoulders to knees. C) Navel to knees. ✅ D) Ankles to neck.

BIOMIMICRY DESIGN	**Description**
Step 6 – Evaluate	**INFO** In the context of biomimicry, the "Evaluate" step involves the following tasks: ● **Assess performance:** Evaluate the performance of your biomimetic design against the criteria and constraints defined

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earlier. This involves testing the design to see how well it meets the desired impact and functional requirements.

- **Compare with biological models:** Compare the effectiveness of your design with the biological models that inspired it, and determine whether the design successfully emulates natural strategies and achieves similar results.
- **Gather feedback:** Collect feedback from users, stakeholders, and experts to understand how well the design performs in real-world conditions. This feedback is crucial for identifying areas of improvement.
- **Analyse data:** Analyse the data collected during testing and feedback to identify strengths and weaknesses in the design. Look for patterns and insights that can inform further refinements.
- **Iterate and improve:** Based on the evaluation, make necessary adjustments and improvements to the design. This iterative process ensures that the final product is optimised for performance and sustainability.

TASKS

Task 1

Evaluate the design concept in relation to its alignment with the design challenge's criteria and constraints, as well as its compatibility with Earth's systems. Assess the feasibility of both the technical and business models.

Task 2

Revise and revisit previous steps as necessary to generate a viable solution.

STUDENT ASSIGNMENTS

[Collaborative space]

[Take your notes]

Task 1

The best way to assess whether the product meets the design challenges and constraints is to determine whether the product developed meets the following parameters:

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- Drag reduction.
- Improvement in hydrodynamics.
- Comfort and flexibility.
- Durability.

The design should aim to improve swim speed and efficiency while also considering sustainability and environmental impact. Any materials used must be non-toxic, environmentally friendly, and sustainable, and must meet performance standards for competitive swimming.

In terms of compatibility with Earth's systems, the use of synthetic materials poses environmental concerns regarding pollution and waste. Ideally, a design that mimics natural systems would use biodegradable or recyclable materials to minimise its impact on Earth's systems.

Finally, regarding the technical and business model, the feasibility of the Speedo swimsuit's technical model hinges on its performance and innovation. Additionally, there is a robust demand for high-performance swimwear in competitive sports, but consumers are increasingly prioritising sustainability. Therefore, a successful business model must emphasise eco-friendly practices while balancing performance and affordability.

Task 2

After determining that sharkskin was our natural model, we examined its hydrodynamic characteristics, especially its drag-reducing texture. Important tactics centred on surface interaction and performance improvement were taken from this. By using eco-friendly materials that mimic the texture of sharkskin, we were able to translate these insights into a design concept that emphasises usability, longevity, and sustainability.

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TM 03 Efficient water harvesting in arid environments inspired by the beetles that drink water from air

<table>
<tr><th>BIOMIMICRY DESIGN</th><th>Description</th></tr>
<tr><td rowspan="2">Step 1 – Define the challenge</td><td>INFO

Clearly express the desired impact of your design on the world, along with the specific criteria and limitations that will measure its success.

In the context of biomimicry, the "Define" step involves two main tasks:
Describe the challenge: You need to understand what your design needs to do, for whom, and in what context.
Criteria and constraints: These are the standards and limitations that will help you evaluate whether you will be successful. Criteria might include factors like cost-effectiveness, durability, and environmental friendliness. Constraints include budget limits, material availability, or regulatory requirements.</td></tr>
<tr><td>TASKS

Task 1

Define the challenge as a question.

Task 2

Define the exploratory questions.

Task 3

Define the main goal.

Task 4

Define the design needs.

Task 5

Define the target audience.

Task 6

Define the context and the locations or settings for the implementation.</td></tr>
</table>

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	Task 7 Identify the opportunities and/or constraints that might impact achieving a successful outcome. **Task 8** Identify the connections to other solutions or challenges. **Task 9** Identify the favourable circumstances, initiatives or legislation. **Task 10** Identify the limitations or risks. **Task 11** Identify the cost. **Task 12** State your conclusions for the Define step.
	RESOURCES PROVIDED BY TEACHERS TO STUDENTS [Resource 1 - H5P Course presentation/Interactive Book] [Define the challenge] **Challenge** Design an efficient, scalable system to harvest and store water in arid environments, using nature as inspiration. **Key concepts to follow** ● **Water collection:** Efficiently capture moisture from fog or humid air.

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- **Water transportation:** Channel collected water for storage or use.
- **Energy efficiency:** Use passive methods to harvest water without relying on external energy sources.

STUDENT ASSIGNMENTS

[Collaborative space]

[Take your notes]

Task 1: Challenge as a question

How can we design an efficient and scalable system for harvesting and storing water in arid environments?

Task 2: Exploratory questions

How does nature capture water from the air?

What materials and surface structures enhance condensation?

How can passive processes be used to collect water?

Task 3: Primary goal

The primary objective is to provide sustainable and reliable water access for arid communities with minimal energy requirements.

Task 4: Design needs

The design needs to provide a consistent and reliable source of clean water for communities in arid regions. Furthermore, it should utilize available local resources to ensure the system's affordability and ease of implementation, be easy to operate and maintain, even in resource-poor or remote areas, and avoid over-reliance on external resources, ensuring the solution is robust in long-term, low-water scenarios.

Task 5: Target audience

- **Rural communities in arid regions:** These populations face water scarcity and need a reliable and accessible water source. The design should be affordable, easy to install, and

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capable of providing water for drinking, agriculture, and basic sanitation.

- **Governments and NGOS:** Organisations working on water access, climate adaptation, and poverty alleviation could adopt and distribute water harvesting systems in areas suffering from chronic water shortages.
- **Agricultural producers:** Farmers in arid climates would benefit from a water harvesting system that provides irrigation for crops and livestock.
- **Urban planners and municipalities in dry areas:** Cities in arid regions, especially those experiencing rapid growth in deserts or semi-arid zones, require scalable water harvesting systems to support their populations and infrastructure development.
- **Environmentalists and sustainability advocates:** Groups focused on water conservation and environmental sustainability may be interested in promoting and funding efficient water harvesting as a part of broader climate change mitigation strategies.

Task 6: Context and locations

Context

- The growing threat of climate change exacerbates water scarcity, with more frequent droughts and increased evaporation rates. In the coming decades, many already water-stressed regions will see even more extreme weather patterns. Water scarcity in the arid areas leads to migration, conflicts over water resources, and significant health challenges. Improving water access is crucial to the resilience and sustainability of these communities.

Locations or settings for implementation

- **Rural desert communities:** E.g., villages in the Sahel, southwestern U.S., northern Mexico, or Rajasthan (India) that lack centralized water infrastructure but experience morning fog or humidity.
- **Urban slums in arid regions:** Densely populated, low-income zones in growing desert-edge cities (e.g., Thessaly-Greece, Lima, Cairo, Windhoek) where water demand exceeds supply and infrastructure can't keep up.

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- **Agricultural fields in drylands:** Farms in semi-arid regions that rely on seasonal irrigation or rainwater harvesting could benefit from fog nets or passive collectors to support crop/livestock needs.
- **Remote institutions:** Schools, health posts, or refugee camps in arid zones with no reliable water grid, where passive systems could support hygiene and sanitation.
- **Off-grid eco-settlements or sustainable housing projects:** Locations experimenting with circular resource use, especially in harsh environments where resilience is a priority.

Task 7: Opportunities and constraints

Opportunities	Constraints
Advancements in water harvesting technology	High initial investment
Solar power integration	Climate and environmental factors
Government and NGO support	Infrastructure and maintenance challenges
Public awareness and demand for sustainability	Scarcity of water resources
Collaboration with academia	Regulatory and land use constraints
Community engagement	Cultural and social barriers

Task 8: Connections to other solutions or challenges

- Climate adaptation strategies.
- Sustainable architecture and urban design.
- Circular economy principles.
- Agricultural water efficiency.
- Off-grid and renewable energy systems.
- Public health and sanitation solutions.

Task 9: Favourable circumstances, initiatives or legislation

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- International climate agreements that encourage investment in sustainable technologies and adaptation solutions.
- Water access initiatives for improving water access in developing regions.
- Research funding and innovation Grants for technologies that address global water scarcity challenges.
- Policy support for sustainability could provide an enabling environment for water harvesting projects.
- Corporate responsibility and investment in water sustainability could result in private sector support for water harvesting technologies.

Task 10: Limitations or risks

- Environmental dependency.
- Material durability.
- Water yields expectations.
- Community acceptance.
- Legal and regulatory issues.
- Maintenance and skill gaps.

Task 11: Cost

- **Basic household fog collector:** ~100–250 € per unit (mesh, frame, reservoir). It is suitable for family use in rural areas.
- **Community-scale system:** ~2,000–5,000 € to support a small village or institution, depending on size and collection volume.
- **Urban or architectural integration (e.g., building facades):** 300–600 €/m\u00b2 for treated surfaces, custom structures, and integration with water storage systems.

Task 12: Conclusions

Designing a bio-inspired, passive water harvesting system addresses urgent needs in water-scarce areas, but requires careful consideration of environmental, social, and technical challenges.

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BIOMIMICRY DESIGN	Description
Step 2 – Biologize	**INFO** Analyse the essential functions and context your design solution must address. Reframe them in biological terms, so that you can "ask nature" for advice. In the context of biomimicry, the "Biologize" step involves the following tasks: ● **Identify biological models:** Research and identify organisms, ecosystems, or natural processes that exhibit the desired functions or characteristics you want to emulate in your design. ● **Understand biological principles:** Dive deep into understanding the underlying principles and mechanisms that make these biological models effective. This involves studying the anatomy, physiology, and behaviours of the organisms or systems you're interested in. ● **Translate biological strategies and consider opposite functions:** Translate the biological strategies into design principles that can be applied to your project. This involves identifying different natural processes that can be mimicked or adapted in a practical context.
	TASKS **Task 1** Read about the Namib Desert beetle and solve the quiz. **Task 2** What did you observe in the video presented? Write your observation using the concepts you discovered in the resources provided. **Task 3** State your challenge from the natural point of view. Ask yourself how nature can solve this. **Task 4** Identify key functions applicable to nature's contexts.

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Task 5

Look into the opposite function and try to flip the question which describes the challenge from a natural point of view.

Task 6

You are given three natural models: the Namib Desert beetle, cactus spines, lichen or moss. Pick one and note how this organism collects or manages water using its surface structure and environmental interactions.

RESOURCES PROVIDED BY TEACHERS TO STUDENTS

[Resource 1 – Interactive Book]

[Let’s discover the Namib desert beetle]

Context

Certain organisms have developed remarkable natural adaptations that allow them to collect water directly from the air, even in the most arid environments.

One of the most fascinating examples is the Namib Desert beetle, which survives in one of the driest places on Earth by harvesting water from fog. The beetle's back features a unique combination of water-attracting (hydrophilic) bumps and water-repelling (hydrophobic) channels. This clever surface design captures tiny water droplets from the air and directs them to the beetle’s mouth—all without the need for energy-consuming systems.

How does the Namib Desert beetle collect water from the air?

- **Surface texture:** The beetle’s shell is covered in microscopic bumps that attract water molecules from fog or humid air, encouraging condensation.
- **Directional grooves:** Once water forms on the hydrophilic bumps, it is guided by hydrophobic grooves toward the beetle’s mouth.
- **Passive process:** This entire mechanism operates without any external energy, relying solely on smart surface design and natural environmental conditions, such as wind and humidity.

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Fun facts about beetles and biological water collection

- **Fog-harvesting champion:** The Namib Desert beetle can collect enough water for survival by simply facing into the wind, thanks to its evolved shell structure.
- **Nature's engineers:** This passive fog collection strategy has inspired modern designs for fog nets, water bottles, and architectural surfaces.
- **Beyond beetles:** Similar water-collection principles are seen in cactus spines, which channel dew to the plant’s base, and lichen, which absorbs moisture from the air.
- **Desert survival experts:** Organisms like these survive and thrive in arid conditions by tapping into atmospheric moisture.
- **Inspiration for innovation:** Engineers and designers are replicating these biological strategies to develop sustainable water solutions for drought-prone regions worldwide.

[Resource 2 – H5P Flash cards]

[Did you know]

Did you know that desert beetles are designed to harvest water directly from the air?

How?

Their shell surfaces combine tiny water-attracting bumps and water-repelling grooves. This micro-patterned design enables water droplets from fog or humid air to condense on the beetle’s back and roll directly toward its mouth without any external power.

This passive water collection system allows the beetle to survive in environments with less than 1 cm of annual rainfall, making it one of nature’s most efficient fog harvesters. The design ensures that water is gathered steadily and directed efficiently, avoiding evaporation or loss before consumption.

[Resource 3 – H5P Find multiple hotspots]

[I spy with my little eye]

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Instructions

Let’s take a look at what you have discovered until now. Can you identify the Namib Desert beetle in the interactive activity below?

[Image to be used]

[Resource 4 – Link to video]

[Let’s watch]

Take a look at this video about the Namib Desert beetle

https://www.youtube.com/watch?v=IoflT3Uvels

[Resource 5 - Desert beetles and moisture control]

[Document]

Nature has some fascinating ways of managing moisture, not just collecting it, but also transporting and conserving it. While the Namib Desert beetle is best known for water collection, its structure also provides valuable lessons in how surface geometry and texture can be used to control fluid movement:

1. **Surface shape and orientation**

   - The beetle’s shell is curved to face into wind currents, maximising contact with humid air and encouraging condensation.

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- By controlling the angles of the bumps and grooves, the beetle can channel water droplets toward its mouth, thereby reducing waste and ensuring that every drop is utilised.
- These principles can inspire the design of surfaces or nets that guide water directionally, even in windy or unpredictable climates.

2. Surface texture and patterning

- The shell's hydrophilic bumps cause moisture to condense more quickly by attracting water molecules.
- The surrounding hydrophobic channels function like fluid highways, enabling water to flow efficiently toward a collection point without being absorbed or evaporated.
- This strategy can be applied in designing fog-harvesting meshes, rooftops, or even clothing that collects and channels atmospheric moisture.

STUDENT ASSIGNMENT

[Collaborative space]

[Take your notes]

Task 1

Students access the interactive activity and click on the correct image. The platform informs students about their answers (correct or incorrect) and provides a personalised message.

Task 2

In the video, observe how the Namib Desert beetle collects water from fog. For example, the beetle tilts its body into the wind, and small water droplets begin to form on the raised bumps of its back. These droplets then roll down hydrophobic channels toward the beetle's mouth — no pumps, no electricity, just clever surface design.

Task 3

How do beetles in arid environments extract water from the air to survive in extreme conditions?

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	Task 4 **Summary of key functions applicable to nature's contexts** ● **Water collection:** Efficiently capture moisture from fog or humid air. ● **Water transportation:** Channel collected water for storage or use. ● **Energy efficiency:** Use passive methods to harvest water without relying on external energy sources. By studying how organisms like beetles, cacti, and mosses adapt to dry environments, we gain insights into sustainable design strategies for water access in challenging climates. **Task 5** How do organisms in nature passively capture, transport, and store water in arid environments? **Task 6** **Cactus spines** ● **Structure and design:** Cacti have spines that are not just for protection—their angled structure captures dew and fog, guiding water droplets down toward the plant's base. ● **Water movement:** The spine geometry uses surface tension to guide droplets. ● **Efficiency:** This passive water management allows cacti to hydrate even in desert air with very low moisture levels.

BIOMIMICRY DESIGN	Description
Step 3 – Discover	**INFO** Look for natural models (organisms and ecosystems) that require the same functions and context as your design solution. Identify the strategies used that support their survival and success. In the context of biomimicry, the "Discover" step involves the following tasks:

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- **Explore nature:** Spend time discovering natural models to study various ecosystems and organisms.
- **Identify functions:** Look for specific functions or strategies in nature that can solve the design challenge you're facing.
- **Gather information:** Collect detailed information about biological models that exhibit the desired functions, including scientific research, case studies, and firsthand observations.

Look for natural models (organisms or ecosystems) that solve similar challenges.

TASKS

Task 1

Search for other natural models that match the same functions as the Namib Desert beetle and apply some context to your design solution.

Task 2

Identify experts and communities in the field of biomimicry.

RESOURCES PROVIDED BY TEACHERS TO STUDENTS

[Resource 1 – Course presentation]

[Functions of Namib desert beetle]

The Namib Desert beetle is a master of survival in one of Earth's driest environments. Its back is uniquely engineered to harvest water from the air, allowing it to thrive in a place that receives less than 1 cm of rain annually. By combining micro-textures that attract and repel water, the beetle collects, transports, and drinks fog droplets using only the natural forces of wind and condensation.

Detailed functions of the Namib desert beetle:

1. Water collection

- **Hydrophilic bumps:** Tiny raised structures on the beetle's shell attract and condense moisture from fog or humid air.
- **Condensation activation:** These bumps create ideal conditions for water vapour to turn into liquid droplets.

2. Water transportation

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- **Hydrophobic grooves:** Between the bumps, the beetle's shell has water-repelling channels that guide collected droplets toward the beetle's mouth.
- **Passive guidance:** This occurs without mechanical parts or external energy, relying solely on innovative surface geometry.

3. Energy efficiency

- **No power needed:** The beetle uses no biological pumps. The entire system runs passively through gravity, wind, and surface tension.
- **Sustainable design:** This makes it a model for off-grid, low-energy water harvesting solutions.

Additional insights

- **Environmental adaptation:** The beetle's survival technique allows it to access water where none appears to exist — an ideal strategy for remote, drought-prone communities.
- **Inspiration for innovation:** This biological strategy has already inspired the development of fog nets, self-watering bottles, and building materials designed for water harvesting.
- **Ecosystem impact:** As part of the desert ecosystem, the beetle's efficient design helps conserve resources and maintain species balance in extreme conditions.

STUDENTS ASSIGNMENTS

[Collaborative space]

[Take your notes]

Task 1

Natural models

- Namib desert beetle: Uses a combination of hydrophilic bumps and hydrophobic grooves to collect water.
- Cacti: Use ridges and spines to capture and channel dew and fog to their roots.
- Lichen and Moss: Absorb moisture directly from the air using capillary action.

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	Task 2 **Experts** ● University and research institutions, for example, like: ● MIT’s Fog Harvesting Lab: Focuses on water collection technologies inspired by natural processes. ● University of Oxford’s Zoology Department: Studies biomimetic adaptations of desert organisms. **Professional associations,** for example, include: ● Biomimicry Institute: Connects innovators and researchers studying natural water-harvesting solutions. ● International Water Association: Offers research on sustainable water management practices. **Communities** ● Online forums and groups. ● ResearchGate: Engage with material scientists and biomimicry experts studying water-harvesting surfaces. ● LinkedIn groups: Join discussions on sustainable technologies and biomimetic design. **Local organisations and events** ● Water management conferences: Learn about advancements in fog collection and water efficiency. ● Biomimicry workshops: Network with professionals working on bioinspired water solutions. [Course slides: Natural water harvesting models] [List of Biomimicry Experts]

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BIOMIMICRY DESIGN	Description
Step 4 – Abstract	**INFO** Carefully study the essential features or mechanisms that make the biological strategies successful. Restate them in non-biological terms, referring to them as "design strategies." In the context of biomimicry, the "Abstract" step involves the following tasks: ● **Extract principles:** Identify and extract the underlying principles and strategies from the biological model you have studied. This means understanding the core functions and mechanisms that make these natural solutions effective. ● **Generalise concepts:** Generalise these biological principles so they can be applied to a wide range of design challenges. This involves translating specific biological strategies into broader design concepts unrelated to an organism or ecosystem. ● **Create analogies:** Develop analogies that link the biological principles to human design challenges. These analogies help bridge the gap between nature and technology, making it easier to apply natural strategies to human-made systems.
	TASKS **Task 1** From the core function presented, summarise the key elements of the Namib desert beetle's biological strategy by defining the function and identifying relevant keywords. **Task 2** Create a diagram or drawing, and/or find images of the Namib Desert beetle that can inform the design. **Task 3** Translate lessons from nature into design strategies. Rewrite the strategy without using biological terms and connect it to the functions and the context from a human perspective. **Task 4** Create a diagram or drawing, and/or find images of the design of your solution.

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RESOURCES PROVIDED BY TEACHERS TO STUDENTS

[Resource 1 – Core functions of the Namib desert beetle]

[H5P Flashcards]

Core functions

- **Water collection:** Efficiently capture moisture from fog or humid air. biological principles to human design challenges. These analogies help bridge the gap between nature and technology, making it easier to apply natural strategies to human-made systems
- **Water transportation:** Collect water through channels for storage or use.
- **Energy efficiency:** Use passive methods to harvest water without relying on external energy sources.

STUDENT ASSIGNMENTS

[Collaborative space]

[Take your notes]

Task 1

1. Water collection

- **Keywords:** Condensation, moisture capture, fog harvesting.

Description:

- **Natural model:** Namib desert beetle.
- **Function:** Attract and condense water vapour into droplets.

2. Water transportation:

- **Keywords:** Channelling, directional flow, hydrophobic grooves.

Description:

- **Natural model:** Beetle shell grooves, cactus ridges.

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- **Function:** Funnel collected water to a central storage or usage point.

3. Energy efficiency:

- **Keywords:** Passive process, sustainability, no external energy.

Description:

- **Natural model:** Passive water collection by beetles.
- **Function:** Harvest water without relying on energy-intensive methods.

Task 2: Image of a Namib desert beetle

Photo of the Namib Desert beetle. (Copyright (c) Vblinov| Dreamstime.com)

Task 3

- **Water collection:** Utilise materials that combine water-attracting and water-repelling properties to condense and collect water from the air.
- **Water transportation:** Incorporate grooves or channels to guide collected water to a storage area efficiently.
- **Energy efficiency:** Design systems that passively harness water using environmental conditions such as wind and humidity.

Task 4: Image of Dew Bank

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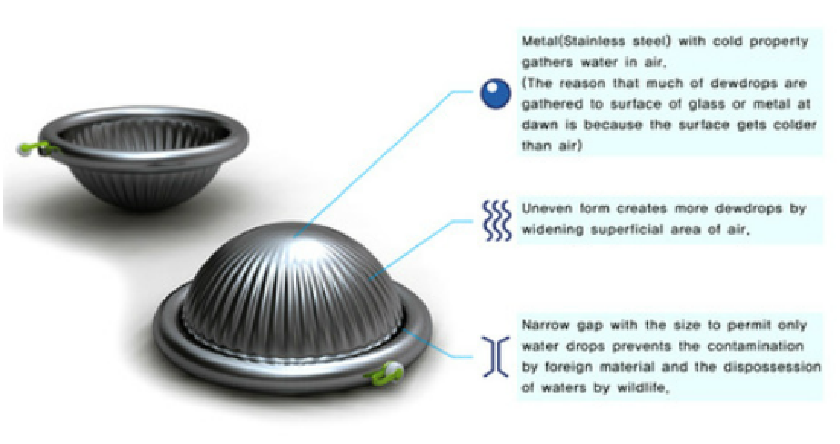

Photo of Dew Bank fan designed by Pak Kitae, under the company Yanko Designs (Copyright: https://dewbankbeetle.weebly.com/dew-bank.html)

BIOMIMICRY DESIGN	Description
Step 5 – Emulate	**INFO** In the context of biomimicry, the “Emulate” step involves the following tasks: ● **Apply biological principles:** Implement the biological strategies and principles you have abstracted into your design. This involves directly applying insights gained from nature to create innovative solutions. ● **Prototype development:** Develop prototypes that incorporate biomimetic principles, creating models or samples that demonstrate how natural strategies can be applied in practical applications. ● **Integration:** Integrate the biomimetic design into the final product or system, ensuring that natural strategies are seamlessly incorporated and that the design meets all necessary criteria and constraints.
	TASKS **Task 1** Do the practical example and note your findings.

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Task 2

Identify as many ideas as possible for designing your solution.

Task 3

Organise your ideas into categories that include features, context, and constraints.

Task 4

Select the design concept (ideas) that best fit your solution.

RESOURCES PROVIDED BY TEACHERS TO STUDENTS

[Resource 1 – Look into]

[H5P Course presentation]

When designing a water harvesting system inspired by the Namib Desert beetle, consider the following essential features to guide your ideas:

- **Passive water collection from air:** Utilise the beetle's strategy of capturing water from fog and humidity using surface patterns that condense and guide droplets. Your design should work without electricity, harvesting water purely from environmental conditions.
- **Smart surface design:** Mimic the beetle's combination of hydrophilic bumps (to collect water) and hydrophobic channels (to move water). These features improve both efficiency and flow control in fog or dew collectors.
- **Low-maintenance, durable materials:** Design surfaces that resist dirt and UV damage—ideally self-cleaning or easy to rinse—to function effectively in desert or dusty settings. Lightweight, modular materials will allow easy transport and installation in remote areas.
- **Eco-friendly materials:** Choose sustainable and recyclable materials for frames or meshes, and consider biodegradable options whenever possible to minimise environmental impact at the end of their life.

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[Resource 2 - Fog Collector Simulation Activity]

[Document]

Fog collector simulation activity

Materials

Plastic mesh or netting, wax paper or foil, sponge, spray bottle (to simulate fog), measuring cup, small collection container.

Instructions

Stretch mesh or foil over a frame (you can use a coat hanger or cardboard cutout). Lightly spray the surface with a mist (representing fog). Observe how water collects and flows. Use different surface textures, such as wax paper (smooth), foil with bumps, a sponge (absorbent), and mesh with ridges.

Investigation ideas:

1. **Surface comparison**
   - Which surface collects the most water?
   - Which surface transports water the fastest?

2. **Tilt and angle variation**
   - Try different angles (flat, 30°, vertical).
   - Observe how gravity and surface design affect flow and collection.

3. **Material texture**
   - Compare rough vs. smooth materials.
   - Which encourages droplets to form faster?

Template

Sketch your fog collector design inspired by the beetle's back. Label the hydrophilic and hydrophobic zones and describe how water flows through the system.

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	STUDENTS ASSIGNMENT [Collaborative space] [Take your notes] **Task 1** Students record their findings on the provided record sheet. **Task 2** **Ideas** ● Surfaces patterned with hydrophilic bumps and hydrophobic grooves. ● Passive water collection mesh or panel. ● Gravity-fed water channels for easy transport to containers. ● Modular design for easy repair and replacement. ● Self-cleaning surface coating (dust and debris resistant). ● UV-resistant, long-lasting materials. ● Foldable or collapsible structure for portability. ● Use of recycled or biodegradable materials. **Task 3** **Organising your ideas by design priorities** **1. Passive water collection** ● **Surface design:** Create panels or meshes with alternating textures to condense fog effectively. ● **Orientation:** Design the system to face prevailing winds or fog flow for maximum exposure. **2. Water transport** ● **Guiding channels:** Include grooves that use gravity to direct droplets to a container. ● **Material coating:** Hydrophobic pathways prevent water loss from sticking or evaporation. **3. Material optimisation**

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- **Durable but lightweight:** Choose weatherproof materials like recycled plastics or biodegradable composites.
- **Modular construction:** Make components easy to replace or expand.
- **Low-maintenance:** Consider self-cleaning or dust-resistant finishes.

4. Sustainable materials & processes

- Use recycled or natural materials for the frame or mesh.
- Explore biodegradable coatings for water transport surfaces.
- Plan for low-energy production methods and local material sourcing.

Context

- Intended for use in arid and semi-arid regions for households, small farms, or community centres.
- Must be effective in low-humidity but fog-prone environments and function without electricity.

Constraints

1. Technical limitations

- Balancing durability and efficiency in water-harvesting materials.
- Adapting designs for varying humidity levels.

2. Cost considerations

- Ensuring affordability for low-income communities.
- Scaling up production without environmental harm.

3. Environmental impact

- Using sustainable and biodegradable materials.
- Minimising ecological disruption during deployment.

Task 4

A modular fog-harvesting panel made from recycled plastic mesh, featuring hydrophilic and hydrophobic surface zones, is angled for

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	gravity-fed collection and mounted on a lightweight frame suitable for both household and agricultural use. **Inspiration driven by the experiment:** ● **Surface patterning:** Like the beetle's back, some textures in the experiment captured more droplets — these should be replicated in the final design. ● **Water movement:** Observing how mist moves across foil or wax paper can guide the shaping of grooves. ● **Material selection:** Like paper in a spinner, low-cost but functional materials are key to broad accessibility.

BIOMIMICRY DESIGN	Description
Step 6 – Evaluate	**INFO** In the context of biomimicry, the “Evaluate” step involves the following tasks: ● **Assess performance:** Evaluate the performance of your biomimetic design against the criteria and constraints defined earlier. This involves testing the design to see how well it meets the desired impact and functional requirements. ● **Compare with biological models:** Compare the effectiveness of your design with the biological models that inspired it, and determine whether the design successfully emulates natural strategies and achieves similar results. ● **Gather feedback:** Collect feedback from users, stakeholders, and experts to understand how well the design performs in real-world conditions. This feedback is crucial for identifying areas of improvement. ● **Analyse data:** Analyse the data collected during testing and feedback to identify strengths and weaknesses in the design. Look for patterns and insights that can inform further refinements. ● **Iterate and improve:** Based on the evaluation, make necessary adjustments and improvements to the design. This iterative process ensures that the final product is optimised for performance and sustainability. Evaluate your design against your criteria, constraints, and natural inspirations.

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	TASKS **Task 1** Evaluate the design concept's alignment with the design challenge's criteria and constraints, as well as its compatibility with Earth's systems. Assess the feasibility of both the technical and business models to ensure they are viable. **Task 2** Revise and revisit previous steps to generate a viable solution.
	STUDENT ASSIGNMENTS [Collaborative space] [Take your notes] **Task 1** The design concepts for the Namib Desert beetle-inspired water harvesting system align well with the original challenge: providing a passive, sustainable, and scalable method of water collection in arid environments. This solution supports Earth's systems by minimising energy use, encouraging local material sourcing, and promoting water access in vulnerable regions. The technical model is simple yet effective, while the business model could benefit from NGO, government, or community-based distribution channels. To succeed, attention must be given to material durability, user training, and affordability. However, the bio-inspired design positions this system firmly within the growing global demand for sustainable water access solutions. **Task 2** Through iterative improvement, the water harvesting concept can be more closely aligned with the design criteria, especially by refining surface patterns, testing new materials, and exploring modular scalability. Improvements may include enhanced water transport channels, UV-resistant coatings, and integration with simple rain catchment systems. By refining these aspects, the beetle-inspired water-harvesting system can provide a sustainable and accessible solution for water-scarce environments, improving lives and conserving resources globally.

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TM 04 Reflecting road studs inspired by the Cat eyes glow in the dark

<table>
<tr><th>BIOMIMICRY DESIGN</th><th>Description</th></tr>
<tr><td rowspan="2">Step 1 – Define the challenge</td><td>INFO

Clearly express the desired impact of your design on the world, along with the specific criteria and limitations that will measure its success.

In the context of biomimicry, the "Define" step involves two main tasks:
Describe the challenge: This means you need to understand what your design needs to do, for whom, and in what context.
Criteria and constraints: These are the standards and limitations that will help you evaluate your success. Criteria might include factors like cost-effectiveness, durability, and environmental friendliness. Constraints could be things like budget limits, material availability, or regulatory requirements.</td></tr>
<tr><td>TASKS

Task 1

Define the challenge as a question.

Task 2

Define the exploratory questions.

Task 3

Define the primary goal.

Task 4

Define the design needs.

Task 5

Define the target audience.

Task 6

Define the context for the implementation.</td></tr>
</table>

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Task 7

Identify the opportunities that might impact achieving a successful outcome.

Task 8

Identify the connections to other solutions or challenges.

Task 9

Identify the favourable circumstances, initiatives or legislation.

Task 10

Identify the constraints or risks.

RESOURCES PROVIDED BY TEACHERS TO STUDENTS

[Resource 1 - H5P Course presentation/Interactive Book]

[Define the challenge]

Challenge

The challenge given is to design reflecting road studs that combine both aesthetic appeal and high efficiency, drawing inspiration from the unique properties of cat eyes that glow in the dark.

Key concepts to follow

- **Reflective efficiency:** Utilise the principles observed in cat eyes to enhance the visibility and reflective efficiency of the road studs.
- **Elegance:** Ensure the design is visually appealing and integrates seamlessly into modern road environments.
- **Functionality:** The road studs should be easy to install and provide adequate visibility in dark conditions.

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STUDENT ASSIGNMENTS

[Collaborative space]

[Take your notes]

Task 1: Challenge as a question

How can we create effective, durable, and eco-friendly reflecting road studs?

Task 2: Exploratory questions

How can reflective road studs be integrated with other innovative road technologies to create a comprehensive road safety system?

What specific features of cat eyes are mimicked in the reflective road studs to enhance visibility?

Task 3: Main goal

The primary goal is to enhance road safety by improving visibility at night and in adverse weather conditions.

Task 4: Design needs

The design should consider using resistant materials to withstand heavy traffic and harsh weather conditions, ensuring maximum visibility to provide adequate warning to drivers. It should also facilitate continuous operation, feature a smooth, enveloping profile without sharp edges to prevent damage to vehicles, and, if possible, incorporate automatic operation.

Task 5: Target audience

- **Road safety authorities:** They are responsible for implementing and maintaining the reflective road studs, identifying high-risk areas, and promoting public awareness about road safety measures.
- **Drivers:** They benefit from the increased visibility provided by the reflective road studs, which help them navigate roads more safely, especially in poor weather conditions or at night.

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- **Pedestrians:** They also benefit from the enhanced visibility, making it easier for them to be seen by drivers, thereby reducing the risk of accidents.

Task 6: Context

Context

- Rural roads, highways, and expressways; sharp curves and intersections; mountainous or coastal roads; and urban areas with heavy pedestrian traffic.

Task 7: Opportunities

- Rural and country roads.
- Highways and expressways.
- Urban areas and smart cities.
- Pedestrian crosswalks and intersections.
- Sustainability initiatives.
- Infrastructure investment programs.

Task 8: Connections to other solutions or challenges

- Integration with smart street lighting.
- Integration into smart city initiatives.

Task 9: Favourable circumstances, initiatives or legislation

- Vision Zero initiatives.
- Infrastructure investment programs.
- New road safety regulations.
- Vehicle safety regulations.
- Smart city initiatives.
- Public safety campaigns.

Task 10: Constraints or risks

- Initial installation and maintenance costs.
- Impact of extreme weather conditions.

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	● Driver over-reliance. ● Visual landscape changes in urban settings. ● Lack of driver and pedestrian education. ● Overcrowding and visual clutter. ● Vandalism and damage.

BIOMIMICRY DESIGN	Description
Step 2 – Biologize	**INFO** Analyse the essential functions and context your design solution must address. Reframe them in biological terms, so that you can "ask nature" for advice. In the context of biomimicry, the "Biologize" step involves the following tasks: ● **Identify biological models:** Research and identify organisms, ecosystems, or natural processes that exhibit the desired functions or characteristics you want to emulate in your design. ● **Understand biological principles:** Dive deep into understanding the underlying principles and mechanisms that make these biological models effective. This involves studying the anatomy, physiology, and behaviours of the organisms or systems you're interested in. ● **Translate biological strategies and consider opposite functions:** Translate the biological strategies into design principles that can be applied to your project. This involves identifying different natural processes that can be mimicked or adapted in a practical context.
	TASKS **Task 1** Read about cat eyes. **Task 2** What did you observe in the video presented? Please write your observations using the concepts you discovered in the provided resources.

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Task 3

State your challenge from the natural point of view. Ask yourself how nature can solve this.

Task 4

Describe the natural contexts.

Task 5

Consider the opposite function and try to rephrase the question that describes the challenge from a natural perspective.

RESOURCES PROVIDED BY TEACHERS TO STUDENTS

[Resource 1 – Interactive Book]

[Let's discover Sycamore seeds]

Context

In nature, the reflective properties of cat eyes allow them to glow in the dark, providing a unique source of inspiration for road safety designs.

Cat eyes have a fascinating ability to reflect light, which helps them see in low-light conditions. This natural mechanism can be leveraged to enhance the visibility of road studs, making roads safer at night. This is a brilliant example of nature solving the challenge of visibility with minimal energy.

How do cat eyes reflect light?

- **Reflective layer:** The back of a cat's eye contains a layer called the tapetum lucidum, which reflects light that passes through the retina back into the eye, increasing the light available to the photoreceptors.
- **Glow in the dark:** This reflection creates the characteristic glow of cat eyes in the dark, which can be mimicked in road studs to improve night-time visibility.
- **Enhanced vision:** The reflective properties of cat eyes allow them to see better in low-light conditions, a principle that can

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be applied to road studs to ensure they are visible to drivers at night.

Fun facts about cat eyes and their reflective properties

- **Natural reflectors:** Cat eyes are often referred to as "nature's reflectors" due to their ability to reflect light, much like road studs that reflect car headlights.
- **Efficient visibility:** The design of cat eyes enables them to see in almost complete darkness, allowing them to navigate and hunt effectively at night.
- **Inspiration for technology:** The reflective mechanism of cat eyes has inspired engineers in designing more efficient and visible road safety devices.
- **Seasonal adaptation:** Cats' eyes adapt to different light conditions, much like how road studs need to be effective in various weather and lighting conditions.

[Resource 2 – H5P Flash cards]

[Did you know]

Did you know that reflective road studs are designed to enhance visibility in low-light conditions?

How?

Their structure, inspired by the glow of cat eyes in the dark, allows them to reflect light from vehicle headlights, creating a bright and visible marker on the road. This reflective property helps to guide drivers safely, especially at night or in poor weather conditions. The studs' design ensures that they catch and reflect light uniformly, providing a stable and controlled visual cue that helps to distribute the light evenly over a wide area, reducing the risk of accidents and improving road safety.

[Resource 3 – H5P Image Juxtaposition]

[Cat eyes during the day and cat eyes at night

Instructions

Observe the differences in the reflection of the cat's eyes in the two images below: one taken during the day and the other at night.

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[Images to be used]

[Resource 4 – Interactive video/ Video]

[Let’s watch]

Take a look at this video, which captures a cat at night.

What did you see in the video?

https://www.youtube.com/watch?v=0m5vGHQLQzI

[Resource 5 - Cat eyes vs visibility enhancement in low-light conditions]

[Document]

Nature has some fascinating ways of enhancing visibility in low-light conditions, and while cat eyes are primarily designed for efficient night vision, we can draw some interesting parallels.

Cat eyes are designed to maximise their ability to see in the dark by reflecting light. However, their structure can also provide insights into how visibility can be enhanced in low-light conditions, such as:

1. Reflective surface and orientation

- The reflective layer in cat eyes creates a bright glow by bouncing light back towards its source. By adjusting the angle and shape of the reflective surface, a cat's eyes can manage light reflection, ensuring they are visible even in the dark.
- This principle can be applied to design road studs that enhance visibility by altering angles and shapes to reflect light more effectively, making them visible to drivers at night.

2. Surface texture

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- The surface of cat eyes can influence how light is reflected. A smooth or polished surface can create a clear reflection, which can enhance visibility in low-light conditions.
- Similarly, surfaces with specific textures can be designed to reflect light in various applications, such as in road studs or other safety devices.

STUDENT ASSIGNMENT

[Collaborative space]

[Take your notes]

Task 1

Students access the interactive activity and reads the content.

Task 2

In the video, I can see a cat and her eyes. The eyes of the cat are very bright. This design helps the cat to see at night.

Task 3

How do animals' eyes reflect light efficiently in various lighting conditions?

Task 4

Context: Animal eyes reflect light efficiently through specialised adaptations that enhance vision in various lighting conditions. Key features include the tapetum lucidum, a reflective layer behind the retina that bounces light back into the eye, improving night vision. Many animals have a high density of rod cells in their retinas, which are sensitive to low light, and large, rounded pupils that let in more light. The curvature of the cornea and lens is optimised to focus light effectively onto the retina. Some animals also have reflective pigments in their eyes, which further enhance vision in dark or murky environments. These adaptations improve vision across diverse lighting conditions, supporting survival in the wild.

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	Task 5 How do eyes contribute to the survival of animals through their reflective properties?

BIOMIMICRY DESIGN	Description
Step 3 – Discover	**INFO** Look for natural models (organisms and ecosystems) that require the same functions and context as your design solution. Identify the strategies used that support their survival and success. In the context of biomimicry, the “Discover” step involves the following tasks: ● **Explore nature:** Spend time discovering natural models to study various ecosystems and organisms. ● **Identify functions:** Look for specific functions or strategies in nature that can solve the design challenge you're facing. ● **Gather information:** Collect detailed information about biological models that exhibit the desired functions, including scientific research, case studies, and firsthand observations.
	TASKS **Task 1** Search for other natural models that match the same functions of the Cat eye and apply some context to your design solution. **Task 2** Identify experts and communities in the field of biomimicry.
	RESOURCES PROVIDED BY TEACHERS TO STUDENTS [Resource 1 – Course presentation] [Functions of cat eyes]

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Cat eyes are a marvel of natural engineering, designed to maximise visual efficiency. Their unique structure allows them to see in low-light conditions, making them excellent nocturnal hunters. The elliptical shape of their pupils helps control the amount of light entering the eye, enhancing their ability to detect movement in the dark.

Detailed Functions of cat eyes

1. Efficient light reflection

- **Elliptical pupils:** The unique shape of a cat's pupils allows them to adjust quickly to changes in light. This design minimizes the energy required to see in various lighting conditions, enabling cats to hunt effectively at night.
- **Tapetum Lucidum:** This reflective layer, located behind the retina, increases the amount of light available to the photoreceptors, thereby enhancing night vision and enabling cats to see in near darkness.

2. Silent operation

- **Quiet movement:** Cats can move silently, thanks to their soft paws and agile bodies. This stealthy approach helps them observe their surroundings without alerting potential prey.
- **Stealthy hunting:** The silent operation enables cats to stalk their prey without being detected, thereby increasing their chances of a successful hunt.

3. Additional insights

- **Environmental adaptation:** The ability to see in low light enables cats to adapt to diverse environments, allowing them to hunt in various conditions, from urban areas to dense forests.
- **Biodiversity contribution:** By being effective hunters, cats contribute to the biodiversity of their ecosystem. They help control the population of small animals and maintain the balance within their habitat.

STUDENTS ASSIGNMENTS

[Collaborative space]

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[Take your notes]

Task 1

Natural models

- **Bioluminescence of fireflies:** Fireflies use a chemical reaction involving luciferin and luciferase to emit light, which could inspire road studs that glow at night using stored energy.
- **Tapetum Lucidum in Nocturnal Animals: Nocturnal animals, such as raccoons,** have a reflective layer behind their retinas called the tapetum lucidum, which enhances night vision by reflecting light back through the retina. Road studs could mimic this reflective layer to maximise light reflection when illuminated by car headlights
- **Fluorescent exoskeletons of scorpions:** Scorpions fluoresce under ultraviolet (UV) light due to compounds in their exoskeleton. This natural glow could inspire road studs that are visible under both headlights and specific street lighting.
- **Reflective scales of fish:** Fish like sardines and herrings have reflective scales that help them blend with light in the water. Road studs could use similar reflective materials to maximise light efficiency and visibility in poor lighting conditions.
- **Bioluminescent fungi and glowworms:** Bioluminescent fungi and glowworms emit light to attract insects or for reproduction. These organisms could inspire self-sustaining road studs that provide steady illumination throughout the night without external energy sources.

Task 2

- AskNature.
- American Institute of Biological Sciences (AIBS).
- Society for Conservation Biology.
- Online forums and social media groups.

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BIOMIMICRY DESIGN	Description
Step 4 – Abstract	**INFO** Carefully study the essential features or mechanisms that make the biological strategies successful. Restate them in non-biological terms, as “design strategies.” In the context of biomimicry, the “Abstract” step involves the following tasks: ● **Extract principles:** Identify and extract the underlying principles and strategies from the biological model you have studied. This means understanding the core functions and mechanisms that make these natural solutions effective. ● **Generalise concepts: Generalise** these biological principles so they can be applied to a wide range of design challenges. This involves translating specific biological strategies into broader design concepts that are not tied to a particular organism or ecosystem. ● **Create analogies:** Develop analogies that link the biological principles to human design challenges. These analogies help bridge the gap between nature and technology, making it easier to apply natural strategies to human-made systems.
	TASKS **Task 1** From the core function presented, summarise the key elements of the biological strategy of the cat's eyes by defining the function and identifying relevant keywords. **Task 2** Create a diagram or drawing, and/or find images of Cat eyes that can inform the design. **Task 3** Translate lessons from nature into design strategies. Rewrite the strategy without using biological terms and connect it to the functions and the context from a human perspective.

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Task 4

Create a diagram or drawing, and/or find images of the design of your solution.

RESOURCES PROVIDED BY TEACHERS TO STUDENTS

[Resource 1 – Core functions of Cat eyes]

[H5P Flashcards]

Core functions

- **Light reflection:** The tapetum lucidum, a reflective layer behind the retina, acts like a mirror, bouncing light back through the retina to enhance vision in low-light conditions.
- **Light amplification:** This reflection increases the amount of light available to photoreceptors, giving cats a second chance to absorb light and improving their night vision.
- **Eyeshine:** The reflected light exiting the eye causes the characteristic glow seen in the dark.

STUDENT ASSIGNMENTS

[Collaborative space]

[Take your notes]

Task 1

1. **Light reflection**

- **Keywords:** Tapetum lucidum, Reflection, Retina, Low-light vision
- **Description:** The tapetum lucidum, a reflective layer located behind the retina, functions like a mirror. It reflects light that passes through the retina back into the eye, effectively doubling the amount of light available to the photoreceptors. This adaptation significantly enhances vision in low-light conditions, allowing cats to see better in the dark. The

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tapetum lucidum is a crucial feature for nocturnal animals, aiding in their ability to hunt and navigate during the night.

2. **Light amplification**

- **Keywords:** Photoreceptors, Light absorption, Night vision, Reflection
- **Description:** The reflection of light by the tapetum lucidum increases the amount of light available to the photoreceptors in the retina. This process gives the photoreceptors a second opportunity to absorb light, thereby amplifying the overall light intake. This enhanced light absorption is vital for improving night vision, enabling cats to detect movement and objects in very low-light environments. This adaptation is essential for their survival, as it allows them to be effective hunters even in the dark.

3. **Eyeshine**

- **Keywords:** Reflected light, Glow, Dark, Tapetum lucidum
- **Description:** The tapetum lucidum is responsible for the phenomenon known as eyeshine. When light enters the eye, it is reflected off the tapetum lucidum and exits the eye, creating a visible glow in the dark. This glow is often seen when a light source, such as car headlights or a flashlight, illuminates a cat's eyes. The eyeshine not only helps improve the cat's night vision but also serves as a distinctive feature that can be observed in many nocturnal animals. This adaptation is crucial for survival, allowing cats to hunt and navigate effectively in low-light environments.

Task 2: Image of a cat

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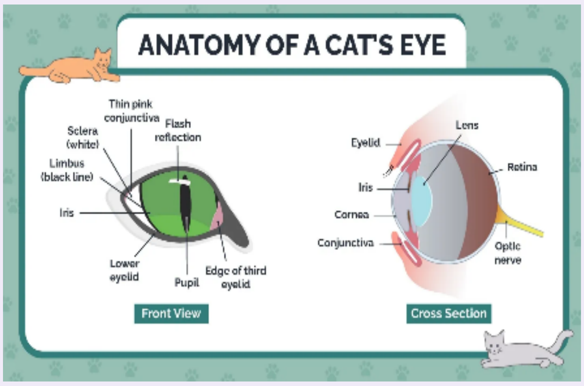

Photo of cat's eye structure (Copyright @ https://articles.hepper.com/wp-content/uploads/2023/04/Hepper_Anatomy-of-Cats-Eye_Infographic_v4_Apr-6-2023-01.webp, Hepper.com)

Task 3

- **Reflective and amplifying materials:** Use special materials that reflect and amplify light from car headlights, making the studs glow and stand out clearly on the road. Ensure these materials are durable enough to withstand heavy traffic and harsh weather conditions, providing consistent visibility over time.
- **Self-illuminating properties:** Explore materials that can absorb light during the day and glow at night, similar to certain natural materials. This ensures the studs are visible even without direct light from car headlights, adding an extra layer of safety on dark or unlit roads.
- **Sustainability and longevity:** Opt for eco-friendly and long-lasting materials to minimise the need for frequent replacements. Design the studs to be energy-efficient, minimising environmental impact while improving road safety
- **Testing and collaboration:** Conduct thorough testing and real-world trials to ensure the road studs are effective in all types of weather and lighting conditions. Collaborate with experts in road safety, material science, and design to ensure the studs meet safety standards and perform well in diverse driving environments.

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	Task 4: Image of a road stud   Photo of Road stud (Copyright: https://www.wistronchina.com/what-is-the-difference-between-cat-eyes-and-road-studs/)

BIOMIMICRY DESIGN	Description
Step 5 – Emulate	**INFO** In the context of biomimicry, the “Emulate” step involves the following tasks: ● **Apply biological principles:** Implement the biological strategies and principles you have abstracted into your design. This involves applying the insights gained from nature directly to create innovative solutions. ● **Prototype development:** Develop prototypes that incorporate the biomimetic principles. This involves creating models or samples that demonstrate how the natural strategies can be used in practical applications. ● **Integration:** Integrate the biomimetic design into the final product or system, ensuring that natural strategies are seamlessly incorporated and that the design meets all necessary criteria and constraints.
	TASKS **Task 1** Do the practical example and note your findings. **Task 2** Identify as many ideas as possible for designing your solution.

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Task 3

Organise your ideas into categories that include features, context, and constraints.

Task 4

Select the design concept (ideas) that best fit your solution.

RESOURCES PROVIDED BY TEACHERS TO STUDENTS

[Resource 1 – Look into]

[H5P Course presentation]

When designing reflecting road studs inspired by the glow of cat eyes in the dark, consider the following essential features to guide your ideas:

- **Maximise visibility with minimal energy:** Utilise the natural efficiency of cat eyes, which reflect light and glow in the dark. Your design should aim to replicate this efficiency, ensuring that the road studs are obvious while consuming as little energy as possible.
- **Durability and weather resistance:** Cat eyes are resilient and can function effectively in various conditions. Incorporate design elements that ensure the road studs are durable and can withstand different weather conditions, providing long-lasting performance.
- **Material optimisation:** Just as cat eyes are lightweight yet durable, your road stud design should use materials that provide strength without unnecessary weight. This optimisation will enhance performance and reduce energy consumption.
- **Sustainable materials:** Nature is inherently sustainable. Choose eco-friendly and sustainable materials for your road stud design, ensuring that the production and disposal processes have minimal environmental impact.

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[Resource 2 - Flying Helicopter Seeds Experiment]

[Document]

Cat eyes science experiment

Materials

Lantern, clean or empty tin can, black plastic bag, felt, scissors, elastic band, sticky tack or sticky tape.

Instructions

Cut out a circle from tin foil, place it at the bottom of a tin can, and cover the top with a plastic sheet secured by an elastic band. Shine a lantern into the can in a dark room. Watch as the light reflects, mimicking the glowing eyes of a cat in the dark.

Investigation ideas

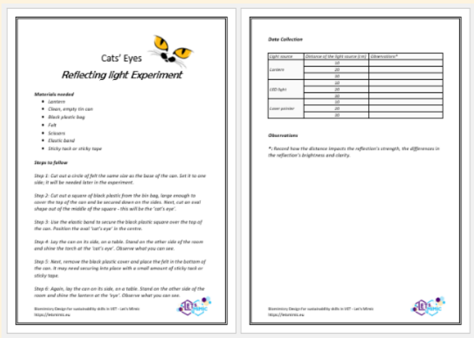
1. Distance of the light source

- Change the distance between the light source and the can (10 cm, 20 cm, 30 cm).
- Shine the torch from different distances into the can.
- Record how the distance impacts the reflection's strength.

2. Light source variation

- Use different light sources (torch, LED light, laser pointer).
- Shine each light source into the can with the reflective material in place. Observe and record the differences in the reflection's brightness and clarity.

Template



Cats' Eyes

Reflecting light Experiment

Materials needed

- Lantern
- Clean, empty tin can
- Black plastic bag
- Felt
- Scissors
- Elastic band
- Sticky tack or sticky tape

Steps to follow

Step 1: Cut out a circle of felt the same size as the base of the can. Set it to one side; it will be needed later in the experiment.

Step 2: Cut out a square of black plastic from the bin bag, large enough to cover the top of the can and be secured down on the sides. Next, cut an oval shape out of the middle of the square - this will be the 'cat's eye'.

Step 3: Use the elastic band to secure the black plastic square over the top of the can. Position the oval 'cat's eye' in the centre.

Step 4: Lay the can on its side, on a table. Stand on the other side of the room and shine the torch at the 'cat's eye'. Observe what you can see.

Step 5: Next, remove the black plastic cover and place the felt in the bottom of the can. It may need securing into place with a small amount of sticky tack or sticky tape.

Step 6: Again, lay the can on its side, on a table. Stand on the other side of the room and shine the lantern at the 'eye'. Observe what you can see.

Data Collection

Light source	Distance of the light source (cm)	Observations*
Lantern	10	
	20	
	30	
LED light	10	
	20	
	30	
Laser pointer	10	
	20	
	30	

Observations

*: Record how the distance impacts the reflection's strength, the differences in the reflection's brightness and clarity.

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STUDENTS ASSIGNMENT

[Collaborative space]

[Take your notes]

Task 1

Students record their findings on the provided record sheet.

Task 2

Ideas

- Enhanced visibility.
- Advanced materials and technologies.
- Sustainability.

Task 3

1. Enhance visibility with reflective materials

- **Reflective properties:** Use materials inspired by cat eyes to reflect light to its source.
- **Applications:** Implement these materials in road studs, safety gear like vests and helmets.
- **Innovations:** Develop intelligent road studs with LEDs and sensors for dynamic lighting and real-time information.

2. Design road studs for high visibility in various conditions

- **Advanced materials:** Use retroreflective glass beads and prismatic lenses.
- **Durability:** Utilise polycarbonate or stainless steel.
- **Illumination:** Integrate solar-powered LEDs and smart sensors.

3. Ensure durability and eco-friendliness

- **Materials:** Use recycled polycarbonate and stainless steel.
- **Energy efficiency:** Integrate high-efficiency solar panels and LEDs.

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	● **Protection:** Seal against water and dust. **Context** ● Design road studs that are highly visible under various conditions by utilising smart sensors to adjust brightness according to weather conditions. **Constraints:** ● Cost, production feasibility, and durability. **Task 4:** Reflective road studs that mimic the mysterious glow of cat eyes in the dark, enhancing night-time visibility and safety, are made from durable and eco-friendly materials. **1. Inspiration driven by the experiment** ● **Stud design:** Just like cat eyes, the road studs should be designed to capture and reflect light efficiently, ensuring maximum visibility at night. ● **Light efficiency:** The natural and enigmatic glow of cat eyes can inspire the use of high-efficiency reflective materials in the studs. ● **Eco-friendly materials:** The adaptability and natural resilience of cat eyes can inspire the use of durable and recyclable materials for the studs.

BIOMIMICRY DESIGN	Description
Step 6 – Evaluate	**INFO** In the context of biomimicry, the “Evaluate” step involves the following tasks: ● **Assess performance:** Evaluate the performance of your biomimetic design against the criteria and constraints defined earlier. This involves testing the design to see how well it meets the desired impact and functional requirements.

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- **Compare with biological models:** Compare the effectiveness of your design with the biological models that inspired it, and determine whether the design successfully emulates natural strategies and achieves similar results.
- **Gather feedback:** Collect feedback from users, stakeholders, and experts to understand how well the design performs in real-world conditions. This feedback is crucial for identifying areas of improvement.
- **Analyse data:** Analyse the data collected during testing and feedback to identify strengths and weaknesses in the design. Look for patterns and insights that can inform further refinements.
- Iterate and improve: Based on the evaluation, make necessary adjustments and improvements to the design. This iterative process ensures that the final product is optimised for performance and sustainability.

TASKS

Task 1

Evaluate the design concept concerning its alignment with the design challenge's criteria and constraints, as well as its compatibility with Earth's systems. Assess the feasibility of both the technical and business models.

Task 2

Revise and revisit previous steps as necessary to generate a viable solution.

STUDENT ASSIGNMENTS

[Collaborative space]

[Take your notes]

Task 1

The cat-eye-inspired road stud prototype aligns well with the challenge's criteria, offering excellent reflectivity and durability. High visibility is ensured by retroreflective glass beads and prismatic lenses, even in low light. The recycled polycarbonate housing, reinforced with stainless steel, offers robust protection. The design is water and

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	dust-sealed, featuring solar panels and energy-efficient LEDs with smart sensors for long-lasting performance. Overall, it meets reflectivity and durability standards, making it a viable road safety solution. Such a design can be compatible with Earth's systems by promoting cost-effectiveness and eco-friendliness. Using recycled polycarbonate for the housing cuts costs and reduces environmental impact. Stainless steel reinforcement ensures durability, minimizing replacements. High-efficiency solar panels and LEDs offer long-term savings, while smart sensors adjust LED brightness to conserve energy. A modular design allows easy part replacement, extending lifespan and reducing waste. This approach balances economic viability and environmental sustainability, enhancing road safety. The technical and business models are feasible, although considerations for cost and market education will be necessary for successful implementation. The innovative features and eco-friendly design position the road stud favourably in a growing market for sustainable road safety products. **Task 2** By revising and refining each design concept to create effective cat-eye-inspired road studs, it's crucial to optimise all aspects. Utilising recycled polycarbonate for the housing helps cut costs and reduce environmental impact, while reinforcing critical components with stainless steel ensures durability. Integrating high-efficiency solar panels and energy-efficient LEDs with smart sensors for long-term energy savings and minimal maintenance maximises reflectivity with retroreflective glass beads and prismatic lenses for visibility in various conditions. A modular design allows easy part replacement, extending lifespan and reducing waste. This balanced approach ensures cost-effectiveness, durability, and environmental sustainability, enhancing road safety. Regularly revisiting these steps ensures the final product meets all standards.

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TM 05 Multi-functional biodegradable shoes inspired by the biodegradability of algal organic matter

<table>
<tr><th>BIOMIMICRY DESIGN</th><th>Description</th></tr>
<tr><td rowspan="2">Step 1 – Define the challenge</td><td>INFO
Clearly express the desired impact of your design on the world, along with the specific criteria and limitations that will measure its success.
In the context of biomimicry, the "Define" step involves two main tasks:
Describe the challenge: This means you need to understand what your design needs to do, for whom, and in what context.
Criteria and constraints: These are the standards and limitations that will help you evaluate whether you will be successful. Criteria might include factors like cost-effectiveness, durability, and environmental friendliness. Constraints could be things like budget limits, material availability, or regulatory requirements.</td></tr>
<tr><td>TASKS
Task 1
Define the challenge as a question.

Task 2
Define the exploratory questions.

Task 3
Define the main goal.

Task 4
Define the design needs.

Task 5
Define the target audience.</td></tr>
</table>

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	Task 6 Define the context or settings for the implementation. **Task 7** Identify the opportunities that might impact achieving a successful outcome. **Task 8** Identify the connections to other solutions or challenges. **Task 9** Identify the favourable circumstances, initiatives or legislation. **Task 10** Identify the constraints or risks.
	RESOURCES PROVIDED BY TEACHERS TO STUDENTS [Resource 1 - H5P Course presentation/Interactive Book] [Define the challenge] **Challenge** The challenge given is to design shoes that combine both aesthetic appeal and high efficiency, drawing inspiration from the biodegradable properties of Algae. **Key concepts to follow** ● **Material selection:** Use algal-derived materials known for their biodegradability. Algal biomass can be processed into bioplastics or biofoams. ● **Biodegradation process:** Design the shoes to break down through microbial action in composting conditions. This involves selecting materials that microorganisms can easily decompose.

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- **Sustainability and environmental impact:** The fan should be easy to install, operate quietly, and provide effective cooling.

STUDENT ASSIGNMENTS

[Collaborative space]

[Take your notes]

Task 1: Challenge as a question

How can we create multi-functional, biodegradable fashion products?

Task 2: Exploratory questions

What strategies can be implemented to ensure that biodegradable footwear is easily recyclable or compostable?

What are the environmental benefits of using algae-based materials in the production of footwear?

Task 3: Main goal

To develop versatile, eco-friendly shoes by utilising renewable, biodegradable materials and innovative design techniques that ensure durability, comfort, and adaptability for various uses, while minimising environmental impact throughout the product lifecycle.

Task 4: Design needs

The design needs to look into methods for replacing traditional synthetic materials with biodegradable options like algae-based foam, natural rubber, and organic fibers, to be easily recyclable or compostable, to use non-toxic, eco-friendly adhesives and dyes.

Task 5: Target audience

Eco-conscious consumers, fashion brands and sustainable fashion startups, outdoor and athletic gear manufacturers, educational institutions and research organizations.

Task 6: Context

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	Footwear. **Task 7: Opportunities** ● Material innovation. ● Design and functionality. ● Production and manufacturing. ● Market expansion. ● Lifecycle management. **Task 8: Connections to other solutions or challenges** Connections to other challenges: ● Circular economy. ● Material innovation. ● Sustainable manufacturing. ● Consumer trends. ● Waste reduction. ● Climate change mitigation. Connections to other solutions: Outdoor apparel, activewear, casual wear, accessories, children's clothing, packaging, manufacturing **Task 9:** Favo**urable circumstances, initiatives or legislation** ● Growing consumer demand. ● Technological advances. ● Research and development grants. ● Partnerships with environmental organisations. ● Stricter regulations on plastic use and waste management. ● Policies fostering a circular economy. **Task 10: Constraints or risks** ● Durability of algae-based materials. ● Production costs.

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	• Supply chain challenges. • Consumer perception. • Ecological consequences of large-scale cultivation. • Regulatory compliance. • Competition in the sustainable market. • Consumer education.

BIOMIMICRY DESIGN	Description
Step 2 – Biologize	**INFO** Analyse the essential functions and context your design solution must address. Reframe them in biological terms, so that you can "ask nature" for advice. In the context of biomimicry, the "Biologise" step involves the following tasks: • **Identify biological models:** Research and identify organisms, ecosystems, or natural processes that exhibit the desired functions or characteristics you want to emulate in your design. • **Understand biological principles:** Dive deep into understanding the underlying principles and mechanisms that make these biological models effective. This involves studying the anatomy, physiology, and behaviours of the organisms or systems you're interested in. • **Translate biological strategies and consider opposite functions:** Translate the biological strategies into design principles that can be applied to your project. This involves identifying different natural processes that can be mimicked or adapted in a practical context.
	TASKS **Task 1** Read about the Algae and solve the quiz. **Task 2**

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What did you observe in the video presented? Write your observations using the concepts you discovered in the provided resources.

Task 3

State your challenge from the natural point of view. Ask yourself how nature can address this issue.

Task 4

Describe the natural contexts.

Task 5

Consider the opposite function and try to rephrase the question that describes the challenge from a natural perspective.

RESOURCES PROVIDED BY TEACHERS TO STUDENTS

[Resource 1 – Interactive Book]

[Let's discover Algae]

Context

In nature, the structure of algal organic matter plays a crucial role in its biodegradability.

Algal organic matter, composed of various biochemical compounds, has a unique composition that allows it to break down efficiently in natural environments. This biodegradability is facilitated by microbial activity, which decomposes the organic matter into simpler substances. This process is a brilliant example of nature's ability to recycle nutrients and maintain ecological balance with minimal energy input.

How does algal organic matter biodegrade?

- **Composition:** Algal organic matter consists of various biochemical compounds, including carbohydrates, proteins, and lipids, which are essential for the growth and energy needs of microorganisms that facilitate biodegradation.
- **Microbial activity:** Microorganisms, such as bacteria and fungi, play a crucial role in breaking down algal organic matter. They secrete enzymes that decompose complex organic molecules into simpler substances, which can then be absorbed and utilized by other organisms in the ecosystem.

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- **Environmental factors:** The rate of biodegradation is influenced by environmental conditions such as temperature, pH, and oxygen availability. Optimal conditions enhance microbial activity, leading to more efficient breakdown of algal organic matter.
- **Nutrient cycling:** The biodegradation process recycles nutrients back into the ecosystem, supporting the growth of new algal populations and maintaining ecological balance. This natural recycling is vital for sustaining aquatic environments.

Fun facts about the biodegradability of algal organic matter

- **Natural recyclers:** Algal organic matter is often referred to as "nature's recyclers" due to its ability to break down and efficiently return nutrients to the ecosystem.
- **Efficient decomposition:** The structure of algal organic matter enables it to decompose rapidly, providing essential nutrients to microorganisms and promoting the growth of new algae.
- **Microbial activity:** The decomposition process involves various microorganisms, such as bacteria and fungi, which play a crucial role in breaking down complex organic compounds into simpler substances.
- **Inspiration for sustainability:** The natural biodegradation of algal organic matter has inspired research into sustainable waste management practices and the development of eco-friendly materials.
- Seasonal cycles: Algal blooms often occur in specific seasons, leading to a natural cycle of growth and decay that supports the overall health of aquatic ecosystems.

[Resource 2 – H5P Flash cards]

[Did you know]

Did you know that algal organic matter is designed to biodegrade efficiently in aquatic environments?

How?

Algal organic matter is composed of various biochemical compounds, such as carbohydrates, proteins, and lipids, which are easily broken down by microorganisms. These microorganisms, such as bacteria and fungi, play a crucial role in the biodegradation process. They secrete

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enzymes that break down complex organic molecules into simpler substances, facilitating efficient decomposition.

[Resource 3 – H5P Find multiple hotspots/Image choice]

[I spy with my little eye]

Instructions

Let's take a look at what you've discovered so far. Can you identify what an algae looks like in the interactive activity below?




[Image to be used]

[Resource 4 – Link to video]

[Let's watch]

Take a look at this video, which captures the slow motion of algae

https://www.youtube.com/shorts/iFj6dT5erOw

[Resource 5 - Algae vs environmental factors]

[Document]

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Nature offers fascinating insights into the biodegradability of organic matter, particularly in the context of algal blooms. By examining the factors that influence the breakdown of algal organic matter, we can draw parallels and develop strategies to enhance biodegradation processes:

1. **Environmental conditions**
    - Higher temperatures generally accelerate the biodegradation of algal organic matter by increasing microbial activity.
    - The pH of the environment can significantly affect the rate of biodegradation. Particular algal species degrade more efficiently under specific pH conditions.
    - The presence and diversity of microbial communities play a crucial role in breaking down algal organic matter. Different microbes specialize in degrading various components of the organic matter.
2. **Algal species and composition**
    - The structural complexity of algal cells can influence their biodegradability. Species with simpler cell structures tend to degrade more quickly.
    - The biochemical makeup of the algae, including the presence of resistant compounds like cellulose or lignin, affects the rate of biodegradation.

STUDENT ASSIGNMENT

[Collaborative space]

[Take your notes]

Task 1

Students access the interactive activity and click on the correct image. The platform will inform students about their answers (correct or wrong and a personalised message will be provided.

Task 2

In the video, I can see a giant algae.

Task 3

How does marine life produce organic biodegradable compounds?

ΙΔΡΥΜΑ ΚΡΑΤΙΚΩΝ ΥΠΟΤΡΟΦΙΩΝ IKY

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	Task 4 Algae produce biodegradable materials through photosynthesis, converting sunlight, carbon dioxide, and water into organic compounds like carbohydrates, proteins, and lipids. Some algae generate biopolymers, including alginate, agar, and carrageenan, which can replace synthetic polymers. These compounds are inherently biodegradable and environmentally friendly. Algae can be cultivated in various environments, including freshwater, seawater, and wastewater, making them a sustainable resource with rapid growth rates. Researchers are enhancing the properties of algal materials to improve strength, flexibility, and water resistance, making them suitable for products such as biodegradable shoes. This aligns with the growing demand for eco-friendly alternatives. **Task 5** How do marine ecosystems support nutrient cycling?

BIOMIMICRY DESIGN	**Description**
Step 3 – Discover	**INFO** Look for natural models (organisms and ecosystems) that require the same functions and context as your design solution. Identify the strategies used that support their survival and success. In the context of biomimicry, the "Discover" step involves the following tasks: ● Explore nature: Spend time discovering natural models to study various ecosystems and organisms. ● Identify functions: Look for specific functions or strategies in nature that can solve the design challenge you're facing. ● Gather information: Collect detailed information about biological models that exhibit the desired functions, including scientific research, case studies, and firsthand observations.
	TASKS **Task 1** Search for other natural models that match the same functions as the algae and consider the context applied in your design solution.

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Task 2

Identify experts and communities in the field of biomimicry.

RESOURCES PROVIDED BY TEACHERS TO STUDENTS

[Resource 1 – Course presentation]

[Functions of Algae]

The biodegradability of algal organic matter is a fascinating aspect of natural decomposition. Algal organic matter, composed of various biochemical compounds, is designed to break down efficiently in aquatic environments. When algae die, their organic matter is decomposed by microorganisms, which convert it into simpler substances. This process not only recycles nutrients back into the ecosystem but also helps maintain the balance of aquatic environments. The efficient breakdown of algal organic matter ensures that nutrients are available for other organisms, promoting a healthy and sustainable ecosystem.

Detailed functions of Algal organic matter biodegradability

1. Efficient decomposition

- **Biochemical composition:** The diverse biochemical compounds in algal organic matter, such as proteins, lipids, and carbohydrates, are designed to break down efficiently in aquatic environments. This composition minimises the time required for decomposition, enabling rapid nutrient recycling.
- **Microbial activity:** By utilising minimal energy to decompose algal matter, microorganisms can efficiently convert it into simpler substances, which is crucial for maintaining ecosystem balance.

2. Silent operation

- Quiet breakdown: The decomposition of algal organic matter occurs almost silently, due to the natural processes involved that reduce turbulence and noise as microorganisms break down the matter.
- **Stealthy nutrient release:** The quiet operation ensures that nutrients are released into the environment without

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disrupting the aquatic ecosystem, increasing the chances of maintaining ecological stability.

3. Additional insights

- **Environmental adaptation:** The ability to decompose efficiently helps algal organic matter adapt to various aquatic environments. This ensures that nutrients are available in areas with optimal conditions for growth, such as adequate sunlight, suitable water quality, and a suitable temperature.
- **Biodiversity contribution:** By breaking down over a wide area, algal organic matter contributes to the biodiversity of aquatic ecosystems, helping to maintain genetic diversity within microbial communities and supporting the overall health of the ecosystem.

STUDENTS ASSIGNMENTS

[Collaborative space]

[Take your notes]

Task 1

Natural models

- **Pineapple leather:** Made from the fibres of pineapple leaves, Piñatex is used in fashion for shoes, bags, and accessories. It is a by-product of the pineapple harvest, making it an eco-friendly alternative to synthetic materials.
- **Mushroom leather:** Created from mycelium, the root structure of mushrooms, Mylo is utilised in footwear and fashion, offering a sustainable alternative to animal leather and synthetic materials.
- **Cork:** Harvested from the bark of cork oak trees, cork is used in shoe soles and insoles, offering a renewable resource that provides comfort and sustainability.
- **Apple leather:** Made from apple waste, AppleSkin is used in fashion for shoes and accessories, combining apple waste with a small amount of PU to create a sustainable alternative to traditional leather.

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	● **Cactus leather:** Derived from the leaves of the nopal cactus, cactus leather is utilised in footwear and fashion, serving as an organic and sustainable alternative to synthetic leathers. **Task 2** Dr. Stephen Mayfield, professor of Biology at UC San Diego, is the director of the California Centre for Algae Biotechnology, and chief executive officer of BLUEVIEW.

BIOMIMICRY DESIGN	Description
Step 4 – Abstract	**INFO** Carefully study the essential features or mechanisms that make the biological strategies successful. Restate them in non-biological terms, as "design strategies." In the context of biomimicry, the "Abstract" step involves the following tasks: ● **Extract principles:** Identify and extract the underlying principles and strategies from the biological model you have studied. This means understanding the core functions and mechanisms that make these natural solutions effective. ● **Generalise concepts: Generalise** these biological principles so they can be applied to a wide range of design challenges. This involves translating specific biological strategies into broader design concepts that are not tied to a particular organism or ecosystem. ● **Create analogies:** Develop analogies that link the biological principles to human design challenges. These analogies help bridge the gap between nature and technology, making it easier to apply natural strategies to human-made systems.
	TASKS **Task 1** From the core function presented, summarise the key elements of the biological strategy of the algae by defining the function and identifying relevant keywords. **Task 2**

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	Create a diagram or drawing, and/or find images of Algae that can inform the design. **Task 3** Translate lessons from nature into design strategies. Rewrite the strategy without using biological terms and connect it to the functions and the context from a human perspective. **Task 4** Create a diagram or drawing, and/or find images of the design of your solution.
	RESOURCES PROVIDED BY TEACHERS TO STUDENTS [Resource 1 – Core functions of Algae] [H5P Flashcards] **Core functions** ● **Efficient decomposition:** Achieves rapid and efficient breakdown of organic matter with minimal energy input, ensuring quick nutrient recycling. ● **Microbial activity:** Enables microorganisms to decompose algal matter effectively, converting it into simpler substances that are beneficial for the ecosystem. ● **Biochemical composition:** Facilitates the efficient breakdown of algal organic matter due to its diverse biochemical compounds. ● **Environmental balance:** Ensures that the decomposition process maintains ecological stability and supports the health of aquatic environments.
	STUDENT ASSIGNMENTS [Collaborative space] [Take your notes]

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Task 1

1. **Renewable resource**
   - **Keywords:** Rapid growth, No fertile soil, Minimal fresh water.
   - **Description:** Algae proliferate without the need for fertile soil or large amounts of fresh water, making them a highly renewable resource.

2. **Water resistance**
   - **Keywords:** Smooth, water-repellent, dry, clean.
   - **Description:** The smooth, water-repellent nature of algae helps keep shoes dry and clean.

3. Biodegradable

- **Keywords:** Natural Decomposition, Environmental Impact
- **Description:** Algae decompose naturally, which helps reduce their environmental impact.

4. Durability and flexibility

- **Keywords:** Structural properties, dynamic environments, shoe materials.
- **Description:** Algae possess structural properties that allow them to survive in dynamic aquatic environments. These properties inspire the creation of durable and flexible shoe materials.

5. Breathability

- **Keywords:** Gas exchange, air circulation, odour prevention.
- **Description:** Inspired by algae's natural gas exchange. Processes, materials derived from algae ensure air circulation and prevent odour build-up.

6. Sustainability

- **Keywords:** Reduced synthetic materials, environmental impact.
- **Description:** Using algae reduces reliance on synthetic, non-degradable materials and minimises the environmental impact of production.

Task 2: Image of an algae

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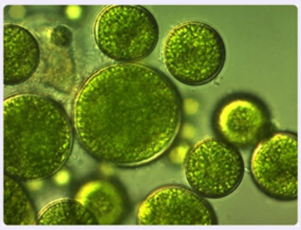

Photo of Algae molecules. (Copyright @ https://www.news-medical.net/life-sciences/What-are-Algae.aspx, Ye.Maltsev/Shutterstock.com)

Task 3

- **Renewable resource:** Using materials that grow quickly and don't require extensive resources.
- **Biodegradable:** Ensuring materials break down naturally, reducing waste.
- **Durability and flexibility:** Creating shoes that are strong and adaptable to various conditions.
- **Water resistance:** Making shoes that repel water and stay dry.
- **Breathability:** Designing shoes that allow air circulation to keep feet comfortable and odour-free.
- **Sustainability:** Reducing reliance on synthetic materials and minimising environmental impact.

Task 4: Image of a shoes

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	 Photo of Shoes (Copyright: https://newatlas.com/environment/blueview-fully-biodegradable-shoes/)

BIOMIMICRY DESIGN	Description
Step 5 – Emulate	**INFO** In the context of biomimicry, the “Emulate” step involves the following tasks: ● **Apply biological principles:** Implement the biological strategies and principles you have abstracted into your design. This involves taking the insights gained from nature and applying them directly to create innovative solutions. ● **Prototype development:** Develop prototypes that incorporate the biomimetic principles. This involves creating models or samples that demonstrate how the natural strategies can be used in practical applications. ● **Integration:** Integrate the biomimetic design into the final product or system, ensuring that natural strategies are seamlessly incorporated and that the design meets all necessary criteria and constraints.
	TASKS **Task 1** Do the practical example and note your findings. **Task 2** Identify as many ideas as possible for designing your solution.

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Task 3

Organise your ideas into categories that include features, context, and constraints.

Task 4

Select the design concept (ideas) that best fit your solution.

RESOURCES PROVIDED BY TEACHERS TO STUDENTS

[Resource 1 – Look into]

[H5P Course presentation]

When designing multi-functional biodegradable shoes inspired by the biodegradability of algal organic matter, consider the following essential features to guide your ideas:

Material composition: Utilise biodegradable materials derived from algal organic matter. These materials decompose naturally, reducing environmental impact and ensuring sustainability.

Design features: Incorporate design elements that make the shoes multi-functional. Inspired by the structural properties of algae, ensure the boots are durable and flexible to withstand various environments. Additionally, leverage algae's natural water resistance to keep the shoes dry and clean, and its breathability to ensure air circulation and prevent odour build-up.

Sustainability: Using algal organic matter reduces reliance on synthetic, non-degradable materials. This choice minimises the environmental impact of production and disposal, aligning with sustainable practices.

[Resource 2 - Shoes Case studies]

[Document]

Shoe case studies

Materials

Cardboard, Scissors, Glue, Ruler, Fabric, Elastic, Paper template.

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	Instructions Cut out the shape of the slippers from cardboard using the paper template. Then, cut two strips of cardboard for the upper part and attach them to the soles with glue. Cover the soles and strips with fabric for added comfort. If necessary, add elastic to secure the slippers more firmly to your feet. Hold the slippers and test them for comfort and durability. **Investigation ideas** **1. Most challenging part** ● Identify the most challenging part of the process. ● Explain why it was challenging and how you addressed it. **2. New learnings** ● Describe any new skills or knowledge you gained while making the slippers. ● Explain how these new learnings helped you in the process. ● Encountered problems: ● List any problems you encountered during the process. ● Describe how you solved each problem. **3. Changes to the initial plan** ● Identify any changes you made to the initial plan. ● Explain why you made these changes and how they affected the final product. **4. Satisfaction with final result** ● Rate your satisfaction with the final result. ● Provide reasons for your level of satisfaction. **5. Process improvements** ● Suggest what you would do differently if you repeated the process. ● Explain how these changes could improve the outcome. ● Time spent on each stage: ● Break down the time spent on each stage of the slipper-making process. ● Provide a brief explanation for the time allocation.

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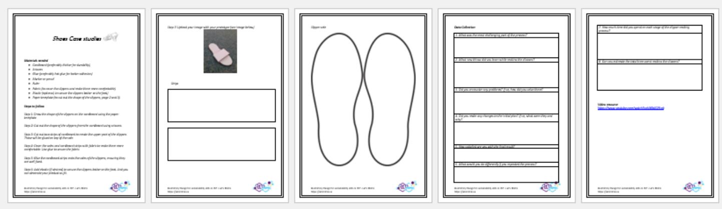
6. Total time estimate

- Estimate the total time spent making the slippers.
- Compare this estimate with your initial expectations.

Template



STUDENTS ASSIGNMENT

[Collaborative space]

[Take your notes]

Task 1

Students record their findings on the provided record sheet.

Task 2

Ideas:

- Lightweight, water-resistant, compostable
- Organic cotton or hemp for breathability and comfort
- Durable, shock-absorbing sole
- Non-toxic colouring
- Detachable and changeable based on terrain.
- Algae-based hydrophobic treatments.
- Personalised fit.
- Organic shapes and textures of algae, wavy surface patterns, and a nature-inspired colour palette.
- All components can be composted.
- Suitable for various activities and environments.
- Switch from sneaker to sandal style.

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	Task 3 **1. Material composition** ● **Algae-derived bioplastic:** Lightweight, water-resistant, compostable. ● **Natural fibres:** Organic cotton or hemp for breathability and comfort. ● **Algae-derived foam:** Durable, shock-absorbing sole. ● **Algae-based pigments:** Non-toxic colouring. **2. Design features** ● **Modular sole:** Detachable and changeable based on terrain. ● **Waterproof and breathable:** Algae-based hydrophobic treatments. ● **Adjustable lacing/strap system:** Personalised fit. ● **Aesthetic inspiration:** Organic shapes and textures of algae, wavy surface patterns, nature-inspired colour palette. **3. Sustainability** ● **Fully biodegradable:** All components can be composted. ● **Versatility:** Suitable for various activities and environments. ● **Transformable design:** Switch from sneaker to sandal style. **Context** ● Urban, outdoor, travel. **Constraints** ● **Cost:** Algae-derived bioplastic and natural materials like hemp and organic cotton are more expensive than synthetic materials. ● **Production feasibility:** Biodegradable materials must match the flexibility, strength, and waterproofing properties of traditional plastics. ● **Durability:** Biodegradable materials may not be as wear-resistant as traditional synthetics. Shoes must withstand daily wear, particularly in outdoor and travel contexts.

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	Task 4 Curved and lightweight shoe components that mimic the natural structure of algal cells to enhance comfort and flexibility, combined with a high-efficiency manufacturing process, are made of eco-friendly materials. **Inspiration drawn from the experiment** ● **Component design:** Just like the natural structure of algal cells, shoe components should be designed to mimic the flexibility and resilience of algal organic matter. ● **Manufacturing efficiency:** The natural efficiency of algal growth can inspire the use of high-efficiency, low-impact manufacturing processes for the shoes. ● **Eco-friendly materials:** The use of biodegradable algal matter can inspire the choice of recycled or sustainably sourced materials for the shoes.

BIOMIMICRY DESIGN	Description
Step 6 - Evaluate	**INFO** In the context of biomimicry, the "Evaluate" step involves the following tasks: ● **Assess performance:** Evaluate the performance of your biomimetic design against the criteria and constraints defined earlier. This involves testing the design to see how well it meets the desired impact and functional requirements. ● **Compare with biological models:** Compare the effectiveness of your design with the biological models that inspired it, and determine whether the design successfully emulates natural strategies and achieves similar results. ● **Gather feedback:** Collect feedback from users, stakeholders, and experts to understand how well the design performs in real-world conditions. This feedback is crucial for identifying areas of improvement. ● **Analyse data:** Analyse the data collected during testing and feedback to identify strengths and weaknesses in the design. Look for patterns and insights that can inform further refinements. ● **Iterate and improve:** Based on the evaluation, make necessary adjustments and improvements to the design. This

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iterative process ensures that the final product is optimised for performance and sustainability.

TASKS

Task 1

Evaluate the design concept in terms of its alignment with the design challenge's criteria and constraints, as well as its compatibility with Earth's systems. Assess the feasibility of both the technical and business models.

Task 2

Revise and revisit previous steps as necessary to generate a viable solution.

STUDENT ASSIGNMENTS

[Collaborative space]

[Take your notes]

Task 1

The prototype is biodegradable and functional, using algae-derived bioplastics and natural fibres like organic cotton or hemp for compostability. Certification would validate this. Comfort is ensured by breathable fibres and adjustable lacing, with modular soles adding versatility. However, durability, grip, and water resistance need testing. Its organic shapes and natural colours appeal to consumers. Overall, it's eco-friendly and functional, but thorough testing and user feedback are required before mass production.

To make algae-inspired biodegradable shoes cost-effective and eco-friendly, use locally sourced algae and natural fibres to reduce costs and support local economies—bulk purchasing and efficient manufacturing, like 3D printing, lower costs and waste. Collaborations with eco-conscious brands can share resources and reduce overhead. Biodegradable materials and natural dyes ensure natural decomposition, avoiding the use of harmful chemicals. Minimal, recyclable, or compostable packaging reduces waste, and renewable energy sources minimise the carbon footprint. A take-back program

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	for recycling or composting promotes a circular economy, with clear composting guidelines ensuring responsible disposal. **Task 2** To refine algae-inspired biodegradable shoes, collect user feedback through surveys, interviews, focus groups, and social media. Test prototypes with diverse users to assess performance, durability, and flexibility. Analyse feedback to prioritise adjustments, refine materials, improve design, and enhance aesthetics. Develop and test updated prototypes, maintaining a continuous feedback loop. This approach ensures the shoes meet consumer needs, improving functionality and satisfaction while supporting sustainability and innovation. To improve algae-inspired biodegradable shoes, analyse user feedback to identify pain points in comfort, fit, durability, and aesthetics. Enhance insoles for better support, add padding, and offer adjustable sizing options. Expand modular soles for various activities and refine aesthetics based on user preferences. Test new features and materials, develop updated prototypes, and gather further feedback. Maintain ongoing dialogue with testers to foster a community and continuously improve the design. This approach enhances functionality, user satisfaction, and customer loyalty, aligning with the demand for sustainable, high-performance footwear.

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TM 06 The termite mounds' tunnels and building design for efficient cooling and ventilation

BIOMIMICRY DESIGN	Description
Step 1 – Define the challenge	**INFO** Clearly express the desired impact of your design on the world, along with the specific criteria and limitations that will measure its success. In the context of biomimicry, the "Define" step involves two main tasks: ● **Describe the challenge:** This means you need to understand what your design needs to do, for whom, and in what context. ● **Criteria and constraints:** These are the standards and limitations that will help you evaluate whether you will be successful. Criteria might include factors like cost-effectiveness, durability, and environmental friendliness. Constraints could be things like budget limits, material availability, or regulatory requirements.
	TASKS **Task 1** Define the challenge as a question. **Task 2** Define the exploratory questions. **Task 3** Define the primary goal. **Task 4** Define the design needs. **Task 5** Define the target audience. **Task 6** Define the context and the locations or settings for the implementation

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Task 7

Identify the opportunities and/ or constraints that might impact achieving a successful outcome.

Task 8

Identify the connections to other solutions or challenges.

RESOURCES PROVIDED BY TEACHERS TO STUDENTS

[Resource 1 - H5P Course presentation/Interactive Book]

[Define the challenge]

Challenge

The challenge given is to design a building ventilation system that combines both efficiency and sustainability, drawing inspiration from the unique cooling and ventilation properties of termite mounds.

Key concepts to follow

- **Efficient cooling and ventilation:** Utilise the principles observed in termite mounds to enhance the building's airflow and temperature regulation.
- **Sustainability:** Ensure the design is environmentally friendly, using natural materials and passive cooling techniques.
- **Functionality:** The system should be easy to install, operate quietly, and maintain a stable internal environment.

STUDENT ASSIGNMENTS

[Collaborative space]

[Take your notes]

Task 1: Challenge as a question

How can we design urban buildings that significantly reduce energy consumption while providing comfort?

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Task 2: Exploratory questions

How can construction materials contribute to a building's climate control system?

How do termite mounds maintain stable internal climates?

Task 3: Main goal

The primary objective is to maintain a controlled internal climate for buildings in urban areas, utilising passive and energy-efficient mechanisms.

Task 4: Design needs

The design must address the challenge of maintaining a stable and comfortable internal climate within the building without relying on traditional fuel-based air conditioning systems. The design should use passive climate control mechanisms, maximize energy efficiency, ensure cost-effectiveness, incorporate sustainable practices and provide comfort for occupants.

Task 5: Target audience

- **Urban residents and office workers:** They experience the direct impact of energy consumption in buildings, including comfort levels, air quality, and lighting conditions.
- **Local governments and urban planners:** They are involved in setting regulations and standards for building sustainability

Task 6: Context

Context: The design can be implemented in densely populated cities where high-rise and multi-use buildings are typical. Urban settings face unique challenges, including high energy demand, limited space, and varying climate conditions.

Task 7: Opportunities and constraints

Opportunities

- Smart city initiatives.
- Renewable energy integration.

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	● Green building certifications. ● Government Incentives. ● Urban sustainability goals. **Constraints** ● High initial costs. ● Long payback periods. ● Compatibility with existing systems. ● Technical expertise. ● Rigid building codes. ● Approval processes. **Task 8: Connections to other solutions or challenges** ● **Thermal regulation:** passive cooling and temperature regulation. ● **Natural ventilation:** minimal energy usage.

BIOMIMICRY DESIGN	Description
Step 2 – Biologize	**INFO** Analyse the essential functions and context your design solution must address. Reframe them in biological terms, so that you can "ask nature" for advice. In the context of biomimicry, the "Biologize" step involves the following tasks: ● **Identify biological models:** Research and identify organisms, ecosystems, or natural processes that exhibit the desired functions or characteristics you want to emulate in your design. ● **Understand biological principles:** Dive deep into understanding the underlying principles and mechanisms that make these biological models effective. This involves studying the anatomy, physiology, and behaviours of the organisms or systems you're interested in. ● **Translate biological strategies and consider opposite functions:** Translate the biological strategies into design

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	principles that can be applied to your project. This involves identifying different natural processes that can be mimicked or adapted in a practical context.
	TASKS **Task 1. Discover** Read about termite mounds and ask yourself how nature can solve this. **Task 2. Ask yourself what your design wants to do** Determine the key functions of your design and identify contexts in nature. Functions can refer to the role played by an organism's adaptations or behaviours that enable it to survive. They can also refer to something your design solution needs to do. **Task 3. Flip the question** What is nature's strategy for regulating its temperature? **Task 4. Summarise** Summarise the key elements of the biological strategy, highlighting the core functions and relevant keywords. If possible, create a diagram/ drawing and/ or find images that can inform the design. **Task 5. List key information** List your key information and explore as many ideas as possible. **Task 6. Search for natural models** Search for natural models that match the same functions and context as your design solution.
	RESOURCES PROVIDED BY TEACHERS TO STUDENTS [Resource 1 – Interactive Book] [Let's discover termite mounds]

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Context

In nature, the design of termite mounds' tunnels and building structures allows for efficient cooling and ventilation, creating a stable internal environment. Termite mounds, constructed by various species of termites, have a fascinating architecture that enables them to maintain a consistent temperature and humidity level inside the mound. This mechanism is a brilliant example of nature solving the challenge of creating substantial airflow with minimal energy.

How do termite mounds achieve efficient cooling and ventilation?

- **Tunnel design:** The tunnels within termite mounds are intricately designed to facilitate airflow. These tunnels are narrow and winding, which helps to regulate the flow of air and maintain a stable internal climate.
- **Chimney effect:** The structure of the mound often includes a central chimney. As the air inside the mound warms up, it rises and exits through the chimney, creating a natural ventilation system. Cooler air is drawn in from the lower parts of the mound, maintaining a consistent temperature.
- **Porous walls:** The walls of termite mounds are porous, allowing for the exchange of gases and moisture. This porosity helps to keep the mound cool and prevents the buildup of harmful gases inside.
- **Thermal mass:** The materials used in building the mound, such as soil and saliva, have a high thermal mass. This means they can absorb and store heat during the day and release it slowly at night, helping to regulate the internal temperature.

Fun facts about termite mounds and their efficient design

- **Natural air conditioners:** Termite mounds are often referred to as "nature's air conditioners" because of their ability to maintain a stable internal environment despite external temperature fluctuations.
- **Energy efficiency:** The design of termite mounds enables them to achieve efficient cooling and ventilation without relying on external energy sources, making them a model of sustainable architecture.
- **Inspiration for architecture:** The principles of termite mound construction have inspired architects and engineers in designing energy-efficient buildings and ventilation systems.

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- **Complex societies:** Termites live in highly organized colonies, and the construction of their mounds is a collective effort that demonstrates their complex social structure and cooperation.
- **Biodiversity hotspots:** Termite mounds can support a diverse range of other organisms, including plants, fungi, and various animal species, creating microhabitats within the larger ecosystem.

[Resource 2 – H5P Flash cards]

[Did you know]

Did you know that termite mounds are designed to maintain efficient cooling and ventilation?

How?

Termite mounds utilize a complex network of tunnels and openings to facilitate natural airflow. This design allows for the regulation of temperature and humidity within the mound, creating a stable and controlled internal environment. The tunnels act as ventilation shafts, enabling hot air to escape and cooler air to enter, which helps to dissipate heat and maintain a consistent internal climate. This natural ventilation system ensures that the mound remains habitable for the termites, even in extreme external conditions.

[Resource 3 – H5P Find multiple hotspots/Image choice]

[I spy with my little eye]

Instructions

Let’s take a look at what you have discovered until now. Can you identify what a termite mound looks like in the interactive activity below?

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[Image to be used]

[Resource 4 – Link to video]

[Let’s watch]

Take a look at this video and see how termites inspired a building that can cool itself

https://www.youtube.com/watch?v=620omdSZzBs

STUDENT ASSIGNMENTS

[Collaborative space]

[Take your notes]

Task 1. Read about termite mounds and consider how nature addresses this issue

What is nature's strategy for creating natural ventilation systems to regulate temperature and airflow without the need for external energy?

Context

The termite mounds are designed with a network of tunnels that draw in cool air from the base and expel warm air from the top, utilising convection currents. Termite mounds harness the natural flow of air, using temperature differences to create circulation. Even in extreme heat, termite mounds maintain a stable internal environment. The mound structure provides cooling and airflow with zero energy input, relying solely on the design and natural airflow dynamics.

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Task 2: Ask yourself what your design wants to do

Determine the key functions of your design and identify contexts in nature. Functions can refer to the role played by an organism's adaptations or behaviours that enable it to survive. They can also refer to something your design solution needs to do.

- **Enhance energy efficiency:** Termite mounds use natural ventilation and thermal mass to regulate internal temperatures with minimal energy input.
- **Maintain thermal comfort: The** construction materials of termite mounds, such as soil and clay, have high thermal capacity. This allows the mound to absorb and store heat during the day and release it during the cooler night, helping to stabilize internal temperatures.
- **Humidity regulation:** Termites maintain a moist environment within the mound, which helps regulate temperature and humidity. The moisture in the soil and the termites' activities contribute to a stable microclimate.
- **Adaptive architecture:** The architecture of termite mounds can vary depending on the external environment. In cooler habitats, mounds are designed to minimise heat loss, while in warmer areas, they are structured to enhance ventilation and cooling

Task 3: Flip the question

What is nature's strategy for creating natural humidity control systems to maintain optimal moisture levels?

Task 4. Summarise key elements

Summarise the key elements of the biological strategy, highlighting the core functions and relevant keywords. If possible, make a diagram/ drawing and/ or find images that can inform the design.

Core functions

- **Thermal regulation:** The mounds are constructed based on soil and clay, which have high thermal capacity. This allows the mound to absorb and store heat during the day and release it during the cooler night, stabilising internal temperatures.

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- **Natural ventilation:** Termite mounds have a network of tunnels and chimneys that facilitate natural airflow. Warm air rises and exits through the chimneys, creating a convection current that draws in cooler air from the base.

Task 5. List your key information and explore as many ideas as possible

- **Features:** Stable indoor temperatures with minimal energy use, improve air quality and reduce reliance on mechanical systems.
- **Ideas:** Stack ventilation, wind catchers, high thermal capacity materials, phase change materials, green roofs, living walls, operable windows and louvres, dynamic facades, night purge ventilation, shading devices, building orientation, courtyards, and atria.

Task 6: Search for natural models

Search for natural models that match the same functions and context as your design solution.

Functions

- **Thermal regulation:** Passive cooling and temperature regulation.
- **Natural ventilation:** minimal energy usage.

Natural models

- **Termite mounds (Macrotermes michaelseni):** Termite mounds in Africa maintain stable internal temperatures despite extreme external conditions. They achieve this through a complex ventilation system, thermal mass, and the use of insulating materials.
- **Fish gills and their lungs:** The gills in fish and the lungs in air-breathing animals are highly efficient at gas exchange, enabling optimal respiratory function with minimal energy expenditure.
- **Beehives:** Bees regulate the temperature inside their hives through fanning their wings to create airflow and clustering to generate heat. This natural ventilation system helps maintain a stable environment for the hive.

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	● **Cactus spines:** Cacti in arid environments use their spines to collect and direct water droplets from fog. The spines also provide shade and reduce air movement around the cactus, minimizing water loss and helping to regulate temperature. ● **Ant nests:** Certain ant species construct nests with intricate tunnel systems that facilitate airflow and regulate temperature. These tunnels allow for passive ventilation, helping to keep the nest cool in hot climates. ● **Leaf structures:** Many plants have leaves with structures that promote natural ventilation and cooling. For example, the stomata on leaves open and close to regulate gas exchange and water loss, helping to maintain optimal internal conditions. ● **Penguin huddles:** Emperor penguins huddle together to conserve heat and protect themselves from the cold. This collective behaviour reduces heat loss and helps maintain a stable temperature within the huddle.

BIOMIMICRY DESIGN	Description
Step 4 – Abstract	**INFO** Carefully study the essential features or mechanisms that make the biological strategies successful. Restate them in non-biological terms, referring to them as "design strategies." In the context of biomimicry, the "Abstract" step involves the following tasks: ● **Extract principles:** Identify and extract the underlying principles and strategies from the biological model you have studied. This means understanding the core functions and mechanisms that make these natural solutions effective. ● **Generalise concepts:** Generalise these biological principles so they can be applied to a wide range of design challenges. This involves translating specific biological strategies into broader design concepts that are not tied to a particular organism or ecosystem. ● **Create analogies:** Develop analogies that link the biological principles to human design challenges. These analogies help bridge the gap between nature and technology, making it easier to apply natural strategies to human-made systems.

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TASKS

Task 1

From the core function presented, summarise the key elements of the biological strategy of the termite mounds' tunnels and building design for efficient cooling and ventilation, by defining the function and identifying relevant keywords.

Task 2

Create a diagram/drawing and/or find images of termite mounds that can inform the design.

Task 3

Translate lessons from nature into design strategies. Rewrite the strategy without using biological terms and connect it to the functions and the context from a human perspective.

Task 4

Create a diagram/ drawing and/ or find images of the design of your solution.

RESOURCES PROVIDED BY TEACHERS TO STUDENTS

[Resource 1 – Core functions of Sycamore seeds]

[H5P Flashcards]

Core functions

- **Temperature regulation:** Enables the mound to maintain stable internal temperatures.
- **Tunnel structure:** The curved and interconnected tunnels facilitate natural airflow and heat dissipation.
- **Material balance:** The balance of soil and organic materials ensures smooth temperature regulation during varying external conditions.
- **Autorotation:** Rotates naturally.
- **Silent operation:** Achieves quiet ventilation and cooling.

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- **Quiet ventilation:** The airflow within termite mounds is almost silent, due to the smooth, aerodynamic design of the tunnels, which reduces turbulence and noise as air moves through them.
- **Stealthy cooling:** The quiet operation ensures that the mound can regulate its temperature without attracting attention from potential predators, increasing the colony's chances of survival.

STUDENT ASSIGNMENTS

[Collaborative space]

[Take your notes]

Task 1

- **Thermal regulation:** The mounds are constructed based on soil and clay, which have high thermal capacity. This allows the mound to absorb and store heat during the day and release it during the cooler night, stabilising internal temperatures.
- **Natural ventilation:** Termite mounds have a network of tunnels and chimneys that facilitate natural airflow. Warm air rises and exits through the chimneys, creating a convection current that draws in cooler air from the base.
- **Function:** Efficient cooling and ventilation through natural means.

Keywords

- **Ventilation:** Airflow, tunnels, openings.
- **Cooling:** Heat dissipation, temperature regulation.
- **Structure:** Termite mounds, architecture, design.
- **Efficiency:** Energy-saving, sustainable, passive cooling.

Task 2: Image of a termite mound

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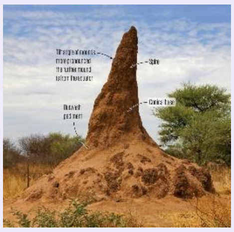

(Copyright @ https://www.jlconline.com/how-to/hvac/termite-hvac-passive-mound-ventilation_o)

One of the most fascinating examples of this is the study of termite mounds by architects and scientists. Believe it or not, these seemingly insignificant structures have been a goldmine of insights for sustainable and efficient building design, particularly in terms of ventilation. (Architects Look to Termite Mounds to Improve Building Ventilation)

Task 3

1. Biological strategy

Termite mounds utilise a network of tunnels and openings to facilitate airflow, which helps in cooling and maintaining a stable internal temperature.

2. Design strategy (human perspective)

- **Ventilation system:** Implement a network of ducts and vents to enhance airflow throughout the building.
- **Cooling mechanism:** Use materials with high thermal capacity and strategically place openings to dissipate heat naturally.

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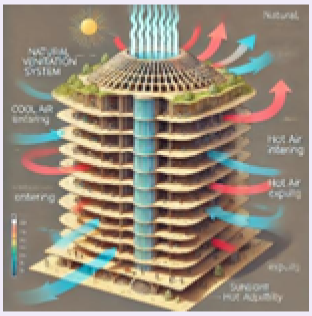
	● **Architectural design:** Design the building structure to mimic the efficient layout of termite mounds, optimizing for natural ventilation and cooling. ● **Sustainability:** Emphasise passive cooling techniques to minimise energy consumption and promote sustainability. **Task 4** Image of an efficient building design  Generated with AI tool

BIOMIMICRY DESIGN	Description
Step 5 – Emulate	**INFO** In the context of biomimicry, the “Emulate” step involves the following tasks: ● **Apply biological principles:** Implement the biological strategies and principles you have abstracted into your design. This involves directly applying insights gained from nature to create innovative solutions. ● **Prototype development:** Develop prototypes that incorporate the biomimetic principles. This involves creating models or samples that demonstrate how the natural strategies can be used in practical applications. ● **Integration:** Integrate the biomimetic design into the final product or system, ensuring that natural strategies are seamlessly incorporated and that the design meets all necessary criteria and constraints.

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TASKS

Task 1

Do the practical example and note your findings.

Task 2

Identify as many ideas as possible for designing your solution.

Task 3

Organise your ideas into categories that include the features, the context, and the constraints.

Task 4

Select the design concept (ideas) that best fit your solution.

RESOURCES PROVIDED BY TEACHERS TO STUDENTS

[Resource 1 – Look into]

[H5P Course presentation]

When designing a cooling and ventilation system inspired by the tunnels and building design of termite mounds, consider the following essential features to guide your ideas:

- **Maximise airflow with minimal energy: Utilise** the natural efficiency of termite mounds, which maintain a stable internal climate through their intricate tunnel systems. Your design should aim to replicate this efficiency, ensuring that the system moves a large volume of air while consuming as little energy as possible.
- **Temperature regulation:** Termite mounds are renowned for their ability to regulate temperature, maintaining a cool interior even in extreme heat. Incorporate design elements that mimic this natural cooling effect, creating a comfortable environment that relies less heavily on external energy sources.
- **Material optimisation:** Just as termite mounds are constructed from locally sourced, durable materials, your design should use materials that provide strength and

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	longevity without unnecessary weight. This optimisation will enhance performance and reduce energy consumption. ● **Sustainable materials:** Nature is inherently sustainable. Choose eco-friendly and sustainable materials for your design, ensuring that the production and disposal processes have minimal environmental impact.
	STUDENTS ASSIGNMENT [Collaborative space] [Take your notes] **Task 1** Students record their findings on the provided record sheet. **Task 2** Ideas: stack ventilation, wind catchers, high thermal capacity materials, phase change materials, green roofs, living walls, operable windows and louvres, dynamic facades, night purge ventilation, shading devices, building orientation, courtyards and atriums **Task 3** **Features** ● **Thermal regulation (stable indoor temperatures with minimal energy use):** high thermal capacity materials, phase change materials (PCMs), green roofs, living walls, dynamic facades, building orientation. ● **Natural ventilation (improves air quality and reduces reliance on mechanical systems):** stack ventilation, wind catchers, operable windows, ventilation louvres, night purge ventilation, shading devices, courtyards, and atria. **Context** ● Climates with significant temperature variations. ● Climates where natural ventilation can significantly improve indoor air quality.

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	● New constructions or major renovations where thermal management can be integrated early in the design process. ● New buildings and renovations where airflow can be optimised. **Constraints** ● Higher initial costs and potential complexity in installation. ● Additional structural support may be required, and maintenance can be intensive. ● Limited flexibility for existing structures and retrofits. ● May require significant structural modifications. ● Potential for mechanical failure and maintenance. **Task 4** **Idea selected** ● **High thermal capacity materials:** Just like termite mounds use soil and clay to absorb and store heat, using materials with high thermal mass in buildings can help stabilize indoor temperatures by storing heat during the day and releasing it at night.

BIOMIMICRY DESIGN	Description
Step 6 – Evaluate	**INFO** In the context of biomimicry, the “Evaluate” step involves the following tasks: ● **Assess performance:** Evaluate the performance of your biomimetic design against the criteria and constraints defined earlier. This involves testing the design to see how well it meets the desired impact and functional requirements. ● **Compare with biological models:** Compare the effectiveness of your design with the biological models that inspired it, and determine whether the design successfully emulates natural strategies and achieves similar results. ● **Gather feedback:** Collect feedback from users, stakeholders, and experts to understand how well the design performs in real-world conditions. This feedback is crucial for identifying areas of improvement.

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- **Analyse data:** Analyse the data collected during testing and feedback to identify strengths and weaknesses in the design. Look for patterns and insights that can inform further refinements.
- **Iterate and improve:** Based on the evaluation, make necessary adjustments and improvements to the design. This iterative process ensures that the final product is optimised for performance and sustainability.

TASKS

Task 1

Evaluate the design concept in terms of its alignment with the design challenge's criteria and constraints, as well as its compatibility with Earth's systems. Assess the feasibility of the technical and business model.

Task 2

Revise and revisit previous steps as necessary to generate a viable solution.

STUDENT ASSIGNMENTS

[Collaborative space]

[Take your notes]

Task 1

High-thermal-capacity materials can absorb, store, and release significant amounts of heat. In buildings, using materials with high thermal mass can help stabilise indoor temperatures by moderating temperature fluctuations.

Constraints

- **Climate suitability:** Thermal mass materials are most effective in climates with significant temperature variations between day and night. In regions with consistently mild or extreme temperatures, their benefits may be limited.

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	● **Initial construction costs:** Incorporating high thermal mass materials like concrete, brick, or rammed earth can increase initial construction costs due to the need for specialised materials and construction techniques. ● **Structural considerations:** The weight of thermal mass materials requires strong structural support, which can complicate the design and increase costs. ● **Design integration:** Effective use of thermal mass requires careful design and placement within the building to maximise heat absorption and release. Poor integration can lead to suboptimal performance. ● **Insulation requirements:** Adequate insulation is necessary to ensure that the stored heat is retained and not lost to the external environment. **Compatibility with Earth's systems** ● Reduce Energy Consumption ● Promote Sustainability ● Enhance Indoor Air Quality **Technical feasibility** ● **Material availability:** High thermal mass materials, such as concrete, brick, and rammed earth, are widely available and can be sourced locally, making them technically feasible for most construction projects. ● **Design flexibility:** These materials can be integrated into various building designs, from traditional to modern, allowing for flexibility in architectural styles. ● **Performance:** When properly designed and integrated, thermal mass materials can significantly enhance a building's thermal performance, reducing energy consumption and improving occupant comfort. **Business model feasibility** ● **Cost savings:** While initial construction costs may be higher, the long-term savings in energy costs can make thermal mass materials economically viable. Reduced reliance on mechanical systems translates to lower operational costs.

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	• **Market demand:** There is growing demand for energy-efficient and sustainable building solutions, making thermal mass materials an attractive option for developers and investors. • **Regulatory support:** Increasingly stringent building codes and regulations promoting energy efficiency and sustainability support the adoption of thermal mass materials. **Task 2** To generate a viable solution for maintaining stable indoor temperatures with minimal energy use, improving air quality, and reducing reliance on mechanical systems, the proposed design should look into: climate suitability, design integration, evaluation of structural support and balancing initial costs with long-term savings.

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TM 07 Design a subway or railway network less prone to disruption inspired by the adaptive behaviour of slime mould

BIOMIMICRY DESIGN	Description
Step 1 – Define the challenge	**INFO** Clearly express the desired impact of your design on the world, along with the specific criteria and limitations that will measure its success. In the context of biomimicry, the "Define" step involves two main tasks: ● **Describe the challenge:** This means you need to understand what your design needs to do, for whom, and in what context. ● **Criteria and constraints:** These are the standards and limitations that will help you evaluate whether you will be successful. Criteria might include factors like cost-effectiveness, durability, and environmental friendliness. Constraints could be things like budget limits, material availability, or regulatory requirements.
	TASKS **Task 1** Define the challenge as a question. **Task 2** Define the exploratory questions. **Task 3** Define the primary goal. **Task 4** Define the design needs. **Task 5** Define the target audience. **Task 6**

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Define the context.

Task 7

Identify the opportunities that might impact achieving a successful outcome.

Task 8

Identify the connections to other solutions or challenges.

Task 9

Identify the favourable circumstances, initiatives or legislation.

Task 10

Identify the risks.

RESOURCES PROVIDED BY TEACHERS TO STUDENTS

[Resource 1 - H5P Course presentation/Interactive Book]

[Define the challenge]

Challenge

The challenge given is to design a railway or subway network that is cost-efficient, decentralised, resilient and scalable, drawing inspiration from the unique way the Slime Mould connects different sources of food.

Key concepts to follow

1. **Decentralised decision-making**
   - Slime moulds operate without a central brain, yet they form efficient networks.
   - **Design implication**: Use decentralised algorithms or simulations to allow the network to evolve based on local conditions and needs.
2. **Adaptive growth**

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- **Slime mould** dynamically adjust their paths based on environmental feedback.
- **Design implication**: Incorporate feedback loops (e.g., passenger flow, congestion data) to adapt routes or schedules over time.

3. **Redundancy and resilience**
    - **Slime mould** creates redundant paths to maintain connectivity if one route is blocked.
    - **Design implication**: Build in alternative routes or loops to ensure robustness against failures or overloads.
4. **Cost-efficiency vs. coverage trade-off**
    - **Slime mould** balances between minimising energy (path length) and maximising resource access.
    - **Design implication**: Optimise for both cost (construction/maintenance) and accessibility (coverage of key urban areas).
5. **Network optimisation via simulation**
    - **Slime mould-inspired a**lgorithms can simulate how the mould would grow between urban hubs.
    - **Design implication**: Use bio-inspired algorithms to simulate and refine the network layout.
6. **Environmental sensitivity**
    - **Slime mould** avoids light and unfavourable terrain.
    - **Design implication**: Factor in geographical constraints, land use, and urban density when planning routes.
7. **Experimentation and iteration**
    - **Slime mould** experiments often use oat flakes on agar to represent cities.
    - **Design implication**: Utilise physical or digital simulations to evaluate various configurations prior to implementation.

STUDENT ASSIGNMENTS

[Collaborative space]

[Take your notes]

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	Task 1: Challenge as a question How can we design a subway or railway less prone to disruption? **Task 2: Exploratory questions** How can a railway network dynamically adjust to varying passenger loads and traffic conditions? What mechanisms allow the slime mould to optimise its network without a central brain? **Task 3: Primary goal** The primary objective is to establish a highly efficient, resilient, and adaptable transportation network. **Task 4: Design needs** The design must consider network efficiency, disruption management, structural design, technological integration, and environmental adaptation. **Task 5: Target audience** The target groups that could benefit from this design include commuters and passengers, businesses and employers, tourists and leisure travellers, public transit authorities and operators, government and policymakers, logistics and supply chain companies, local communities and neighbourhoods, environmental advocates and sustainability groups, vulnerable populations, educational institutions (both students and staff), and emergency services. **Task 6: Context and locations** **Context:** The design can be implemented in urban transportation networks, disaster zones, smart cities, military and emergency zones. **Task 7: Opportunities** **Opportunities** ● Optimised route planning. ● Resilient infrastructure.

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- Smart systems.
- Innovative urban planning.

Task 8: Connections to other solutions or challenges

- Urban planning and infrastructure design.
- Computer science and artificial intelligence (AI).
- Logistics and supply chain management.
- Telecommunications and network theory.
- Resilience and disaster management.
- Biomimicry in sustainability and resource management.
- Healthcare and biological systems.
- Traffic flow and road networks.
- Energy and power grid optimisation.

Task 9: Favourable circumstances, initiatives or legislation

- Sustainability and green infrastructure initiatives (Green New Deal, The Paris Agreement and local carbon reduction goals)
- Smart city initiatives (EU Smart Cities Marketplace and Japan's Society 5.0, National Infrastructure Investments)
- Innovation grants and research funding (EU Horizon 2020 or Horizon Europe, U.S. Federal Transit Administration (FTA), Japanese Ministry of Land, Infrastructure, Transport and Tourism (MLIT))
- Resilience and disaster management policies (National Disaster Resilience Programs, Resilience 2050)
- Urban mobility and transport innovation policies (EU Urban Mobility Framework, Urban Mobility Innovations)
- Technological innovation and biomimicry support (U.S. National Science Foundation (NSF), European Commission's Circular Economy Action Plan)
- Environmental regulations and low-emission zones
- Public-private partnerships and infrastructure development
- Public health and air quality initiatives

Task 10: Risks

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	• Scalability and complexity of urban networks. • Dynamic human behaviour and traffic patterns. • Technological limitations. • Integration with existing infrastructure. • Initial Investment and development costs. • Adaptability to future urban growth. • Public acceptance and usability. • Regulatory and bureaucratic hurdles. • Security and vulnerability concerns. • Environmental and spatial constraints. • Ethical and environmental considerations.

BIOMIMICRY DESIGN	Description
Step 2 – Biologize	**INFO** Analyse the essential functions and context your design solution must address. Reframe them in biological terms, so that you can "ask nature" for advice. In the context of biomimicry, the "Biologize" step involves the following tasks: • **Identify biological models:** Research and identify organisms, ecosystems, or natural processes that exhibit the desired functions or characteristics you want to emulate in your design. • **Understand biological principles:** Dive deep into understanding the underlying principles and mechanisms that make these biological models effective. This involves studying the anatomy, physiology, and behaviours of the organisms or systems you're interested in. • **Translate biological strategies and consider opposite functions:** Translate the biological strategies into design principles that can be applied to your project. This involves identifying different natural processes that can be mimicked or adapted in a practical context.

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	TASKS **Task 1** Read about the slime mould and solve the quiz. **Task 2** What did you observe in the video presented? Write your observations using the concepts you discovered in the provided resources. **Task 3** State your challenge from the natural point of view. Ask yourself how nature can address this issue. **Task 4** Identify key functions applicable to nature's contexts. **Task 5** Consider the opposite function and try to rephrase the question that describes the challenge from a natural perspective.
	RESOURCES PROVIDED BY TEACHERS TO STUDENTS [Resource 1 – Interactive Book] [Let's discover The Slime Mould] **Context** In nature, more than 900 species of Slime Mould have been discovered. They can be found all over the Earth, including deserts and in the Arctic. They are one of the planet's oldest living organisms, dating back to the time of the dinosaurs. They first appeared in the scientific literature in the seventeenth century, yet 300 years later, very little is known about them, and very few people study them. Slime moulds, particularly Physarum polycephalum, are single-celled, multinucleate organisms that exhibit remarkable problem-solving abilities despite lacking a nervous system.

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The Slime Mould thrives in moist, shaded environments and is known for its ability to form dynamic, efficient networks to forage for food. In the plasmodial stage of its life cycle, it extends pseudopodia to explore its surroundings, responding to chemical gradients and environmental stimuli. Notably, P. polycephalum has demonstrated the capacity to solve mazes, optimise transport networks, and adapt to changing conditions, making it a model organism in studies of decentralised intelligence and bio-inspired computing. Its behaviour has inspired algorithms in fields such as robotics, urban planning, and network design, highlighting the potential of biological systems to inform technological innovation.

How does Slime Mould form dynamic and efficient networks to forage for food?

- **Chemotaxis-driven exploration:** Slime mould detects chemical gradients emitted by food sources (e.g., sugars, amino acids) and moves toward higher concentrations via chemotaxis, extending pseudopodia in multiple directions.
- **Protoplasmic tube formation:** As it moves, the Slime Mould forms a network of protoplasmic tubes. These tubes serve as conduits for cytoplasmic streaming, transporting nutrients and signalling molecules.
- **Positive feedback reinforcement:** Tubes that lead to nutrient-rich areas experience increased cytoplasmic flow, which strengthens the tubes by depositing more actin and myosin filaments, thereby reinforcing successful paths.
- **Negative feedback and retraction:** Tubes that do not lead to food or are inefficient receive less flow, causing them to shrink and be reabsorbed, thereby conserving energy and resources over time.
- **Oscillatory dynamics:** The organism exhibits rhythmic contractions that help regulate flow and assess path efficiency. These oscillations enable the slime mould to dynamically compare alternative routes.
- **Network optimisation: Over time, the slime mould minimises** total path length while maintaining connectivity. The resulting network often resembles solutions to graph-theoretic problems like the shortest path or minimum spanning tree.
- **Environmental feedback integration:** The organism continuously adapts its network in response to environmental

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changes (e.g., new food sources, obstacles). This allows for real-time optimisation and resilience.

Fun facts about the Slime Mould and its fascinating way of foraging for food

- **No brain, no problem:** Despite lacking a nervous system, slime mould can solve complex problems, such as mazes and shortest-path puzzles.
- **Maze solvers:** In lab experiments, Physarum polycephalum has been shown to find the shortest path through a maze to reach food—essentially "solving" it.
- **Memory without neurons:** Slime mould can "remember" past conditions by altering its internal state, allowing it to avoid previously explored or unfavourable areas.
- **Self-healing networks:** If a part of the slime mould is damaged or cut, it can reroute its network and continue functioning, like a living, self-repairing transport system.
- **Efficient yet redundant:** Their networks are not only efficient but also include backup paths, making them resilient to disruptions—something engineers strive for in real-world systems.
- **They can learn:** Studies have shown that slime mould can habituate to stimuli (like bitter substances), a basic form of learning previously thought to be exclusive to animals.
- **They "pulse" to move:** Slime mould moves by rhythmic contractions of its cytoplasm, creating a pulsing flow that pushes it forward.
- **They can fuse:** Two slime moulds of the same species can merge into one larger organism, sharing information and resources.
- **They're giant cells:** A single slime mould can span several square meters and still be one continuous cell with many nuclei, called a syncytium.

[Resource 2 – H5P Flash cards]

[Did you know]

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Did you know that Slime Moulds are designed to be efficient and have backup paths?

How?

Slime mould exhibits a biologically optimised strategy for forming transport networks that are both efficient and resilient. Their efficiency arises from a process of chemotactic exploration. These tubes are dynamically reinforced based on cytoplasmic flow, with frequently used paths becoming thicker and more stable, while less efficient routes are retracted. This self-organising behaviour enables the slime mould to approximate solutions to shortest-path and minimum spanning tree problems. Simultaneously, the organism maintains network resilience by forming redundant loops and alternative connections, which serve as backup paths in case of damage or environmental change. This redundancy ensures continued access to resources and adaptability, even in unpredictable conditions. The combination of local decision-making, continuous environmental feedback, and dynamic restructuring allows the slime mould to maintain a balance between cost-effective transport and fault tolerance, making it a model system for studying decentralised optimisation and robust network design.

[Resource 3 – H5P Find multiple hotspots]

[I spy with my little eye]

Instructions

Let’s take a look at what you've discovered until now. Can you identify what a Slime Mould looks like in the interactive activity below?

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[Image to be used]

[Resource 4 – Link to video]

[Let's watch]

Take a look at this video, which captures the way Slime Mould forages for food sources and expands.

https://www.youtube.com/watch?v=GY_uMH8Xpy0

[Resource 5 – Slime Mould vs centralised decision making]

[Document]

Slime mould operates through decentralized decision-making, where no central control exists and actions emerge from the collective behaviour of individual cells responding to local conditions. This allows it to adapt rapidly, reroute around obstacles, and efficiently solve problems, such as finding the shortest path, all without a leader.

Aspect	Slime Mould (Decentralised System)	Centralised Decision-Making System
Control Structure	No central command; decisions emerge locally	A central authority or node makes all major decisions
Adaptability	Highly adaptive; can rapidly reorganize based on feedback	Less responsive; changes require top-down reauthorization
Decision Flow	Emergent from multiple local interactions	Linear, top-down communication from a central source
Fault Tolerance	Resilient—if one area is damaged, others compensate	Vulnerable—failure at the centre can collapse the system

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Efficiency	Finds optimal paths using feedback and trial-error	May follow pre-set paths even if inefficient
Example Behaviour	Navigates mazes, reconfigures routes, self-heals	Executes fixed plans unless redirected by leadership
Scalability	Scales well with complexity and environment changes	Becomes inefficient or slow as complexity increases
Information Sharing	Distributed and real-time via chemical signals or local cues	Central node gathers, processes, and redistributes data

STUDENT ASSIGNMENT

[Collaborative space]

[Take your notes]

Task 1

Students access the interactive activity and click on the correct image. The platform will inform students about their answers (correct or wrong and a personalised message will be provided.

Task 2

In the video, I can see how the slime mould expands between food sources and how it multiplies.

Task 3

How can slime mould connect different sources of food?

Task 4

Summary of key functions applicable to nature's contexts

- Design a more efficient, adaptable, and resilient transportation network by mimicking slime mould's natural behaviour in finding optimal pathways. This network should

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	use fewer resources, consume less energy, and have a lower environmental impact. ● Develop a subway system that is resilient to disruptions, such as breakdowns, construction, or natural disasters, and can adapt to urban growth and changing population patterns. Address urban transportation complexities, such as congestion, by optimizing for multiple factors. **Task 5** How can Slime Mould efficiently transport nutrients throughout its body?

BIOMIMICRY DESIGN	Description
Step 3 – Discover	**INFO** Look for natural models (organisms and ecosystems) that require the same functions and context as your design solution. Identify the strategies used that support their survival and success. In the context of biomimicry, the “Discover” step involves the following tasks: ● **Explore nature:** Spend time discovering natural models to study various ecosystems and organisms. ● **Identify functions:** Look for specific functions or strategies in nature that can solve the design challenge you're facing. ● **Gather information:** Collect detailed information about biological models that exhibit the desired functions, including scientific research, case studies, and firsthand observations.
	TASKS **Task 1** Search for other natural models that match the same functions of the Slime Mould and apply some context to your design solution. **Task 2** Identify experts and communities in the field of biomimicry.

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RESOURCES PROVIDED BY TEACHERS TO STUDENTS

[Resource 1 – Course presentation]

[Functions of Slime Mould]

Slime mould serves several ecological and biological functions, playing a critical role in nutrient cycling and soil health. As decomposers, they break down organic matter - particularly dead plant material - releasing nutrients back into the ecosystem and supporting microbial biodiversity. Slime mould also exhibits complex behaviours despite being single-celled organisms; they can move, solve mazes, and optimise nutrient foraging paths, making them a model organism in studies of decentralised intelligence, collective behaviour, and biological computation. Their life cycle, which includes both unicellular and multicellular stages, offers valuable insight into the evolution of cooperation and multicellularity in living organisms.

Detailed functions of Slime Moulds

1. **Ecological functions**
   - **Decomposition:** Slime mould (especially plasmodial types like Physarum polycephalum) feed on decaying organic matter, bacteria, and fungi. They play a crucial role in breaking down leaf litter and dead organisms, facilitating decomposition.
   - **Nutrient cycling:** By consuming and breaking down organic substances, slime moulds release essential nutrients (e.g., nitrogen, phosphorus) into the soil. These nutrients support plant growth and microbial diversity in ecosystems.
   - **Soil health and structure:** Their movement and feeding activity help aerate the soil and maintain its microstructure. Slime moulds indirectly contribute to the formation of healthy soil ecosystems, benefiting fungi, bacteria, and plants.
2. **Biological and developmental functions**
   - **Model for studying multicellularity:** Slime moulds, such as Dictyostelium discoideum, transition from a unicellular to a multicellular form during their life cycle. This makes them ideal models for studying the evolution of cooperation, cell signalling, and differentiation.
   - **Cellular communication:** During aggregation, slime mould cells communicate using chemical signals such as cyclic AMP

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(cAMP). This allows for coordinated movement and behaviour, which is critical for studies in chemotaxis and cellular signalling pathways.

- **Developmental biology:** The transformation from individual amoebae to a fruiting body involves gene regulation, morphogenesis, and cell fate determination. They help researchers understand how complex structures emerge from simple organisms.

3. **Behavioural and cognitive-like functions**

   - **Decision-making without a brain:** Slime moulds can assess multiple paths and choose the most efficient one to reach food. They respond to environmental stimuli such as light, chemicals, and temperature in a purposeful, adaptive manner.
   - **Spatial memory and learning:** Physarum polycephalum exhibits habituation (a simple form of learning) by "remembering" areas it has explored or hazards it has encountered. It can anticipate periodic events (e.g., cold shocks), showing primitive forms of memory.
   - **Network optimisation:** Their behaviour has been used as a biological model for efficient systems, such as transport, data networks, and supply chains. Their growth patterns mimic solutions to problems like the shortest path or minimal spanning trees.

4. **Scientific and technological applications**

   - **Unconventional computing:** Slime moulds have inspired biological computing systems, such as using their movement to simulate logic gates or solve computational problems.
   - **Biomimicry in network design:** Their ability to connect multiple food sources efficiently has been used to model urban infrastructure, such as rail or road networks.
   - **Swarm intelligence and robotics:** Algorithms based on slime mould behaviour inform distributed artificial intelligence, swarm robotics, and autonomous system design.

5. **Interactions within ecosystems**

   - **Predator and prey relationships:** Slime moulds feed on bacteria, fungal spores, and small organic particles. They, in turn, serve as prey for soil invertebrates, making them a vital part of soil food webs.
   - **Microbial community regulation:** Through selective feeding and movement, they can influence microbial population

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dynamics, potentially reducing the presence of harmful bacteria or fungi.

6. **Educational and research value**
    - Widely used in school and university biology labs to demonstrate cellular behaviour, chemotaxis, and developmental biology. They serve as accessible, safe organisms for citizen science and STEM education projects.

Additional insights

- **Not fungi or animals:** Although once classified as fungi, slime moulds are now known to be protists—a broad group that doesn't fit neatly into the plant, animal, or fungal kingdoms.
- **Convergent evolution:** Their ability to form multicellular fruiting bodies mimics fungi, but evolved independently, making them a powerful model for studying convergent evolution.
- **Living fossils:** Fossil records of slime moulds date back over 100 million years, indicating their long-standing ecological role and stability.
- **Sensitive to environmental change:** Slime moulds are highly responsive to changes in temperature, moisture, and pollutants, making them potential bioindicators for ecosystem health.
- **Carbon cycling role:** Through decomposition, they indirectly influence carbon fluxes in soil systems, which is essential in climate modelling and soil carbon research.

STUDENT ASSIGNMENTS

[Collaborative space]

[Take your notes]

Task 1

Natural models

- **Fungal networks**: Mycelium forms underground networks that transport nutrients and reorganise to optimise resource distribution.

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	● **Vascular systems in plants**: Xylem and phloem transport water, nutrients, and sugars, adapting to environmental changes for efficient distribution. ● **Ant trails**: Ant colonies create optimised trails through pheromone signalling to find the shortest paths to food. ● **Animal circulatory systems**: Animal circulatory systems efficiently transport blood, oxygen, and nutrients, adapting to changes in demand. ● **Microbial colonies**: Bacterial colonies form networks to optimise nutrient uptake and waste removal, reorganising in response to environmental changes. **Task 2** **Experts** ● Institute of Experimental Design and Media Cultures (IXDM). ● Physarum Network. ● Slime Mould Time Mould.

BIOMIMICRY DESIGN	Description
Step 4 – Abstract	**INFO** Carefully study the essential features or mechanisms that make the biological strategies successful. Restate them in non-biological terms, referring to them as "design strategies." the context of biomimicry, the "Abstract" step involves the following tasks: ● **Extract principles:** Identify and extract the underlying principles and strategies from the biological model you have studied. This means understanding the core functions and mechanisms that make these natural solutions effective. ● **Generalise concepts:** Generalise these biological principles so they can be applied to a wide range of design challenges. This involves translating specific biological strategies into broader design concepts that are not tied to a particular organism or ecosystem. ● **Create analogies:** Develop analogies that link the biological principles to human design challenges. These analogies help

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bridge the gap between nature and technology, making it easier to apply natural strategies to human-made systems.

TASKS

Task 1

From the core function presented, summarise the key elements of the biological strategy of the Slime Mould by defining the function and identifying relevant keywords.

Task 2

Create a diagram or drawing, and/or find images of Slime Mould that can inform the design.

Task 3

Translate lessons from nature into design strategies. Rewrite the strategy without using biological terms and connect it to the functions and the context from a human perspective.

Task 4

Create a diagram or drawing, and/or find images of the design of your solution.

RESOURCES PROVIDED BY TEACHERS TO STUDENTS

[Resource 1 – Core functions of Slime Mould]

[H5P Flashcards]

Core functions

- **Decomposition:** Break down dead organic matter, aiding in nutrient recycling in ecosystems.
- **Soil Health Maintenance:** Regulate microbial populations and contribute to soil structure and fertility.
- **Microbial Predator:** Feeds on bacteria, fungi, and other microorganisms, helping balance microbial communities.

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- **Biological Intelligence:** Exhibits problem-solving abilities, such as finding the shortest path to food, despite lacking a central nervous system.
- **Scientific Model Organism:** Used in research on cell motility, decision-making, and decentralised systems.
- **Inspiration for Human Systems:** Inform designs in network optimisation, urban planning, and computing algorithms.

STUDENT ASSIGNMENTS

[Collaborative space]

[Take your notes]

Task 1

1. **Exploration and detection:**
   - **Keywords**: Protoplasmic tubes.
   - **Description:** Slime mould extends its network of protoplasmic tubes in various directions to explore its environment and detect food sources.
2. **Signal response**
   - **Keywords:** Chemical signalling; network reinforcement.
   - **Description:** Upon finding food, chemical signals are released, attracting more protoplasm to the area and causing the tubes to thicken.
3. **Selective reinforcement:**
   - **Keywords:** Nutrient transport; dynamic reorganisation.
   - **Description:** Tubes that efficiently transport nutrients are reinforced, while less efficient or redundant tubes are reabsorbed.
4. **Dynamic adjustment:**
   - **Keywords:** Environmental adaptation.
   - **Description:** The network continuously adjusts based on the availability of food and environmental conditions.
5. **Memory and efficiency**
   - **Keywords:** Optimisation; Problem-solving.

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- **Description:** The Slime Mould retains a "memory" of previous food locations by maintaining thicker tubes in those areas, allowing quick reconnection if the food becomes available again.

Task 2: Image of a Slime Mould

A graphical representation of a slime mould that spreads and establishes connective networks around different points marked with oat flakes.

Copyright @Adobe Stock

Photo of Slime Mould (Physarum polycephalum)

Task 3

Researchers in Japan used the behaviour of a simple organism to redesign Tokyo's subway system. In a 2010 study, they placed the organism in a dish with food scraps arranged to mimic major sites in Tokyo. The organism's network formation closely mirrored the actual subway system, showcasing an efficient and resilient design.

This experiment demonstrated that natural strategies could inspire urban infrastructure design. The organism's network was efficient in connecting key points and robust against disruptions, highlighting the potential for creating more efficient, adaptable, and resilient transportation networks.

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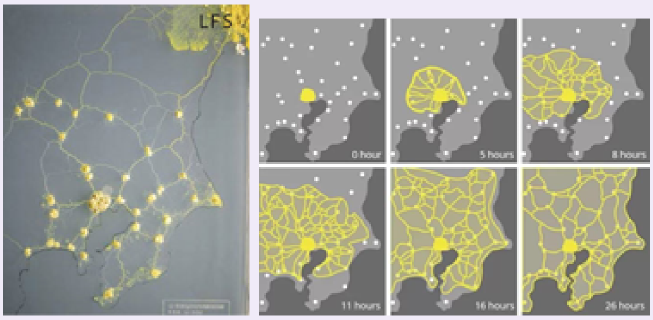
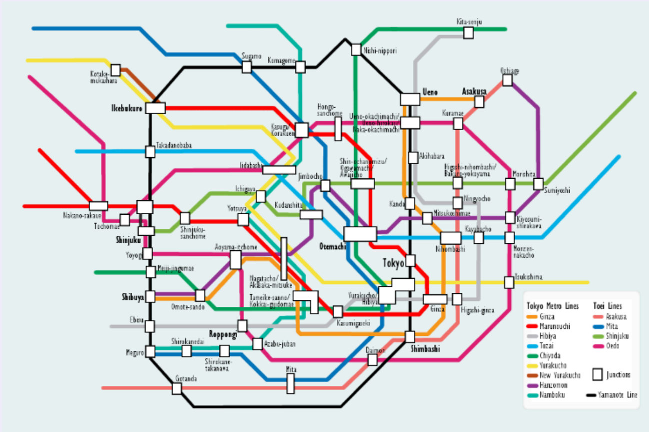
	Task 4: Image of the Tokyo Subway  *Photo of Slime Mould (Physarum polycephalum)*  Photo of Tokyo Subway (Copyright: https://saugatadastider.medium.com/nature-as-an-innovator-lessons-from-slime-mold-to-tokyos-subway-265cdb1904ff)

BIOMIMICRY DESIGN	Description
Step 5 – Emulate	**INFO** In the context of biomimicry, the “Emulate” step involves the following tasks: ● **Apply biological principles:** Implement the biological strategies and principles you have abstracted into your design. This involves applying the insights gained from nature directly to create innovative solutions. ● **Prototype development:** Develop prototypes that incorporate the biomimetic principles. This involves creating models or

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samples that demonstrate how the natural strategies can be used in practical applications.

- **Integration:** Integrate the biomimetic design into the final product or system, ensuring that natural strategies are seamlessly incorporated and that the design meets all necessary criteria and constraints.

TASKS

Task 1

Do the practical example and note your findings.

Task 2

Identify as many ideas as possible for designing your solution.

Task 3

Organise your ideas into categories that include features, context, and constraints.

Task 4

Select the design concept (ideas) that best fit your solution.

RESOURCES PROVIDED BY TEACHERS TO STUDENTS

[Resource 1 – Look into]

[H5P Course presentation]

When designing a railway or subway inspired by the way Slime Mould creates networks when foraging for food, consider the following essential features to guide your ideas:

- **Efficiency through minimalism:** Slime mould naturally forms the shortest and most cost-effective paths between food sources. Your design should prioritise minimal track length while maintaining maximum connectivity.
- **Redundancy for resilience:** Slime mould networks often include backup routes to maintain flow if one path is blocked.

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	Incorporate looped or alternative routes to handle disruptions and improve reliability. ● **Decentralised decision-making:** Slime mould adapts locally to environmental changes. Use modular planning and local optimisation algorithms to allow parts of the network to evolve independently based on demand. ● **Dynamic adaptability:** Slime mould reconfigures its networks in real time. Consider adaptive scheduling or smart routing systems that respond to passenger flow and traffic conditions. ● **Resource optimisation:** Slime mould balances energy cost with benefit. Apply cost-benefit analysis to station placement and route planning to ensure optimal resource use. ● **Environmental integration:** Slime mould navigates around obstacles and through complex terrain. Design your system to integrate with natural and urban landscapes, avoiding disruption and reducing construction costs. ● **Scalability:** Slime mould networks grow organically. Your design should allow for incremental expansion without requiring an overhaul of the entire system.
	STUDENT ASSIGNMENTS [Collaborative space] [Take your notes] **Task 1** Students record their findings on the provided record sheet. **Task 2:** **Ideas** ● Monitor performance and conditions continuously. ● Adjust pathways in real-time to optimise resource distribution and minimise disruptions. ● Prioritise efficient routes. ● Discover alternative routes to handle unexpected changes. ● Create networks that grow and evolve seamlessly with increasing demands and new nodes.

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- Create individual nodes for faster decisions and responsive adjustments.

Task 3

Features

1. **Dynamic adaptation**

   - Monitor performance and conditions continuously.
   - Adjust pathways in real-time to optimise resource distribution and minimise disruptions.

2. Resource efficiency

- Prioritise efficient routes.
- Quickly reconfigure to avoid bottlenecks and maintain optimal flow.

3. Resilience

- Build flexibility with multiple alternative routes.
- Adapt quickly to unexpected changes or challenges.

4. Scalability

- Design the network to grow and evolve seamlessly.
- Integrate new nodes and increase demands without compromising performance.

5. Decentralised control

- Empower individual nodes to make local decisions.
- Allow for faster, more responsive adjustments.

Task 4

- **The best idea is related to resilience:** Build flexibility with multiple alternative routes that can adapt quickly to unexpected changes or challenges.

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<table>
<tr><th>BIOMIMICRY DESIGN</th><th>Description</th></tr>
<tr><td rowspan="3">Step 6 – Evaluate</td><td>INFO

In the context of biomimicry, the “Evaluate” step involves the following tasks:
Assess performance: Evaluate the performance of your biomimetic design against the criteria and constraints defined earlier. This involves testing the design to see how well it meets the desired impact and functional requirements.
Compare with biological models: Compare the effectiveness of your design with the biological models that inspired it, and determine whether the design successfully emulates natural strategies and achieves similar results.
Gather feedback: Collect feedback from users, stakeholders, and experts to understand how well the design performs in real-world conditions. This feedback is crucial for identifying areas of improvement.
Analyse data: Analyse the data collected during testing and feedback to identify strengths and weaknesses in the design. Look for patterns and insights that can inform further refinements.
Iterate and improve: Based on the evaluation, make necessary adjustments and improvements to the design. This iterative process ensures that the final product is optimised for performance and sustainability.</td></tr>
<tr><td>TASKS

Task 1

Evaluate the design concept concerning its alignment with the design challenge's criteria and constraints, as well as its compatibility with Earth's systems. Assess the feasibility of both the technical and business models.

Task 2

Revise and revisit previous steps as necessary to generate a viable solution.</td></tr>
<tr><td>STUDENT ASSIGNMENTS

[Collaborative space]

[Take your notes]</td></tr>
</table>

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	Task 1 The design concepts for the Slime Mould-inspired railway or subway align well with the challenge's criteria, offering optimisation for the networks in question, balancing cost, travel time and vulnerability to disruptions and scalability, allowing adaptations to various scales, from small urban networks to large regional systems. Integrating a design-inspired Slime Mould railway or subway network with the current transportation planning tools is feasible but may require significant computational resources and expertise. Such a design can be compatible with Earth's systems by promoting energy efficiency and sustainability. The technical and business models are also feasible, because it’s cost efficient, resilient and reliable, sustainable because it reduces energy consumption, market differentiated because it’s innovative and nature-inspired and because demonstrating the efficiency and resilience can help secure regulatory approval and policy support. **Task 2** By revising and refining each design concept, the subway can be better aligned with the design challenge criteria, ensuring cost efficiency, resilience, sustainability and scalability. The revised approach addresses technical and business feasibility, with a focus on sustainability, resilience and scalability. The final design will incorporate advanced features and environmentally conscious practices, positioning it as a competitive and innovative urban transportation planning.

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TM 08 High-speed and quieter passenger trains inspired by the kingfisher, the owl and the penguin

BIOMIMICRY DESIGN	Description
Step 1 – Define the challenge	**INFO** Clearly express the desired impact of your design on the world, along with the specific criteria and limitations that will measure its success. In the context of biomimicry, the "Define" step involves two main tasks: ● **Describe the challenge:** This means you need to understand what your design needs to do, for whom, and in what context. ● **Criteria and constraints:** These are the standards and limitations that will help you evaluate whether your will be successful. Criteria might include factors like cost-effectiveness, durability, and environmental friendliness. Constraints could be things like budget limits, material availability, or regulatory requirements.
	TASKS **Task 1** Define the challenge as a question. **Task 2** Define the exploratory questions. **Task 3** Define the primary goal. **Task 4** Define the design needs. **Task 5** Define the target audience. **Task 6**

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Identify the opportunities that might impact achieving a successful outcome.

Task 7

Identify the connections to other solutions or challenges.

Task 8

Identify the favourable circumstances, initiatives or legislation.

Task 9

Identify the constraints or risks.

RESOURCES PROVIDED BY TEACHERS TO STUDENTS

[Resource 1 - H5P Course presentation/Interactive Book]

[Define the challenge]

Challenge

The challenge is to design a high-speed train that combines high speed, reduced noise pollution, and energy efficiency, drawing inspiration from the silent flight of the owl, the streamlined body of the Adélie penguin, and the kingfisher's head and beak shape, which allows it to glide through air and water efficiently and seamlessly.

Key concepts to follow

- **Aerodynamics**: The train's shape is crucial for reducing air resistance and noise. Engineers took inspiration from the kingfisher bird, designing the nose of the train to minimise air pressure changes when entering tunnels.
- **High-speed stability**: The train must remain stable at high speeds, requiring advanced suspension systems and precise track alignment.
- **Safety measures**: Shinkansen trains are designed to minimise earthquake detection systems, automatic braking, and zero-fatality safety records.

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- **Energy efficiency**: The design incorporates lightweight materials and efficient power consumption, reducing environmental impact.
- **Passenger comfort**: Features like low vibration, noise reduction, and spacious seating ensure a smooth and enjoyable ride.

STUDENT ASSIGNMENTS

[Collaborative space]

[Take your notes]

Task 1: Challenge as a question

How can we build a faster and quieter passenger train?

Task 2: Exploratory questions

How can we further minimize the noise generated by high-speed trains, especially when passing through tunnels?

How does the kingfisher's beak shape reduce water resistance and noise during its dive?

Task 3: Primary goal

The primary goal is to design a high-speed train that addresses the noise pollution issue, particularly the "tunnel boom," while enhancing energy efficiency and maintaining high-speed performance.

Task 4: Design needs

The design must address the disruptive "tunnel boom" caused by high-speed trains passing through tunnels, which creates a loud sonic boom. It should also reduce air resistance to improve overall performance and reduce noise generated by aerodynamic factors, and enhance the train's speed and energy efficiency, allowing it to travel faster while consuming less electricity.

Task 5: Target audience

The target audience comprises engineers and designers, railway operators, residents near railways, and commuters.

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Task 6: Opportunities

- Innovative design inspiration.
- Noise reduction.
- Energy efficiency.
- Speed and performance.
- Market differentiation.
- Cross-industry applications.

Task 7: Connections to other solutions or challenges

- Aviation and aerospace.
- Automotive industry.
- Wind energy.
- Architecture and building design.
- Marine vessel design.
- Drones and UAVS (Unmanned Aerial Vehicles).
- Consumer products.
- Robotics.

Task 8: Favourable circumstances, initiatives or legislation

- Environmental legislation and green transportation Initiatives.
- Technological innovation initiatives.
- The Society 5.0 initiative.
- Noise and environmental regulations.
- International cooperation and agreements.
- Public and political support for high-speed rail.
- Investment in next-generation Shinkansen (the ALFA-X Project).

Task 9: Constraints or risks

1. Technical and engineering challenges

- Scaling biological designs for high-speed travel.

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	● Material limitations. **2. Cost and economic considerations** ● High R&D costs. ● Maintenance costs. **3. Environmental and operational risks** ● Weather and climate impact. ● Tunnel aerodynamics and pressure waves. **4. Biomimicry adaptations for different rail systems** ● Transferability to different rail networks. ● Adaptation to maglev and future technologies. **5. Regulatory and environmental constraints** ● Regulatory hurdles. ● Environmental impacts.

BIOMIMICRY DESIGN	Description
Step 2 – Biologize	**INFO** Analyse the essential functions and context your design solution must address. Reframe them in biological terms, so that you can "ask nature" for advice. In the context of biomimicry, the "Biologize" step involves the following tasks: ● **Identify biological models:** Research and identify organisms, ecosystems, or natural processes that exhibit the desired functions or characteristics you want to emulate in your design. ● **Understand biological principles:** Dive deep into understanding the underlying principles and mechanisms that make these biological models effective. This involves studying the anatomy, physiology, and behaviours of the organisms or systems you're interested in. ● **Translate biological strategies and consider opposite functions:** Translate the biological strategies into design principles that can be applied to your project. This means figuring out different natural processes that can be mimicked or adapted in a practical context.

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TASKS

Task 1

Read about the kingfisher, the owl and the penguin and solve the quiz.

Task 2

What did you observe in the videos presented? Write your observation using the concepts you discovered in the resources provided.

Task 3

State your challenge from the natural point of view. Ask yourself how nature can solve this.

Task 4

Identify what challenges the design aims to resolve.

Task 5

Look into an opposite function and try to flip the question which describes the challenge from the nature point of view.

RESOURCES PROVIDED BY TEACHERS TO STUDENTS

[Resource 1 – Interactive Book]

[Let's discover The Kingfisher]

Context

In nature, the **Kingfishers** can be found in deep forests near calm ponds and small rivers. They consume a wide range of prey, usually caught by swooping down from a perch. While kingfishers are generally thought to live near rivers and eat fish, many species live away from water and eat small invertebrates.

The Kingfisher's head and beak shape allow it to glide through the air and dive into water efficiently, transitioning from air to water

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seamlessly. Flying at speeds of up to 25 mph, its sharp, long beak slices through water silently, allowing for stealthy dives to catch fish. Despite the beak's length being a challenge in dark nests, Kingfisher chicks have white-tipped beaks, and parents have white facial flashes, providing visual cues for feeding.

How do Kingfishers dive and hunt?

- **Aerodynamics and precision:** Their streamlined body and sharp beak minimise water resistance, enabling a smooth entry into the water.
- **Vision adaptations:** Kingfishers have specialised binocular vision that compensates for light refraction in water, enabling them to judge the position of prey accurately.
- **Neurological protection:** Recent studies suggest that genetic mutations in the MAPT gene may help stabilise their brain structure, preventing concussions despite repeated high-impact dives.
- **Shock absorption:** Their skull structure and neck muscles are adapted to absorb the force of impact, similar to how woodpeckers protect their brains from injury.
- **Hunting strategy:** They hover or perch above water, lock onto their target, and dive at speeds of up to 25 miles per hour, grabbing fish with their sharp beak before resurfacing.

Fun facts about kingfishers and their fascinating dive while hunting

- **Minimal splash entry:** The kingfishers possess a streamlined beak and body that allows them to enter the water almost splash-free, thus helping them reduce the disturbance and improving their hunting success.
- **High-speed dives:** Some species of kingfisher dive at speeds of up to 25 miles per hour, ensuring a swift and accurate catch.
- **Shock absorption:** The skull structure of the kingfisher is adapted to absorb the impact of hitting the water, all the while preventing injuries.
- **Vision adaptation:** Kingfishers possess binocular vision, which compensates for light refraction in water, enabling them to pinpoint prey with remarkable accuracy.

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- **Instant capture:** Once the kingfisher spots a fish, they dives swiftly, grabs it with their beak, and returns to a perch to eat it.

[Resource 2 – Interactive Book]

[Let’s discover The Owl]

Context

In nature, **the owls** possess large, forward-facing eyes and ear-holes, a hawk-like beak, a flat face, and usually a conspicuous circle of feathers, a facial disc, around each eye. The feathers making up this disc can be adjusted to sharply focus sounds from varying distances onto the owls' asymmetrically placed ear cavities. Most owls share an innate ability to fly almost silently and also more slowly in comparison to other birds of prey. Most owls live a mainly nocturnal lifestyle, and being able to fly without making any noise gives them a strong advantage over prey alert to the slightest sound in the night. A silent, slow flight is not as necessary for diurnal and crepuscular owls, given that prey can usually see an owl approaching. Owls' feathers are generally larger than the average bird's feathers, have fewer radiates, longer pennulum, and smooth edges with different rachis structures.

How do owls fly so silently?

- **Wing structure:** Owls have large wings relative to their body size, allowing them to glide more and flap less, reducing noise.
- **Feather modifications**: Their flight feathers have comb-like serrations on the leading edge, which break up air turbulence. The trailing edge has a soft fringe, further dampening sound.
- **Velvety feather texture:** The surface of their feathers is covered in a soft, velvety layer, which absorbs sound waves and prevents noise from escaping.

Fun facts about owls and their fascinating silent flight

- **Feather engineering:** The owl’s flight feathers have serrated edges that break up air turbulence, while the soft fringe on the trailing edge absorbs sound, making their flight nearly noiseless.

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- **Velvety texture:** The surface of the owl's feathers has a soft, velvety layer that dampens sound waves, allowing them to approach prey undetected.
- **Large wings, slow flaps:** Owls have large wings relative to their body size, which lets them glide more and flap less, reducing noise even further.
- **Asymmetrical ears:** The owl's uneven ear placement helps them pinpoint sounds with extreme accuracy, making them a deadly hunter even in complete darkness.
- **Inspired technology:** Scientists have studied owl flight to develop quieter aircraft and wind turbines, applying nature's genius to engineering.

[Resource 3 – Interactive Book]

[Let's discover the Adélie penguins]

Context

In nature, the Adélie penguin is a species of penguin found along the entire coast of the Antarctic continent, which is the only place where it is found. The Adélie penguin is a truly Antarctic creature – one of only four penguin species to nest on the continent itself. Like all penguins, Adélies are excellent swimmers. They are also very determined and successful long-distance walkers, travelling across many kilometres of fast ice on the return journey to their colonies. Breeding adults swim between 5 and 120 km offshore to catch food for their chicks. Feeding trips range from 5 to 72 hours in duration.

Some Adélie penguins are capable of diving to depths of up to 175 meters, but they usually feed within the upper 70 meters of the water column.

How do Adélie penguins travel such great distances underwater to find food?

- **Streamlined body:** Their torpedo-shaped body minimises drag, allowing them to swim efficiently through the water.
- **Powerful flippers:** Their rigid, paddle-like wings function as flippers, generating strong propulsion with minimal energy expenditure.

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- **Efficient oxygen use:** They can slow their heart rate and redirect oxygen to vital organs, enabling them to hold their breath for several minutes while diving.
- **Deep diving ability:** Adélie penguins can dive to depths of 150 meters (490 feet) and stay submerged for extended periods to reach prey.
- **Hydrodynamic feathers:** Their dense, waterproof feathers trap air, reducing drag and providing insulation against freezing Antarctic waters.
- **Keen vision:** Their adapted eyesight enables them to see underwater, allowing them to track fast-moving prey such as krill and fish.

Fun facts about Adélie penguins and their fascinating long-distance swimming abilities

- **Speedy swimmers:** They can reach speeds of up to 9.3 mph (15 km/h) while hunting or escaping predators.
- **Deep divers:** Adélie penguins can dive to depths of 150 meters (490 feet), but the deepest recorded dive is 180 meters (590 feet)—like diving off a tall building.
- **Efficient hunters:** They can hold their breath for up to six minutes, allowing them to chase krill and fish underwater.
- **Built for the cold:** Their dense, waterproof feathers trap air, providing insulation and reducing drag while swimming.
- **Long Journeys:** Some Adélie penguins travel over 8,000 miles in a year, migrating between breeding and feeding grounds.

[Resource 4 – H5P Flash cards]

[Did you know]

Did you know that the kingfisher can hover before diving, allowing it to pinpoint its prey with incredible accuracy?

How?

Kingfishers can suspend themselves mid-air, using rapid wingbeats to maintain position while scanning the water below. Once they spot a fish, they tuck their wings and dive like a bullet, reaching speeds that

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	ensure a swift and efficient catch. Their eyes are adapted to compensate for water refraction, allowing them to judge the exact location of their prey even when looking through the water. After catching a fish, they often flip it headfirst before swallowing to avoid choking on its contents. [Resource 5 – H5P Flash cards] [Did you know] Did you know that the Adélie penguins are built for speed in water? They may waddle on land, but they transform into agile swimmers, reaching speeds of up to 9.3 mph when hunting or escaping predators. **How?** Their sleek, torpedo-shaped bodies reduce drag, allowing them to glide effortlessly through the water. Unlike typical bird wings, their flippers are rigid and strong, enabling rapid propulsion. When threatened by predators like leopard seals or orcas, they can accelerate quickly to evade capture. Adélie penguins often leap in and out of the water, reducing resistance and conserving energy. They can hold their breath for up to six minutes and dive as deep as 180 meters in search of food. [Resource 6 – H5P Find multiple hotspots] [I spy with my little eye] **Instructions** Let’s take a look at what you've discovered until now. Can you identify a Kingfisher in the interactive activity below?

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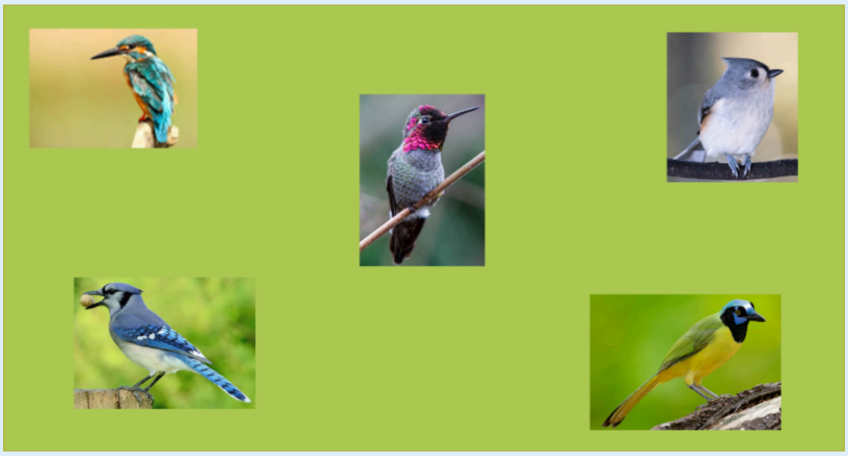
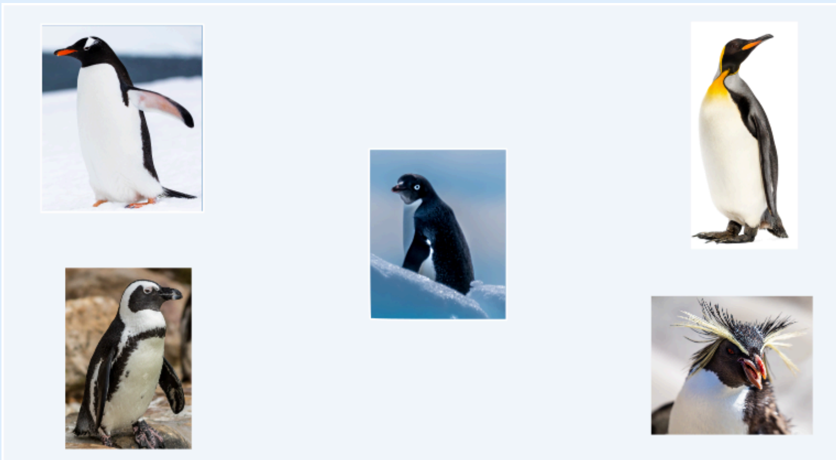


[Image to be used]

[Resource 7 – H5P Find multiple hotspots]

[I spy with my little eye]

Instructions: Let's take a look at what you discovered until now. Can you identify in the interactive activity below what an Adélie penguin looks like?



[Image to be used]

[Resource 8 – Link to video]

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[Let's watch]

Take a look at this video, which captures the life of an Adélie Penguin

https://www.youtube.com/watch?v=YKqXGNNPNaQ

[Resource 9 – Link to video]

[Let's watch]

Take a look at this video, which captures the feeding dive of a Kingfisher

https://www.youtube.com/watch?v=1CsyenHROSE

[Resource 10 – Link to video]

[Let's watch]

Take a look at this video, which captures the silent flight of an owl

https://www.youtube.com/watch?v=-WigEGNnuTE

[Resource 11 – The Kingfisher vs resistance & inaccuracy]

[Document]

The kingfisher represents a remarkable example of biomechanical optimisation in avian species, characterised by aerodynamic efficiency and precision targeting during flight and predation. Its anatomical adaptations include a streamlined body, a narrow conical beak, and a highly coordinated visual-motor system, which allow it to penetrate water with minimal splash and energy loss. These features have not only fascinated ornithologists but also inspired innovations in engineering and design.

In contrast, the conceptual framework of resistance and inaccuracy embodies the absence of such optimisation. Resistance, in this context, refers to increased drag forces acting against motion through

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air or fluid, typically due to suboptimal shape, turbulent flow interactions, or inefficient kinetic transfer. Inaccuracy, meanwhile, denotes a failure in spatial or temporal targeting, often resulting from deficiencies in sensorimotor coordination, control systems, or environmental adaptation.

Whereas the kingfisher exemplifies nature's pursuit of form-function synergy - minimising energy expenditure while maximising effectiveness - systems plagued by resistance and inaccuracy incur higher energy costs, reduced reliability, and diminished performance outcomes. This contrast underscores the kingfisher's relevance in fields such as biomimetic design, robotics, and aerodynamics, where minimizing drag and enhancing precision are critical to performance.

[Resource 12 – The Adélie penguins vs drag]

[Document]

Adélie penguins are a highly specialised Antarctic seabird species that demonstrate exceptional aquatic locomotion despite their flightless nature. As pursuit divers, Adélie penguins have evolved a suite of morphological and behavioural adaptations that minimize hydrodynamic drag, thereby enhancing swimming efficiency in cold, viscous marine environments.

Hydrodynamic drag is a form of resistance encountered by a body moving through water and is influenced by body shape, surface roughness, speed, and fluid properties. To reduce this resistance, Adélie penguins possess a fusiform (torpedo-shaped) body, enabling streamlined movement through water. Their feathers are densely packed and coated with a waterproofing layer of oil, creating a smooth, low-friction surface that reduces skin friction drag.

Additionally, microscopic air pockets trapped within the plumage may play a role in lowering drag during high-speed dives, a mechanism under active study in marine biomechanics. The penguins' flipper-like wings, which have evolved from avian forelimbs, function analogously to hydrofoils, generating both thrust and lift while minimizing turbulence. During locomotion, Adélie penguins exhibit precise control of body orientation and flipper motion to reduce pressure drag and avoid flow separation, particularly during rapid manoeuvres.

Research using high-speed video and computational fluid dynamics (CFD) simulations has confirmed that Adélie penguins can attain burst speeds exceeding 2 meters per second with remarkable agility. These performance traits are crucial not only for efficient foraging but also

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	for predator evasion, where minimizing drag translates directly into survival advantages. The study of Adélie penguins provides a compelling example of evolutionary engineering against not only hydrodynamic drag but drag in general, offering valuable insights for the fields of biomimetics, underwater robotics, and fluid dynamics.
	STUDENT ASSIGNMENT [Collaborative space] [Take your notes] **Task 1** Students access the interactive activity and click on the correct image. The platform will inform students about their answers (correct or incorrect) and provide a personalised message. **Task 2** In the first video, I can see that the Adélie penguins have a torpedo-shaped body that allows them to swim very fast and long distances. In the second video, I can see how the Kingfisher dives for its food, and in the third video, I can distinguish the silent flight of owls, in comparison to the flight of other birds, in this case, a pigeon and a falcon. **Task 3** ● How do owls fly so silently? ● How do Adélie penguins reduce air resistance? ● How do kingfishers dive into the water without a splash? **Task 4** **Identify what challenges the design aims to resolve** ● **High-speed, safer transportation:** Facilitates economic growth, regional development, and social integration by

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	linking major cities, improving business travel, commuting, and tourism. ● **Reduce congestion:** Offers a high-capacity rail service to ease road and air traffic, thereby relieving pressure on other rail systems. ● **Environmentally friendly:** It emits significantly less CO_2 per passenger-kilometre compared to cars or aeroplanes, supporting goals to reduce greenhouse gas emissions and promote sustainable transportation. **Task 5** How do birds improve their flight or swimming efficiency in their environmental conditions?

BIOMIMICRY DESIGN	Description
Step 3 – Discover	**INFO** Look for natural models (organisms and ecosystems) that require the same functions and context as your design solution. Identify the strategies used that support their survival and success. In the context of biomimicry, the “Discover” step involves the following tasks: ● **Explore nature:** Spend time discovering natural models to study various ecosystems and organisms. ● **Identify functions:** Look for specific functions or strategies in nature that can solve the design challenge you're facing. ● **Gather information:** Collect detailed information about biological models that exhibit the desired functions, including scientific research, case studies, and firsthand observations.
	TASKS **Task 1** Search for other natural models that match the same functions as the kingfisher, the owl, and the Adélie Penguin, and consider the context applied in your design solution. **Task 2** Identify experts and communities in the field of biomimicry.

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RESOURCES PROVIDED BY TEACHERS TO STUDENTS

[Resource 1 – Course presentation]

[Functions of the Kingfisher]

The kingfisher is an iconic bird worldwide, and it’s one of the most incredible species in the avian world. It’ll come as no surprise, given their name, that they’re expert fishers and feed on a diet of fish and other aquatic life, such as amphibians and crustaceans, when they are available. They swoop down and dive into the water to catch their prey, but some species live in wooded areas, employing hunting techniques that're a little less conventional. Aside from forests, kingfishers are found in a range of different habitats around the globe, including coastal regions, grasslands, deserts, rivers, and lakes. They’re so widespread and diverse that they’re found on every continent except for Antarctica.

Detailed functions of Kingfishers

- **Ecosystem indicator:** Kingfishers rely on clean, unpolluted water to hunt for fish and aquatic insects. Their presence often signals a healthy environment, while their decline can indicate pollution or habitat degradation.
- **Seed dispersers:** Some kingfisher species consume fruits and berries, unintentionally aiding in seed dispersal as they excrete seeds in various locations, thereby facilitating plant regeneration.
- **Cultural symbol:** Across various cultures, kingfishers symbolize peace, prosperity, and patience. In Greek mythology, the Halcyon bird (often linked to kingfishers) was believed to bring calm seas.

Additional insights

- **Environmental adaptation:** Depending on the different habitats in which they live, kingfisher have adapted their feeding techniques. For example, there have been reports of the red-backed kingfisher using its beak to hammer into fairy martin nests to feed on the young. This demonstrates how different species adapt to their environment.

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[Resource 2 – Course presentation]

[Functions of the Owl]

All owls share the same general body plan. The wings are long and rounded, the tail short. The legs and toes are of medium length and exceptionally strong for the size of the bird. Owls vary in colour from white through many shades of tan, grey, brown, or rufous (reddish) to deep brown. A few are solidly coloured, but most are cryptically patterned with streaks, bars, or spots, often resulting in the birds being almost invisible against tree bark.

Detailed functions of owls

- **Top predator:** As nocturnal hunters, owls help regulate populations of rodents, insects, and small mammals, maintaining ecological balance.
- **Ecosystem indicator:** Owls are sensitive to environmental changes, and their presence often signals a healthy habitat.
- **Natural pest control:** By feeding on rodents, owls help control populations that might otherwise damage crops or spread disease.
- **Cultural symbol:** Owls have been associated with wisdom, mystery, and protection in various cultures throughout history.

Additional insights

- **Ecosystem stability**: By keeping prey populations in check, owls prevent resource depletion and maintain biodiversity.
- **Adaptability**: Owls thrive in various environments, from dense forests to urban areas, showcasing their ability to adjust to changing landscapes.

[Resource 3 – Course presentation]

[Functions of the Adélie penguins]

Of the 18 penguin species currently recognized by science, none are quite as mischievous as the Adélie Penguin (Pygoscelis adeliae). These birds live in large colonies along the rocky banks of Antarctica. Adélies, like most penguins, are very dedicated parents, building small nests out of stones to protect their chicks. Many of these parents even steal

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stones from other nests to protect their own! Although Adélie Penguins fit the typical morphological description of most penguins (awkward, round, and stubby-legged), they are capable of accomplishing incredible physical feats. They migrate up to 31 miles every spring on foot! Like all penguins, they are also capable swimmers. Adélie penguin chicks can swim on their own at the young age of 9 weeks.

Detailed functions of Adélie penguins

- **Ecosystem indicator:** Adélie penguins are considered indicator species because their population trends reflect environmental changes, particularly in response to climate shifts and sea ice conditions.
- **Krill population control:** Their diet consists mainly of krill, helping regulate krill populations and maintain balance in the Antarctic food web.
- **Prey for larger predators:** They serve as an essential food source for leopard seals and orcas, contributing to the predator-prey dynamics of the Antarctic ecosystem.
- **Nutrient cycling:** Their colonies produce large amounts of guano (penguin droppings), which enriches the soil and supports microbial life in Antarctica.
- **Climate change indicators:** Changes in their population and breeding patterns provide valuable insights into the effects of global warming on Antarctic ecosystems.

Additional insights

- **Feisty fighters:** Despite their small size, Adélie penguins are known to be aggressive when defending their nests, sometimes even slapping intruders with their flippers.
- **Pebble thieves:** Males build nests using small rocks to attract mates, but if they need more, they steal pebbles from their neighbours' nests.
- **Ancient DNA secrets:** Studies of ancient Adélie penguin DNA have revealed how their diet and habitat have changed over 6,000 years, offering insights into Antarctic climate history.

STUDENTS ASSIGNMENTS

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	[Collaborative space] [Take your notes] **Task 1** **Natural models** ● **Sharks**: Their skin texture reduces drag and prevents biofouling, inspiring efficient ship and aircraft surfaces. ● **Dolphins**: Streamlined bodies and powerful tails enable high-speed swimming and acrobatics. They use echolocation for efficient navigation and hunting. ● **Birds of prey**: Wing shapes and flight mechanics of falcons and eagles influence aircraft wing design for better lift and manoeuvrability. ● **Hummingbirds**: Agile and fast, they hover, fly backwards, and change direction rapidly due to their unique wing structure and high metabolism. ● **Albatrosses**: Masters of gliding flight, they travel vast distances with minimal energy using long, narrow wings for dynamic soaring. ● **Bats**: Only mammals capable of sustained flight, they possess flexible wings that enable precise control. They use echolocation to navigate and hunt efficiently in the dark. **Task 2** **Identify experts and communities in the field of biomimicry.** ● National Geographic. ● Journal of Ornithology. ● University Research Departments. ● iNaturalist. ● American Society of Naturalists. ● AskNature.

BIOMIMICRY DESIGN	Description
Step 4 – Abstract	**INFO**

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Carefully study the essential features or mechanisms that make the biological strategies successful. Restate them in non-biological terms, referring to them as "design strategies."

In the context of biomimicry, the "Abstract" step involves the following tasks:

- **Extract principles:** Identify and extract the underlying principles and strategies from the biological model you have studied. This means understanding the core functions and mechanisms that make these natural solutions effective.
- **Generalise concepts:** Generalise these biological principles so they can be applied to a wide range of design challenges. This involves translating specific biological strategies into broader design concepts that are not tied to a particular organism or ecosystem.
- **Create analogies:** Develop analogies that link the biological principles to human design challenges. These analogies help bridge the gap between nature and technology, making it easier to apply natural strategies to human-made systems.

TASKS

Task 1

From the core function presented, summarise the key elements of the biological strategy of the kingfisher, the owl and the Adélie Penguins, by defining the function and identifying relevant keywords.

Task 2

Make a diagram/ drawing and/ or find images of a kingfisher, an owl and an Adélie Penguin.

Task 3

Translate lessons from nature into design strategies. Rewrite the strategy without using biological terms and connect it to the functions and the context from a human perspective.

Task 4

Describe the context and the human perspective of the design.

Task 5

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Create a diagram or drawing, and/or find images of the design of your solution.

RESOURCES PROVIDED BY TEACHERS TO STUDENTS

[Resource 1 – Core functions of Kingfishers]

[H5P Flashcards]

Core functions

- **Predation and feeding:** Most kingfishers feed on fish, but many also eat insects, amphibians, crustaceans, and small reptiles. They use sharp vision to spot prey, often from a perch, then dive swiftly to catch it with their strong beaks.
- **Nesting and breeding:** Kingfishers typically nest in burrows that they dig into riverbanks, sandy soil, or tree cavities. Both parents usually share duties like incubating eggs and feeding chicks.
- **Territorial behaviour:** Most species are highly territorial, especially during the breeding season, when they aggressively defend their feeding and nesting areas.
- **Ecosystem role:** Insects and small animals in their diet make them natural pest controllers. They are also part of the food web, serving as prey for larger birds and mammals.
- **Communication:** Use calls, posturing, and sometimes displays to communicate territory, mating intentions, or warnings.

[Resource 2 – Core functions of Owls]

[H5P Flashcards]

Core functions

- **Nocturnal predation:** Most owls are carnivorous, feeding on rodents, insects, birds, and other small animals. Their exceptional night vision, silent flight, and acute hearing enable them to hunt efficiently in the dark.
- **Nesting and reproduction:** Owls use tree cavities, abandoned nests, cliffs, or nest boxes, depending on species. Both

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parents, especially the female, care for the eggs and young, providing food and protection.

- **Camouflage and stealth:** Many owls have plumage that blends into their surroundings, helping them remain undetected by both prey and predators.
- **Territorial defence:** Owls are generally territorial, especially during breeding season, using calls and sometimes physical aggression to defend their range.
- **Communication:** Vocalisations (hoots, screeches, whistles) serve to establish territory, attract mates, and communicate with offspring.

[Resource 3 – Core functions of Adélie Penguins]

[H5P Flashcards]

Core functions

- **Foraging and feeding:** They feed mainly on krill, fish, and squid. Adélie penguins are excellent swimmers and divers, using their flippers to chase prey underwater.
- **Nesting and reproduction:** They breed in large colonies on ice-free coastal areas during the Antarctic summer. Both parents take turns incubating eggs and feeding chicks, ensuring high parental investment.
- **Prey and predator:** They help regulate the populations of krill and small fish, serving as prey for leopard seals, skuas, and orcas.
- **Nutrient cycling:** Their guano (droppings) enriches the terrestrial ecosystem, supporting mosses and microbes in an otherwise nutrient-poor environment.
- **Migration and sea ice dependency:** They migrate between breeding colonies and foraging grounds, often travelling hundreds of kilometres. Their life cycle is tightly linked to the seasonal formation and melting of sea ice.
- **Social structure and communication:** They rely on vocalisations and body language for mate recognition, territory defence, and chick rearing in crowded colonies.

STUDENT ASSIGNMENTS

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[Collaborative space]

[Take your notes]

Task 1

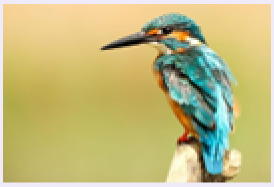
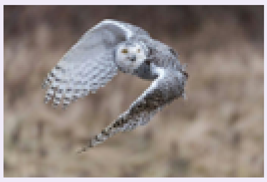
1. **Owls**
   - **Core functions:** Silent flight, noise reduction.
   - **Keywords:** Silent hunters, feather structures, serrated. Feathers, fringe-like structures, turbulence, concave faces, downy bodies.
2. **Adélie penguins**
   - **Core functions:** Efficient swimming, drag reduction, deep diving.
   - **Keywords:** Exceptional swimmers, powerful flippers, torpedo-shaped bodies, rear-placed legs, drag reduction, fluffing feathers, releasing bubbles, porpoising, diving, swallowing stones.

3. Kingfisher

- **Core functions:** Efficient diving, stealthy hunting
- **Keywords:** Head and beak shape, glide, dive, transition, sharp beaks, silent dives, visual cues, white-tipped beaks, white facial flashes

Task 2

Image of a kingfisher, an owl and an Adélie penguin.


Photos of a kingfisher, an owl and an Adélie penguin

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Task 3

1. **Noise reduction and efficiency**
    - **Problem:** The trains created disruptive noise when exiting the tunnels.
    - **Solution:** Redesign the train's front to minimize noise and enhance efficiency.
    - **Outcome:** The new design enabled the train to travel 10% faster, use 15% less electricity, and eliminate the need for the tunnel boom.
2. **Aerodynamic optimisation**
    - **Problem:** High-speed travel caused significant air resistance.
    - **Solution:** Streamline the train's body to reduce air resistance.
    - **Outcome:** The streamlined design further reduced air resistance, contributing to the train's improved performance.

Task 3

Describe the context and the human perspective of the design.

- **Function:** The primary goal is to create a quieter, more efficient high-speed train.
- **Human impact:** The redesign not only solved the noise problem, making the environment more pleasant for nearby residents, but also improved the train's speed and energy efficiency. This innovation demonstrated the potential for sustainable solutions in transportation and other industries, highlighting how design inspired by natural principles can lead to significant advancements in technology and efficiency.

Task 4

Image of a fan.

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	 Photo of the Japanese Shinkansen bullet train (Copyright: https://medium.com/@StammBio/what-is-biomimicry-the-train-and-the-kingfisher-1a459ef21af0)

BIOMIMICRY DESIGN	**Description**
Step 5 – Emulate	**INFO** In the context of biomimicry, the "Emulate" step involves the following tasks: ● **Apply biological principles:** Implement the biological strategies and principles you have abstracted into your design. This involves taking the insights gained from nature and applying them directly to create innovative solutions. ● **Prototype development:** Develop prototypes that incorporate the biomimetic principles. This involves creating models or samples that demonstrate how the natural strategies can be used in practical applications. ● **Integration:** Integrate the biomimetic design into the final product or system, ensuring that natural strategies are seamlessly incorporated and that the design meets all necessary criteria and constraints.
	TASKS **Task 1** Do the practical example and note your findings. **Task 2** Identify as many ideas as possible for designing your solution.

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Task 3

Organise your ideas into categories that include features, context, and constraints.

Task 4

Select the design concept (ideas) that best fit your solution.

RESOURCES PROVIDED BY TEACHERS TO STUDENTS

H5P [Resource 1 – Look into]

[H5P Course presentation]

When designing a high-speed train inspired by the head and beak of a Kingfisher, the silent flight of an Owl and the streamlined body of an Adélie Penguin, consider the following essential features to guide your ideas:

1. **Aerodynamics (Adélie penguin influence)**
   - **Streamlined body**: The train should have smooth, curved surfaces to minimize air resistance, just like how Adélie penguins glide through water effortlessly.
   - **Reduced drag**: Incorporate a shape that allows high-speed movement with minimal energy consumption.
2. **Noise reduction (owl Influence)**
   - **Serrated edge technology**: Inspired by the owl's silent flight, using fine-edge structures on the train's surfaces can reduce wind turbulence and minimize sound.
   - **Sound-absorbing materials**: Apply special coatings to dampen noise generated by airflow and vibrations.
3. **Speed and efficiency (Kingfisher influence)**
   - **Beak-shaped nose**: Mimic the kingfisher's beak for smooth entry into tunnels, preventing sudden air pressure changes and shockwaves.
   - **Precision engineering**: Lightweight materials for enhanced speed without sacrificing durability.

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4. Environmental adaptability

- **Climate-responsive adjustments**: Like how animals instinctively adjust to their environments, the train's aerodynamics should optimise for wind resistance.
- **Energy efficiency**: Advanced propulsion systems should reduce energy waste while maximising acceleration.

STUDENTS ASSIGNMENT

[Collaborative space]

[Take your notes]

Task 1: *Students record their findings in the Record sheet provided.*

Task 2:

Ideas:

1. Noise reduction:

- Mimic natural shapes to reduce aerodynamic noise.
- Implement serrations or other noise-dampening features on critical components.
- Use materials that absorb or deflect sound.

2. Efficiency improvement:

- Streamline designs to reduce air resistance.
- Optimise energy consumption through design changes.
- Incorporate features that enhance speed without increasing energy use.

3. Sustainable innovation

- Apply biomimicry principles to other transportation modes.
- Explore natural solutions for common engineering problems.
- Promote designs that balance performance with environmental impact.

Task 3

Features

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	● **Redesigned front end:** Mimics kingfisher's beak to reduce noise. ● **Serrations on the pantograph:** Reduce aerodynamic noise. ● **Streamlined body:** Influenced by the Adélie penguin to reduce air resistance. **Context** ● **High-speed travel:** Trains travelling at 200+ mph. ● **Noise pollution:** The Tunnel boom is disturbing residents. ● **Energy efficiency:** Need to reduce electricity consumption. **Constraints** ● **Decibel limit:** Must meet noise regulations (70 dB). ● **Aerodynamic challenges:** High speeds increase noise and resistance. ● **Design integration:** Changes must fit within the existing train infrastructure. **Task 4** Streamlined body design of a train inspired by the Adélie penguin. ● **Function:** Reduce air resistance and improve efficiency. ● **Context:** High-speed, energy-efficient travel.
BIOMIMICRY DESIGN	**Description**
Step 6 – Evaluate	**INFO** In the context of biomimicry, the "Evaluate" step involves the following tasks: ● **Assess performance:** Evaluate the performance of your biomimetic design against the criteria and constraints defined earlier. This involves testing the design to see how well it meets the desired impact and functional requirements. ● **Compare with biological models:** Compare the effectiveness of your design with the biological models that inspired it, and determine whether the design successfully emulates natural strategies and achieves similar results.

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- **Gather feedback:** Collect feedback from users, stakeholders, and experts to understand how well the design performs in real-world conditions. This feedback is crucial for identifying areas of improvement.
- **Analyse data:** Analyse the data collected during testing and feedback to identify strengths and weaknesses in the design. Look for patterns and insights that can inform further refinements.
- **Iterate and improve:** Based on the evaluation, make necessary adjustments and improvements to the design. This iterative process ensures that the final product is optimised for performance and sustainability.

TASKS

Task 1

Evaluate the design concept concerning its alignment with the design challenge's criteria and constraints, as well as its compatibility with Earth's systems. Assess the feasibility of both the technical and business models.

Task 2

Revise and revisit previous steps as necessary to generate a viable solution.

STUDENT ASSIGNMENTS

[Collaborative space]

[Take your notes]

Task 1

The design concepts for the kingfisher, owl, and Adélie penguins-inspired bullet train align well with the challenge's criteria, offering reduced energy consumption, reduced noise pollution, high-speed travel strength, and regulatory compliance.

Such a design can be compatible with Earth's systems by reducing environmental impact, thanks to its reduced energy consumption and lower greenhouse gas emissions, as well as its resource efficiency. The

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	technical model is feasible due to the streamlined design as it involves modifying the train's exterior shape. This can be achieved with current engineering capabilities and materials. The business model is also feasible because the design offers cost savings through reduced energy consumption and maintenance costs. The improved efficiency and compliance with noise regulations can enhance the train's marketability and operational viability. **Task 2** By revising and refining each design concept, the new high-speed train can be better aligned with the design challenge criteria, ensuring that the streamlined body design is compatible with existing train infrastructure and does not require extensive modifications. This will enhance noise reduction features and maintain the sustainability focus. The final design will address the design challenge by reducing air resistance, improving energy efficiency, and minimising noise pollution. By integrating this design with additional noise reduction features and focusing on sustainability, the solution aligns with the criteria and constraints, ensuring technical and business model feasibility.

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TM 09 Safe, waterless and portable toilets

BIOMIMICRY DESIGN	Description
Step 1 – Define the challenge	**INFO** Clearly express the desired impact of your design on the world, along with the specific criteria and limitations that will measure its success. In the context of biomimicry, the "Define" step involves two main tasks: ● **Describe the challenge:** This means you need to understand what your design needs to do, for whom, and in what context. ● **Criteria and constraints:** These are the standards and limitations that will help you evaluate whether you will be successful. Criteria might include factors like cost-effectiveness, durability, and environmental friendliness. Constraints could be things like budget limits, material availability, or regulatory requirements.
	TASKS **Task 1** Define the challenge as a question. **Task 2** Define the exploratory questions. **Task 3** Define the primary goal. **Task 4** Define the design needs. **Task 5** Define the target audience. **Task 6** Define the context and the locations or settings for the implementation.

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	Task 7 Identify the opportunities and/ or constraints that might impact achieving a successful outcome. **Task 8** Identify the connections to other solutions or challenges. **Task 9** Identify the favourable circumstances, initiatives or legislation. **Task 10** Identify the limitations or risks.
	RESOURCES PROVIDED BY TEACHERS TO STUDENTS [Resource 1 - H5P Course presentation/Interactive Book] [Define the challenge] **Challenge** The challenge given is to design a portable toilet that combines both aesthetic appeal and high efficiency, drawing inspiration from the unique properties of waterless sanitation systems. **Key concepts to follow** ● **Regulatory hurdles:** Compliance with local health and safety regulations can complicate the design and implementation process. ● **Technical challenges**: Ensuring the toilets are effective in different environments (e.g., varying climates and soil types) may present engineering challenges**.** ● **Functionality:** The toilet should be easy to install, operate quietly, and provide effective sanitation without the need for water

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	STUDENT ASSIGNMENTS [Collaborative space] [Take your notes] **Task 1: Challenge as a question** How can we build safe portable toilets that effectively manage waste while conserving water and minimizing environmental impact at a low cost? **Task 2: Exploratory questions** How can the design of portable toilets be optimized to reduce water usage without compromising hygiene? How can the principles of evapotranspiration be used to reduce water usage for hygiene further? **Task 3: Main goal** The primary objective is to deliver safe, accessible, and effective sanitation solutions to the 2.6 billion people worldwide who lack adequate toilet access, with a particular focus on addressing the needs of vulnerable communities. **Task 4: Design needs** The design needs to provide safe, accessible, and effective sanitation solutions for communities lacking proper toilet access. It must address the specific needs of vulnerable communities and ensure hygiene without relying on power or plumbing. Additionally, it should be rapidly deployable in off-grid, rural, and post-crisis areas, offering a sustainable and environmentally safe way to manage human waste. **Task 5: Target audience** ● **Users**: Individuals with limited access to traditional sanitation facilities, including those in rural communities, outdoor event attendees, and disaster relief recipients. ● **Local governments:** Authorities responsible for public health and sanitation management, especially in regions with an inadequate waste disposal system.

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	● **Environmental organisations:** Groups focused on sustainability and reducing water usage, advocating for eco-friendly sanitation solutions. ● **Manufacturers:** Companies involved in producing portable sanitation solutions, which may need to adapt their designs to incorporate new technologies. **Task 6: Context and locations** **Context** ● **Rural areas**: Regions with limited infrastructure and access to traditional sewage systems. ● **Disaster relief zones**: Areas affected by natural disasters where rapid deployment of sanitation solutions is critical. ● **Outdoor events**: Festivals, concerts, and sports events where traditional facilities may be insufficient. ● **Developing urban areas**: Growing cities where rapid urbanization outpaces sanitation infrastructure development. **Task 7: Opportunities and constraints** **Opportunities** ● Market demand. ● Sustainability focus. ● Technological advancements. ● Government support. ● Public health improvement. **Constraints** ● **Cost**: Developing and deploying new technologies can be expensive, limiting accessibility for low-income communities. ● **Cultural acceptance**: Variability in cultural attitudes towards sanitation can impact the adoption of new toilet designs. ● **Technical challenges**: Ensuring the toilets are effective in different environments (e.g., varying climates and soil types) may present engineering challenges.

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- **Maintenance**: Users may need training on how to maintain and operate these toilets, which could be a barrier in some areas.
- **Regulatory hurdles**: Compliance with local health and safety regulations can complicate the design and implementation process.

Task 8: Connections to other solutions or challenges

- Composting toilets
- Rainwater harvesting
- Biogas generation
- Eco-friendly building materials
- Mobile health clinics

Task 9: Favourable circumstances, initiatives or legislation

- **Human rights to water and sanitation**: Governments must take a human rights-based approach to water and sanitation improvements, ensuring access to sufficient, safe, acceptable, physically accessible, and affordable water for personal and domestic use
- **Reinvent the toilet challenge**: Initiatives like the Gates Foundation's Reinvent the Toilet Challenge aim to develop affordable, safe sanitation solutions that meet community needs and build climate resilience.
- **Sustainable development goals**: Global goals such as the United Nations Sustainable Development Goal 6.2 and national mandates like China's Toilet Revolution and India's Swachh Bharat Mission emphasize the importance of safe sanitation

Task 10: Limitations or risks

Limitations

- **Capacity constraints**: Portable toilets have limited waste storage capacity, which may require more frequent emptying and maintenance, especially in high-traffic areas.
- **Performance in extreme conditions**: Their effectiveness can vary based on environmental factors, such as temperature, humidity, and soil type, which may affect waste breakdown and odour control.

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	● **User education**: Users may need training to understand how to properly use and maintain the systems, which could limit adoption in some communities. ● **Initial costs**: The upfront investment for advanced technologies may be higher compared to traditional toilets, potentially limiting access in low-income areas. ● **Cultural resistance**: Variations in cultural practices and beliefs about sanitation can pose challenges to the acceptance and widespread adoption of these practices. **Risks** ● **Health risks:** Improper maintenance or malfunction of portable toilets could lead to health hazards, such as exposure to pathogens or odours. ● **Environmental impact: If** not designed properly, systems may leak or improperly treat waste, leading to soil and water contamination. ● **Regulatory compliance:** Navigating local health and safety regulations can be complex, and non-compliance may result in legal issues or project delays. ● **Vandalism and theft:** In specific settings, portable toilets may be vulnerable to vandalism, resulting in additional costs and resources required for repair or replacement. ● Sustainability of resources: Reliance on specific materials or technologies may pose risks if those resources become scarce or if supply chains are disrupted.

BIOMIMICRY DESIGN	Description
Step 2 – Biologize	**INFO** Analyse the essential functions and context your design solution must address. Reframe them in biological terms, so that you can “ask nature” for advice. In the context of biomimicry, the “Biologize” step involves the following tasks: ● **Identify biological models:** Research and identify organisms, ecosystems, or natural processes that exhibit the desired

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	functions or characteristics you want to emulate in your design. ● **Understand biological principles:** Dive deep into understanding the underlying principles and mechanisms that make these biological models effective. This involves studying the anatomy, physiology, and behaviours of the organisms or systems you're interested in. ● **Translate biological strategies and consider opposite functions:** Translate the biological strategies into design principles that can be applied to your project. This involves identifying different natural processes that can be mimicked or adapted in a practical context.
	TASKS **Task 1** Solve the quiz related to safe, waterless, and portable toilets. **Task 2** What did you observe in the video presented? Write your observation using the concepts you discovered in the resources provided. Video Link: [Innovative Waterless Toilets: A Path to Eco-Friendly Sanitation]() **Task 3** State your challenge from the natural point of view. Ask yourself how nature can address this issue. **Task 4** Identify key functions applicable to nature's contexts. **Task 5** Consider the opposite function and try to rephrase the question that describes the challenge from a natural perspective. **Task 6**

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You are given three natural models: termite mounds, cactus spines or animal nostrils. Pick up a natural model, and explain in a note how airflow is restricted or managed.

RESOURCES PROVIDED BY TEACHERS TO STUDENTS

[Resource 1 – Interactive Book]

[Let's discover evapotranspiration]

Context

Nature provides several solutions to sanitation challenges through efficient waste management and resource recycling. For example, Wetlands filter pollutants from water through plant roots and microbial activity. This principle can be applied to sanitation systems that treat waste and recycle water, ensuring cleanliness and ecological balance.

Core functions

- **Water transport:** Evapotranspiration involves the movement of water from the soil through the plant and out through the stomata in the leaves. This process helps transport essential nutrients from the soil to various parts of the plant.
- **Cooling mechanism:** As water evaporates from the stomata, it cools the plant, much like sweating cools the human body. This helps maintain optimal temperatures for metabolic processes.
- **Nutrient uptake:** The upward movement of water through the plant aids in the uptake and distribution of nutrients dissolved in the water. This is crucial for the plant's growth and development.
- **Water cycle contribution:** Evapotranspiration contributes to the water cycle by returning water vapour to the atmosphere. This process is essential for maintaining the balance of water in the environment.

[Resource 2 – H5P Quiz (Question Set]

[Correct answer]

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Quiz

Which of the following descriptions best represents the process of evapotranspiration?

a) The process by which water vapour is released from the leaves of plants and evaporates from the soil.

b) The process by which plants absorb nutrients from the soil.

c) The process by which water condenses to form clouds.

d) The process by which animals release water vapour through respiration.

[Resource 3 – Link to video]

[Let’s watch]

How did trees inspire the ‘sustainable superstar’ of toilets?

https://thekidshouldseethis.com/post/how-did-trees-inspire-the-sustainable-superstar-of-toilets

[Resource 4 - The development of safe, waterless, and portable toilets offers innovative solutions]

[Document]

Sanitation is a critical aspect of public health and environmental sustainability. The development of safe, waterless, and portable toilets offers innovative solutions to address the challenges of traditional sanitation systems. By drawing inspiration from advanced technologies and sustainable practices, we can enhance the efficiency and functionality of these toilets.

1. Waterless efficiency

- **Waterless toilets** utilise advanced sanitation systems to manage waste without the need for water. This principle can be applied in various ways:

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- **Composting toilets**: These toilets use aerobic decomposition to break down waste into compost. By optimizing the design and materials, composting toilets can efficiently manage waste while reducing environmental impact.
- **Chemical toilets**: Chemical toilets use chemicals to neutralise waste and control odours. The design can be enhanced to ensure safe and effective waste management in portable applications.
- **Solar-Powered Toilets**: Innovative designs incorporate solar power to process waste, making them suitable for remote or off-grid locations. Solar-powered toilets offer sustainable sanitation solutions that do not rely on traditional infrastructure.

2. Functionality

Adequate sanitation requires toilets that are easy to install, operate quietly, and provide efficient waste management. Key aspects include:

- **User-friendly operation**: Designing toilets that are simple to use and maintain. Features such as easy-to-clean surfaces and intuitive controls can improve the user experience.
- **Quiet operation**: Ensuring that the toilets operate quietly to avoid disturbance in various settings, including residential areas and public events.
- **Efficient waste management**: Incorporating technologies that effectively process waste and control odours. This can include ventilation systems inspired by natural principles to enhance airflow and reduce unpleasant smells.

STUDENT ASSIGNMENT

[Collaborative space]

[Take your notes]

Task 1

Students access the interactive activity and click on the correct image. The platform will inform students about their answers (correct or incorrect) and provide a personalised message.

Task 2

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	In the video, I can see that the focus is on how these toilets contribute to sustainable sanitation solutions by eliminating the need for water, thus conserving resources and reducing environmental impact. Key points include the eco-friendly design of the toilets, expert insights into their benefits and functionality, real-life application experiences, and the sustainability benefits of conserving water and promoting environmental health. **Task 3** How does nature solve natural filtration? **Task 4** **Summary of key functions applicable to nature's contexts** ● Waste containment. ● Natural decomposition. ● Odour control. ● Water conservation. ● Ease of transport. **Contexts in nature** ● Wetland ecosystems. ● Composting systems. ● Plant water storage. ● Forest canopies. ● Insect habitats. **Task 5** How can nature restrict or block natural filtration? **Task 6** **Cactus spines** Cactus spines play a crucial role in managing airflow around the plant. They create a microclimate by reducing wind speed and providing shade, which helps to minimize water loss through evaporation. This

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	principle can be applied to the design of safe, waterless, and portable toilets in the following ways: ● **Ventilation management**: By incorporating structures similar to cactus spines, portable toilets can have improved airflow management. This can help in reducing odours and maintaining a more comfortable environment inside the bathroom. ● **Temperature regulation:** The shading effect of cactus spines can inspire designs that keep the interior of portable toilets cooler, especially in hot climates. This can be achieved by using materials or structures that mimic the shading and airflow reduction properties of cactus spines. ● **Water conservation**: Just as cactus spines help in conserving water by reducing evaporation, similar design elements can help in minimizing the need for water in portable toilets. This can be particularly useful in creating efficient, waterless sanitation solutions.

BIOMIMICRY DESIGN	Description
Step 3 – Discover	**INFO** Look for natural models (organisms and ecosystems) that require the same functions and context as your design solution. Identify the strategies used that support their survival and success. In the context of biomimicry, the "Discover" step involves the following tasks: ● **Explore nature:** Spend time discovering natural models to study various ecosystems and organisms. ● **Identify functions:** Look for specific functions or strategies in nature that can solve the design challenge you're facing. ● **Gather information:** Collect detailed information about biological models that exhibit the desired functions, including scientific research, case studies, and firsthand observations.
	TASKS **Task 1** Search for other natural models that match the same functions as the Sycamore seeds and apply some context to your design solution.

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	Task 2 Identify experts and communities in the field of biomimicry.
	RESOURCES PROVIDED BY TEACHERS TO STUDENTS [Resource 1 – Course presentation] [Functions of Safe, waterless, and portable toilets] **Safe, waterless, and portable toilets: A marvel of modern engineering** Safe, waterless, and portable toilets represent a significant advancement in sanitation technology. Their design is optimised to provide hygienic and efficient waste management without the need for water. These toilets are crucial in areas where water is scarce or where traditional plumbing is not feasible. **Detailed functions of safe, waterless, and portable toilets** **1. Efficient waste management** ● **Innovative design:** The unique structure of these toilets allows for effective waste separation and containment. This design minimises the risk of contamination and ensures that waste is managed hygienically. ● **Energy conservation:** By eliminating the need for water, these toilets conserve energy and resources, making them ideal for use in remote or resource-limited areas. **2. Silent operation** ● **Quiet operation:** The operation of these toilets is almost silent, thanks to their smooth and efficient design, which minimises noise during use. ● **Stealthy disposal:** The quiet operation ensures that waste can be managed discreetly, without attracting attention or causing disturbance. **3. Additional insights** ● **Environmental adaptation:** The ability to function without water helps these toilets adapt to various environments. They

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can be used in areas with limited water supply, ensuring sanitation even in challenging conditions.

- **Biodiversity contribution:** By providing safe and hygienic waste management, these toilets contribute to the health of the ecosystem, helping to prevent contamination of water sources and supporting the well-being of the community.

STUDENTS ASSIGNMENTS

[Collaborative space]

[Take your notes]

Task 1

Natural models

1. Wetland plants (e.g., cattails and reeds)

- **Function:** Waste containment and natural filtration
- **Model:** Wetland plants thrive in waterlogged environments, helping to filter pollutants from water through their root systems. They contain and manage nutrients, making them effective at maintaining ecosystem health.

2. Termite mounds

- **Function:** Natural decomposition and odour control
- **Model:** Termite mounds maintain a stable internal environment that promotes the breakdown of organic materials. The mounds have ventilation systems that regulate temperature and humidity, helping to control odours and facilitate decomposition.

3. Composting worms (e.g., red wigglers)

- **Function:** Waste breakdown and nutrient cycling
- **Model:** These worms play a crucial role in composting by breaking down organic waste into nutrient-rich soil. Their burrowing behaviour aerates the compost, promoting decomposition and improving soil quality.

4. Succulent plants (e.g., aloe vera)

- **Function:** Water conservation and storage
- **Model:** Succulents store water in their leaves, allowing them to survive in arid conditions. This adaptive strategy can inspire

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	designs that minimise water use and effectively manage waste without requiring large amounts of water. **5. Nutrient cycling in forest ecosystems** ● **Function:** Decomposition and soil enrichment ● **Model:** The natural process in forest ecosystems, where dead plant material decomposes and enriches the soil, can inform composting toilet designs that recycle waste into usable compost to enrich the soil. **Task 2** **Experts and communities in the Biomimicry area** ● Universities with environmental science or biology departments. ● Research centres. ● Ecological Society of America (ESA). ● Society for Conservation Biology. ● The Nature Conservancy. ● ResearchGate. ● Ecological conferences. ● Local nature workshops.

BIOMIMICRY DESIGN	Description
Step 4 – Abstract	**INFO** Carefully study the essential features or mechanisms that make the biological strategies successful. Restate them in non-biological terms, as “design strategies.” In the context of biomimicry, the “Abstract” step involves the following tasks: ● **Extract principles:** Identify and extract the underlying principles and strategies from the biological model you have studied. This means understanding the core functions and mechanisms that make these natural solutions effective.

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- **Generalise concepts:** Generalise these biological principles so they can be applied to a wide range of design challenges. This involves translating specific biological strategies into broader design concepts that are not tied to a particular organism or ecosystem.
- **Create analogies:** Develop analogies that link the biological principles to human design challenges. These analogies help bridge the gap between nature and technology, making it easier to apply natural strategies to human-made systems.

TASKS

Task 1

From the core function presented, summarise the key elements of the biological strategy of the Sycamore seed by defining the function and identifying relevant keywords.

Task 2

Create a diagram or drawing, and/or find images of Sycamore seeds that can inform the design.

Task 3

Translate lessons from nature into design strategies. Rewrite the strategy without using biological terms and connect it to the functions and the context from a human perspective.

Task 4

Create a diagram or drawing, and/or find images of the design of your solution.

RESOURCES PROVIDED BY TEACHERS TO STUDENTS

[Resource 1 – Core functions of Safe, water less and portable toilets][H5P Flashcards]

Core functions

- **Water transport:** Evapotranspiration involves the movement of water from the soil through the plant and out through the

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	stomata in the leaves. This process helps transport essential nutrients from the soil to various parts of the plant. ● **Cooling mechanism:** As water evaporates from the stomata, it cools the plant, much like sweating cools the human body. This helps maintain optimal temperatures for metabolic processes. ● **Nutrient uptake:** The upward movement of water through the plant facilitates the uptake and distribution of nutrients dissolved in the water, which is crucial for the plant's growth and development. ● **Water cycle contribution:** Evapotranspiration contributes to the water cycle by returning water vapour to the atmosphere. This process is essential for maintaining the balance of water in the environment.
	STUDENT ASSIGNMENTS [Collaborative space] [Take your notes] **Task 1** **1. Efficient air circulation** ● **Keywords:** Waste separation, containment, hygiene, contamination minimisation ● **Description:** Safe, waterless, and portable toilets are designed to maximize efficient waste management through innovative waste separation and containment. This design minimises contamination risks and ensures hygienic waste management, making it ideal for use in various environments. **2. Environmental adaptation** ● **Keywords:** Waterless operation, environmental adaptation, resource-limited areas ● **Description:** The ability to function without water enables these toilets to adapt to various environments, particularly in areas with limited water supplies. This ensures sanitation and hygiene even in challenging conditions, making them versatile and essential for resource-limited regions.

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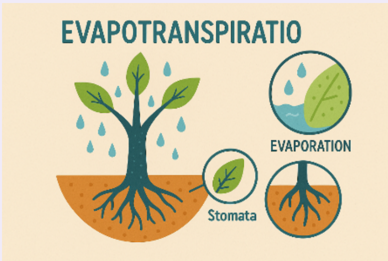
3. **Biodiversity contribution**

- **Keywords:** Biodiversity contribution, ecosystem health, water source protection
- **Description:** By providing safe and hygienic waste management, these toilets prevent contamination of water sources and support the health of the ecosystem, thereby contributing to the maintenance of biodiversity and the well-being of the community.

4. **Silent operation**

- **Keywords:** Quiet functioning, noise reduction, discreet operation
- **Description**: These toilets operate almost silently due to their smooth and efficient design. The reduction in noise during use allows for discreet waste management, ensuring minimal disturbance and maintaining privacy.

Task 2: Image of evapotranspiration



ChatGPT Image May 9, 2025, 08_52_38 AM

[How did trees inspire the 'sustainable superstar' of toilets?]

Task 3

Design strategies inspired by nature

- **Waste containment:** Create a robust structure that securely holds waste to prevent leaks and odours, ensuring safety and hygiene.
- **Natural breakdown**: Implement a system that encourages the breakdown of waste into harmless materials, using processes that are simple and effective.

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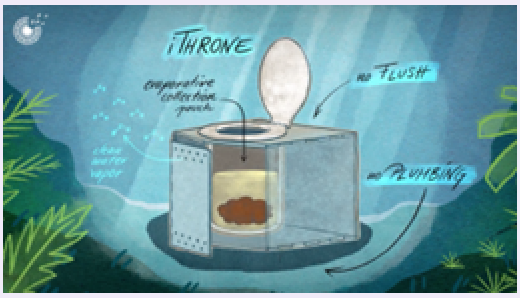
Odour management: Design a ventilation system that allows fresh air to circulate while effectively controlling unpleasant smells.
Water efficiency: Use minimal or no water for operation, maximizing efficiency and reducing reliance on water resources.
Portability: Make the toilet lightweight and easy to transport, allowing for quick setup in various locations, whether for events, rural areas, or emergencies.

Task 4: Image of a portable toilet


https://thekidshouldseethis.com/post/how-did-trees-inspire-the-sustainable-superstar-of-toilets
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<th>BIOMIMICRY DESIGN</th>
<th>Description</th>
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<tr>
<td>Step 5 – Emulate</td>
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INFO
In the context of biomimicry, the “Emulate” step involves the following tasks:

Apply biological principles: Implement the biological strategies and principles you have abstracted into your design. This involves taking the insights gained from nature and applying them directly to create innovative solutions.
Prototype development: Develop prototypes that incorporate the biomimetic principles. This involves creating models or samples that demonstrate how the natural strategies can be used in practical applications.
Integration: Integrate the biomimetic design into the final product or system, ensuring that natural strategies are

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seamlessly incorporated and that the design meets all necessary criteria and constraints.

TASKS

Task 1

Identify as many ideas as possible for the design of your solution.

Task 2

Organise your ideas into categories that include features, context, and constraints.

Task 3

Select the design concept (ideas) that best fit your solution.

RESOURCES PROVIDED BY TEACHERS TO STUDENTS

[Resource 1 – Look into]

[H5P Course presentation]

When designing safe, waterless, and portable toilets, consider the following essential features to guide your ideas:

- **Waste management:** Ensure the toilet effectively contains and decomposes waste, promoting sustainability and hygiene. Utilize composting or other eco-friendly methods to manage waste without the need for water.
- **Water efficiency:** Design the toilet to operate without water, aligning with conservation goals. This feature is crucial for areas with limited water resources and helps reduce overall water consumption.
- **Portability:** Focus on creating a toilet that is easy to transport and set up in various locations. This includes lightweight materials, compact design, and user-friendly assembly instructions.
- **Safety:** Incorporate features that ensure user safety, such as stable construction, secure waste containment, and non-slip

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surfaces. Consider ventilation systems to prevent odour buildup and maintain a clean environment.

- **Durability:** Use robust materials that can withstand different environmental conditions and frequent use. The toilet should be designed to last, reducing the need for replacements and contributing to sustainability.
- **Ease of use:** Ensure the toilet is user-friendly, with straightforward instructions for setup, use, and maintenance. Accessibility features should be included to accommodate all users, including those with disabilities.
- **Environmental compatibility:** Design the toilet to be compatible with Earth's systems, such as nutrient recycling and resource conservation. This includes converting waste into compost to enrich soil and support local ecosystems.
- **Cost-effectiveness:** Aim for a design that is affordable and accessible to a wide range of users, including those in low-income areas. Consider the initial costs and long-term savings from reduced water usage and waste management.

By integrating these features, you can create a toilet that is safe, waterless, and portable, meeting the needs of diverse users while promoting sustainability and environmental conservation.

STUDENTS ASSIGNMENT

Task 1

Features

preventing leaks and odours, secure storage of human waste, safely decomposing waste through the use of microbial processes or composting techniques, adequate ventilation and odour control, ensuring comfort and hygiene, minimising water usage, offering dry or minimal-flush options, facilitating easy transport and quick setup.

Ideas

- Modular design.
- Biodegradable materials.
- Integration of composting feature.
- Fan or passive airflow system.

Task 2

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	Features ● **Waste containment:** Secure storage to prevent leaks and odours. ● **Natural breakdown:** Composting mechanism for nutrient recycling, Biodegradable materials to enhance sustainability. ● **Odor management:** Effective ventilation system (passive or active). ● **Water efficiency:** Dry or minimal-flush options. ● **Portability:** Lightweight, modular design for easy transport. ● **Smart features:** Sensors for monitoring waste levels. **Context** Rural areas with limited infrastructure, Outdoor events (festivals, concerts), Disaster relief zones, and developing urban areas. **Constraints** ● **Cost:** Initial investment limits, especially for low-income communities. ● **Maintenance:** Need for user education and ongoing maintenance. ● **Regulatory compliance:** Navigating local health and safety regulations. ● **Environmental impact:** Ensuring that materials and processes do not harm local ecosystems. **Task 3** **Idea selected** ● **Modular composting toilet:** Combines secure waste storage with a composting feature. Lightweight and portable, it can be easily set up in various locations.

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BIOMIMICRY DESIGN	Description
Step 6 – Evaluate	**INFO** In the context of biomimicry, the “Evaluate” step involves the following tasks: ● **Assess performance:** Evaluate the performance of your biomimetic design against the criteria and constraints defined earlier. This involves testing the design to see how well it meets the desired impact and functional requirements. ● **Compare with biological models:** Compare the effectiveness of your design with the biological models that inspired it, and determine whether the design successfully emulates natural strategies and achieves similar results. ● **Gather feedback:** Collect feedback from users, stakeholders, and experts to understand how well the design performs in real-world conditions. This feedback is crucial for identifying areas of improvement. ● **Analyse data:** Analyse the data collected during testing and feedback to identify strengths and weaknesses in the design. Look for patterns and insights that can inform further refinements. ● **Iterate and improve:** Based on the evaluation, make necessary adjustments and improvements to the design. This iterative process ensures that the final product is optimised for performance and sustainability.
	TASKS **Task 1** Evaluate the design concept concerning its alignment with the design challenge's criteria and constraints, as well as its compatibility with Earth's systems. Assess the feasibility of both the technical and business models. **Task 2** Revise and revisit previous steps as necessary to generate a viable solution.
	STUDENT ASSIGNMENTS [Collaborative space] [Take your notes]

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	Task 1 The design aligns with the challenge criteria by effectively managing waste, promoting sustainability, and requiring minimal water, which supports conservation goals. It is portable, allowing for easy transport and setup in various locations. The design is compatible with Earth's systems by converting waste into compost, enriching soil, and supporting local ecosystems while minimizing water use and leveraging natural decomposition processes. Feasibility considerations include technical aspects such as researching materials and design for effective composting and odour control, with potential challenges in ensuring effective decomposition in diverse climates. The business model targets both individual consumers and organizations, though initial costs may limit accessibility in low-income areas. **Task 2** The integrated modular composting toilet features customisable modular components to suit user needs and environmental conditions, such as additional composting units and different sizes. It includes a natural ventilation system with vents or chimneys to promote airflow and control odours without mechanical components. The toilet uses biodegradable materials that break down over time, supporting sustainability goals. It ensures user-friendly access for maintenance, educational materials, and waste management.

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TM10 Eco-friendly urban noise reduction inspired by nature

BIOMIMICRY DESIGN	Description
Step 1 – Define the challenge	**INFO** Clearly express the desired impact of your design on the world, along with the specific criteria and limitations that will measure its success. In the context of biomimicry, the "Define" step involves two main tasks: ● **Describe the challenge:** This means you need to understand what your design needs to do, for whom, and in what context. ● **Criteria and constraints:** These are the standards and limitations that will help you evaluate whether you will be successful. Criteria might include factors like cost-effectiveness, durability, and environmental friendliness. Constraints could be things like budget limits, material availability, or regulatory requirements.
	TASKS **Task 1** Define the challenge as a question. **Task 2** Define the exploratory questions. **Task 3** Define the primary goal. **Task 4** Define the design needs. **Task 5** Define the target audience. **Task 6** Define the context and the locations or settings for the implementation.

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Task 7

Identify the opportunities and/or constraints that may impact achieving a successful outcome.

Task 8

Identify the connections to other solutions or challenges.

Task 9

Identify the favourable circumstances, initiatives or legislation.

Task 10

Identify the limitations or risks.

Task 11

Identify the cost.

Task 12

State your conclusions for the Define step.

RESOURCES PROVIDED BY TEACHERS TO STUDENTS

[Resource 1 - H5P Course presentation/Interactive Book] [Define the challenge]

Challenge

The challenge given is to design a noise reduction solution for urban environments that is both effective and environmentally friendly, inspired by nature's ways of managing.

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Key concepts to follow

- **Natural sound management:** Use strategies observed in forests, animal adaptations, and natural structures to absorb, diffuse, or block noise passively.
- **Integration:** Ensure the design seamlessly blends into urban settings, such as parks, streets, or building facades, without disrupting the surrounding landscape.
- **Simplicity & sustainability:** The solution should require no power, be easy to install or maintain, and be made from eco-friendly materials.

STUDENT ASSIGNMENTS

[Collaborative space]

[Take your notes]

Task 1: Challenge as a question

How can we reduce urban noise pollution naturally and sustainably?

Task 2: Exploratory questions

How does nature reduce, absorb, or deflect sound?

What organisms or natural environments are effective in dampening noise?

Can these strategies be adapted to urban environments?

Task 3: Primary goal

To create a passive, scalable, and eco-friendly solution that reduces urban noise by at least 20–30 dB, while also enhancing biodiversity and aesthetic value.

Task 4: Design needs

- Absorb, deflect, or scatter urban noise passively (no electricity or mechanical systems).
- Use sustainable, locally available materials.
- Integrate easily into existing public infrastructure.
- Be low-maintenance and durable.

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Task 5: Target audience

- **Urban planners and architects**: These professionals are responsible for designing and shaping city landscapes. They are in a key position to integrate biomimicry-inspired noise-reduction features into urban master plans, public infrastructure, and private developments. Their choices impact long-term soundscapes and environmental quality.
- **Local municipalities and public space designers**: Municipal officials and technical departments are responsible for maintaining livable cities. They manage public budgets and oversee infrastructure upgrades. By adopting nature-inspired sound barriers, they can enhance public health, reduce complaints, and meet sustainability targets while demonstrating innovative urban governance.
- **NGOs and environmental advocacy groups**: These actors raise awareness about environmental issues and advocate for healthier, greener cities. They may support or promote the adoption of eco-friendly noise reduction measures in campaigns, grant applications, or public policy recommendations. Their influence can accelerate adoption through community pressure or collaboration.
- **Residents and community associations affected by noise**: These are the end users who experience the effects of noise pollution on a daily basis. Whether in residential zones near busy roads or schools next to construction sites, their quality of life is impacted. Engaging them in the design process ensures that solutions meet real needs and gain social acceptance.

Task 6: Context and the locations or settings for the implementation

- **High-traffic streets and intersections**: These areas are among the most affected by continuous and high-decibel noise generated by vehicle engines, honking, and braking. They often run through both commercial and residential neighbourhoods, making them key targets for noise reduction. Integrating nature-inspired sound barriers along sidewalks, medians, or building facades can help buffer this noise for pedestrians and nearby residents.
- **Transport hubs (bus/train stations, airports)**: Transport facilities generate loud and persistent sounds through engines, PA systems, crowds, and the movement of vehicles or aircraft. Nature-based noise solutions can be installed around

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perimeters, waiting areas, or internal walls to *enhance* traveller comfort and protect surrounding communities from noise spill over.

- **Public parks, schools, hospitals, and residential zones**: These spaces require quiet and calm environments to fulfil their functions. Parks are intended for relaxation; schools for concentration and learning; hospitals for rest and recovery; homes for personal well-being. Using layered green walls, tree buffers, or bio-inspired noise-absorbing materials in these areas can preserve tranquillity and improve public health outcomes.
- **Construction zones and industrial areas**: These sites are hotspots for high-volume, irregular noise due to heavy machinery, tools, and ongoing activity. Biomimetic sound-dampening solutions, such as mobile green barriers or textured panels inspired by owl wings or moss, can reduce the impact of noise on nearby neighbourhoods, especially when work is long-term or close to sensitive areas.

Task 7: Opportunities and/or constraints

Opportunities	Constraints
Increased public awareness of noise pollution effects	Space limitations in dense cities
Integration with existing green infrastructure	Budget restrictions
Support from urban sustainability policies	Need for modularity/adaptability for different environments
Increased public awareness of noise pollution effects	Space limitations in dense cities

Task 8: Connections to other solutions or challenges

- Green walls and urban biodiversity initiatives.
- Sustainable architecture and bio-based insulation.
- Urban climate adaptation measures (like heat islands).

Task 9: Favourable circumstances, initiatives or legislation

- Urban greening grants and EU green deals.

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	• Public health initiatives related to noise reduction. • Municipal incentives for eco-friendly building retrofits. **Task 10: Limitations or risks** • Lack of public acceptance or awareness of biomimicry. • Maintenance challenges (e.g., watering green walls). • Vandalism or damage in public spaces. **Task 11: Cost** • **Basic living barrier**: €150–300/m² depending on plant type and infrastructure. • **Acoustic panel prototypes**: €500–700 per unit for natural fibre-based panels. • **Shell-shaped modular panels**: Mid-range depending on the material used (wood, cork, etc.). **Task 12: Conclusions** Nature offers a wide range of passive, energy-free mechanisms to control and reduce sound, from forests and feathers to shells and moss. By translating these biological principles into green infrastructure, we can co-create cities that are not only quieter but also more liveable, resilient, and aesthetically pleasant. The challenge now lies in adapting these ideas for diverse urban contexts while maintaining affordability and impact.

BIOMIMICRY DESIGN	Description
Step 2 – Biologize	**INFO** Analyse the essential functions and context your design solution must address. Reframe them in biological terms, so that you can "ask nature" for advice. In the context of biomimicry, the "Biologize" step involves the following tasks: • **Identify biological models:** Research and identify organisms, ecosystems, or natural processes that exhibit the desired

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	functions or characteristics you want to emulate in your design. ● **Understand biological principles:** Dive deep into understanding the underlying principles and mechanisms that make these biological models effective. This involves studying the anatomy, physiology, and behaviours of the organisms or systems you're interested in. ● **Translate biological strategies and consider opposite functions:** Translate the biological strategies into design principles that can be applied to your project. This involves identifying different natural processes that can be mimicked or adapted in a practical context.
	TASKS **Task 1** Read about how forests, owl feathers, and shells reduce noise and solve the quiz. **Task 2** What did you observe in the video presented? Write your observation using the concepts you discovered in the resources provided. **Task 3** State your challenge from the natural point of view. Ask yourself how nature can solve this. **Task 4** Identify key functions applicable to nature's contexts. **Task 5** Consider the opposite function and try to rephrase the question that describes the challenge from a natural perspective. **Task 6** You are given three natural models: forests, owl feathers, or seashells. Pick up a natural model, and explain in a note how sound is restricted or managed.

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RESOURCES PROVIDED BY TEACHERS TO STUDENTS

[Resource 1 – Interactive Book]
[Let's discover nature's sound barriers]

Context

In nature, forests, animals, and natural structures have developed ways to reduce, absorb, or scatter sound. Forests use dense, layered vegetation to dampen external noise. Owls fly silently thanks to the soft, fringed edges of their feathers. Caves and seashells deflect and scatter sound due to their curved, irregular shapes. These natural examples demonstrate how sound can be controlled without relying on energy or electronics.

How does nature manage sound?

- **Layering:** Forests reduce noise with overlapping plant layers that trap and diffuse sound.
- **Soft texture:** Owl feathers have velvety surfaces and serrated edges that reduce noise during flight.
- **Curved shapes:** Caves and shells scatter sound waves in different directions, lowering echo and intensity.

Fun facts about natural sound reduction

- **Owls as silent predators:** Their wings make almost no sound, allowing them to hunt without being heard.
- **Forest acoustics:** Forests can reduce noise levels by several decibels through vegetation alone.
- **Echo-free caves:** Natural curves and textures in caves absorb sound and prevent reverberation.
- **Inspiration for quiet tech:** Designs inspired by owl feathers are used in quieter wind turbines and aircraft.
- **Sound-sheltering plants:** Moss, bark, and dense shrubs are natural sound absorbers in many ecosystems.

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[Resource 2 – H5P Flash cards]

[Did you know]

Did you know that owl feathers are specially shaped to reduce noise during flight?

How?

They have serrated edges and soft textures that break up airflow and reduce turbulence, making them nearly silent. This principle is being used to design quieter fans and turbine blades.

[Resource 3 – H5P Find multiple hotspots]

[I spy with my little ear]

Based on what you've learned, can you identify the natural sound-dampening elements in the images below? Click on the correct parts, such as soft feathers, layered leaves, and curved surfaces.

[Image to be used]

[Resource 4 – Link to video]

[Let's watch]

Watch this video showing an owl in slow motion.

https://youtu.be/d_FEaFgJyfA?feature=shared

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	[Resource 5 – Natural sound absorption vs diffusion] [Document] Nature uses both absorption and diffusion to manage sound. Forests absorb noise with plants, while curved shells scatter it. **1. Layered vegetation** ● Forests and shrubs reduce sound levels through overlapping leaves and branches. ● This concept is used in green walls to absorb traffic noise. **2. Soft textures** ● Owl feathers and moss trap vibrations and reduce echo. ● Textured materials inspired by these can reduce sound indoors or in public spaces. **3. Curved forms** ● Caves and seashells bounce sound in many directions. ● Curved panels in urban design help reduce echo and concentrate sound away from sensitive areas.
	STUDENT ASSIGNMENTS [Collaborative space] [Take your notes] **Task 1** Students access the interactive activity and click on the correct image. The platform will inform students about their answers (correct or incorrect) and provide a personalised message. **Task 2** In the video, I can see that the owl's wings move without making noise. The edges of the feathers are soft and fringed, which breaks up the air and reduces turbulence. The owl's design helps it fly silently through the air, avoiding detection. **Task 3**

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	How can nature address the challenge of reducing noise without relying on energy or machines? **Task 4** Summary of key functions applicable to nature's contexts: ● Sound absorption: Moss, tree bark. ● Silent movement: Owl feathers, bat wings. ● Noise diffusion: Forest canopies, leaf clusters. ● Curved shapes for deflection: Seashells, cave walls. ● Porous structures: Coral, sponges. ● Natural insulation: Fur, nests, burrows. ● Surface textures: Rough leaves, soft feathers. By understanding how nature manages sound, we can develop more effective urban solutions that are quiet, efficient, and environmentally friendly. **Task 5** How can nature block, scatter, or muffle sound waves in dynamic environments? **Task 6** Owl feathers: ● **Structure and design:** Owl feathers have a soft, velvety surface and comb-like edges. These reduce the sound created by air turbulence. ● **Sound reduction:** The serrated edges break up air as the owl flies, preventing loud flapping sounds. ● **Efficiency:** This silent flight helps the owl sneak up on prey while using no additional energy for noise control.

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BIOMIMICRY DESIGN	Description
Step 3 – Discover	**INFO** Look for natural models (organisms and ecosystems) that require the same functions and context as your design solution. Identify the strategies used that support their survival and success. In the context of biomimicry, the “Discover” step involves the following tasks: ● **Explore nature:** Spend time discovering natural models to study various ecosystems and organisms. ● **Identify functions:** Look for specific functions or strategies in nature that can solve the design challenge you're facing. ● **Gather information:** Collect detailed information about biological models that exhibit the desired functions, including scientific research, case studies, and firsthand observations.
	TASKS **Task 1** Search for other natural models that match the same functions as the Sycamore seeds and apply some context to your design solution. **Task 2** Identify experts and communities in the field of biomimicry.
	RESOURCES PROVIDED BY TEACHERS TO STUDENTS [Resource 1 – Course presentation] [Functions of Nature’s Sound Barriers] Many organisms and ecosystems in nature have developed passive methods to manage and reduce sound. Forests use dense layers of vegetation to absorb and diffuse noise. Owls have feather structures that allow for near-silent flight. Curved surfaces in natural formations like caves or shells scatter sound waves, reducing their intensity. These natural features offer inspiration for creating quieter environments in urban areas.

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Detailed functions of nature's sound management systems

1. Sound absorption

- **Natural insulation:** Moss, tree bark, and leaf litter absorb sound by trapping vibrations in their soft and porous textures.
- **Energy-free buffering:** These materials reduce sound without needing power or machinery, offering a sustainable solution for quiet zones.

2. Silent operation

- **Noise reduction through structure:** Owl feathers are soft and fringed, reducing turbulence and noise during flight.
- **Stealth adaptation:** This silent movement allows owls to hunt effectively without being detected, showing how form alone can reduce sound.

3. Additional insights

- **Environmental protection:** Natural sound barriers protect species that rely on quiet for hunting or nesting.
- **Biodiversity support:** By reducing noise, ecosystems help preserve animal behaviour patterns and promote healthier environments for all living organisms.

STUDENTS ASSIGNMENTS

[Collaborative space]

[Take your notes]

Task 1
Search for other natural models that match the same functions of the owl feathers and forest vegetation, and apply some context in your design solution.

- **Owl feathers:** Soft and serrated, they reduce turbulence and allow for silent movement.
- **Moss and tree bark:** Dense, fibrous, and porous materials that naturally absorb sound in forests.

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- **Seashells and caves:** Their curved surfaces scatter sound, reducing echoes and reverberation.
- **Elephant ears:** Thick and flexible, they offer natural insulation and control of sound and heat.
- **Burrows and nests:** Built for quiet, they use soft materials and structural layering to create calm environments.

Task 2
Identify experts and communities in the field of biomimicry.

1. Experts

a. University and research institutions, for example

- University of Groningen – Acoustic Ecology and Environmental Psychology.
- University of Freiburg – Institute of Forest Sciences.

b. Specific experts, for example

- Julian Treasure – Sound expert known for research on urban soundscapes.
- Janine Benyus – Biomimicry pioneer and biologist.
- Trevor Cox – Acoustics professor at the University of Salford.

c. Professional associations, for example

- Biomimicry Institute – Noise-related nature-based design experts.
- Institute of Acoustics (UK) – Focused on sound and environmental noise.
- Ecological Acoustics Research Organisation (EARO)

d. Specialised journals and publications

- Bioacoustics: The International Journal of Animal Sound and Its Recording.
- Urban Forestry & Urban Greening – Research on vegetation and city environments.
- Science of the Total Environment.

2. Communities
a. Online forums and social media

- Reddit: r/urbanplanning, r/biomimicry, r/acoustics.

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	● LinkedIn Groups: "Nature-Inspired Urban Design", "Eco-Acoustic Design". **b. Conferences and workshops** ● Biomimicry Global Design Challenge. ● Urban Sound Symposium. ● International Congress on Acoustics (ICA). **c. Academic and professional societies** ● International Society of Ecoacoustics. ● European Acoustics Association (EAA). ● American Institute of Architects (AIA) – Sustainable design divisions. **d. Local naturalist groups** ● Urban forestry centres. ● Regional botanic gardens and ecological associations. **e. Online communities and platforms** ● ResearchGate – Search for urban noise, bioacoustics, sound ecology. ● Academia.edu – Follow researchers in environmental acoustics and biomimicry.

BIOMIMICRY DESIGN	Description
Step 4 – Abstract	**INFO** Carefully study the essential features or mechanisms that make the biological strategies successful. Restate them in non-biological terms, as "design strategies." In the context of biomimicry, the "Abstract" step involves the following tasks: ● **Extract principles:** Identify and extract the underlying principles and strategies from the biological model you have studied. This means understanding the core functions and mechanisms that make these natural solutions effective. ● **Generalize concepts:** Generalize these biological principles so they can be applied to a wide range of design challenges. This involves translating specific biological strategies into broader

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design concepts that are not tied to a particular organism or ecosystem.

- **Create analogies:** Develop analogies that link the biological principles to human design challenges. These analogies help bridge the gap between nature and technology, making it easier to apply natural strategies to human-made systems.

TASKS

Task 1

From the core function presented, summarize the key elements of the biological strategy of the Sycamore seed, by defining the function and identifying relevant keywords.

Task 2

Create a diagram/ drawing and/ or find images of Sycamore seeds that can inform the design.

Task 3

Translate lessons from nature into design strategies. Rewrite the strategy without using biological terms and connect it to the functions and the context from a human perspective.

Task 4

Crate a diagram/ drawing and/ or find images of the design of your solution.

RESOURCES PROVIDED BY TEACHERS TO STUDENTS

[Resource 1 – Core functions of Sycamore seeds]

[H5P Flashcards]

Core functions

- **Efficient air circulation:** Achieves smooth and efficient air movement with minimal energy and less noise
- **Autorotation:** Enables the seedpod to stay in the air for longer and travel greater distances.

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- **Curved shape:** Facilitates the autorotation of the seedpod.
- **Weight and wing length balance:** Ensures smooth autorotation during free fall.

STUDENT ASSIGNMENTS

[Collaborative space]

[Take your notes]

Task 1

1. Sound absorption

- **Keywords**: Porous, soft texture, vibration damping.
- **Description**: Natural materials like moss and bark absorb sound by trapping vibrations within their fibrous and spongy structure. These soft textures reduce sound reflection, making the environment quieter.

2. Silent movement

- **Keywords**: Serrated edges, air disruption, quiet flight.
- **Description**: Owl feathers are fringed and soft, which reduces turbulence and suppresses sound during flight. This natural adaptation minimises noise in motion and serves as inspiration for quieter surfaces.

3. Curved shape for sound diffusion

- **Keywords**: Irregular form, wave deflection, echo reduction.
- **Description**: Natural shapes such as seashells or caves reflect sound waves in multiple directions. This reduces echo and prevents sound from concentrating in one spot.

4. Layered structure

- **Keywords**: Density, overlapping surfaces, buffer zones.
- **Description**: Forests use multiple layers of leaves and branches to break up and absorb noise. The complexity of this structure effectively and consistently dampens sound.

Task 2: Image of a Sycamore seed

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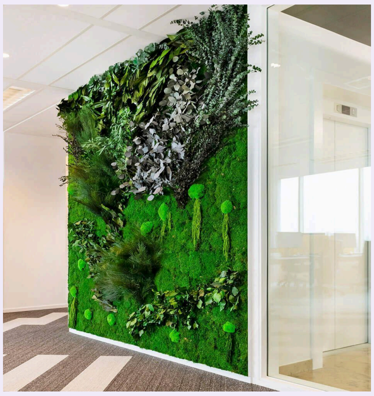

Copyright @Greenmood

Task 3

- **Sound absorption**: Use soft, porous materials like recycled cork, hemp, or moss panels to absorb urban noise effectively.
- **Diffusion**: Apply curved or irregular surfaces to scatter sound in multiple directions, reducing echo.
- **Silent materials**: Design surfaces inspired by owl feathers—layered and textured to reduce turbulence and sound reflection.
- **Layered design**: Incorporate vegetation or modular layers to mimic the buffering effect of forest canopies.

Task 4: Image of a fan

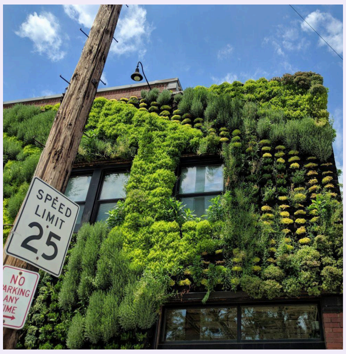

Photo of Florafelt Pockets Living Wall in Cleveland, Ohio by Architect Marika Shiori-Clark for Northeast Ohio Regional Sewer District. (https://www.plantsonwalls.com/blog/living-walls-absorb-noise-outperform-most-materials/)

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BIOMIMICRY DESIGN	Description
Step 5 – Emulate	**INFO** In the context of biomimicry, the "Emulate" step involves the following tasks: ● **Apply biological principles:** Implement the biological strategies and principles you have abstracted into your design. This involves taking the insights gained from nature and applying them directly to create innovative solutions. ● **Prototype development:** Develop prototypes that incorporate the biomimetic principles. This involves creating models or samples that demonstrate how the natural strategies can be used in practical applications. ● **Integration:** Integrate the biomimetic design into the final product or system, ensuring that natural strategies are seamlessly incorporated and that the design meets all necessary criteria and constraints.
	TASKS **Task 1** Do the practical example and note your findings. **Task 2** Identify as many ideas as possible for designing your solution. **Task 3** Organise your ideas into categories that include the features, the context, and the constraints. **Task 4** Select the design concept (ideas) that best fit your solution.
	RESOURCES PROVIDED BY TEACHERS TO STUDENTS [Resource 1 – Look into] [H5P Course presentation]

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When designing a noise reduction solution inspired by natural systems, consider the following essential features to guide your ideas:

- **Passive sound absorption**: Forests and mossy environments naturally absorb sound without the need for mechanical systems. Your design should aim to replicate this passive approach using materials or structures that trap or dampen sound waves naturally.
- **Noise diffusion through shape**: Curved surfaces in nature, like seashells or caves, scatter sound in various directions. Incorporate similar forms into your design to reduce echoes and concentrated noise in urban environments.
- **Material optimization**: Like feathers or bark, natural materials balance softness and resilience. Select lightweight, durable, and porous materials that are effective in reducing noise while being easy to install and maintain.
- **Sustainable construction**: Nature builds efficiently with what's available. Use recycled, biodegradable, or plant-based materials to minimize environmental impact throughout the product's life cycle.

[Resource 2 – Sound Diffusion and Absorption Experiment]

[Document]

Nature-inspired noise buffer experiment

Materials

cardboard, fabric, sponge, plant leaves (optional), plastic cup, and a sound source (such as a phone or speaker).
Instructions: Build small panels using different materials. Place each panel between a sound source and a decibel meter or a smartphone with a sound-measuring app.

Investigation ideas

1. **Material comparison**
   - Create panels using various materials, such as sponge, cork, cloth, and plastic.
   - Measure how each one affects the sound level behind it.
   - Record which materials absorb or block the most sound.
2. **Shape variation**

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	● Try placing curved surfaces in front of the speaker. ● Observe how the shape redirects or scatters the sound. ● Test both indoor and outdoor settings.
	STUDENTS ASSIGNMENT [Collaborative space] [Take your notes] **Task 1** Students record their findings on the provided record sheet. **Task 2** **Ideas** ● Vertical green walls made of layered plants. ● Curved wooden or clay panels that diffuse sound. ● Modular sound-absorbing panels using cork or hemp. ● Sound barriers inspired by owl feather structure. ● Panels with porous surfaces like moss or bark. ● Recycled textile-based acoustic curtains. ● Urban benches or shelters integrating soft sound-absorbing surfaces. ● Natural materials combined with sculpted forms for sound diffusion. **Task 3** **1. Passive sound absorption** ● **Surface design:** Use soft, textured materials like moss panels or cork composites. ● **Material layering:** Integrate multiple natural layers to trap and absorb vibrations. ● **Placement:** Position elements where sound reflection is highest (e.g. walls, near roads). **2. Noise diffusion through natural shape**

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- **Form:** Use curved or irregular shapes to scatter sound waves.
- **Surface texture:** Mimic natural surfaces like bark or feathers to disrupt sound.
- **Structure:** Combine hard shells and soft interiors to dampen and deflect noise.

3. **Material optimisation**

- **Natural composites:** Use light but dense materials such as hempcrete or bamboo.
- **Durability:** Select weather-resistant plant-based or biodegradable materials.
- **Dual function:** Combine acoustic use with aesthetic or shading value.

4. **Sustainable materials**

- **Eco-sourcing:** Use recycled wood, cork, wool, or natural fibres.
- **Low-impact production:** Favour manufacturing methods with minimal emissions.
- **End-of-life:** Ensure materials can be reused or composted after use.

Context

- **Urban settings:** The solution should work in public spaces, parks, building facades, or transport stops.

Constraints

- **Space and budget:** Solutions must fit dense cityscapes and remain affordable for public use.

Task 4

Design modular green panels using recycled materials and curved forms that absorb and scatter urban noise, inspired by the silent flow of owl feathers and the buffering effect of forests.

Inspiration drawn from the experiment

- **Material:** Like soft paper dampens vibration, use soft, plant-based layers.

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	● **Shape:** Curved edges, like in the acoustic test, reduce echo and sound direction. ● **Eco-thinking:** Simple, low-tech designs show how nature-based materials can solve complex problems.

BIOMIMICRY DESIGN	Description
Step 6 - Evaluate	**INFO** In the context of biomimicry, the "Evaluate" step involves the following tasks: ● **Assess performance:** Evaluate the performance of your biomimetic design against the criteria and constraints defined earlier. This involves testing the design to see how well it meets the desired impact and functional requirements. ● **Compare with biological models:** Compare the effectiveness of your design with the biological models that inspired it, and determine whether the design successfully emulates natural strategies and achieves similar results. ● **Gather feedback:** Collect feedback from users, stakeholders, and experts to understand how well the design performs in real-world conditions. This feedback is crucial for identifying areas of improvement. ● **Analyse data:** Analyse the data collected during testing and feedback to identify strengths and weaknesses in the design. Look for patterns and insights that can inform further refinements. ● **Iterate and improve:** Based on the evaluation, make necessary adjustments and improvements to the design. This iterative process ensures that the final product is optimized for performance and sustainability.
	TASKS **Task 1** Evaluate the design concept concerning its alignment with the design challenge's criteria and constraints, as well as its compatibility with Earth's systems. Assess the feasibility of both the technical and business models.

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	Task 2 Revise and revisit previous steps as necessary to generate a viable solution.
	STUDENT ASSIGNMENTS [Collaborative space] [Take your notes] **Task 1** The design concepts for the nature-inspired urban noise barrier align well with the challenge's criteria, offering passive sound reduction, visual integration in public spaces, use of natural materials, and environmental sustainability. Such a design is compatible with Earth's systems by reducing noise pollution without energy consumption and by encouraging biodiversity. The technical and business models are feasible, though urban space constraints and awareness-raising may influence implementation. The solution fits the increasing need for healthy, sustainable, and liveable cities. **Task 2** By revising and refining each design concept, the noise barrier can better meet the defined criteria, ensuring effective sound absorption, natural integration, and ecological value. The updated approach enhances feasibility through modular options and the use of locally sourced materials. With proper adaptation to context and a clear sustainability focus, the final solution can position itself as a practical, eco-friendly innovation for noise control in urban environments.

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