# InNature

## TOOLKIT

# INNOVATION IN SCHOOLS
# INSPIRED BY NATURE SOLUTIONS

**Biomimicry approach** defends that sustainable answers to many problems faced today were already developed by nature and **defines that solutions to many problems can be found through the emulation of nature patterns.**

What are InNature Project aims? Enhance competencies and awareness on biomimicry in the School Community, including students, parents, teachers and directors and Informal Science Education Providers. **Reinforce the sustainability principle** in schools for the whole school community, **Develop new teaching resources** to be used inside the classroom and outside, **Reinforce STEAM competences** in the school community, Learn more about sustainability, Have access to new and innovative teaching methodologies to apply in schools, To **scale up knowledge on nature-based solutions**. The goals behind the project were based on the need to **increase the interest and knowledge about Biomimicry and sustainable development in the school community.**

## About InNature Project

The InNature project is linked to biomimicry, an approach that defends that sustainable answers to many problems faced today were already developed by nature. This approach defines that many problems' solutions could be found through the emulation of the natural patterns. Hence, this project aims to enhance competences and awareness on biomimicry in the School Community, including students, parents, teachers and directors and Informal Science Education Providers through the development and implementation in classroom of a set activities related to this approach and events, such as a fair about this theme in schools.

InNature has been designed to develop a set of resources to be used and integrated in schools, aiming to enhance the inclusion of biomimicry in classes and schools activities. Among is results are:

- **Catalogue of good practices** – a collection of several good practices in the European countries regarding biomimicry in different contexts, and some of those practices have potential to be adapted or transferred to primary and lower secondary schools;
- **InNature Toolkit** – the current document, which is a set of educational activities for teachers to use in classes, workshops or other school activities with students of different ages, described in a way that allows the independent use of activities in the classroom;
- **InNature Fair** – a concept and a programme to organize the "InNature Fair", a 3 days event in schools with activities and presentations to enhance the school community and Informal Science Education Providers curiosity on the biomimicry theme. Similar events have been piloted in partner schools during the project lifetime to receive feedback from the project target groups. The programme can be adaptable to different schools and activities, enhancing the probability to be used in other moments by different stakeholders.

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# KNOW THE PARTNERS

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## About the IO2 InNature TOOLKIT

This Toolkit is a reference material developed within the InNature project, with an aim to 'boost innovation in schools inspired by nature solutions'. It presents a series of activities to be used in a school context, but you are free to adapt the proposed activities to the specificity of your situation and the needs of the group with which you will work. We strongly encourage you to take the initiative and personalize the exercises suggested in this book by using your own experience, knowledge, imagination, as well as any new technologies and other resources available. Do not hesitate to apply the teaching techniques that you feel best in and that are most attractive to your students. We hope that this educational booklet will become a great source of inspiration and will serve you and your students well!

The IO2 InNature Toolkit is divided into 2 parts:

1. **Teacher Section** which contains theoretical background for teachers about individual issues in the field of biomimicry, as well as scenarios of lessons with information about objectives, duration, level of difficulty, students age and equipment needed.
2. **Student Section** where worksheets with activities for students and information about the lesson can be found.

And 5 topics:

A. Introduction – Philosophy of Biomimicry
B. Biomimicry: examples
C. Biomimicry: strategies and functions of living organisms
D. Biomimicry: the principles of living
E. Biomimicry: methodology

# TABLE OF CONTENTS


| | |
|---|---|
| A. Introduction – Philosophy of Biomimicry | **A1. Techno or life?** ( 9-11, 84-86)<br>**A2. To be inspired by nature, for what purposes?** (12-14, 87-90)<br>**A3. Overview effect** (15-16, 91-93)<br>**A4. Video Nature = Futur! "Biomimicry, life as a model"** (17-19, 94-96)<br>**A5. From planetary boundaries to biomimicry** (20-22, 97-99) |
| B. Biomimicry: examples | **B1. Kingfisher and Shinkansen** (23-25, 100-102)<br>**B2. Coral and cement** (26-28, 103-104)<br>**B3. Bite like a mosquito** (29-30, 105-107)<br>**B4. Colourful like a morpho butterfly** (31-33, 108-110)<br>**B5. Discover and draw the anatomy of the wing** (34-36, 111-112)<br>**B6. History: the desire to fly, from Leonard de Vinci to Airbus** (37-40, 113-115)<br>**B7. Winglets and aerodynamics** (41-42, 116-117)<br>**B8. Experience: lift of a wing according to its profile** (43-44, 118-119)<br>**B9. Shine like a cat's eye** (45-47, 120-121) |
| C. Biomimicry: strategies and functions of living organisms | **C1. How does the gecko hang on?** (48-49, 122-123)<br>**C2. Velcro© and burdock** (50-52, 124-125)<br>**C3. Adhere without toxic glue** (53-54, 126-127)<br>**C4. Protecting against heat and cold** (55-56, 128-129)<br>**C5. Protecting against cold** (57-58, 130)<br>**C6. Protecting against heat** (59-60, 131)<br>**C7. The termite mound, a model of natural air conditioning** (61-62, 132-134)<br>**C8. Experience: termite mound** (63-64, 135-137)<br>**C9. Observation & nature: the leaf** (65-66, 138-139)<br>**C10.Zoom on the leaf and its multiple functions** (67-69, 140-143)<br>**C11. Artificial Photosynthesis – reality or fiction?** (70-71, 144) |
| D. Biomimicry: the principles of living | **D1. The tree / the building: observation and inspiration** (72-73, 145-147)<br>**D2. Photovoltaic sheets** (74-75, 148-154)<br>**D3. The city of the future, a bio-inspired and regenerative city** (76-77, 155-158) |
| E. Biomimicry: methodology | **E1. In the shoes of a biomimetician: different steps** (78-79, 159-160)<br>**E2. In the shoes of a biomimetician: ethics and sustainability** (80-82, 161-162) |

# TEACHER SECTION

# Topic: Philosophy of biomimicry

## Title of activity: A1. Biomimicry: techno or life?

**Lesson Duration: 45 min**

**Level of difficulty: easy-moderate-difficult**

**Students' age: 12-15**

**Materials / equipment:**

*PPT presentation about the topic prepared by the teacher*

*Student Worksheets "Biomimicry: Techno or life" p.84-86*

**Learning Objective:**

- to highlight our ignorance of the surrounding nature for the benefit of a better knowledge of the technological world
- to test our ability to recognize 6 common animal or plant species before recognizing 6 famous international brands or symbols of our artificialized world
- to point out the genius of the living, its exploits but also our lack of knowledge of the common species that surround us
- to reflect on above points
- to introduce what biomimicry is

**For teachers - Description of activity/Theoretical background**

This activity aims to highlight our ignorance of the surrounding nature for the benefit of a better knowledge of the technological world. By simply checking or testing our ability to recognize 6 common animal or plant species before recognizing 6 famous international brands, symbols of our artificialized world, we can point out the genius of the living, its exploits but also our lack of knowledge of the common species that surround us.

This activity helps us also to reflect on the limits of the aboveground model of society. The emergence of life on Earth, and of humanity, has been made possible by a unique natural balance. Because it dissociated itself from the living, Homo sapiens upset the balances of climate and life. With our ecosystems running out of steam, there is an urgent need to invent a model based on a new relationship with nature, based on cooperation and adaptation rather than competition, domination and exploitation.

Therefore we need to make an alliance with the living, which is the condition of our future. The living rehabilitates in the long term and invites us to consider the interdependencies between humans and the dynamics of ecosystems and to re-examine the material conditions of existence. Observing living things allows us to take a fresh look at ourselves, our technologies and our organizations. This reconnection with the biosphere, intellectual, technical, philosophical, ethical and even emotional, will orient our trajectories towards a new, more sober, more cooperative civilization.

Reconciling ourselves with nature will guide political and economic decisions towards scenarios compatible with the living things for our own survival. We have the responsibility to rethink our relationship with nature and to seize the magnificent opportunity to reinvent ourselves to realign ourselves with the living. We have a duty to invite the younger generations to realize that humanity is part of a complex whole on which it depends.

Biomimicry brings potential solutions to our current problems, but also a new collective imagination based on wonder at the abundance and ingenuity of all forms of life. Let us therefore take note of our deep interdependence with respect to biodiversity to make possible the emergence of a new and more capable relation with non-human living things. It will involve in particular the equitable sharing of resources and space, respect, acceptance of all forms of diversity and the non-reducibility of living things to any form of utilitarianism.

In this activity, we test our ability to recognize 6 common animal or plant species, as shown below, before trying to recognize 6 famous international brands, symbols of our artificialized world. Which task do we find easier or more difficult? Why is that? In this way we can point out the genius of the living, its exploits but also our lack of knowledge of the common species that surround us.

| | | |
|---|---|---|
| **Butterfly – Bombyx**<br><br>The bombyx, a moth, detects the pheromones of its female up to 11 km away. | **Black Swift**<br><br>The black swift, which lives most of its life in flight, peaks at speeds of up to 200 kph. | **Fly - Forcipomyia**<br><br>This insect beats its wings at almost 1000 b/s (beats per second) thanks not to muscular effort but to a resonance phenomenon of its shell. |
| **Ivy**<br><br>Ivy has the ability to climb and cling to all types of supports. Both thanks to its roots and a form of glue that can support almost a ton per gram of glue. All this without volatile emissions into the air and completely biodegradable. | **Abalone**<br><br>Abalone is ten times stronger than conventional ceramics: hardness and resistance. However, it has the same composition as chalk: calcium carbonate (CaCO3). It is the organisation of these atoms on a microscopic scale that gives it these properties of hardness and strength. | **Sponge - Éponge euplectella**<br><br>The sponge is capable of making glass in water at room temperature, whereas humans need to heat to over 1000°C to make glass. |

**Lesson activities:**

| Time | Activity / Main content |
|---|---|
| 5 min | Brief introduction about the focus and the aims of the lesson |
| 5 min | Showing presentation in PPT |
| 5 min | Distribution of student worksheets<br>Explaining their tasks |
| 15 min | Students work on their worksheets individually or in small groups of 2-4 persons |
| 10 min | Discussion on main findings<br>Introduction what biomimicry is and which its objectives are |
| 5 min | Conclusions, summary and wrap-up of key points |

**References, link, bibliography:**

Defining Biomimicry or Biomimetics, https://en.wikipedia.org/wiki/Biomimetics, Wikipedia

# Topic: Philosophy of biomimicry

## Title of activity: A2. To be inspired by nature, for what purposes?

**Lesson Duration: 45 min**

**Level of difficulty: easy-moderate-difficult**

**Students' age: 12-15**

**Materials / equipment:**

*PPT presentation about the topic prepared by the teacher*

*Student Worksheets "To be inspired by nature, for what purposes?" p.87-90*

**Learning Objective:**

- to define the concepts of biomimicry, bioinspiration, biomimetics and bionics
- to differentiate between the different levels of inspiration from nature
- to question and reflect on the purposes of bio-inspired inventions and their sustainability
- to understand the philosophical, ethical and sustainable dimensions of biomimicry
- to raise a critical spirit about inventions inspired by nature and based on the principles of the living world

**For teachers - Description of activity/Theoretical Background**

This activity encourages us to question the ethics of bio-inspired practices.

We first need to define the concepts of biomimicry, bioinspiration, biomimetics and bionics.

Nature inspires us and so we can find its inspiration in poems, writings, songs, paintings, works of art. But also in all kinds of inventions, for example, airplane wings, artificial hands, buildings and many more.

We can discuss these examples and whether they correspond to bio-inspiration, biomimicry, biomimetics or bionics.

We can also question the purposes of bio-inspired and their sustainability.

In this way we can understand the philosophical, ethical and sustainable dimensions of biomimicry and therefore raise a critical spirit about inventions inspired by nature and based on the principles of the living world.

Some useful definitions are the followings:

**Bioinspiration**: general term for creative approaches inspired by the living (including music, poetry, etc.).

**Biomimetics**: a more technical approach that consists of looking at the relevant models in living organisms that respond to a given function, trying to understand the mechanisms in order to be able to transpose them to technological fields.

**Biomimicry**: drawing inspiration from the living to innovate sustainably, to meet eco-design specifications (intersection with eco-design)

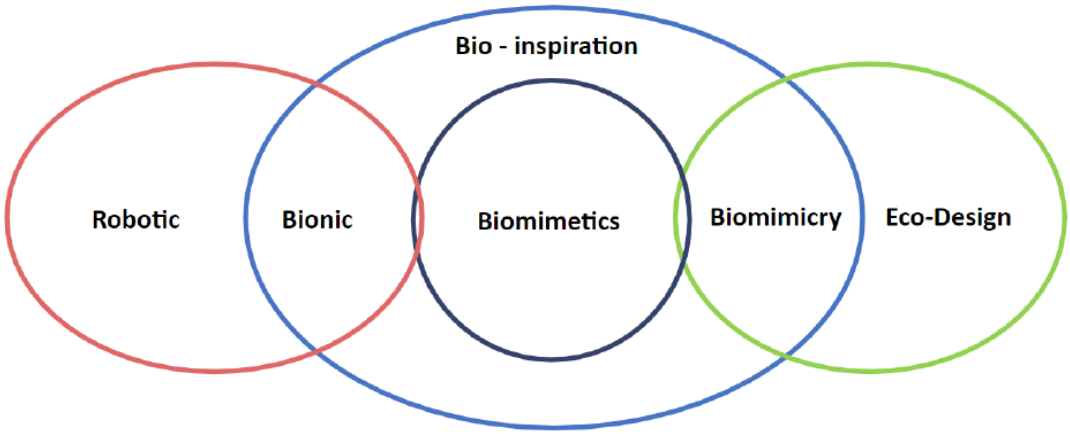
Biomimicry, biomimetics, bioinspiration, bionics are standard concepts and these terminologies are defined in ISO standards. The approach has been defined by the ISO TC 266 - ISO 18458 standard with related notions.

**Bio-inspiration**: a creative approach based on the observation of biological systems.

Biomimicry can be also defined as interdisciplinary cooperation of biology and technology or other fields of innovation with the aim of solving practical problems through the functional analysis of biological systems, their abstraction into models and the transfer and application of these models to the solution. As well as, interdisciplinary philosophy and conceptual approaches using nature as a model to address the challenges of sustainable development (social, environmental and economic).

**Bionics**: a technical discipline that seeks to reproduce, improve or replace biological functions with their electronic and/or mechanical equivalents.

All above terms are interconnected and interrelated as shown at the schematic drawing below.




This activity focuses on studying examples of inspiration and questioning their sustainability. Students can be asked to study these examples in detail, categorize them in different concepts and the question and discuss their inspiration, purpose and sustainability.

| | |
|---|---|
| Hand prostheses | The human hand |
| Fuselage of TGV | A kingfisher beak |
| Shark skin | Antibacterial coatings |
| Bamboo | Buildings |

**Lesson activities:**

| Time | Activity / Main content |
|---|---|
| 3 min | Brief introduction about the focus and the aims of the lesson |
| 10 min | Showing presentation in PPT<br>Definition and highlight of different concepts and their interrelations |
| 2 min | Distribution of student worksheets<br>Explaining their tasks |
| 15 min | Students work on their worksheets individually or in small groups of 2-4 persons<br>They can pick some or all examples to study and discuss |
| 10 min | Discussion on main findings<br>The discussion should focus on bio-inspiration and categorisation according to different concepts but also on purpose and sustainability |
| 5 min | Wrap-up and summary |

**References, link, bibliography:**

Defining Biomimicry or Biomimetics, https://en.wikipedia.org/wiki/Biomimetics, Wikipedia

Online repository of resources, https://asknature.org/

# Topic: Philosophy of biomimicry

## Title of activity: A3. Overview Effect

**Lesson Duration: 45 min**

**Level of difficulty: easy-moderate-difficult**

**Students' age: 10-18**

**Materials / equipment:**

*PPT presentation about the topic prepared by the teacher*

*Student Worksheets "Overview Effect" p.91-93*

*PC with internet connection*

*Video*

**Learning Objective:**

- to discover the Earth as seen from space, in its entirety
- to understand and experience the overview effect

**For teachers - Description of activity/Theoretical Background**

Astronauts in orbit have experienced a profound love for the Earth and felt that we all share one home. It is called the Overview Effect and it changed them forever. Using unique Earth images taken from one million miles away by NASA, the One Home's mission is to bring the overview effect to millions of people. Admiring the Earth from space can change us. Although environmental awareness is rising, unfortunately what divides us seems stronger than what unites us. Let's ask ourselves what if a single view of our planet could make us realize our chance and experience unity? What if an overview of our planet could make us experience the interconnectedness of life? What if planetary boundaries became suddenly obvious?

The overview effect as defined in Wikipedia, the free encyclopaedia, is a cognitive shift in awareness reported by some astronauts during spaceflight, often while viewing the Earth from outer space. It is the experience of seeing first-hand the reality of the Earth in space, which is immediately understood to be a tiny, fragile ball of life, "hanging in the void", shielded and nourished by a paper-thin atmosphere. From space, national boundaries vanish, the conflicts that divide people become less important, and the need to create a planetary society with the united will to protect this "pale blue dot" becomes both obvious and imperative. Here are the words of Michael Collins, astronaut of Apollo 11: "The thing that really surprised me was that Earth projected an air of fragility. And why, I don't know. I don't know to this day. I had a feeling it's tiny, it's shiny, it's beautiful, its home, and it's fragile"

Astronauts Michael Collins, Ron Garan, Rusty Schweikart, Edgar Mitchell, Tom Jones, Scott Kelly, James Irwin, Mike Massimino, André Kuipers, Chris Hadfield, Sally Ride, and Anne McClain are all reported to have experienced the effect. The term and concept were coined in 1987 by Frank White, who explored the theme in his book The Overview Effect — Space Exploration and Human Evolution (Houghton-Mifflin, 1987). In 2018, the Space buzz project was created so "children around the world can also get to experience the Overview Effect. It was announced in a press release on December 20 by astronaut André Kuipers on the European Space Agency's

(ESA) website. Space buzz aims to give children an overview effect like experience using virtual reality (VR) in order to have the same insight astronauts have when seeing planet Earth from space. Space Buzz is a project started by the Overview Effect Foundation backed by ESA and the Netherlands Space Office.

In this activity we watch the video by One Home with Jean-François Clervoy, French astronaut, and try to sum up his main message and emotions when he observed the Earth from space.

**Lesson activities:**

| Time | Activity / Main content |
|---|---|
| 5 min | Brief introduction about the focus and the aims of the lesson |
| 10 min | Showing presentation in PPT. Watching video One Home. |
| 5 min | Distribution of student worksheets. Explaining their tasks. |
| 15 min | Students work on their worksheets individually.<br>They can express and write/discuss their views and feelings freely |
| 5 min | Discussion on key message points |
| 5 min | Wrap-up and summary |

**References, link, bibliography:**

Overview effect, https://en.wikipedia.org/wiki/Overview_effect, Wikipedia

OneHome online repository of resources, https://www.onehome.org/

# Topic: Philosophy of biomimicry

## Title of activity: A4. Nature = Future! - Biomimicry, life as a model

**Lesson Duration: 45 min**

**Level of difficulty: easy-moderate-difficult**

**Students' age: 12-18**

**Materials / equipment:**

*PPT presentation about the topic prepared by the teacher*

*Student Worksheets "Nature = Future! - Biomimicry, life as a model" p.94-96*

*PC with internet connection*

*Video*

**Learning Objective:**

- understand biomimicry, its principles, ethics and approach

**For teachers - Description of activity/Theoretical Background**

In this activity we discover, with French experts, the biomimicry approach, which allows us to rethink our production, design and consumption methods, to meet the challenges of climate change, the collapse of biodiversity, the depletion of resources on Earth and pollution. We watch the video "Nature = Future!" and discuss the main messages contained. The full transcript of the video is as follows:

When we look at natural landscapes, when we contemplate the beauty of all kinds of living organisms, we do not guess at the technological advances that these organisms have developed, nor at their functioning in perfectly balanced ecosystems. The approach that studies the living world for inspiration is called biomimicry. What are the aims of mankind's quest to understand nature today? And why be inspired by the living? The living will group together all the species that live on the surface of the planet. And so it goes from bacteria to human beings, up to the Homo sapiens species. The species that we observe today are the result of nearly 4 billion years of evolution, and these 4 billion years of evolution, we must be aware that it is trial and error that will be selected or not by the process of natural selection. And, in this sense, the fact of having had 4 billion years of research and development makes biology, the living, a reservoir of potential innovations.

Why are we inspired by living things today?

There is currently a conjunction of several crises and I won't teach anyone anything by citing the climate crisis. There is also the biodiversity crisis, but I will also add a certain social crisis, linked to the distribution of wealth. The conjunction of these three crises is questioning our modes of production and consumption, and what were perhaps the solutions of the 20th century have become the problems of the 21st. What is interesting is that nature and the living provide answers to all the major challenges facing society today. For example, the living world has relied on renewable energies since the beginning, in particular solar energy. There are indeed many things that we don't do and that the living world has been doing for a very long time. Use what is abundant rather than what is rare. The economy of living things is not based on scarcity because it is a dead end, but on abundance. Another principle is to manufacture under pressure and at room temperature. The living excels in the elaboration of materials which are complex, multifunctional materials. And these material properties range from hydrophobicity to remarkable optical properties, lightness in their structure and mechanical resistance. For example, there is waste in living organisms, but it is still a resource for other organisms. The sheet which is a magnificent solar panel manufactured at room temperature and pressure with abundant elements. Once it fades, it becomes a resource that will create humus. So we are not in a linear economy, we are in a circular economy where waste becomes a resource for someone else. It is thanks to recent advances in science that we can explore the richness of life and discover its prowess. Could the transposition of this knowledge to our human societies transform them in a sustainable way and encourage us to better preserve biodiversity? Let's imagine, for example, that a designer asks himself the question of substituting, finding new adhesives. The right way to ask oneself the question when one wants to do biomimicry is not to think what kind of glue there is in living things, it will be to think about the different assembly strategies in living things. And perhaps at that moment we will be able to come across strategies other than glue. For example, we might come across the way in which a gecko can cling to a glass pane that is not dependent on glue. It is a completely different physico-chemical system. One example is the company Tissium, which is working on imitating the composition of the saliva of tubeworms, which are able to glue small grains of sand together thanks to their saliva. And understanding the chemical mechanisms inside this saliva has led to the development of innovative surgical glues. We can also use living things to design new sustainable cities, for example, based on the way organisms exchange materials, energy and information.

Biomimicry is necessarily a multidisciplinary approach, it is necessarily a dialogue between biology, in the broadest sense, and other disciplines. In management, material sciences, engineering sciences, architecture, we need philosophers, we need artists, and we need different sensibilities. This biomimicry offers an opportunity to rethink our design systems, to rethink the specifications of the different products and services that we are going to develop, so as to make them compatible with the biosphere and therefore sustainable. We are really in a biodiversity that is indispensable to us, we depend on it, we human species. We depend on it in many ways that scientists describe as ecosystem services. What we take from nature for our food, our fibre, our medicines, which allows us to regulate things, like the climate, the forests that grow, that fix carbon. So there is an enormous link between the stakes of biomimicry and innovation and ensuring that we do not destroy this fabric of living things of which we are a motif. Biomimicry offers concrete responses to the challenges of sustainable development, the fight against global warming and the protection of biodiversity. Learning from nature and reconciling with it is a promise full of hope for a humanity that is aware of the changes in which it must engage.

The key points of the video are around the following questions: When did life appear on Earth? Which crises invite us to rethink our modes of production and consumption? Is the living economy based on abundance or scarcity? Why is it interesting that nature manufactures at room temperature and pressure? Why is biomimicry described as a multidisciplinary approach?

**Lesson activities:**

| Time | Activity / Main content |
|---|---|
| 5 min | Brief introduction about the focus and the aims of the lesson |
| 5 min | Showing presentation in PPT<br>Focus on key questions |
| 5 min | Distribution of student worksheets<br>Explain that they may need to take notes during the video |
| 5 min | Watching video |
| 10 min | Students work on their worksheets individually |
| 10 min | Discussion on key message points |
| 5 min | Wrap-up and summary |

**References, link, bibliography:**

Online repository of resources, https://asknature.org/

# Topic: Philosophy of biomimicry

## Title of activity: A5. From planetary boundaries to biomimicry

**Lesson Duration: 60 min or 2x30 min**

**Level of difficulty: easy-moderate-difficult**

**Students' age: 12-15**

**Materials / equipment:**

*PPT presentation about the topic prepared by the teacher*

*Student Worksheets "From planetary boundaries to biomimicry" p.97-99*

**Learning Objective:**

- to understand the concept of planetary limits
- to discover the 9 planetary boundaries
- to realise the need for humanity to function differently, respecting planetary limits, reconnecting with the living world
- to learn the principles of life
- to link them to biomimicry

**For teachers - Description of activity/Theoretical Background**

In this activity we introduce and discuss the planetary limits. The planetary limits or boundaries are the thresholds that humanity must not exceed so as not to compromise the favourable conditions in which it has been able to develop and to be able to live sustainably in a safe ecosystem, that is to say, avoiding sudden and difficult to predict changes to the planetary environment.

These nine natural processes are selected, because together they allow and regulate the stability of the biosphere: climate change, erosion of biodiversity, disruption of biogeochemical cycles of nitrogen and phosphorus, changes in land use, ocean acidification, global water use, stratospheric ozone depletion and increasing aerosols in the atmosphere.

Today we know that we will not be able to continue to consume at the same rate as before, and solutions are being studied to find a balance with the earth and other species. Of course, there is no single miracle cure. But by observing living beings and how they function in nature, we can all together draw inspiration from them to invent and innovate. This scientific approach is called biomimicry. It involves not only inventing or perfecting objects, materials or techniques, but also imagining new, more sustainable ways of living, consuming and producing. The aim is to live with the rest of the living world, since humans are also part of the Earth's ecosystem.

## The Planetary Boundaries of Earth

According to Wikipedia, the free encyclopaedia, the planetary boundaries is a concept involving Earth system processes that contain environmental boundaries. It was proposed in 2009 by a group of Earth system and environmental scientists, led by Johan Rockström from the Stockholm Resilience Centre and Will Steffen from the Australian National University.

The group wanted to define a "safe operating space for humanity" for the international community, including governments at all levels, international organizations, civil society, the scientific community and the private sector, as a precondition for sustainable development. The framework is based on scientific evidence that human actions since the Industrial Revolution have become the main driver of global environmental change.

According to the paradigm, "transgressing one or more planetary boundaries may be deleterious or even catastrophic due to the risk of crossing thresholds that will trigger non-linear, abrupt environmental change within continental-scale to planetary-scale systems." The Earth system process boundaries mark the safe zone for the planet to the extent that they are not crossed. As of 2009, two boundaries have already been crossed, while others are in imminent danger of being crossed.

In a sustainable society, nature is not subject to a systematic increase. And in such a society people are not subject to conditions that systematically diminish their ability to provide for themselves.

## Our planet Earth

Earth forms a vast whole, a great ecosystem in which air, water, animals and plants naturally function in harmony. For example, in a marsh, plants are used as food for animals. They clean the water the animals drink and renew the air they breathe. Animals, on the other hand, aerate the soil by digging tunnels and their droppings are used as fertilizer by the plants. Dead plants and wilted flowers make up the humus that enriches the soil. Water allows new plants to grow and develop. Plants also make up the bulk of the matter of every living being.

Life appeared on earth 3.8 billion years ago, and although it has changed a lot, nothing has been able to make it disappear: neither the glaciers covering the land and the seas, nor the eruptions of giant volcanoes, nor the shocks of meteorites!

But over the last two centuries, imbalances have appeared. Humans have almost exhausted the reserves of fossil fuels, such as coal and oil. By burning them, they have polluted the air and warmed the atmosphere. To produce their food, they have used toxic substances, such as insecticides in the fields or antibiotics in animal husbandry.

Today we know that we will not be able to continue to consume at the same rate as before, and solutions are being studied to find a balance with the earth and other species. Of course, there is no single miracle cure. But by observing living beings and how they function in nature, we can all together draw inspiration from them to invent and innovate.

This scientific approach is called biomimicry. It involves not only inventing or perfecting objects, materials or techniques, but also imagining new, more sustainable ways of living, consuming and producing. The aim is to live with the rest of the living world, since us humans are also part of the Earth's ecosystem. We can learn a lot from Nature. Because Nature is constantly innovating in the service of resilience and diversity, and it uses constraints as opportunities. Biomimicry is an approach that aims to draw inspiration from living things and their principles to invent new ways of living, consuming and producing, while respecting planetary limits .**Let's discover the life principles. And link them with biomimicry.**

- Nature works in cycles
- Nature optimises the use of resources and means
- Nature favours the use of local resources
- Nature uses mostly flow energy (mainly solar energy)
- Nature is based on dynamic and interconnected balances

**Lesson activities:**

| Time | Activity / Main content |
|---|---|
| 5 min | Brief introduction about the focus and the aims of the lesson |
| 15 min | Showing presentation in PPT. Focus on key concepts (planetary boundaries, life principles, biomimicry). |
| 5 min | Discussion with students. Answering questions. |
| 5 min | Distribution of student worksheets. Explaining their task. |
| 15 min | Students work on their worksheets individually. |
| 10 min | Overall discussion and wrap up on key points. |
| 5 min | Summary and conclusions. |

**References, link, bibliography:**

Planetary boundaries, https://en.wikipedia.org/wiki/Planetary_boundaries, Wikipedia

Online repository of resources, https://asknature.org/

# Topic: Biomimicry: examples

## Title of activity: B1: Kingfisher and Shinkansen

**Lesson Duration: 45 min**

**Level of difficulty: easy-moderate-difficult**

**Students' age: 12**

**Materials / equipment:** *PPT presentation about the topic prepared by the teacher, Student Worksheets "Kingfisher and Shinkansen" p.100-102, Play dough, a bowl, water, Cards with questions of the topic "Kingfisher and Shinkansen"*

**Learning Objective:**

- Interpret the concept of biomimicry
- Explain the influence of nature in our life.
- List three examples of natural solutions used in our everyday life
- Describe the structure of Kingfisher's head
- List elements that enable the bird being a more efficient hunter
- Explain how sound moves around
- List elements that enable Shinkansen being the fast-moving train

**For teachers - Description of activity**

Birds are well-suited to their living style and the environment. One of them is the Kingfisher. Kingfisher is a small brightly coloured bird found in the tropical regions of the Earth such as Africa, Asia, and Oceania. This bird is especially interesting in the biomimicry context. Engineers used the beak of the bird to construct the front of Shinkansen- the very fast-moving train. Why did they choose this pattern? The construction of the bird's beak enables it to dive without splashing or waves. Its streamlined shape allows it to hunt with limited disturbance due to aerodynamic and hydrodynamic drag, allowing it not to lose speed and not alert its prey when it enters the water.

The kingfisher can sit still and patiently on a branch above the water, waiting for a fish in the river current. After seeing its prey, it drops into the water at a speed of over 40 km / h. Its eyes, covered by a transparent membrane and protected by a bony casque attached to the prefrontal bone of the skull, enable the bird to dive and see the potential meal. Its feathers store the air that facilitates the ascent from water, due to Archimedes' thrust. All the action: jumping into the water, catching a fish and surfacing took only 2 seconds.

The Japanese high-speed train "Shinkansen" connects Osaka and Hakata through numerous tunnels. However, in the tunnels, the air is compressed so its resistance increases. How can we lose as little energy as possible and fight against these changes in pressure, which cause inconvenience to passengers in particular? The first train was in a different shape which caused it to slow down during passing tunnels. If it did not do it, the fabric of the tunnels would be impeded. The reason for it was the train pushed the whole air across the tunnel, when it went out, huge masses of air generated tremendous rumble. The sound pulses could have damaged the tunnel or caused it to collapse.

Considering the arguments described above, the engineers decided to choose a kingfisher's beak as the pattern. This bird dives in the water almost without a splash. Now, trains with kingfisher-like locomotives leave the tunnels silently. Later on, engineers, when designing other high-speed locomotives, took their inspiration from the Shinkansen, the kingfisher's head.

Lesson activities:

| Time | Activity / Main content |
|---|---|
| 2 min | Presentation of the aims of the lesson.<br>Understanding the meaning of nature in our live<br>Using solutions from the nature to solve day-to-day problems<br>Finding correlation between kingfisher and Shinkansen |
| 5 min | Introduction<br>-Describing the concept of Biomimicry. Brainstorming is recommended.<br>Questions:<br>“What do you think the word Biomimicry means?”<br>“What two words do the word Biomimicry consist of?”<br>Students on their own formulate the definition of Biomimicry. Looking for some examples of Biomimicry around them. |
| 3 min<br>5 min | Watching the video: Un splendide martin-pêcheur en slow motion - ZAPPING SAUVAGE<br>Discussing the way of living and achieving food by kingfisher.<br>Paying attention to both the structure of the bird's head and the way of obtaining food.<br>Questions:<br>What can you say about kingfishers?<br>How do they live?<br>Looking at the birds, describe the structure of the body. |
| 12 min | *Handing out Activity 1. Students prepare: play dough, a bowl with water.*<br>Activity 1.<br>Part One<br>Students form the head of the bird with play dough.<br>Students form the cuboid of 7cm long, 3 cm wide, 3 cm hide with play dough.<br>Part Two<br>Students throw formed objects into a previously prepared bowl of water. Students do that from the same height at the same force. The head of the bird should be put in water as it would dive, Similarly, the cuboid should be thrown into water from the wider side. |

| | |
|---|---|
| | *Students observe the behaviour of the water when throwing objects. Then, they write down the observation to the worksheet.*<br>They answer the questions:<br>1. What can you see when you drop the bird's head into the water?<br>2. What can you see when you drop the cuboid into the water?<br>3. Compare the effects during putting objects to the water.<br><br>As a start point of discussion, show students a presentation. Title of the presentation: *Kingfisher and Shinkansen* |
| **7 min** | Initiating the discussion about the correlation between the structure of the kingfisher and Shinkansen<br>Questions:<br>How do birds adapt to their natural environment? Give some examples of adjusting.<br>"The engineers who designed the profile of the Japanese "Shinkansen" train were inspired by a bird: the kingfisher. Why did they choose this biological model?"<br>List similarities in structure of kingfisher and Shinkansen.<br>Which elements of the structure of the train make it fast-moving?<br>Which elements enable this bird to be a more efficient hunter?<br><br>Hint: On its journey, the train passes through many tunnels. |
| **5 min** | Handing out Activity two.<br>Activity two.<br>Based on the following video, can you draw a profile of kingfisher and<br>Shinkansen train? |
| **6 min** | Summary of the classes<br>Activity three:<br>Each student draws one of the cards of the current topic questions. In case of the correct answer, that person points out the next person to draw a card and answer the question. |

**References, link, bibliography:**

Un splendide martin-pêcheur en slow motion - ZAPPING SAUVAGE

Holmes Hannah, „Blaze of blue. Kingfishers", „National Geographic", 2009

Kruszewicz. A. „Polish birds", Multico 2005.

# Topic: Biomimicry: examples

## Title of activity: B2: Coral and cement

**Lesson Duration: 45 min**

**Level of difficulty: easy-moderate-difficult**

**Students' age: 10-11**

**Materials / equipment:**

*PPT presentation about the topic prepared by the teacher,*

*Student Worksheets "Coral and cement" p.103-104,*

*Wordwall game*

**Learning Objective:**

- To promote students' understanding of the cyclical nature of nature, the interactions that allow ecosystems to exist and develop.
- To help understand how the coral lime skeleton is formed and what is its role in biomimicry.
- Use of natural solutions in solving everyday problems.

**For teachers - Description of activity/Theoretical Background**

**Biomimicry** brings potential solutions to our current problems, but also a new collective imagination based on wonder at the abundance and ingenuity of forms of life. Let us therefore take note of our deep interdependence with respect to biodiversity to make possible the emergence of a capable of guiding our relations with non-human living things. It will involve in particular the equitable sharing of resources and space, respect, acceptance of all forms of diversity and the non-reducibility of living things to any form of utilitarianism. **Corals** live in colonies in warm sea atolls and coral reefs. They build skeletons throughout their lives. Depending on the species they take on different shapes, colours and consistencies. Coral takes carbon and dissolved calcium from seawater and transforms it into calcium carbonate through a chemical reaction. The ore produced is called aragonite. Coral makes a calcium carbonate ($CaCO_3$) **cement** from carbon dioxide ($CO_2$). Scientists have created eco-cements, a new type of material that absorbs, as it dries, the $CO_2$ contained in the air and in which we can incorporate waste (ash for example). These new cements therefore help both to recycle waste and to capture carbon (buildings become carbon sinks) A Californian Company, Calera, produces a building material close to the coral skeleton. The $CO_2$ used comes from a nearby power plant. While the traditional cement industry is a major $CO_2$ emitter, Calera obtains cement by capturing $CO_2$ emissions from the plants. Carbon dioxide is no longer the problem, it becomes the solution. **Cement (and the carbon cycle).** Throughout the history of our planet, enormous quantities of carbon have been sequestered in limestone, sediments and hydrocarbons by the activity of the living world; shellfish have used it to make their shells and trees have transformed it into woody material. One solution to the problem of carbon dioxide ($CO_2$) build-up and waste production would be to imitate nature and incorporate it into building materials. By emulating nature, which recycles all its materials, we can even dream of fully recyclable cities.

Lesson activities:

| Time | Activity / Main content |
|---|---|
| 2 min | Word wall game<br>At the beginning of the lesson, students are offered a game, the aim of which is to create an idea of the diversity of coral shapes and similarities with other objects (nature, objects). |
| 5 min | **Introduction**<br>Presentation -Coral and cement<br>Understanding the meaning of nature in our live<br>Using solutions from the nature to solve day-to-day problems |
| 4 min | **Main activity**<br>Question: Do you know what corals are and what makes them special?<br>Watching the video: https://www.youtube.com/watch?v=IEWJAEkGeNk |
| 10 min | **Discussion**<br>What can you say about corals? What do you find most interesting and amazing about your life?<br>Let's look inside a polyp to see how it helps build a reef. It takes carbon from algae and seawater, turns it into calcium carbonate, and uses this chalky substance to build an internal skeleton. This visualization showing the interior of the polyp during the skeleton-building process will change your understanding of how hard corals construct entire reefs! |
| 2 min | *Watching the video:* How Do Corals Build Reefs? \| California Academy of Sciences |
| 8 min | **Worksheet**<br>**Activity 1**<br>Answer to the question: (worksheet question)<br>What problem do you think people could use to learn from coral building abilities?<br>**Mark appropriate answers!**<br>**People have used the experience of corals to:**<br>___ create eco-cements, a new type of material that absorbs |

| | |
|---|---|
| | __ create new cements therefore help both to recycle waste and to capture carbon (buildings become carbon sinks)<br>___ produces a building material close to the coral skeleton<br>___ imitate nature and incorporate it into building materials |
| 2min | Watching video: Making Cement The Way Coral Does It: Out Of Thin Air |
| 10 min | **Activity 2**<br>Draw where you would use such cement, what are your ideas? |
| 2 min | **Conclusion**<br>Evaluation of the lesson.<br>What new things have you learned?<br>Why is it so important to study natural processes? |

**References, link, bibliography:**

How Coral Reefs and Carbon Dioxide Can Change the Future | Think Like a Tree

How Do Corals Build Reefs? | California Academy of Sciences

Coral: What is it?

Biomimicry: Using Nature's Perfect Innovation Systems To Design The Future

Koraļļi — Vikipēdija

Brent Constantz būvē cementu tāpat kā koraļļi - Cits - 2021

# Topic: Biomimicry: examples

**Title of activity: B3: Bite like a mosquito**

**Lesson Duration: 45 min**

**Level of difficulty: easy-moderate-difficult**

**Students' age: 10**

**Materials / equipment:** *PPT presentation about the topic prepared by the teacher, Student Worksheets "Bite like a mosquito" p.105-107, Word wall game, Different kind of needles, an orange or an apple.*

**Learning Objective:**

- Explore mosquito's bite anatomy
- Analyse mosquito's bite
- Understanding the biomimetic process

**For teachers - Description of activity/Theoretical Background**

The female's proboscis (proboscis) is made up of vulnar mouthparts or styli (maxilla, labia, hypopharynx) which are enveloped by the flexible labium (i) which folds up at the time of the bite. The mosquito pushes the styli into the epidermis up to a blood capillary thanks to the jaws which perforate the skin and allow the tube to remain in place during blood collection. The styluses delimit two channels: one (salivary channel), formed by the hypopharynx, through which an anticoagulant saliva is injected, and the other (alimentary channel), at the level of the labra, through which blood is drawn which, if infected, will contaminate the mosquito. The amount of blood drawn varies from 4 to 10 mm3 in 1 to 2 minutes48. According to the American Mosquito Control Association website, the average blood collection is 5 millionths of a litre; the insect ingests 5 mg of blood, which is twice its own mass as it weighs an average of 2.5 mg49. If one day you receive a painless injection, it is thanks to a new micro-needle that will be on the market in the near future. This needle is inspired by mosquitoes. The reason? Because probably the least loved insect in the animal kingdom, is the inspiration for new research by scientists at Ohio State University (OSU).

**A needle inspired by nature**

"The reason we look at nature as a clue is that nature has gone through a long period of evolution to discover the simplest and most effective methods," said Bharat Bhushan, professor of mechanical engineering at OSU. "In this work, what interested us was the way mosquitoes bite, because they are able to do that for several minutes without us feeling anything. We wanted to use it to see if we could develop a micro-needle that would be painless."

**Analyse how mosquitoes bite**

So far, they have not developed a prototype of this needle. What they have done is take a closer look at the components that allow the mosquito to bite people without causing them discomfort. Mosquitoes use a combination of four substances. These include the use of a saliva-based numbing agent during the biting process, a serrated design for the "needle" during the piercing process, and a combination of soft and hard parts on the proboscis, the elongated sucking part of the insect. This combination allows the mosquito to pierce the skin with only a third of the force required by an artificial needle, while the numbing agent allows the mosquito to bite without the target individual feeling the bite. Based on this research, Bhushan suggests that it would be possible to create a micro-needle containing two needles. One would inject a numbing agent, while the second could be used to draw blood or inject a drug. This second needle, which would also have a serrated edge like a mosquito's trunk, would be flexible and softer on the tip and sides, and would vibrate once inserted. This researcher says the materials and technology to create such a needle already exist.

| Time | Activity / Main content |
|---|---|
| 2 min | **Introduction** |
| | Wordwall game, where students have to match different needles with relevant pictures. |
| | https://wordwall.net/resource/12582808 |
| 5 min | **Presentation of the aims of the lesson.** |
| | Understanding the meaning of nature in our live |
| | Using solutions from the nature to solve day-to-day problems |
| 3 min | **Questions:** |
| | "What do you think about how people imagine using needles for very many types of employment?" |
| | "How can you define this process in a few words?" |
| | Students on their own words formulate the definition of Biomimicry/ Biomimetics |
| 5 min | **Watching the video:** How Mosquitoes Use Six Needles to Suck Your Blood \| Deep Look |
| 15 min | **Discussing the way of living by mosquitoes.** Paying attention to both the structure of mosquito's needle and the way of getting blood. |
| | **Questions:** |
| | "What can you say about mosquitos?" |
| | "How do they live?" |
| | "Looking at the mosquito, describe the structure of the bite." |
| 2 min | **"Watch the surprising video of a mosquito biting and answer the questions!"** Mechanism of a Mosquito Bite |
| 10 min | ***Handing out Activity 1.***<br>1. Draw a mosquito, indicating where the labium and the fascicle are located! 2. One company was inspired by the mosquito to develop medical needles. What do you think were the engineers' reasons for choosing this biological model? How can these needles perform better? |
| | Show presentation – Bite like mosquito |
| | ***Handing out Activity 2.*** |
| | **Imagine that You are medical and have to inject medicine or take a blood test. Let's try to do it!** Students choose different sizes of needles, make injections for an apple or take a blood test from an orange. |
| 3min | **Summary of the classes**. |
| | Evaluation of the lesson – discussion. |
| | What new things have you learned? Why is it so important to research processes of nature? How do You think mosquito bite could be improved in the future? |

**References, link, bibliography:**

Mechanism of a Mosquito Bite

How Mosquitoes Use Six Needles to Suck Your Blood | Deep Look

Mosquito bite helps create the ideal injection needle

Biomimicry: What We Can Learn from Nature

# Topic: Biomimicry: examples

Title of activity: B4: Colourful like a morpho butterfly

**Lesson Duration: 1 hour 5 minutes**

**Level of difficulty: easy-moderate-difficult**

**Students' age: 14-16 years**

**Materials / equipment:**

*PPT presentation about the topic prepared by the teacher,*

*Student Worksheets "Colourful like a morpho butterfly" p. 108-110,*

*Microscopes, Petri dishes, probes, Drawing paper, pencil, book with butterfly scale images, boxes of crayons, white paper, Flashlights.*

**Learning Objective:**

- Understand the concept of biomimicry.
- Explain the structure of a butterfly wing and why it is covered in scales.
- Drawing butterfly wings.
- Describe the patterns on butterfly wings and speculate about their functions.
- Diffraction principle
- Explain how water bends light
- Elaborate on the concept of bending light and how the micro-structures of a Morpho butterfly's wings work.
- The operation of a photovoltaic panel and efficiency

**For teachers - Description of activity/Theoretical Background**

Morpho is a genus of butterfly with 80 known species. They range in size from 3"-20" and are mostly found in tropical regions such as Central and South America. Adult Morphos feed exclusively on rotting fruit juices. The estimated life cycle of the morpho butterfly is approximately four and a half months. Morphos are most notable for the extremely vibrant coloration in the males of the species, which are usually a metallic blue or green.

Fot: Cindy Gustafson/Pexels.com

Blue morpho butterflies that do not use pigment to create the bright blue colour on their wings. Instead, their wings have a layered microstructure that causes light waves that hit the surface of the wing to diffract and interfere with each other, so that certain colour wavelengths cancel out while others, such as blue, are intensified and reflected.

Coatings and colour are restricted by aesthetics, ease of application, expense, range, and toxicity. Innovation in industries from various sectors like automotive, construction and customer products are all similarly limited by their surface chemistry. In industry, colours are typically produced by the inclusion of potentially toxic pigments, dyes and binders within the coatings.

Butterfly winds have a double membrane lined with scales that overlap like shingles on the roof of a house. The beautiful iridescent wings of the Blue Morpho are structured on five levels. According to Serge Berthier, author of Photonique des Morphos: “While it is true that Morphos are mainly known for their vivid blue colouring of physical origin, pigments are a fundamental element of their chromatic characteristic.” In fact, each scale contributes to a given effect, and any modification at one level can influence the final result: the wind, covered with tiny scales fixed to the membrane, scatters light rays; the scales, covered with thin parallel, evenly spaced striations, have an overall structure of two-dimensional photonic crystal; the striations, consisting of a stack of lamellae, form a diffraction network by reflection; the chitin lamellae, kept at a constant distance, create interference; the cells formed between the striations let the light penetrate to the pigments in the deep layers.

The wings of a butterfly have inspired a new type of solar cell that can harvest light twice as efficiently as before and could one day improve our solar panels. Solar panels are usually made of thick solar cells, and are positioned at an angle to get the most amount of light from the sun as it moves throughout the day. The wings of this butterfly have an extremely fine surface texture that reflects a narrow range of specific wavelengths, which is to say a certain colour. The Fraunhofer ISE experts apply a similar surface texture and coating to the back of the protective glass on photovoltaic modules using vacuum technology. Depending on the tailoring of the coating, cover glass can be made in say a crisp blue, green, or red. “Around 93 percent of light can penetrate this layer, with only around 7 percent being reflected to cause the colour effect,” explains Thomas Kroyer. The Fraunhofer Research Institute based in Freiburg named its technology Morpho Colour after the bright blue morpho butterfly.

Lesson activities:

| Time | Activity / Main content |
|---|---|
| 10 min | See the following videos:<br>Animals Cannot Be Blue \| Explorer<br>What Gives the Morpho Butterfly Its Magnificent Blue? \| Deep Look |
| 30 min | Explaining the structure of a butterfly wing and why it is covered in scales.<br>Describe the patterns on butterfly wings and speculate about their functions. |
| 5 min | **Activity 1:** Discussion: why can't animals be blue? |
| 15 min | **Activity 2:** Look up the structure of the Morpho butterfly and try to draw its wings |
| 5 mins | Where does the blue colour of the morpho butterfly come from? (making sure that the students understood the lesson) |

References, link, bibliography:

What Gives the Morpho Butterfly Its Magnificent Blue? | Deep Look

Nature = Futur ! Un papillon solaire

Blue Morpho Butterfly | Untamed

Structural color of Morpho butterflies: American Journal of Physics: Vol 77, No 11

Butterfly wings inspire a better way to absorb light in solar panels

Solar technology with the beauty of butterfly wings

# Topic: Biomimicry: examples

Title of activity: B5: Discover and draw the anatomy of the wing

**Lesson Duration: 45 min**

**Level of difficulty: easy-moderate-difficult**

**Students' age: 11**

**Materials / equipment:**

*PPT presentation about the topic prepared by the teacher,*

*Student Worksheets "Discover and draw the anatomy of a wing" p.111-112,*

*Feathers,*

*Bingo Cards*

*The video* The Anatomy of Flight

**Learning Objective:**

- Interpret the concept of biomimicry
- Explain the influence of nature on our life.
- List three examples of natural solutions used in our everyday life.
- Explain the structure of the feather.
- Describe kinds of feathers on the body of a bird.
- Describe the anatomy of birds' wings.
- Draw structure of a bird's wing.

**For teachers - Description of activity/Theoretical Background**

The wings of the birds are modified forelimbs that enable them to fly. Similarly to the human hand, it bends at three points. It is covered with feathers being suitably spread and with the help of cutaneous muscles, creates extensive load-bearing planes. The wings are set in motion with the help of very strong pectoral muscles which are attached by means of a bone crest located on the sternum. Birds' wings are light, strong and flexible. They have fewer feathers than the body, each feather weighs very little, but together they weigh more than the skeleton. A bird's wing is divided into 2 large parts, which in turn are divided into several smaller parts. The most important in terms of the flight are remiges:

- Primary: located at the end of the wing; provides propulsion and manoeuvring of the bird.
- Secondary: located in the middle of the wing; gives the wing the curved shape necessary for flight.
- Tertiary: part closest to the body; reduces air turbulence.
- Alula: is located at the front of the wing; used to stabilise the flight in case of gusts of wind and to glide safely at low speed.

Feathers, made of keratin, have the spine down the middle called the shaft. That part is hollow in the middle. The vanes are on the two halves of the feather. They are made of thousands of branches called barbs. Because there are many spaces between these barbs, a feather has a lot of air.

Lesson activities:

| Time | Activity / Main content |
|---|---|
| 2 min | **Presentation of the aims of the lesson.**<br>Understanding the meaning of nature in our live<br>Using solutions from the nature to solve day-to-day problems |
| 5 min | **Introduction**<br>-Describing the concept of Biomimicry. Brainstorming is recommended.<br>Questions:<br>"What do you think the word Biomimicry means?"<br>"What two words do the word Biomimicry consist of?"<br>Students on their own formulate the definition of Biomimicry.<br>Looking for some examples of Biomimicry around in terms of flying. |
| 15 min | **Show the presentation "The anatomy of a bird's wing"**<br>Issues raised during the presentation:<br>The meaning of a wing for a bird<br>The structure of a bird's wing<br>Shapes of bird's wings<br>The structure of a bird's feather<br>Comparison of a plane with a bird |
| 3 min | **Main activity**<br>*Hand out feathers (one per person). Students try to gently tear them apart. Then they try to put it back together.*<br>*Students draw conclusions.* |
| 7 min | *Firstly, students watch the video:*<br>*The Anatomy of Flight* |

| | |
|---|---|
| 8 min | *Hand out the worksheet – Activity one.*<br>*Students fill in a worksheet – Activity one.*<br>**Activity 1**<br>A. Draw a bird's wing, showing primary, secondary and tertiary remiges and scapulars.<br>B. Compare bird and plane on the different phases of flight: take-off, flight, and landing. Feel free to make drawings |
| 5 min | **Summary:**<br>As a summary use bingo cards: |

| | | | |
|---|---|---|---|
| hook | barb | remiges | wing |
| biomimicry | duck | bone crest | feather |
| rachis | bird | quill | alula |
| tertially | primary | eagle | secondary |

**References, link, bibliography:**


The Anatomy of Flight

Einhard Bezzel “Birds” Multico Oficyna Wydawnicza 2010 PL

Przemysław Busse “A small zoological dictionary. Birds" Wiedza Powszechna Publishing House 1990 PL

Bird wing

# Topic: Biomimicry: examples

**Title of activity: B6:** History: The desire to fly, from Leonardo da Vinci to Airbus

**Lesson Duration:** 45 min

**Level of difficulty:** easy-moderate-difficult

**Students' age:** 12

**Materials / equipment:**

*PPT presentation about the topic prepared by the teacher,*

*Student Worksheets "History: the desire to fly, from Leonardo da Vinci to Airbus" p. 113-115*

*Video: The history of aviation in 11 incredible objects*

**Learning Objective:**

- Interpret the concept of Biomimicry.
- Explain the influence of nature on our life.
- List three examples of natural solutions used in our everyday life.
- Describe the history of aviation

**For teachers - Description of activity/Theoretical Background**

Aeronautics is a sector that has historically been bio-inspired. For this reason, it is easy to understand. Man has always dreamed of flying like a bird.

**15th century:** Leonardo da Vinci created the foundations of aeronautics. His creative mind bubbling with ideas and his insatiable curiosity worked in so many fields. His thirst for innovation, his creativity have been revealed to us by all the manuscripts that have come down to us. His quest for perfection, in the way he learned and understood the world, has led him to doodle a lot. His reflections, thoughts, ideas, projects with diagrams and drawings have been carefully recorded in notebooks that he carried everywhere with him! For a long time after his death, these manuscripts were scattered all around the world. Some of them lost, but thousands of pages eventually reappeared a few hundred years after his death.

**Leonardo da Vinci lays the foundations of aeronautics.** Laid by his curiosity and a scientific personality made the foundations of aeronautics. For ages, he was fascinated by the possibility of flight, which resulted in countless plans with detailed comments and explanations to build flying machines. A study of these documents shows that he was one of the first people who had laid the foundations of aeronautics.

**Leonardo da Vinci's manuscript on the study of the flight of birds** According to the scientific approach, it started with an observation: birds are the model and an incredible source of knowledge in this field, so he used it. From the manuscripts, we understand that Leonardo studied the beating of the wings, the way the bird stays in balance, gains altitude. During his observations, he considered the impact of the wind on the way a change of direction in flight! His knowledge of anatomy and mechanics (the study of movements and forces) supported his work. Then, he wrote down drawings of mechanical wings or flying machines, diagrams with detailed notes.

**In the Manuscript of a flying machine (1488), Leonardo da Vinci described his observations and conclusions:**

- Lift, caused by the difference in pressure between the top and the bottom of a wing, is the force counteracting weight for sustentation.

-Drag is the force of resistance to penetration into the air when a body is in motion. It must be compensated by propulsion.

He noticed that flapping of the wing does not contribute to lift but to propulsion. He understood that these two forces were a function of the surface of the object. The shape and speed of air circulation around it have tremendous importance.

Although his flying machine was unable to take off, he formed the basic principles of aeronautics. It must be said that current research on design and materials (both on the aircraft and the engines) is focused on both optimisation of lift and the minimisation of drag.

**Clément Ader's plane III (1897) is, for example, very inspired by the bat's wing.**

Bio-inspiration remains an approach in developments of this sector, improvement of shapes, surfaces, or even the material structures of devices. Over the centuries, our ancestors were already imitating nature. They have been inspired by the shapes existing in nature. Among them: Leonardo da Vinci (1452-1519) showed his genius not only as an extraordinary scientist but also as a champion of biomimicry. His motto? "Go and take lessons in nature, that's where our future is". To draw his ornithopter, with which he hoped that a human could fly with the strength of his arms, Leonardo da Vinci carefully observed the flight of birds, bats and dragonflies. Nothing escaped him: neither the shape of the wings, nor the function and arrangement of the feathers, nor the sequence of movements for taking off, flying nor landing. Leonardo da Vinci's various projects for flying machines remained in the form of sketches and plans: the manufacturing materials that existed at the time were too heavy. No human would have had the muscles to fly a prototype.

**Winglets: discovery of the winglet in 1974 at NASA**

The winglet was developed at the NASA research centre in Langley (USA) in 1974 by the American aerodynamicist Richard Whitcomb, also known for his work on area law and supercritical wing profiles. Whitcomb published his work on winglets in 1976.

**Boeing and first winglets**

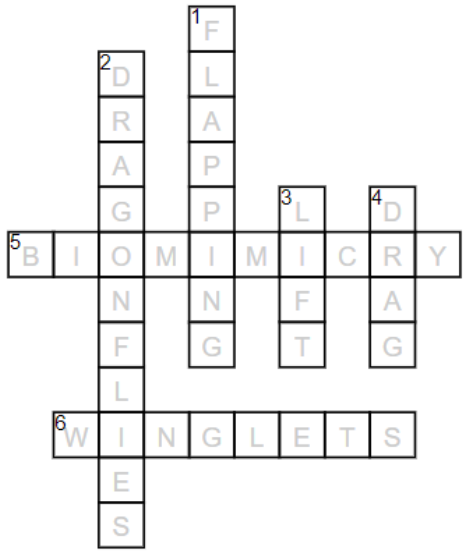
Boeing announced in 1985 a new version of the B-747, the 747-400 with increased range and cargo capacity. The wing of this model had an increased wingspan and the fitting of winglets. We find the same gains in energy efficiency on the Airbus models. Airbus has developed winglets and Sharklets wingtips for its Airbus ranges. Directly inspired by the curved tips of raptors' wings, the winglets have increased the lift of the A380 wings and reduced the size of the wings, keeping the wingspan within the possible limits of today's airports. The "sharklets", additionally inspired by shark fins, improve stability and reduce fuel consumption by up to 3.5%, representing an annual CO2 reduction of around 700 tonnes per aircraft (Airbus, 2012).

**Business aviation**

Winglets have been used in many jet aircraft to obtain the benefits of a higher effective aspect ratio: reducing the distance to take off and landing at secondary airports and increasing flight altitude. Not only can it be installed on new planes but on the older ones as well. The winglet has been used on business aircraft; only Dassault has temporarily resisted this trend. Cessna recently announced a partnership with Winglet Technology to test elliptical winglets.

Lesson activities:

| Time | Activity / Main content |
|---|---|
| 2 min | **Presentation of the aims of the lesson.**<br>Understanding the meaning of nature in our live<br>Using solutions from the nature to solve day-to-day problems |
| 6 min | **Introduction**<br>Describing the concept of Biomimicry. The brainstorm is recommended.<br>**Questions:**<br>"What do you think the word Biomimicry means?"<br>"What two words do the word Biomimicry consist of?"<br>Students on their own formulate the definition of Biomimicry.<br>Students look for some examples of Biomimicry to get somewhere faster. |
| 10 min | Showing students the presentation "The desire to fly, from Leonardo da Vinci to Airbus "<br>Discussing during the presentation. |
| 15 min | **Hand out students Activity one (worksheet). Show students the video:**<br>The history of aviation in 11 incredible objects<br>Then, using their knowledge and information in the video students trace, in the form of a chronological frieze, the main events in aviation. |
| 8 min | **Start a discussion about the results of the activity**. Checking the results of students' work.<br>Questions that could be used:<br>"Who one was the first person who desired to fly? How did it end?"<br>"Who one was the second person who desired to fly?"<br>"Give the order of events in aviation?" |
| 5 min | **Summary.** *Hand out the crossword – Activity two.* |




**Across**

**5.** The practice of making technological and industrial design copy natural processes

**6.** Discovered by NASA scientist.

**Down**

**1.** Which activity of birds contributes to their propulsion?

**2.** Which species of animals did Leonardo da Vinci carefully observe ?

**3.** It is caused by the difference in pressure between the top and the bottom of a wing, is the force counteracting weight for sustentation.

**4.** It is the force of resistance to penetration into the air when a body is in motion. It must be compensated by propulsion.

References, link, bibliography:

The history of aviation in 11 incredible objects

https://www.thermal-engineering.org/

# Topic: Biomimicry: examples

## Title of activity: B7: Winglets and aerodynamics

**Lesson Duration: 45 min**

**Level of difficulty: easy-moderate-difficult**

**Students' age: 12**

**Materials / equipment:** *PPT presentation about the topic prepared by the teacher, Student Worksheets "Winglets and aerodynamics" p.116-117*

**Learning Objective:**

- Interpret the concept of Biomimicry.
- Explain the influence of nature on our life.
- List three examples of natural solutions used in our everyday life.
- Describe the adaptation of birds to fly.
- Describe lows enabling planes to float in the air.
- Explain applying Winglets on the plane wings.
- Compare the body structure of birds with plane shape in terms of flying.

**For teachers - Description of activity/Theoretical Background**

**Winglets: definition**

Winglet: A substantially vertical winglet located at the wingtips of an aircraft reduces fuel consumption and increases in flight range. It works by reduction of the drag of the wing induced by lift. Winglets also have a great influence on the effective elongation of the wings. They make the flight more comfortable as they help to dampen vibrations. Improving performances of airplanes, they shorten the run-up of the planes and decrease the level of the noise during take-off and landing. This English word is still the most widely used, although French equivalents penne or "ailerette" have been proposed. Scientists of Wroclaw Technical University explain winglets are lurking in birds' life. Although birds do not bend the wings upwards, they outstretch feathers on the tips.

**Winglets: principle**

Overcoming gravity enables flying in the air. For overcoming that force a lifting force is responsible. But it could not occur if not for the special structure of wings. Especially shaped wings cause that the air flows around them with different lengths. At the top, it has a longer path than at the bottom. At the end of the wing surface, the air flowing over them from above and below meets simultaneously. Because it has different lengths to cover, the top one moves faster, and the bottom one moves slower. The difference in velocity between the air flowing over the top of the wing and that one flowing over the bottom causes pressure differences. The slower it goes, the lower its pressure. So the air from the bottom of the wing lifts a plane upwards. The pressure difference between the upper and lower surfaces of the wing is called a lifting force.

There is only one problem, the wing does not have an infinite length. The air with higher pressure from the bottom of the wing curls upwards at the tip of the wing, causing air vortices called edge vortices to form at the wing tip. Thus, the induced resistance increases. One way of counteracting this effect is to lengthen the wing. However, a higher aspect ratio (at the same surface area) causes an increase in the bending forces of the wing and an increase in its thickness, thus increasing its mass. The other solution should be applied. To overcome edge vortices, there is a need of either more engine power during the flight or the installation of diffusers of these vortices, i.e. winglets.

Correctly positioned, the winglet can recover some of the energy from the vortex. This has the effect of increasing the effective aspect ratio of the wing and reducing the drag induced by lift, without increasing the wingspan. A winglet receiving oblique airflow can straighten the airflow and develop slightly forward lateral lift, which can cancel out its own drag. The efficiency gain is a few percent.

**Bird aerodynamics**

Birds are vertebrates whose bones make up 10% of their body mass. They have hollow bones, which allows them to reduce their body mass. They are both strong but very light. The bird's beak is an extension of their skull which, if it were heavier, would prevent them from flying and deteriorate their sight. These characteristics contribute to the lightness of their skeleton. The wing bones are adapted to flight and are similar to the arms of a human. The muscles of birds make up 40% of their weight and produce heat that warms them up. The muscles on the legs allow the birds to propel themselves, while those on the rib cage allow them to flap their wings and stay in the air. The bird's bone is mainly hollow to allow it to be lighter and thus to perform better in flight.

**Lesson activities:**

| Time | Activity / Main content |
|---|---|
| 2 min | **Presentation of the aims of the lesson.**<br>Understanding the meaning of nature in our live<br>Using solutions from nature to solve day-to-day problems in terms of flying.<br>Finding correlation between birds wings and Winglets |
| 5 min | **Introduction**<br>-Describing the concept of Biomimicry. The brainstorm is recommended.<br>Questions:<br>"What do you think the word Biomimicry means?"<br>"What two words do the word Biomimicry consist of?"<br>Students on their own formulate the definition of Biomimicry.<br>Looking for some examples of Biomimicry around them. |
| 20 min | **Introduce the topic using the presentation "Winglets and birds wings"**<br>Issues discussed during the presentation:<br>-What makes the birds fly? Discussion about adaptation of birds to fly.<br>-Description of the bird's wings.<br>-Description of the plane structure that enables it to fly.<br>-Explaining why planes float in the air.<br>-Reducing the fuel consumptions and Winglets. Describing the role of Winglets.<br>-Highlighting the similarities in the structure of birds and plane wings. |
| 8 min | **Main activity** *Handing out The activity one (Worksheet)*<br>A. Describe the shape of raptors' wings and the shape of aeroplane wings.<br>B. Look for information (from your teacher, on the internet...) to explain why these winglets improve the flight efficiency of aircraft (reduction in fuel consumption of about 4%). |
| 10 min | **Summary of the classes**<br>Initiating a discussion on the topic "Did scientists mimic nature during the creation of planes? Did they use examples existing in nature to improve the performances of planes and minimise the exploitation costs?" |

**References, link, bibliography:**

https://www.thermal-engineering.org

# Topic: Biomimicry: examples

Title of activity: B 8: Experience: lift of a wing according to its profile

**Lesson Duration: 45 min**

**Level of difficulty: easy-moderate-difficult**

**Students' age: 12**

**Materials / equipment:**

*PPT presentation about the topic prepared by the teacher,*

*Student Worksheets "Experience: lift of a wing according to its profile" p. 118-119*

*String, paper, tape, Hairdryer, Metal tripods.*

**Learning Objective:**

- Interpret the concept of Biomimicry.
- Explain the influence of nature on our life.
- List three examples of natural solutions used in our everyday life.
- Describe the adaptation of birds to fly.
- Describe lows enabling planes to float in the air.
- Demonstrate an experiment to lift a sheet of paper with given tools.

**For teachers - Description of activity/Theoretical Background**

Overcoming gravity enables flying in the air. A lifting force is responsible for overcoming that force. But it could not occur if it was not for the special structure of wings. Specially shaped wings result in the flow of air around them. At the top, it has a longer path than at the bottom. At the end of the wing surface, the air flowing over them from above and below meets simultaneously. Because it has different lengths to cover, the top one moves faster, and the bottom one moves more slowly. The difference in velocity between the air flowing over the top of the wing and that one flowing over the bottom causes pressure differences. The slower it goes, the lower its pressure. So the air from the bottom of the wing lifts a plane upwards. The pressure difference between the upper and lower surfaces of the wing is called a lifting force.

Vultures can give us aerodynamic lessons. Variations in air pressure at the tips of aircraft wings create marginal vortices, which affect flight performance. This causes a turbulent flow that persists for long distances behind the plane. It is particularly dangerous to enter the vortices produced by a jumbo jet. Due to this fact, air traffic controllers leave a minimum separation time and distance between take-offs. Observation of vultures reveals that while they fly they open their remiges, the large feathers at the tips of their wings, just as when you open your fingers. Aeronautical engineers and biologists have understood that by reducing the resistance exerted by the vortices that is a possibility to save energy during flight, both for an aircraft and for the vulture. This is why upward-pointing structures called winglets, invented in 1974 by NASA engineer Richard Whitcomb, can be seen at the tips of the wings of planes. But usually, there is only one point per wing. By continuing to draw inspiration from vulture flight technology, airlines could further reduce their energy consumption and impact on the environment.

Lesson activities:

| Time | Activity / Main content |
|---|---|
| 2 min | **Presentation of the aims of the lesson.**<br>Understanding the meaning of nature in our live<br>Using solutions from the nature to solve day-to-day problems |
| 7 min | Introduction ***Show the presentation "Why do birds fly?"***<br>Issues discussed during the presentation:<br>-What makes birds fly?<br>-Describing the shape of birds' wings.<br>-Describing why a plane flies.<br>-Describing the shape of a plane wing.<br>-Comparing a bird's wing with plane wings. |
| 30 min | **Main activity** Students watch the video: Quand Airbus s'inspire de l'Albatros<br>*Divide students into groups. Hand out the worksheet - activity one.* Then, each group should receive tools to carry out the experiment: string, paper, tape, a hairdryer, and metal tripods. Initiate the discussion "How to lift a sheet of paper with received tools?" Students on their own propose the experiment, they manipulate it to carry out it. Then, they fill in the worksheet.<br>Hint for a teacher: TPE: le vol de l'avion-1ère expérience |
| 6 min | **Summary** One of the groups shows the result of their trials. |

References, link, bibliography:

TPE: le vol de l'avion-1ère expérience

https://www.thermal-engineering.org/

# Topic: Biomimicry: examples

## Title of activity B9: Shine like a cat's eye

**Lesson Duration: 45 min**

**Level of difficulty: easy-moderate-difficult**

**Students' age: 11**

**Materials / equipment:**

*PPT presentation about the topic prepared by the teacher,*

*Student Worksheets "Shine like a cats eye" p.120-121*

*The Video* All about Cats Eyes (Are We There Yet: Guide to Roads)

**Learning Objective:**

- Interpret the concept of biomimicry
- Explain the influence of nature in our life.
- List three examples of natural solutions used in our everyday life
- Explain why cats are good hunters
- Describe the structure of cats eye
- Find using the structure of a cat's eye as an example of Biomimicry

**For teachers - Description of activity/Theoretical Background**

Felines have highly developed night vision. When they encounter a light source, such as the headlights of a car, their eyes shine in the night. Cats, like all felines, have a membrane lining the retina, the tapetum lucidum. Like a mirror, it reflects the light and makes it pass through the retina a second time. Its eyes need six times less light than those of humans. The retina, the eye's most concentrated nerve, has two main types of cells i.e. rods and cones. Rod cells enable cats to see in low light conditions such as a night light. Comparing the number of rod cells in the human and cats' eye, there are 6-8 times more in the case of felines. Moreover, rod cells allow cats to feel the motion in the dark to a greater extent than a human's eye. Felines have a large number of rods but very few cones. Cones are the main factor that gives cats the ability to perceive and distinguish colours. Cat eyes have three types of cones that can determine the combination of red, blue and green. It absorbs mainly green light and very little blue and red. Felines see their environment in shades of grey, but they detect movement very well. Living beings have adopted three main strategies for finding their bearings, hunting or communicating at night: maximising the little natural light present, producing their own light (bioluminescence) or appealing to other senses that do not use light. Have you ever noticed that many animals suddenly exposed to light betray their presence with eyes that become extremely bright in the dark? Moths, on the other hand, can easily go unnoticed thanks to their very poorly reflecting corneas. In the dark, some amplify the light they receive, others collect as much light as possible without reflecting it, and still, others exploit wavelengths invisible to us. In most nocturnal animals, a special reflective layer, called tapetum lucidum (shiny carpet), acts as a mirror that reflects light that has passed through the retina without being absorbed. When light is directed at the eyes of an animal with a tapetum lucidum, the pupil appears to glow. Even a flashlight can produce this visible glow.

Lesson activities:

| | |
|---|---|
| 2 min | **Introduction**<br>Presentation of the aims of the lesson.<br>Understanding the meaning of nature in our live<br>Using solutions from the nature to solve day-to-day problems |
| 5 min | **Introduction**<br>-Describing the concept of Biomimicry. Brainstorming is recommended.<br>Questions:<br>"What do you think the word Biomimicry means?"<br>"What two words do the word Biomimicry consist of?"<br>Students on their own formulate the definition of Biomimicry.<br>Looking for some examples of Biomimicry around them. |
| 3 min | **Main activity**<br>Students describe on their own life style of cats |
| 4 min | Then, students watch the video All about Cats Eyes (Are We There Yet: Guide to Roads)<br>They conclude "Why cats are night animals" |
| 2 min | *Show presentation "Cats eyes as an example of Biomimicry"*<br>Issues discussed during presentation: |
| 10 min | The structure of a cats eye<br>A Cat's eye as an example of Biomimicry. |
| 9 min | Hand out workbook – Activity one.<br>Activity one<br>Activity 1<br>A.What are the three main strategies developed by living beings to find their bearings, hunt or |

| | |
|---|---|
| | communicate at night?<br>B. The cat is famous for its good night vision. What do you notice when it crosses the headlights of a car?<br>C. The cat, like all felines, has a membrane lining the retina, the tapetum lucidum. Like a mirror, it reflects light and makes it pass through the retina a second time. Its eyes need six times less light than those of humans.<br>Felines have a large number of rods but very few cones. Their cones absorb mainly green light and very little blue and red: felines see their environment in shades of grey, but they detect movement very well.<br>Anatomy: Represents a cat's eye, with its cones, sticks, tapetum and pupil.<br>Which object was inspired by the cat's eye (hint: we come across it on the roads) |
| 10 min | **Summary of the classes**<br>Each student creates three questions in terms of the topic. Later, one of the persons asks a question to one freely chosen colleague. If the answer is correct, that person asks his or her question to someone else. In case of an incorrect answer, the first person keeps questioning other colleagues. The person who uses the questions as the first one wins. |

**References, link, bibliography:**

Cat Eyes: Anatomy, Function and Vision

Zintegrowana Platforma Edukacyjna

All about Cats Eyes (Are We There Yet: Guide to Roads)

# Topic: Biomimicry: strategies and functions of living organisms

## Title of activity: C1. How does the gecko hang on? - Inspiration for the Human Being - Spiderman and Gecko of the PJ Masks - reality or fiction?

**Lesson Duration: 3 classes of 45 min**

**Level of difficulty: easy-moderate-difficult**

**Students' age: 10**

**Materials / equipment:**

*PPT presentation about the topic prepared by the teacher, Student Worksheets " How does the gecko hang on? - Inspiration for the Human Being - Spiderman and Gecko of the PJ Masks - reality or fiction? P. 122-123, books, computers, tablets.*

**Learning Objective:**

- Recognize a new field of science, Biomimetics, its potential and its tools for the production of new materials
- Evaluate the development of new technologies and new materials to help reduce the impacts that human activities cause on the environment
- Recognize materials produced from the observation of natural materials, considering aspects of the development of these products.

**For teachers - Description of activity/Theoretical Background**

The "gecko" is a small lizard (gecko) whose ability to "climb" the walls (and walk on the ceiling) and intelligence fascinates biologists and physicists. This adherence has been studied and, in part, explained by numerous works. At the centre of the ability to cling to the gecko spiderman are its specialized pads, located on the toes of the reptiles, composed of several setae (structures similar to bristles or hair) at the tip of which there are small structures called spatulas, each less than a micron wide. This allows attractive forces called van der Waals interactions to emerge between the adhesive bristles and the surface. A single spatula shows very weak molecular forces, however, when coupled in the thousands of thousands in the setae, the attraction becomes very strong. These forces are so strong that they not only support the weight of the gecko, but also for highly robust humans - up to 133 kg can be sustained by the adhesion forces between the gecko's fingers and the surface. However, a recent publication shows that the animal is so agile, it's because its feet are greasy! Adhesive soles of the gecko are a hobby of biomimetic specialists, a discipline that draws inspiration from nature to develop new tools and materials. This is the very example of a technology transfer, almost out of the wild to the laboratory. The study published in Interface magazine, of the Royal Society, by a team from the University Of Akron, Ohio (USA), could well lift the last veil on an increasingly better understood phenomenon.

Many studies have tried to explain this exceptional adhesion: undone and renewed up to twenty times per second, with each step of the reptile. All demonstrated that cunning, "the trick" resides in the forest of microscopic hair, the setula's, which cover the back of their paws. Each hair will, in fact, interact on a nanometric scale with the support, being able to support a fraction (very small) of the lizard's weight, thanks to the Van-der-Waals forces, responsible for the attraction between molecules. The accumulated action of millions of hairs will allow the animal to perform its acrobatics. What's more, a single finger is sufficient for the gecko to remain suspended from the ceiling. The discovery of this small secretion profoundly alters the theoretical models of "dry" adhesion. The principle, integrated with existing research, will refine the development of biomimetic materials, making them even closer to the natural example and, therefore, with greater performance.

## Lesson activities:

| Time | Activity / Main content |
|---|---|
| Lesson 1 | **Introduction:**<br>Understand and Discover what Biomimetics is by watching short videos. |
| Lesson 2 | **Main activity:**<br>Asking the question "Would you like to be like Spiderman?"<br>View video<br>Conduct targeted research that leads students to see how Gecko manages to scale walls defying gravity.<br>Research whether Gecko can inspire Human Being by creating new technologies |
| Lesson 3 | **Summary of the classes:**<br>The research papers prepared by the students (all their research and collection of information) will be worked on by older students in the Genially program and will later be presented to the class |

**References, link, bibliography:**

Em Pauta - Novidades

Patented Gecko-inspired Technology | Setex Technologies

# Topic: Biomimicry: strategies and functions of living organisms

## Title of activity: C2: Velcro and burdock

**Lesson Duration: 45 min**

**Level of difficulty: easy-moderate-difficult**

**Students' age: 10**

**Materials / equipment:**

*PPT presentation about the topic prepared by the teacher,*

*Student Worksheets "Velcro and burdock" p.124-125*

*Video:* Inventing with Plants!

*Yarn glove. Floorball. Floorball with Velcro. Magnifier. Velcro tape. Colourful toy designer, Velcro, burdock.*

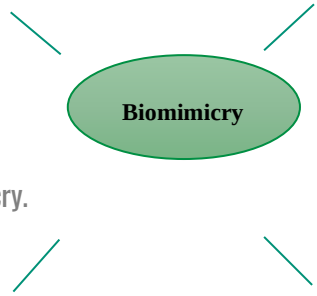
**Learning Objective:**

- Interpret the concept of biomimicry.
- Explain the influence of nature on our life.
- Describe the structure of burdock.
- Study the strategy deployed by the bardane to adhere to dog hair.
- Explains how Velcro works.
- Explain whether Velcro (R) meets all biomimicry criteria.

**For teachers - Description of activity/Theoretical Background**

**Burdock.** Everybody knows Velcro, the quick fastening system for clothing. Better known as "scratch", the Velcro tape is an invention by the Swiss engineer George de Mestral. But did you know that this invention is a clever imitation of nature and more precisely of the fruit of the Burdock? The story goes that in 1941, on his return from a hunting trip to the Alps, George de Mestral had to remove a lot of burdock fruit hanging on his clothes and in the hair of his dog. Burdock (Arctium lappa) is a wild plant that has fruits that cling to the hair of animals, allowing the seeds to spread. George de Mestral had the idea of observing the Burdock fruit under a microscope, and he noticed that the spines of the fruit end in deformable hooks. These hooks get caught in the hairs and looped tissues and return to their original shape when pulled out of a support. This observation gives him the idea of creating a type of quick-release fastener for clothing. After several years of development, he achieves the desired result with a soft cotton strip and a polyester strip with hooks. He named his invention Velcro, an apocope of the words "velvet" and "hook", and filed patents in the early 1950s (registration of the trademark in 1952), and industrial production of Velcro was launched right away!

Lesson activities:

| Time | Activity / Main content |
|---|---|
| 2 min | **Presentation of the aims of the lesson.**<br>Understanding the meaning of nature in our live<br>Using solutions from the nature to solve day-to-day problems<br>Finding correlation between Velcro and burdock. |
| 4 min | **Introduction**<br>Watching the video: Inventing with Plants! |
| 7 min | Describing the concept of Biomimicry. The brainstorm is recommended.<br>***The teacher writes down the ideas on a mind map.***<br>Questions:<br>"What do you think the word Biomimicry means?"<br>"What two words do the word Biomimicry consist of?"<br>Students have their own formulation of the definition of Biomimicry.<br>Looking for some examples of Biomimicry around them.<br>  |
| 7 min | **Activity 1.** Students split into pairs. Perform an experiment.<br>The first student puts on a glove (yarn). The second student takes two balls. One ball is with Velcro and the other without. Pupils stand five meters apart. The first is trying to catch the ball with one hand. Students exchange places. Then we ask Which ball was easier to catch? Why? |
| 7 min | As an introductory starting point to show students the presentation.<br>**Title of the presentation: Velcro© and burdock.**<br>Questions (during the presentation):<br>1. Do you recognize this plant?<br>2. Observe the properties of burdock? |

| | |
|---|---|
| | 3. Describe the structure of burdock?<br>4. What conclusion do you draw from it?<br>5. To name a few examples where Velcro is used.<br>6. What is the role of Velcro in everyday life? |
| 12 min | **Activity 2.** Question: ***How does Velcro work?***<br>Watching the video How Does Velcro Work? \| Design Squad<br>***Explore both sides of the Velcro tape with a magnifying glass. The student completes the first task of the worksheet.***<br>Velcro© was invented by an engineer who observed burdock seeds hanging on his dogs hair. Can you draw, in zoom mode, the two sides of a Velcro strip and explain in a few words the principle of adhesion? |
| 6 min | **Summary of the classes. Activity 3.** Uses Colourful toy designer, Velcro, burdock and creates creative work.<br>Question: Velcro© is inspired by nature. Do you think that this invention corresponds well to a biomimicry approach? As a reminder, biomimicry is an approach that consists of taking inspiration from living things to develop new ways of living, consuming and producing in a sustainable spirit. |

**References, link, bibliography:**

Inventing with Plants!

How Does Velcro Work? | Design Squad

Burdock Thistle | Kids Answers

# Topic: Biomimicry: strategies and functions of living organisms

## Title of activity: C3: Adhere without toxic glue

**Lesson Duration: 55 minutes**

**Level of difficulty: easy-moderate-difficult**

**Students' age: all ages**

**Materials / equipment:**

*PPT presentation about the topic prepared by the teacher,*

*Student Worksheets „Adhere without toxic glue" p.126-127,*

*YouTube video Why a Geckos Feet Can Stick to Almost Anything*

**Learning Objective:**

- What kind of feet do geckos have?
- Why does a gecko's feet stick to almost everything?
- Do geckos stick to skin?
- Can geckos swim?
- Look at everyday examples of manufactured objects that involve the adhesion of two or more pieces. Are these objects recyclable or reusable? How have they been manufactured

**For teachers - Description of activity/Theoretical Background**

Geckos are officially the largest animals capable of sticking to smooth walls. Spider-Man's ability to scale vertical walls may help the web-slinger catch the bad guys in comic books, but he could never pull this trick off in reality. A new study by zoologists at the University of Cambridge has found that geckos are the largest animals capable of sticking to smooth vertical surfaces – an ability that requires increasingly larger adhesive foot pads as a percentage of overall body surface as animals themselves become bigger. "As animals increase in size, the amount of body surface area per volume decreases – an ant has a lot of surface area and very little volume, and an elephant is mostly volume with not much surface area. "This poses a problem for larger climbing animals because, when they are bigger and heavier, they need more sticking power, but they have comparatively less body surface available for sticky footpads. This implies that there is a maximum size for animals climbing with sticky footpads – and that turns out to be about the size of a gecko." Geckos run up walls and scurry across ceilings with the help of tiny rows of hairs on their feet. The hairs, known as setae, generate a multitude of weak attractions between molecules on the two surfaces that add up to a secure foothold. Moreover, making and breaking the bonds that hold individual setae to a surface is easy. So, unlike glue or tape, a gecko's sticky feet attach and detach effortlessly, a trait envied by mechanical engineers.

The researchers compared the weight and footpad size of 225 climbing animal species. From the smallest (mites) to the largest (geckos) that use adhesion to stick to surfaces, this range of species spans more than seven orders of magnitude in weight – which, as Labonte points out, is like comparing the weight of a cockroach to that of Big Ben. That massive difference in weight is why the size of adhesive pads in small and large animals varies so widely. Tiny mites, for example, use approximately 200 times less of their total body area for sticky pads than geckos – the unofficial Big Ben of the adhesive climbing animal world – do. Larger animals would be able to climb vertical walls by adhesion if they surrendered more body surface area to sticky footpads.

Scientists have recreated gecko-like adhesion using silicones, plastics, carbon nanotubes, and other materials—but they've run into a scaling problem: The stickiness diminishes when the size of the adhesive exceeds a few square centimetres, severely limiting its practical applications. Even the gecko hasn't solved this problem. In theory, each gecko's hair is so sticky that the animal, which has about 6.5 million setae, should be able to hold up a 130-kilogram line-backer. In reality, a gecko can lift only 2 kilograms with its front feet. The scaling problem stems in part from the fact that loads don't distribute uniformly across large areas of adhesives, report researchers from Stanford University in Palo Alto, California, in a study published online today in the *Journal of the Royal Society Interface*. In gecko toes, for example, only a fraction of the setae are in close contact with the surface, and those that are don't share the load equally among themselves. This could be because the gecko skin, like a rubber band, becomes stiffer to stretch as more force is applied to it, the team suggests. When a gecko runs up a wall, the seats are stretched unevenly such that some have more force applied to them than others. So some hairs max out their stickiness, whereas others are underutilized or not attached to the surface at all. So a gecko patch's stickiness should increase if researchers can find a way to distribute forces more evenly.

**Lesson activities:**

| Time | Activity / Main content |
|---|---|
| 6Min | **Activity 1:** class discussion. Why can geckos stick to almost everything? |
| 24Min | **Activity 2:** PowerPoint presentation |
| 20Min | **Activity 3:** worksheet + class discussion |
| 5Min | **Lesson summary** |

**References, link, bibliography:**

Why a Gecko's Feet Can Stick to Almost Anything

New research investigates the physics of sticky gecko feet

Gecko-inspired adhesives allow people to climb walls

# Topic: Biomimicry: strategies and functions of living organisms

Title of activity: C4: Protecting against heat and cold

**Lesson Duration: 45 minutes**

**Level of difficulty: easy-moderate-difficult**

**Students' age: 9-11 years**

**Materials / equipment:**

*PPT presentation about the topic prepared by the teacher,*

*Student Worksheets "Protecting against heat and cold" p. 128-129,*

*YouTube video* How Do Animals Survive in the Arctic? 🐻‍❄️ - Animals for Kids - Educational Video

**Learning Objective:**

- How polar bears protect themselves.
- How polar bears control their body temperature.
- Animals that can withstand the coldest temperatures.
- Animals that can survive in hot weather.

**For teachers - Description of activity/Theoretical Background**

Wildlife can succumb to frostbite and hypothermia, just like people and pets. In the northern United States, the unfurred tails of opossums are a common casualty of cold exposure. Every so often an unusual cold snap in Florida results in iguanas falling from trees and manatees dying from cold stress.

Avoiding the cold is important for preserving life or limb (or, in the opossum's case, tail) and the opportunity to reproduce. These biological imperatives mean that wildlife must be able to feel cold in order to try to avoid the damaging effects of its extremes. Animal species have their own equivalent to what human beings experience as that unpleasant biting mixed with a pins-and-needles sensation that urges us to warm up soon or suffer the consequences. In fact, the nervous system mechanisms for sensing a range of temperatures are pretty much the same among all vertebrates.

One winter challenge for warm-blooded animals, or endotherms, as they're scientifically known, is to maintain their internal body temperature in cold conditions. Interestingly though, temperature-sensing thresholds can vary depending on physiology. For instance, a cold-blooded — that is, ectothermic — frog will sense cold starting at a lower temperature compared to a mouse. Recent research shows that hibernating mammals, like the thirteen-lined ground squirrel, don't sense the cold until lower temperatures than endotherms that don't hibernate.

Polar bears (Ursus maritimus) are not just one of the most beautiful animals in the world. They are also extremely interesting from a scientific perspective, as these bears live in the Arctic Circle and thus, are adapted to survive in one of the most extreme climates in the world. Polar bears can weigh between 150 and 700 kilos (330 to 1540 lb), and are about 1.20 to 1.60m (3'1" to 5'2") tall at the shoulders, although some specimens are much taller. Their tails are actually quite short. Female polar bears are much smaller than males, almost half their size. However, when they are pregnant, they try to store large amounts of fat, since this is what they survive on during their pregnancy and the first months of the cubs' lives. Although polar bears can walk on two feet, they are clumsy; these bears feel more comfortable walking on all fours and running, and especially swimming. In fact, they can swim incredibly long distances over the course of days; they average at 155 km (96 mi), which is an amazing feat. They are considered marine mammals due to the amount of time they spend in the water. Out of all habitats, their favourite is the sea ice on the Arctic Circle, where there are many small archipelagos. As mentioned earlier, polar bears are carnivores, and they have 42 impressive teeth to prove it. When they rise to the land, it's usually to hunt. Their most common prey includes the different seals of the Northern Hemisphere, belugas and young walruses.

**Lesson activities:**

| Time | Activity / Main content |
|---|---|
| 20Min | **Introduction of the topic**. Understanding how animals adapt and survive to the environment.<br>What are the animals? |
| 20Min | **Presentation of the topic** by using the PowerPoint presentation titled 'C4: Protecting Against Heat and Cold'. Main activity – class discussion<br>Question 1: By observing nature, which species have the ability to protect them from the extreme to intense heat? Can you name at least three of each?<br>Question 2: How does the penguin fight against cold?<br>Question 3: Which animal can survive extreme cold? |
| 5Min | Have a look at this video and see whether the questions above were answered correctly. How Do Animals Survive in the Arctic? 🐻❄ - Animals for Kids - Educational Video<br><br>**Summary of the classes**: How can animals protect themselves and survive in both extreme heat and cold conditions? |

**References, link, bibliography:**

How Do Animals Survive in the Arctic? 🐻❄ - Animals for Kids - Educational Video

Adaptation in Animals: Polar Bear, Penguins, Tropical Animals, Video, Q&A

How Do Animals Survive the Cold? Antifreeze and Fur Are Just the Beginning

# Topic: Biomimicry: strategies and functions of living organisms

## Title of activity: C5. Protecting against Cold

**Lesson Duration: 90 min**

**Level of difficulty: easy-moderate-difficult**

**Students' age: 9-10-11**

**Materials / equipment:**

*PPT presentation about the topic prepared by the teacher,*

*Student Worksheets "Protecting against Cold" p.130,*

*Video watching YouTube,*

*Computer for research and produce .*

**Learning Objective:**

- Learn about Biomimicry and how animals inspire Humankind to solve problems
- Research for animals that have inspired Mankind by having characteristics of protection against cold.

**For teachers - Description of activity/Theoretical Background**

We aim at recognizing the uniqueness of animals' characteristics that inspire the construction of lots of the things that we use in our daily life.

Students must be able to research for animals that are an inspiration for man, regarding their abilities to protect themselves against cold.

An oral presentation will be asked as a final product by following a worksheet with guidelines on the animal students researched.

**Lesson activities:**

| Time | Activity / Main content |
|---|---|
| 15 min | **Visualizing and understanding the message in the video**<br>Biomimicry for Young Children - Animals in Snow |
| 35 min | **Main Part:**<br>1. Class divided in small groups:<br>– finds out the definition of Biomimicry<br>– Identifies the animals mentioned in the video<br>– identify what did the animals mentioned inspired to build/construct<br>2. Short Presentation to the class of the findings – moment for dialogue/discussion about the importance of nature as an inspiration<br>3. In groups do research about other animals that Protect themselves from cold, how they do it and how it inspired man to create similar situations.<br>4. Each group presents their research to the class. |
| 40 min | **Summary:** Biomimicry: Animals in the snow: How do they cope with the cold? |

**References, link, bibliography:**

11 awesome technologies Inspired by animals

# Topic: Biomimicry: strategies and functions of living organisms

## Title of activity: C6. Protecting against Heat

**Lesson Duration: 90 min**

**Level of difficulty: easy-moderate-difficult**

**Students' age: 9-10-11**

**Materials / equipment:**

*PPT presentation about the topic prepared by the teacher,*

*Student Worksheets "Protecting against Heat" p.131,*

*Video watching YouTube,*

*Computer for research and produce.*

**Learning Objective:**

- Learn about Biomimicry and how animals inspire Humankind to solve problems
- Research for animals that have inspired Mankind by having characteristics of protection against heat

**For teachers - Description of activity/Theoretical Background**

We aim at recognizing the uniqueness of animals' characteristics that inspire the construction of lots of the things that we use in our daily life.

Students must be able to research for animals that are an inspiration for man, regarding their abilities to protect themselves against heat.

An oral presentation will be asked as a final product by following a worksheet with guidelines on the animal students researched.

Lesson activities:

| Time | Activity / Main content |
|---|---|
| 15 min | Visualizing and understanding the message in the video See How Termites Inspired a Building That Can Cool Itself \| Decoder |
| 35min | 1. Class divided in small groups:<br>– Identifies the animals mentioned in the video<br>– identify what did the animals mentioned inspired to build/construct |
| 40 min | 2. Short Presentation to the class of the findings – moment for dialogue/discussion about the importance of nature as an inspiration<br>3. In groups do research about other animals that Protect themselves from heat, how they do it and how it inspired man to create similar situations.<br>4. Each group presents their research to the class.<br>Summary: Biomimicry: Animals that inspire to cope with the Heat |

References, link, bibliography:

11 awesome technologies Inspired by animals

# Topic: Biomimicry: strategies and functions of living organisms

## Title of activity: C7: The termite mound, a model of natural air conditioning

**Lesson Duration: 1 hour 20 mins**

**Level of difficulty: easy-moderate-difficult**

**Students' age: 9-11 years**

**Materials / equipment:**

*PPT presentation about the topic prepared by the teacher,*

*Student Worksheets "The termite mound, a model of natural air conditioning" p.132-134,*

*video See How Termites Inspired a Building That Can Cool Itself | Decoder*

**Learning Objective:**

- Learning what is inside a termite mound.
- Learning how termite mounds regulate their temperature.
- Having a look at a termite inspired building that is designed to cool itself.
- Learning how termites keep cool.

**For teachers - Description of activity/Theoretical Background**

We humans like to congratulate ourselves for our ingenuity. Yet nature's passive designs often outperform our expensive, energy-hungry technologies. And while engineers and architects can improve their designs by mimicking the natural world, nature always has another lesson to teach. That has certainly been the case for termites and air conditioning. Termites deploy a clever strategy to cope with very high temperature amplitudes, and architects were inspired by this principle in the design of the Eastgate Centre in Zimbabwe. The result is a building that is 90% autonomous and 35% less energy consuming than other buildings in the country. The story begins in 1992, when Zimbabwean architect Mick Pearce received a commission to build Eastgate Centre, a two-building office complex and shopping mall, in the country's capital city of Harare. Pearce, however, wanted to do more than just build a new building. He wanted to eliminate the huge heating and cooling plants a 340,000 square feet development typically needed. Pearce already had a solution in mind. He began to formulate it while watching BBC's natural history series, Life, on TV one evening. "I saw David Attenborough climbing inside the chimney of a termite nest in Nigeria," he said, and he realized that evolution had already solved the problem. Pearce had grown up in Zimbabwe and was familiar with such chimneys. They rose six to 30 feet above termite nests and were strong enough for elephants to use to scratch their flanks. Below the chimneys, the termites farmed fungi for food. While the termites relied on soil's thermal storage capacity to help keep temperatures stable, Pearce realized that the termites also had to breathe. It was an elegant design. The hot air generated by the nest and its fungus farm, which had higher concentrations of carbon dioxide and methane, exited through the chimney through convention. As the hot air left, it pulled in fresh air from the surface through moist foraging tunnels, which added water vapor to the stream. The chimney, warmed by the sun, heated the air exiting through it, adding an extra push to the convection cycle. "The termite nest was warmer than the outside, particularly at night," Pearce said in an interview. "You get air rising out the chimney, and that pulls air in from the holes they go out to forage. That's how they breathe."

Lesson activities:

| Time | Activity / Main content |
|---|---|
| 10Min | Introduction of the topic<br>What can termites teach us about cooling buildings? |
| 35Min | Watch the video and discuss how termites can regulate their temperature and keep cool. See How Termites Inspired a Building That Can Cool Itself \| Decoder<br>Question 1: Could the future of air conditioning be found inside a termite mound?<br>Question 2: Termite mound air conditioning is solar, not wind. Can you explain why?<br>Question 3: How do termites regulate their temperature? |
| 30Min | Draw, using the right colours, a termite mound and the natural currents of hot and cold air that explain the ingenious thermoregulation principle put in place by termites. |
| 5Min | Summary of the classes: Students should be able to explain how termite stays cool. Why do termite mounds have a system of vents? |

References, link, bibliography:

See How Termites Inspired a Building That Can Cool Itself | Decoder

Termite Mounds Inspire Energy Neutral Buildings

What Termites Can Teach Us about Cooling Our Buildings (Published 2019)

# Topic: Biomimicry: strategies and functions of living organisms

## Title of activity: C8: Experience: Termite mound

**Lesson Duration: 1hour 20 mins**

**Level of difficulty: easy-moderate-difficult**

**Students' age: 9-11 years**

**Materials / equipment:**

*PPT presentation about the topic prepared by the teacher,*

*Student Worksheets "Experience: termite mound" p.135-137,*

*Newspaper, Masking tape or string, Flour or glue mixture, paints, Wooden beads, Paper towel roll, Scissors and sponges*

*YouTube Video Termite mounds in Namibia inspire energy-efficient buildings*

**Learning Objective:**

- Looking at how termites make their nest.
- Understanding the purpose of termite mounds.
- The importance of termite mounds for other animals.
- Understanding how termite mounds stay cool.
- Having a look at how termites build their huge structure.

**For teachers - Description of activity/Theoretical Background**

Termites live in Africa, Australia and South America. The mounds sometimes have a diameter of 30 metres (98ft). Most of the mounds are in well drained areas. Termite mounds usually outlive the colonies themselves and if the inner tunnels of the nest are exposed, it is usually a dead mound. Sometimes other colonies of the same or different species occupy a mound after the original builders.

The structure of the mound can be very complicated. Inside the mound is an extensive system of tunnels and conduits that serve as a ventilation system for the underground nest. The mound is built above the subterranean nest. The nest itself is a spherical structure consisting of numerous gallery chambers. The magnetic termites' mounds are created tall, thin and wedge-shaped, and are usually oriented north-south.

These centimetre-sized insects build complex, long-standing, meter-sized structures all over the world. How they do it has long puzzled scientists. Now, researchers from the Harvard John A. Paulson School of Engineering and Applied Sciences and the Department of Organismic and Evolutionary Biology have developed a simple model that shows how external environmental factors, such as daytime temperature variations, cause internal flows in the mound which move pheromone-like cues around, triggering building behaviour in individual termites. Those modifications change the internal environment, triggering new behaviours and the cycle continues. The model explains how differences in the environment lead to the distinct morphologies of termite mounds in Asia, Australia, Africa, and South America. This new framework demonstrates how simple rules linking environmental physics and animal behaviour can give rise to complex structures in nature. It sheds light on broader questions of swarm intelligence and may serve as inspiration for designing more sustainable human architecture. Changes in airflow carry information-containing odours to termites inside the mound. These information clouds — made up of pheromones and metabolic gases such as carbon dioxide — tell termites where to adjust the mound. If, for instance, one section of the mound is too warm, that temperature change will trigger a change in air flow, which will carry construction-cues to nearby workers. The termites will follow their senses to that section and adjust the mound to reduce temperature. That change in temperature will change the air flow and the termites will change their behaviour.

**Lesson activities:**

| Time | Activity / Main content |
|---|---|
| 10Min | **Introduction:** What is the meaning of termite mound? Understanding why termites build mounds |
| 20Min | **Activity 1:** Look at the PowerPoint named: 'C8: Experience: The Termite Mound' and then watch the video Termite mounds in Namibia inspire energy-efficient buildings<br>How do termites live in a mound? Do all termites build mounds? Do termites leave mounds of dirt? Do termites bite humans? What do termite nests look like? |
| 30Min | **Activity 2:** Students will either draw or make a termite mound. |
| 20Min | **Activity 3:** After completing Activity C7, imagine an experiment that might allow you to highlight hot and cold droughts. You have at your disposal: water, U-shaped tubes, containers that can hold water and a water-soluble food colouring agent. Draw the assembly that you could set up (you can ask your teacher for help!) |

**References, link, bibliography:**

Termite mounds in Namibia inspire energy-efficient buildings

Termite Mound with Termites | Termites, Insects theme, Crafts

# Topic: Biomimicry: strategies and functions of living organisms

## Title of activity: C9: Observation & nature: the leaf

**Lesson Duration: 45 min**

**Level of difficulty: Scale: easy-moderate-difficult**

**Students' age: 11**

**Materials / equipment:**

*PPT presentation about the topic prepared by the teacher,*

*Student Worksheets "Observation & nature: the leaf" p.138-139,*

*Visual material – laminated tree leaf cards*

**Learning Objective:**

- Describes the shape of tree leaves and the visible elements in it.
- Know main functions of leaf
- Can tell how a person uses the structure and functions of a tree leaf as example of biomimicry
- Try to imagine and draw your own idea of leaf structure and function.

**For teachers - Description of activity/Theoretical background**

LIST OF LEAF FUNCTIONS

- Photosynthesis - to capture the sun's energy,
- Hydrophobia - to allow water to drain off,
- Oxygen production,
- Ombrage,
- Temperature control,
- Protection against herbivores,
- Amino acid synthesis,
- Nutrient uptake,
- Defence against drought (thorns, or succulents),
- Stores water (succulents),
- Spin for hanging and climbing plants,
- Float for aquatic plants,
- Optimal organisation for better sun exposure,
- Thermoregulation and hydroregulation by the leaves, which have become very small and allow a thin layer of air to remain around the cactus.

Lesson activities:

| Time | Activity / Main content |
|---|---|
| 5 min | **Introduction.** Update student experience. To find out the concepts-leaf structure, functions, biomimicry, architecture. **Questions**.<br>"What do students know about tree leaves?"<br>"Do You know what biomimicry is?"<br>"What is architecture?" |
| 10 min | **Presentation**: Observation & nature: the leaf. Discuss each slide.<br>"What do You see in the pictures? What do You think about it?" |
| 15 min | **Activity 1.** Students can go outside to the park or forest or the teacher distributes visual material – laminated tree leaf cards - and a student worksheet. Pupils explore the leaves of trees. What do the students see on the leaf - shape, veining etc? The student draws on the worksheet what elements he sees on the leaves. |
| 10min | **Activity 2**. The teacher is given the task of drawing his idea of biomimicry using the elements he sees on a leaf. |
| 5 min | **Summary**. The teacher compiles the works drawn by the students. The works are displayed in an exhibition. Students look at the exhibited work. Students are able to describe the shapes of tree leaves and see their elements. Students can tell what biomimicry is. |

References, link, bibliography:

When Architecture Mimics Nature

PHOTOS: Beautiful Times Eureka Pavilion Mimics the Structure of a Leaf

Biomimicry of Palm Tree Leaves Form and Pattern on Building Form

La Palme Jumeirah à Dubaï, un incontournable selon le site EXPEDIA

Azerbaijan unveils design of Country Pavilion and breaks ground for Expo 2020 Dubai

# Topic: Biomimicry: strategies and functions of living organisms

## Title of activity: C10: Zoom on the leaf and its multiple functions

**Lesson Duration: 45 min**

**Level of difficulty: Scale: easy-moderate-difficult**

**Students' age: 11**

**Materials / equipment:** *PPT presentation about the topic prepared by the teacher, Student Worksheets "Zoom on the leaf and its multiple functions" p.140-143, , Pen, Magnifier, Compass, Projector, Calculator on solar panels, Garden lighting lamp on solar panels*

**Learning Objective:**

- Understanding many functions of tree leaves
- Finding the common features
- Understanding the concept – a leaf as an energy collector

**For teachers - Description of activity/Theoretical background**

The leaf is, in plant morphology, the organ specialised in photosynthesis in vascular plants. It is also the seat of respiration and transpiration. Leaves can specialise, in particular to store nutrients and water.

**Evolutionary history:**

Plants set out to conquer the land during the Upper Ordovician (~450 million years ago), giving rise to the first land plants. These began to diversify at the end of the Silurian, around 420 million years ago. By the middle Devonian (~400 million years ago), most of the known characteristics of today's plants are already present, including roots, leaves and some secondary tissues such as wood. The first seeds appear at the end of the Devonian (~360 billion years). By this time, plants had already reached a degree of complexity that allowed them to form forests of large trees.

**Plant morphology:**

It is inserted on the stems of the plants at the nodes. The attached figure shows the different parts of the leaf: a flat blade with veins, often with a petiole that connects the leaf to the stem, sometimes widened into a sheath. The petiole may be absent, in which case the leaf is said to be sessile.

**Photosynthesis:**

Each plant owes its survival to a complex phenomenon of exchanges between the ambient air, the water in the soil and the energy of sunlight. The leaf is at the heart of all vital chemical processes. The plant activates its chemical exchanges thanks to the energy of the sun. To make carbohydrates, the leaf captures CO2 from the air. The "capture" is done through microscopic pores called stomata located under the leaves by millions. The stomata suck in air and send it into the sap. When the CO2 molecules come into contact with the water in the sap, they naturally break down into oxygen molecules that the plant releases and carbon molecules that the plant retains. The carbon molecules associated with the hydrogen in the water are transformed into carbohydrates. These nutrients are stored in the trunk during the summer to better meet the energy demand needed to make new leaves in the spring. Some of this carbohydrate manna is stored to form the wood cells of the trunk or stem. In order to fulfil its role, a leaf is generally made up of a thin, flat, aerial blade, the leaf blade, which allows it to expose a maximum surface area to light.

**Order of ideas of numbers of leaves in large trees:**

Large apple trees have 50 to 100,000 leaves, birch trees 200,000 on average, A mature oak can bear 250,000 leaves, 700,000 mature oaks - placed side by side, these 700,000 leaves would cover a surface area of 700 m2 Some American elms have up to 5 million leaves at maturity.

Phyllotaxis (from the ancient Greek φύλλον (phúllon), "leaf", and τάξις (táxis), "arrangement") is the order in which the leaves or twigs are planted on the stem of a plant, or, by extension, the arrangement of the elements of a fruit, flower, bud or flower head.

InSitu project - The layout of the buildings and their orientation are based on the same organisational principle as those of the plants. Like the leaves, the flats all benefit from direct sunlight. This arrangement has been calculated by a biomimetic algorithm which allows the building density and solar gains to be optimised.

**The benefit is twofold:**

It reduces energy consumption by using the sun's passive energy and increases the health of users by regulating their biorhythm. The foliage of the trees is organised in the form of fractal structures (canopy image of the Japanese architect).

**Amino acid synthesis:**

In addition to the manufacture of carbohydrates, the leaf is the tool dedicated to the synthesis of amino acids.

**Evapotranspiration:**

The leaf is also the basis of sap circulation in the plant through the effect of evapotranspiration. When the light is intense during the day, the stomata open to the maximum to capture CO2 but also to release water in abundance. This loss of water through the leaves creates a sucking force which has the effect of raising the sap from the roots. Evapotranspiration allows the plant to draw the nutrients it needs from the soil. To run its "chemical plant", the plant uses the energy of sunlight through the complex process of photosynthesis. This process is mainly based on the photosynthetic pigments of chlorophyll (the green colour of the leaves). The green colour of the chlorophyll acts as an energy catalyst in the reaction that produces carbohydrates. Energy is needed to break the bonds of carbon dioxide and water on the one hand and to create the bonds between the glucose molecules on the other. Photosynthesis thus transforms solar energy into chemical energy.

**Oxygen production:**

Globally, algae and marine phytoplankton produce the most oxygen, followed by forests. For a long time it was thought that only cold, temperate seas had a positive oxygen balance, but a 2009 study shows that oligotrophic subtropical oceans are also oxygen producers, albeit with irregular seasonal production. These oceans therefore play a role in terms of carbon sinks. For the southern part of the northern hemisphere, oxygen production is low at the beginning of winter, increases until August and then decreases in autumn. Similarly, it was long believed that oxygen was only produced in the very superficial layers of the ocean, whereas there is also nanoplankton, generally living at great depths, which is photosynthetic.

**Lesson activities:**

| Time | Activity / Main content |
|---|---|
| 8 min | **Introduction** Discussing student's the concept of biomimicry. Introducing to diversity of tree leaves and their many functions Watching the video about the process of photosynthesis<br>Photosynthesis \| The Dr. Binocs Show \| Learn Videos For Kids |
| 15 min | **Activity 1:** Split students in groups of 3. Go outside and find three different types of leaves. Give students Worksheet. Explore common and different features. Write and fill the worksheet. Discuss the results of the first activity.<br>Question 1.Which common features You can recognise? Question 2. Which features were different? |
| 10 min | **Activity 2:** Using a compass, determine South – North sides. Investigate the location of tree branches on these sides. Investigate and write on the Worksheet conclusions of this activity – why there are more branches on the South side than on the North side. |
| 10min | **Activity 3:** Keywords – house constructions, solar panels. How can you link it to a tree leaf? Draw Your Idea in a Worksheet! |
| 2 min | **Conclusions.** The students conclude that the North-South principle is used in the construction of houses. Make sure that the windows are on the South side so that we can get as much solar energy as possible. |

**References, link, bibliography:**

Ing dep LV

https://articulo.mercadolibre.com.mx/MLM-703388242-piedra-decorativa-con-luz-led-solar-para-jardin-lamparas-_JM EN

Kalkulators Milan, 14 ciparu displejs

An Architect's House That Melds Traditional Japanese and Ukrainian Ethos in a Modern Shell EN

Saules baterijas – mājokļa apgādei ar elektrību. Padomi uzstādīšanā LV

Lapas — Vikipēdija LV

How Does Solar Panels Work? Learn how solar powered system work | Solar panels design, Solar panels, How solar panels work

# Topic: Biomimicry: strategies and functions of living organisms

## Title of activity: C11. Artificial Photosynthesis – reality or fiction?

**Lesson Duration: 2 classes of 45m**

**Level of difficulty: easy-moderate-difficult**

**Students' age: 13-14**

**Materials / equipment:**

*PPT presentation about the topic prepared by the teacher,*

*Student Worksheets "Artificial Photosynthesis – reality or fiction?" p.144,,*

*Books, Computers, Tablets.*

**Learning Objective:**

- Recognize a new field of science, Biomimetics, its potential and its tools for the production of new materials
- Evaluate the development of new technologies and new materials to help reduce the impacts that human activities cause on the environment
- Recognize materials produced from the observation of natural materials, considering aspects of the development of these products.

**For teachers - Description of activity/Theoretical background**

Find out what Photosynthesis is by watching short videos. Asking the question "Do you think it is possible to reproduce Photosynthesis?". View a video. Conduct targeted research that leads students to see how it is possible to create artificial Photosynthesis. Research whether artificial Photosynthesis can serve as an alternative for clean fuel. Is it a reality or just fiction?

Advancements in artificial photosynthesis have the potential to radically transform how societies convert and use energy. Scientific progress on artificial photosynthesis (AP) research—defined as using technology, notably synthetic biology and nanotechnology to capture light, transport electrons, split water and store hydrogen has the potential to radically transform for the better how societies convert and use energy. New technology has the long-term potential to so radically transform the planet towards sustainability as artificial photosynthesis engineered (alone or together with other technologies) in more efficient form as an 'off-grid' zero-carbon energy solution into all our structures (i.e. buildings, roads, vehicles)' In Interface Focus by Sovacool & Gross (2015).

## Lesson activities:

| Time | Activity / Main content |
|---|---|
| Lesson 1 | **Introduction:** Understand and Discover what Photosynthesis is by watching short videos<br>Photosynthesis \| Photosynthesis in plants \| Photosynthesis - Biology basics for children \| eLearning<br><br>Fill in a worksheet about what you learnt about Photosynthesis from the videos<br>Oral discussion about the importance of Photosynthesis for our planet /critical thinking |
| Lesson 2 | **Main activity:** Asking the question "Do you think it is possible to reproduce Photosynthesis?" debate.<br>A-LEAF: exploring artificial photosynthesis \| Shaping Europe's digital future<br>Artificial Photosynthesis \| Adam Hill \| TEDxStLawrenceU<br>View video and take notes on what they understand by answering the questions:<br>a) Definition of artificial photosynthesis<br>b) What is it used for?<br>c) Is it a reality or fiction?<br><br>**Summary of the classes: Sustainability of the planet - artificial photosynthesis an alternative as clean energy.** |

**References, link, bibliography:**

Photosynthesis

Photosynthesis | Photosynthesis in plants | Photosynthesis - Biology basics for children | eLearning

Artificial Photosynthesis | Adam Hill | TEDxStLawrenceU

A-LEAF: exploring artificial photosynthesis | Shaping Europe's digital future

Fotossíntese artificial: um futuro próximo - Brasil

The social acceptance of artificial photosynthesis: towards a conceptual framework | Interface Focus

# Topic: Biomimicry: the principles of living

## Title of activity: D1: The tree / the building: observation and inspiration

**Lesson Duration: 45 min**

**Level of difficulty: easy-moderate-difficult**

**Students' age: 10-12**

**Materials / equipment:**

*PPT presentation about the topic prepared by the teacher,*

*Student Worksheets "The tree / the building: observation and inspiration" p.145-147,*

*Coloured pencils (felt-tip pens, crayons, etc.)*

*Comfortable clothing for a little physical activity*

**Learning Objective:**

- Students get to know the tree as a part of the forest ecosystem.
- Get acquainted with the structure of trees.
- Able to see the opportunity to use the acquired knowledge in building construction, urban environment.

**For teachers - Description of activity/Theoretical background**

Natural forests give us much more than we think: herbs, edible fruits and mushrooms, diverse flora and fauna and refreshing refuge in the summer heat.

Our natural forests also play an important role in the functioning of their environment. They protect the surrounding farmlands from dehydration and strong winds, contribute to the conservation of our drinking water bases, and sequester and store carbon dioxide.

In addition, they provide habitat for far more plant and animal species than cultivated forests. It is made up of trees of different sizes, ages and species, many of them are fallen, rotting dead wood in which a lot of special species find refuge.

This diversity makes natural forests healthy, which are more successful in tackling the challenges posed by climate change.

**Lesson activities:**

| Time | Activity / Main content |
|---|---|
| 2 min | (The activity can be an outdoor activity too). Starting to show presentation slides 1 and 2. Students at the same time listen to Forest sounds |
| 5 min | • In the forest, observe nature and more particularly a tree. Think of all the services it can render to other organisms! Pay attention to the roots, stem, and foliage. What each of them can give us and nature? |
| 10 min | **Activity 1:** After listening to the sounds of the forest, talk about what you heard.<br>• What did you hear? What else could you hear besides the birdsong? What did these sounds remind you of? What can you compare? |
| 8 min | **Activity 2:** After discussions, go to explore the trees or look at the presentation slide 3.<br>• Let's look at the roots, stem, and foliage! Listen to the roar of the trees! Look for which tree has been chosen as the home! Let's see what grows on the trees. At the same time also discuss for each tree organ, what it does, why it is needed. Discuss what the forest can give us? How to help preserve the environment in which we live. Take some notes in Your Worksheet! |
| 15 min | **Activity 3:** Let's play the game "Let's build a tree"! Build a Tree - A Sharing Nature Game<br>**Activity 4: Watching the video** Using Live Oak Trees as a Blueprint for Surviving Hurricanes \| Think Like a Tree |
| 5 min | • Think and feel like a Tree! Draw Your City in the Future!<br>**Conclusion:** Each student puts his / her drawn work in the indicated place. Once again, we discuss the need for trees and forests. Students' drawings, in which they show how much they have understood by working in this lesson. |

**References, link, bibliography:**

Build a Tree - A Sharing Nature Game

Meža skaņas, atslābinošs troksnis: putni širp un dzied, kukaiņi un koki

Using Live Oak Trees as a Blueprint for Surviving Hurricanes | Think Like a Tree

Quel modèle pour une ville vraiment vivante ?

Dreaming of the future cities

# Topic: Biomimicry: the principles of living

## Title of activity: D2: Photovoltaic sheets

**Lesson Duration: Physics and chemistry (FQ) and Natural Sciences (CN) (150 minutes/ 3 lessons)**

**Level of difficulty: easy-moderate-difficult**

**Students' age: 12-13 years**

**Materials / equipment:**

*PPT presentation about the topic prepared by the teacher,*

*Student Worksheets "Photovoltaic sheets" p.148-154,*

*Computer, Writing material.*

**Learning Objective:**

- Identify the sun as a renewable energy source
- Advantages and disadvantages of using photovoltaic panels
- Compare plant leaves with a photovoltaic panel

**For teachers - Description of activity/Theoretical background**

Plants are powerful allies in the fight against global warming as they absorb large amounts of carbon dioxide (CO2) which reduces global warming. In addition to the essential role of synthesizing practically all the energy used on the planet. The leaf of the plant is at the centre of the photosynthesis process. During photosynthesis, leaf pigments capture solar energy and convert it into chemical energy in sugar molecules. The photosynthesis process uses light to combine carbon dioxide with water to produce sugar and oxygen. Part of the glucose is used as energy that is used by various vital processes. Extra glucose can be combined to form large starch molecules and be stored in the roots. These molecules are broken down into sugar and used when the plant needs more energy than is currently available. The carbon molecules associated with hydrogen in water become carbohydrates. These nutrients are stored in the trunk during the summer to better satisfy the energy needed to produce new leaves in the spring. A portion of that amount of carbohydrates is stored to constitute the cells of the stem or stem wood. To fulfil its function, a leaf is usually formed by a flat, thin aerial blade, the blade, which allows it to expose the maximum surface area to light. The anatomy of the leaf is highly specialized for the absorption of light. The outermost layer, that is, the epidermis, is usually transparent to visible light and the individual cells are often convex. The convex structure of the cells of the epidermis allows them to act as a lens, redirecting and focusing the incident light to the chloroplasts that are adjacent to the side walls of the cells of the parenchyma. This is common among herbaceous plants and especially in tropical species that grow within forests (understory), where light levels are very low. The energy flow captured by photosynthesis (on a planetary scale) is about 100 terawatts: which is about 10 times greater than the world energy consumption (integrated in one year). This means that just under a thousandth of the energy received by the Earth is captured by photosynthesis and provides practically all the energy in the biosphere. Through photovoltaic solar energy it is possible to produce electricity by converting a part of the sun's rays using a photovoltaic cell. Photovoltaic panels can be used for small-scale domestic purposes (for example, on roofs) or for large-scale industrial energy production. Artificial photosynthesis is a field of investigation with the objective of imitating the natural photosynthesis of plants, in order to convert carbon dioxide and water into carbohydrates and oxygen, using sunlight. The tree captures solar energy and CO2 to produce matter and emit O2. All the elements it needs are of local origin.

**Lesson activities:**

| Time | Activity / Main content |
|---|---|
| Physics and chemistry (FQ) and Natural Sciences(CN)<br><br>50 min | **Lesson 1**<br>Introduction<br>Distribute the activity sheet to students. Launch the issue questions:<br>1. What makes a photovoltaic panel look like a plant leaf?<br>2. What are the advantages and disadvantages of using photovoltaic panels? Are there alternatives?<br><br>**Activity 1:** Watch the video with students: Disadvantages and Advantages of Solar Energy<br>Students can respond to activity 1 as a group.<br>They prepare an oral presentation of the results and analysis to the class.<br>The teacher guides students in the development of the activity and clarifies the questions posed |
| 100 min | **Lesson 2 and 3**<br>Field trip (20 minutes) to observe the leaves of the trees and photograph some, at the students' choice<br>Students present their results and analysis to the class.<br>Students solve activity 2 in groups.<br>They prepare an oral presentation of the results and analysis to the class.<br>The teacher guides students in the development of the activity and clarifies the questions posed. |

**References, link, bibliography:**

Disadvantages and Advantages of Solar Energy

Artificial Leaf Technology Could One Day Power Our World

# Topic: Biomimicry: the principles of living

## Title of activity: D3. The city of the future, a bio-inspired and regenerative city

**Lesson Duration: 45m**

**Level of difficulty: easy-moderate-difficult**

**Students' age: 14-15**

**Materials / equipment:**

*PPT presentation about the topic prepared by the teacher,*

*Student Worksheets "The city of the future, a bio-inspired and regenerative city" p.155-158,*

*Video YouTube: One Earth*

*Discussion: What is a city of the Future? How can Loureiro be a city of the future?*

**Learning Objective:**

- Highlight the importance of our planet
- Reflect upon our future as a planet, the survival of Mankind and biodiversity
- Rethink our natural resources
- Prepare the students for a project work on "My city of the future"

**For teachers - Description of activity/Theoretical background**

This activity aims to motivate students for the learning process regarding the Observation of our Planet and the importance of changing our attitude towards our daily life actions in the construction of a better future, while protecting our unique Planet earth.

We aim at recognizing the uniqueness of our Planet Earth in our Galaxy, its features of its uniqueness and alert our students for what is happening to the Planet by the hand of Mankind.

Students must be able to recognize the wrong Mankind is doing to the Planet by exploring its Natural resources, and harming our atmosphere, water and land. They must be able to understand that we must look into our Planet, nature, Biodiversity and see how we can do better to survive and live-in unison with Nature.

This activity is an introduction/ motivation to a project on "Making my city a city of the Future" that will take on a different path of work, where students study and prepare a presentation of their work.

**Lesson activities:**

| Time | Activity / Main content |
|---|---|
| 10 min | Visualizing and understanding the message in the video "One Earth"<br><br>- Students take notes on what they learn from the visualization of the video |
| 10 min | Oral activity: sharing their opinion on what the video enhances |
| 15 min - | Using the Mentimeter App students have the opportunity to share their opinion by answering the question: "What is a city of the future?"<br>Followed by a discussion of ideas and identifying the main characteristic and visualizing a video as an inspiration for the next task.<br>Is Copenhagen the World's Most Sustainable City? |
| 10 min | Using Again Mentimeter App students answer the question: "How can Loureiro be a city of the future?"<br>Followed by a discussion and identifying the main characteristics.<br><br>Students decide on the groups to work with and the guidelines of the project "Making my city, a city of the future". |

**References, link, bibliography:**

This is what the future's sustainable cities could look like

# Topic: Biomimicry: methodology

## Title of activity: E1: In the shoes of a biomimetician: different steps

**Lesson Duration: 1 hour 15 minutes**

**Level of difficulty: easy-moderate-difficult**

**Students' age: 9-11 years**

**Materials / equipment:** *PPT presentation about the topic prepared by the teacher, Student Worksheets "In the shoes of a biomimetician: different steps" p.159-160,, YouTube Video* Why This Train Is the Envy of the World: The Shinkansen Story*, YouTube Video* The world is poorly designed. But copying nature helps.

**Learning Objective:** Put oneself in the shoes of a biomimetician and move forward in different steps to solve the problems by taking nature as inspiration.

**For teachers - Description of activity/Theoretical background**

A biomimetician is a person who provides solutions or pathways by getting inspiration from nature.

Biomimetics, a name coined by Otto Schmitt in the 1950s for the transfer of ideas and analogues from biology to technology, has produced some significant and successful devices and concepts in the past 50 years, but is still empirical. We show that TRIZ, the Russian system of problem solving [Theory of Inventive Problem Solving], can be adapted to illuminate and manipulate this process of transfer. Analysis using TRIZ shows that there is only 12% similarity between biology and technology in the principles which solutions to problems illustrate, and while technology solves problems largely by manipulating usage of energy, biology uses information and structure, two factors largely ignored by technology.

Biomimetics is not a new way of adapting ideas from biology, but it is currently empirical in its approach. If it is to build on current successes, and to be able to serve our technological society, then it needs some sort of regularization, best introduced as a set of common principles. Such principles exist in TRIZ, and it is in this area that there seems to be the most promise for establishing a transparent method for technologists to access biology, which they otherwise view as an arcane and complex world. This is because while TRIZ was developed as a systems approach for engineering, biology is, itself, a system. The benefits to be gained from biomimetics are not yet totally obvious, other than to deepen the human race's box of technical tricks. However, if, as our study (and indeed many other studies) suggests, biological functions and processes are less reliant on energy, then the implications could be very significant. That this change in our approach to technology and engineering could be achieved by developing.

The Shinkansen bullet train travels along high-speed railways throughout Japan at speeds of 240–320 km/hr (150–200 mph), carrying millions of passengers every year. However, when it was first designed, the high speeds caused an atmospheric pressure wave to build up in front of the train. When it would travel through tunnels, the wave would cause a loud "tunnel boom" at the exit, disturbing nearby residents. The engineers had to find a way for the train to travel more quietly without sacrificing speed or using more energy. The engineers looked to nature to re-design the bullet train. They noticed how kingfisher birds are able to slice through the air and dive into the water to catch prey while barely making a splash. They then re-designed the front end of the train to mimic the shape of the kingfisher's beak. Not only did this help to reduce noise and eliminate tunnel booms, it also allowed the train to travel 10% faster using 15% less electricity. The kingfisher is a bird that dives into water to catch its prey. It has a long, narrow pointed beak that allows it to enter the water while barely making a splash. The beak steadily increases in diameter from the tip to the head, which helps reduce impact when the bird hits the water. In 1941, Swiss engineer and inventor George de Mestral was intrigued by the burdock burrs that kept sticking to his dog's fur as they passed by the unique plants. What resulted from George de Mestral's routine hike in 1941 is perhaps the most well-known example of biomimicry in history, Velcro.

**Lesson activities:**

| Time | Activity / Main content |
|---|---|
| 10Min | **Introduction of the topic**<br>What is a biomimetician?<br>How does a biomimetician solve the problems from nature or create a model?<br>Refer to the PowerPoint presentation called: 'E1: In the shoes of a biomimetician: different steps' |
| 20Min | **Watching the below YouTube videos**<br>Why This Train Is The Envy Of The World: The Shinkansen Story<br>The world is poorly designed. But copying nature helps. |
| 20Min<br>20Min | **Activity 1**: Showing the presentation and a few innovative ideas created which are inspired from nature.<br>1. How has technology been influenced by nature?<br>2. What inventions are inspired by nature? List 6 of them.<br>3. What was Velcro inspired by?<br><br>**Activity 2**: Illustrate the similarities between Kingfisher and the Shinkansen |
| 5Min | **Summary of the lesson**: Biomimetician use nature as a resource for ideas, clever innovation and great architectural forms. |

**References, link, bibliography:**

Why This Train Is the Envy of the World: The Shinkansen Story

The world is poorly designed. But copying nature helps.

Biomimicry: 9 Ways Engineers Have Been Inspired by Nature

Design Inspired by Nature

(PDF) Innovation inspired by nature: Biomimicry

High Speed Train Inspired by the Kingfisher — Innovation — Ask Nature

Papo de Paisagista - Pergunte à natureza - Casa de Valentina | Árvores e arbustos, Engenheiro biomédico, Protozoários

Teaching #KS3 design?

# Topic: Biomimicry methodology

## Title of activity: E2. In the shoes of a biomimetician. Ethics and sustainability

**Lesson Duration: 45 min**

**Level of difficulty: easy-moderate-difficult**

**Students' age: 12-15**

**Materials / equipment:**

*PPT presentation about the topic prepared by the teacher,*

*Student Worksheets "in the shoes of a biomimetician. Ethics and sustainability" p.161-162.*

**Learning Objective:**

- to understand the biomimicry approach
- to pay attention to the ethics and sustainability of bio-inspired solutions

**For teachers - Description of activity/Theoretical backgrounds**

Becoming a biomimetician means wanting to solve a question or respond to a need in a certain way: firstly, that is compatible with the Earth and the rest of the living world and secondly, that is inspired by the living, both in its technical process and above all in its functioning. The biomimetician must always ask himself questions about the "meaning" of his invention, its ethics and its sustainability. The first important step is to realize what Nature is and the key characteristics of natural processes expressed as the Nature's laws, strategies and principles described by:

- Nature runs on sunlight.
- Nature uses only the energy it needs.
- Nature fits form to function.
- Nature recycles everything.
- Nature rewards cooperation.
- Nature banks on diversity.
- Nature demands local expertise.
- Nature curbs excesses from within.
- Nature taps the power of limits.

Thus, a crucial task for the philosophy of biomimicry is to analyse, understand and assess these statements in terms of their meaning, truth, coherence and comprehensiveness towards biomimicry concepts.

In this sense, we have to understand that the concept of following Nature in a sustainable manner may come to dominate and replace that of protecting Nature. For example, if Nature's services (i.eSolar energy generation, nutrient cycling, food production, climate regulation, etc.) can be reproduced artificially, then we may conclude that there is little reason to protect Nature and Biomimicry would become "*the ultimate ally for 'weak sustainability*".

Based on the aforementioned concerns, future research and future generations have to answer the following questions:

(i) How can we understand the complementarity of biomimicry in practice, and what are the consequences of Biomimicry innovations that are better embedded in, and in harmony with, the ecosystems of planet earth?

(ii) How should nature be conceptualized and integrated in concrete biomimetic designs?

(iii) What is the ontological status of the complementarity of technology if it is not natural in the strict sense of the word?

(iv) To what extent is the ethics of biomimicry derived from nature or imposed on nature?

Considering these fundamental questions and concerns, the objective of this activity is to put ourselves in the shoes of a biomimetician in order to solve a problem by taking inspiration from nature but most importantly, to assess a Biomimicry concept.

The key steps to be followed are:

1. Analyse the problem

2. Express it in simple words

3. Look for a model in nature

4. Identify the reasons why this model addresses the problem

5. Transpose and evaluate.

Following these steps, we need to focus on ensuring the ethical and sustainable nature of the invention. We can do that by questioning and checking as many points as possible from the list below:

- Can be used for something else when it is no longer needed?
- Does not produce waste or waste that can be recycled or reused?
- Uses local and abundant resources and consumes renewable energy?
- Creates respectful links between humans and the rest of the living world?
- Does not degrade the Earth's ecosystem, but improves it?

**Question for further discussion:** Do you think that the above considerations are important or not and why?

**Lesson activities:**

| Time | Activity / Main content |
|---|---|
| 3 min | Brief introduction about the focus and the aims of the lesson |
| 5 min | Showing presentation in PPT and videos related to Biomimicry ethics and sustainability. |
| 5 min | Showing presentation in PPT of one or more biomimicry examples. These examples may incorporate sustainable/viable and controversial Biomimicry concepts. |
| | **Main Activities** |
| 7 min | **Discussion.** Questions eliciting activity: What does the term "Sustainability" and "Ethics" mean? In your opinion, why Biomimicry concepts may be harmful towards Environmental Protection? (Simplify questions or provide specific examples for the moderate version of the activity) |
| 7 min | **Activity 1** *In parallel: Discussion with students/Answering questions*<br>Students work on their worksheets individually or in small groups of 2-3 persons aiming at decomposing a Biomimicry concept. (Help students in the problem decomposition, or propose a predefined Biomimicry concept in order to scale down the level of difficulty) |
| 8 min | **Activity 2** *In parallel: Discussion with students/Answering questions*<br>Group evaluation of the concept's ethics and sustainability in terms of the statements and the research questions described in the theoretical background and the template. (Provide students with open-ended questions rather than bullets in order to scale up the level of difficulty) |
| 5 min | **Overall discussion and wrap up.**<br>Evaluation of the lesson. What new things have you learned? |

**References, link, bibliography:**

Online repository of resources, https://asknature.org/

Dicks H. (2015): The Philosophy of Biomimicry, Philos. Technol.

Dicks H. (2017): Environmental Ethics and Biomimetic Ethics: Nature as Object of Ethics and Nature as Source of Ethics, J. Agric. Environm. Ethics

Blok V. and Gremmen B. (2016): Ecological Innovation: Biomimicry as a New Way of Thinking and Acting Ecologically, J. Agric. Environm. Ethics

# STUDENT SECTION

# Topic: Philosophy of biomimicry

## Title of activity: A1. Biomimicry: techno or life?

**Level of difficulty: easy-moderate-difficult**

**Materials / equipment:**

*Student Worksheets*

*PPT presentation*

**Theoretical background of the activity:**

This activity aims to highlight our ignorance of the surrounding nature for the benefit of a better knowledge of the technological world.

The objective is to test our ability to recognize 6 common animal or plant species before recognizing 6 famous international brands, symbols of our artificialized world.

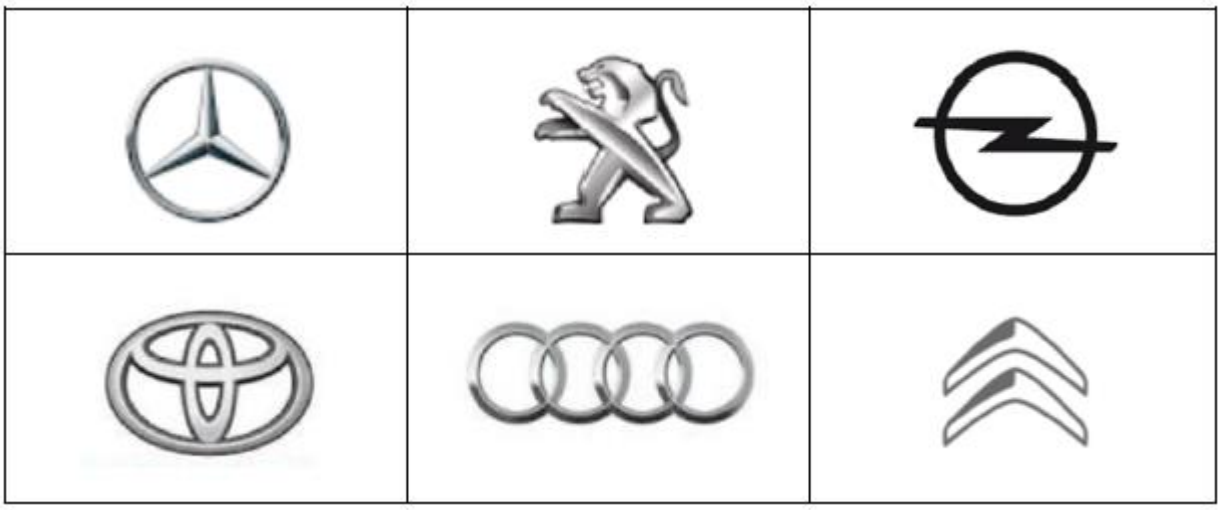
Reminding the theoretical background once again in terms of this activity to enable students to self-solving this task.

**Main activities:**

1. Look carefully at the pictures below
2. Discuss what they show
3. Try to answer the simple questions below

Can you name these species? What do you know about them?

(Write your answer below)



Can you name these car brands? What do you know about them?

(Write your answer below)

Which exercise was the easiest: recognising living species or brands? What conclusion do you draw from it?

(Write your answer below)

# Topic: Philosophy of biomimicry

## Title of activity: A2. To be inspired by nature, for what purposes?

**Level of difficulty: easy-moderate-difficult**

**Materials / equipment:**

*Student Worksheet*

*PPT presentation*

**Theoretical background of the activity:**

Nature inspires us: poems, songs, works of art, all kinds of inventions: airplane wings, artificial hands.

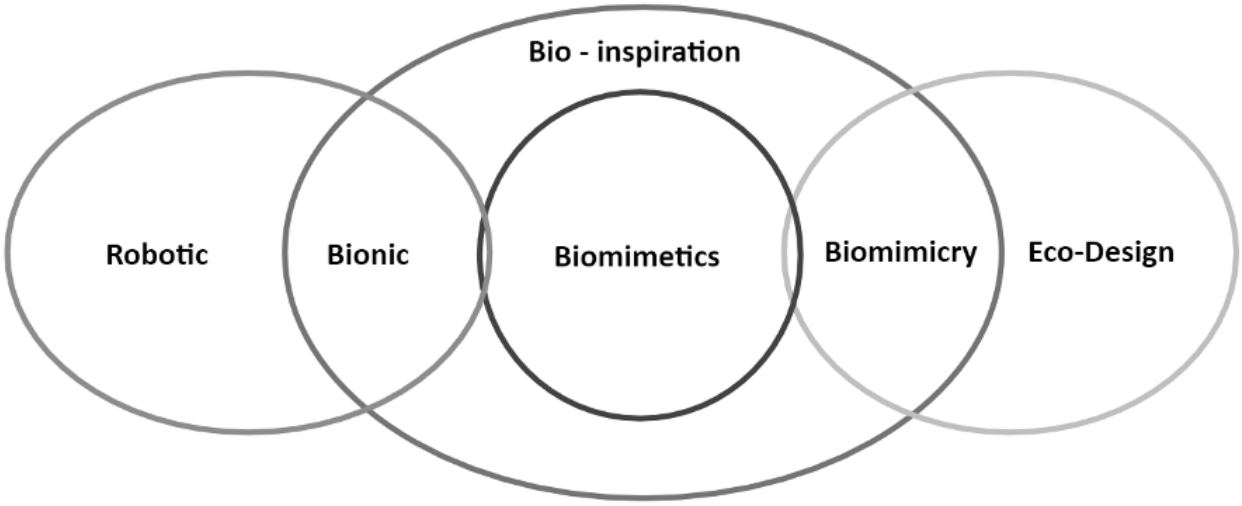
Discuss the following examples and questions.

Do they correspond to bio-inspiration? Biomimicry? Biomimetics? Bionics?

This activity encourages us to question the ethics of bio-inspired practices.

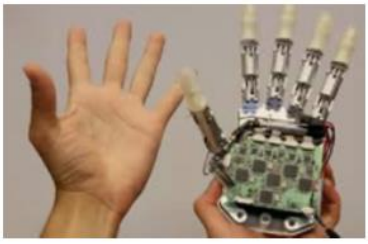
**Main activities:**

1. Look carefully at the pictures below
2. Discuss what they show
3. Try to answer the simple questions below




Try to define with your own words some of the different terms shown above, e.g. bio-inspiration, biomimetics, biomimicry, bionic.

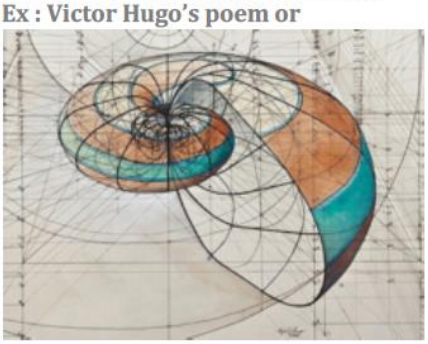
(Write your answer below)

| | |
|---|---|
| **Hand prosthesis**<br>  | **Fuselage of a TGV inspired by a kingfisher's beak**<br>  |
| **Shark skin / antibacterial coatings**<br>Shark skin inspired the development of a special coating on which microbes slide and do not cling. By using it in hospitals to cover floors and walls, much less toxic disinfectants are used.<br>  | **Building in bamboo**<br>Birds build their nests with the materials they find on site: straw, twigs, earth, feathers... A Colombian architect draws on local resources for his constructions: bamboo is an ideal building material. Very resistant, it grows quickly and is available in abundance. It is a material that is both durable and biodegradable.<br>  |

Discuss these examples of inspiration. Do they involve biomimicry? Bionics? Bioinspiration?

(Write your answer below)

**Work of art : poetry,, music, song**
**Ex : Victor Hugo's poem or**

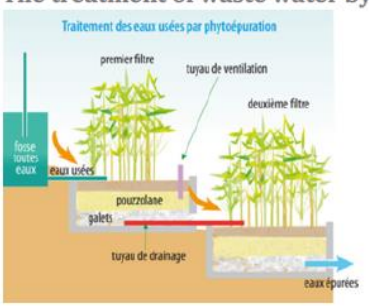


**Pollinating Drone**

Drones to pollinate instead of bees: to respond to the hecatomy of bees, precious pollinators, Japanese researchers are manufacturing drones capable of pollinating from flower to flower.

(Video) https://www.dailymotion.com/video/x7aeegc

**The treatment of waste water by phyto-purification**




**Velcro® / Bardane**

The velcro® imitates the many tiny burdock hooks that cling to the hair of animals and thus to the stitches of certain textiles. `

**Discuss these examples of inspiration. Do they involve biomimicry? Bionics? Bioinspiration?**

**(Write your answer below)**

# Topic: Philosophy of biomimicry

## Title of activity: A3. Overview Effect

**Level of difficulty: easy-moderate-difficult**

**Materials / equipment:**

*Video*

*Student Worksheet*

*PPT presentation*

**Theoretical background of the activity:**

Astronauts in orbit have experienced a profound love for the Earth and felt that we all share one home. It is called the Overview Effect and it changed them forever. Using unique Earth images taken from one million miles away by NASA, the One Home's mission is to bring the overview effect to millions of people. Admiring the Earth from space can change us. Environmental awareness is rising, unfortunately what divides us seems stronger than what unites us. What if a single view of our planet could make us realize our chance and experience unity? What if an overview of our planet could make us experience the interconnectedness of life? What if planetary boundaries became suddenly obvious?

**Main activities:**

1. Watch the video by One Home with Jean-François Clervoy, French astronaut
2. Discuss his main message
3. Try to answer the simple questions below


Watch the OneHome video with Jean-François Clervoy, French astronaut. Can you sum up his message? What were his emotions when he observed the Earth from space?

(Write your answer below)

What is the name of this photo? What year was it taken? Who took it?

(Write your answer below)

# Topic: Philosophy of biomimicry

## Title of activity: A4. Nature = Future! - Biomimicry, life as a model

**Level of difficulty: easy-moderate-difficult**

**Materials / equipment:**

*Video*

*Student Worksheet*

*PPT presentation*

**Theoretical background of the activity:**

Discover with experts the biomimicry approach, which allows us to rethink our production, design and consumption methods, to meet the challenges of climate change, the collapse of biodiversity, the depletion of resources on Earth and pollution.

Understand biomimicry, its ethics and approach.

**Main activities:**

1. Watch the video and presentation. Take notes on most interesting points
2. Discuss the main messages
3. Try to answer the simple questions below


Watch the video, listen carefully and take notes (write your notes below) so that you can answer the questions (next page)

1. When did life appear on Earth?

2. Which crises invite us to rethink our modes of production and consumption?

3. Is the living economy based on abundance or scarcity?

4. Why is it interesting that nature manufactures at room temperature and pressure?

5. Why is biomimicry described as a multidisciplinary approach?

# Topic: Philosophy of biomimicry

## Title of activity: A5. From planetary boundaries to biomimicry

**Level of difficulty: easy-moderate-difficult**

**Materials / equipment:**

*PPT presentation*

*Student Worksheet*

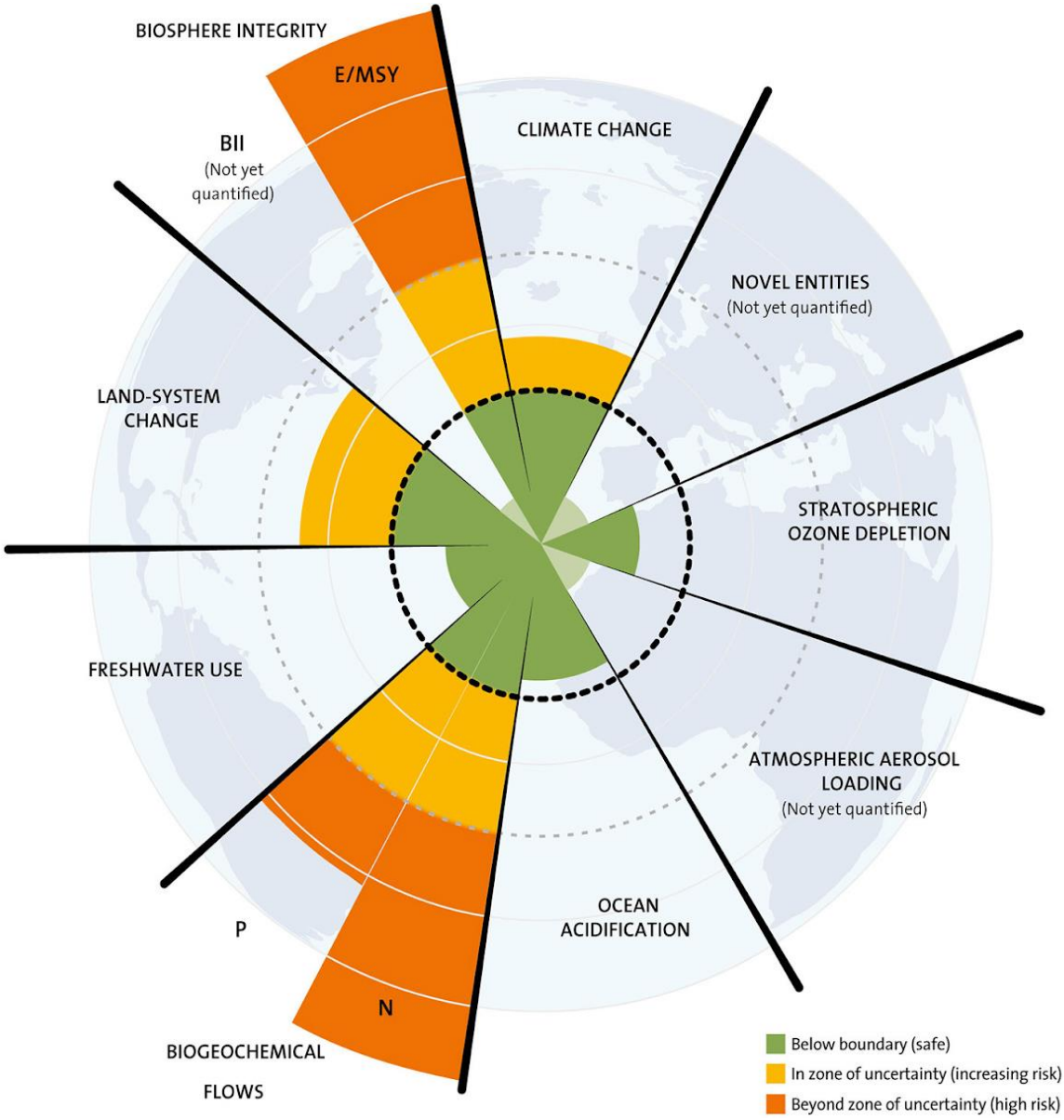
**Theoretical background of the activity:**

The planetary limits are the thresholds that humanity must not exceed so as not to compromise the favourable conditions in which it has been able to develop and to be able to live sustainably in a safe ecosystem, that is to say, avoiding sudden and difficult to predict changes to the planetary environment. These nine natural processes are selected, because together they allow and regulate the stability of the biosphere: climate change, erosion of biodiversity, disruption of biogeochemical cycles of nitrogen and phosphorus, changes in land use, ocean acidification, global water use, stratospheric ozone depletion and increasing aerosols in the atmosphere. Today we know that we will not be able to continue to consume at the same rate as before, and solutions are being studied to find a balance with the earth and other species. Of course, there is no single miracle cure. But by observing living beings and how they function in nature, we can all together draw inspiration from them to invent and innovate. This scientific approach is called biomimicry. It involves not only inventing or perfecting objects, materials or techniques, but also imagining new, more sustainable ways of living, consuming and producing. The aim is to live with the rest of the living world, since us humans are also part of the Earth's ecosystem.

**Main activities:**

1. Watch the presentation. Take notes on most interesting points
2. Discuss the main messages
3. Try to answer the questions below

## Have a look at this graph so that you can answer the questions below (next page)




1. Name the 9 planetary boundaries. Are we close to exceeding the planetary limits? Have we already exceeded some of them? (Write your answer below)

2. The living is ingenious. Humans can draw inspiration from its principles to invent new ways of living, consuming and producing with the aim of respecting planetary limits. What are these principles?

(Write your answer below)

3. Write with your own words what biomimicry is. Give an example.

(Write your answer below)

# Topic: Biomimicry examples

## Title of activity: B1: Kingfisher and Shinkansen

**Level of difficulty: easy-moderate-difficult**

**Materials / equipment:**

*Worksheets-Activity one, Activity two*

*The presentation – Kingfisher and Shinkansen*

*Play dough, a bowl, water*

*Cards with questions of the topic "Kingfisher and Shinkansen"*

**Theoretical background of the activity:**

Birds are well-suited to their living style and the environment. One of them is the Kingfisher. Kingfisher is a small brightly coloured bird found in the tropical regions of the Earth such as Africa, Asia, and Oceania. This bird is especially interesting in the biomimicry context. Engineers used the beak of the bird to construct the front of Shinkansen- the very fast-moving train. Why did they choose this pattern? The construction of the bird's beak enables it to dive without splashing or waves. Its streamlined shape allows it to hunt with limited disturbance due to aerodynamic and hydrodynamic drag, allowing it not to lose speed and not alert its prey when it enters the water.

The kingfisher can sit still and patiently on a branch above the water, waiting for a fish in the river current. After seeing its prey, it drops into the water at a speed of over 40 km / h. Its eyes, covered by a transparent membrane and protected by a bony casque attached to the prefrontal bone of the skull, enable the bird to dive and see the potential meal. Its feathers store the air that facilitates the ascent from water, due to Archimedes' thrust. All the action: jump into the water, catch a fish and surf for only 2 seconds.

The Japanese high-speed train "Shinkansen" connects Osaka and Hakata through numerous tunnels. However, in the tunnels, the air is compressed so its resistance increases. How can we lose as little energy as possible and fight against these changes in pressure, which cause inconvenience to passengers in particular? The first train was in a different shape which caused it to slow down during passing tunnels. If it did not do it, the fabric of the tunnels would be impeded. The reason for it was the train pushed the whole air across the tunnel, when it went out, huge masses of air generated tremendous rumble. The sound pulses could have damaged the tunnel or caused it to collapse.

Considering the arguments described above, the engineers decided to choose a kingfisher's beak as the pattern. This bird dives in the water almost without a splash. Now, trains with kingfisher-like locomotives leave the tunnels silently. Later on, engineers, when designing other high-speed locomotives, took their inspiration from the Shinkansen, the kingfisher's head.

## Activity 1

**Part One** → Looking at the video form the head of the bird with play dough. Form the cuboid of 7cm long, 3 cm wide, 3 cm hide with play dough.

**Part Two** → Throw the formed objects into a previously prepared bowl of water. Do that from the same height at the same force. The head of the bird should be put into water as it would dive. Similarly, the cuboid should be thrown into water from the wider side.

**Part Thee** → Observe the behaviour of the water when throwing the objects. Answer the questions below.

**1. What can you see when you drop the bird's head into water?**

**(Write the answers below)**

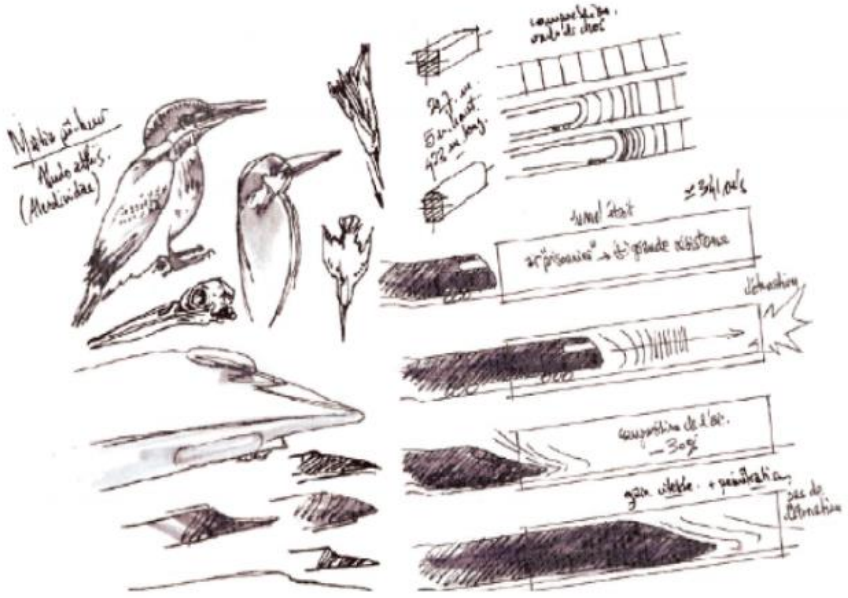
**2. What can you see when you drop the cuboid into water?**

**(Write the answers below)**

**3. Compare the effects of putting objects to water.**

**(Write the answers below)**

## Activity 2



**Based on the following drawings, draw a profile of the Kingfisher and Shinkansen train!**

**References, link, bibliography:**

Holmes Hannah, „Blaze of blue. Kingfishers", „National Geographic", 2009

Kruszewicz. A. „Polish birds", Multico 2005.

# Topic: Biomimicry: examples

## Title of activity: B2: Coral and cement

**Lesson Duration: 45 min**

**Level of difficulty: Scale: easy-moderate-difficult**

**Students' age: 10-11**

**Materials / equipment:** *Wordwall game*, *The presentation – Coral and cement*, *Worksheet – Activity 1, Activity 2.*

**Theoretical backgrounds:**

**Biomimicry**

Biomimicry brings potential solutions to our current problems, but also a new collective imagination based on wonder at the abundance and ingenuity of forms of life. Let us therefore take note of our deep interdependence with respect to biodiversity to make possible the emergence of a b capable of guiding our relations with non-human living things. It will involve in particular the equitable sharing of resources and space, respect, acceptance of all forms of diversity and the non-reducibility of living things to any form of utilitarianism.

**Corals**

Corals live in colonies in warm sea atolls and coral reefs. They build skeletons throughout their lives. Depending on the species they take on different shapes, colours and consistencies. Coral takes carbon and dissolved calcium from seawater and transforms it into calcium carbonate through a chemical reaction. The ore produced is called aragonite. Coral makes a calcium carbonate ($CaCO_3$) cement from carbon dioxide ($CO_2$).

**Eco- Cement**

Scientists have created **eco-cements**, a new type of material that absorbs, as it dries, the $CO_2$ contained in the air and in which we can incorporate waste (ash for example). These new cements therefore help both to recycle waste and to capture carbon (buildings become carbon sinks). A Californian company, Calera, produces a building material close to the coral skeleton. The $CO_2$ used comes from a nearby power plant. While the traditional cement industry is a major $CO_2$ emitter, Calera obtains cement by capturing $CO_2$ emissions from the plants. Carbon dioxide is no longer the problem, it becomes the solution.

**Cement (and the carbon cycle)**

Throughout the history of our planet, enormous quantities of carbon have been sequestered in limestone, sediments and hydrocarbons by the activity of the living world; shellfish have used it to make their shells and trees have transformed it into woody material. One solution to the problem of carbon dioxide ($CO_2$) build-up and waste production would be to imitate nature and incorporate it into building materials. By emulating nature, which recycles all its materials, we can even dream of fully recyclable cities.

Activity 1 - Let's watch a video about corals and their abilities!

1. What problem do you think people could use to learn from coral building abilities?

2. People have used the experience of corals to: (mark appropriate answers)

___ create eco-cements, a new type of material that absorbs

___ create new cements therefore help both to recycle waste and to capture carbon (buildings become carbon sinks)

___ produces a building material close to the coral skeleton

___ imitate nature and incorporate it into building materials

Activity 2 Draw where you would use such cement! What are your ideas?

References, link, bibliography:

Coral: What is it?

How Do Corals Build Reefs? | California Academy of Sciences

Koraļļi — Vikipēdija

Biomimicry: Using Nature's Perfect Innovation Systems To Design The Future

Brent Constantz būvē cementu tāpat kā koraļļi - Cits - 202

# Topic: Biomimicry: examples

## Title of activity: B3: Bite like a mosquito

**Lesson Duration: 45 min**

**Level of difficulty: Scale: easy-moderate-difficult**

**Students' age: 10**

**Materials / equipment:** *Wordwall game, Worksheet – Activity one, Workshop – Activity two, The presentation – Bite like a mosquito, Different kind of needles, an orange or an apple*

**Theoretical background of the activity:**

The female's proboscis (proboscis) is made up of vulnar mouthparts or styli (maxilla, labia, hypopharynx) which are enveloped by the flexible labium (i) which folds up at the time of the bite. The mosquito pushes the styli into the epidermis up to a blood capillary thanks to the jaws which perforate the skin and allow the tube to remain in place during blood collection. The styluses delimit two channels: one (salivary channel), formed by the hypopharynx, through which an anticoagulant saliva is injected, and the other (alimentary channel), at the level of the labra, through which blood is drawn which, if infected, will contaminate the mosquito. The amount of blood drawn varies from 4 to 10 mm3 in 1 to 2 minutes48. According to the American Mosquito Control Association website, the average blood collection is 5 millionths of a litre; the insect ingests 5 mg of blood, which is twice its own mass as it weighs an average of 2.5 mg49. If one day you receive a painless injection, it is thanks to a new micro-needle that will be on the market in the near future. This needle is inspired by mosquitoes. The reason? Because probably the least loved insect in the animal kingdom, is the inspiration for new research by scientists at Ohio State University (OSU).

**A needle inspired by nature**

"The reason we look at nature as a clue is that nature has gone through a long period of evolution to discover the simplest and most effective methods," said Bharat Bhushan, professor of mechanical engineering at OSU. "In this work, what interested us was the way mosquitoes bite, because they are able to do that for several minutes without us feeling anything. We wanted to use it to see if we could develop a micro-needle that would be painless. »

**Analyse how mosquitoes bite**

So far, they have not developed a prototype of this needle. What they have done is take a closer look at the components that allow the mosquito to bite people without causing them discomfort. Mosquitoes use a combination of four substances. These include the use of a saliva-based numbing agent during the biting process, a serrated design for the "needle" during the piercing process, and a combination of soft and hard parts on the proboscis, the elongated sucking part of the insect. This combination allows the mosquito to pierce the skin with only a third of the force required by an artificial needle, while the numbing agent allows the mosquito to bite without the target individual feeling the bite.

Based on this research, Bhushan suggests that it would be possible to create a micro-needle containing two needles. One would inject a numbing agent, while the second could be used to draw blood or inject a drug. This second needle, which would also have a serrated edge like a mosquito's trunk, would be flexible and softer on the tip and sides, and would vibrate once inserted. This researcher says the materials and technology to create such a needle already exist.

## Activity 1

Watch the surprising video of a mosquito biting! Write your answers!

1. **Describe mosquito biting!**

2. **Draw a mosquito, indicating where the labium and the fascicle are located!**

3. **One company was inspired by the mosquito to develop medical needles. What do you think were the engineers' reasons for choosing this biological model?**

**Activity 2**

Imagine that you are medical and have to inject medicine or take a blood test.

Let's try to do it!

Choose different sizes of needles, make injections for an apple or take a blood test from an orange.

Write your opinion!

**How do you think mosquito bite could be improved in the future?**

**References, link, bibliography:**


How Mosquitoes Use Six Needles to Suck Your Blood | Deep Look

Mechanism of a Mosquito Bite

Mosquito bite helps create the ideal injection needle

Biomimicry: What We Can Learn from Nature

Bite like mosquito

# Topic: Biomimicry: examples

## Title of activity: B4: Colourful like a morpho butterfly

**Lesson Duration: 1 hour 5 minutes**

**Level of difficulty: easy-moderate difficulty**

**Students' age: 14-16 years**

**Materials / equipment:**

*Microscopes, Petri dishes, probes, drawing paper, pencil, book with butterfly scale images, boxes of crayons, white paper, flashlights.*

**Theoretical background of the activity:**

Morpho is a genus of butterfly with 80 known species. They range in size from 3"-20" and are mostly found in tropical regions such as Central and South America. Adult Morphos feed exclusively on rotting fruit juices. The estimated life cycle of the morpho butterfly is approximately four and a half months. Morphos are most notable for the extremely vibrant coloration in the males of the species, which are usually a metallic blue or green.

Blue morpho butterflies that do not use pigment to create the bright blue colour on their wings. Instead, their wings have a layered microstructure that causes light waves that hit the surface of the wing to diffract and interfere with each other, so that certain colour wavelengths cancel out while others, such as blue, are intensified and reflected.

1. What is Morpho? Why has the morpho butterfly developed this colour?

   (Write your answers below)

2. What gives the butterfly its blue colour?

   (Write your answers below)

3. How could we be inspired by watching the video Nature=Future about the Sun butterfly? Why is the Researcher Serge Berthier invested in this butterfly?

   (Write your answers below)

4. Draw the structure of the Morpho butterfly by observing the picture on the previous page, paying close attention to the nanostructure of the butterfly. Why is the colour of the butterfly blue? Is this blue colour in the material of the butterfly's wings or is it related to light diffraction?

   (Draw and write your answers below)

References, link, bibliography:

What Gives the Morpho Butterfly Its Magnificent Blue? | Deep Look

Nature = Futur ! Un papillon solaire

Structural color of Morpho butterflies: American Journal of Physics: Vol 77, No 11

# Topic: Biomimicry: examples

## Title of activity: B5: Discover and draw the anatomy of the wing

**Level of difficulty: easy-moderate-difficult**

**Materials / equipment:**

*The presentation "The anatomy of a bird's wing",*

*The workbook – Activity one,*

*The video* The Anatomy of Flight

**Theoretical background of the activity:**

The wings of the birds are modified forelimbs that enable them to fly. Similarly to the human hand, it bends at three points. It is covered with feathers being suitably spread and with the help of cutaneous muscles, creates extensive load-bearing planes. The wings are set in motion with the help of very strong pectoral muscles and are attached by means of a bone crest located on the sternum. Birds' wings are light, strong and flexible. They have fewer feathers than the body, each feather weighs very little, but together they weigh more than the skeleton. A bird's wing is divided into 2 large parts, which in turn are divided into several smaller parts. The most important in terms of the flight are remiges:

- Primary: located at the end of the wing; provides propulsion and manoeuvring of the bird.
- Secondary: located in the middle of the wing; gives the wing the curved shape necessary for flight.
- Tertiary: part closest to the body; reduces air turbulence.
- Alula: is located at the front of the wing; used to stabilise the flight in case of gusts of wind and to glide safely at low speed.

Feathers, made of keratin, have the spine down the middle called the shaft. That part is hollow in the middle. The vanes are on the two halves of the feather. They are made of thousands of branches called barbs. Because there are many spaces between these barbs, a feather has a lot of air. The flight capabilities of birds depend on the shape of wings, aspect ratio and wing loading.

Watch the video: *The Anatomy of Flight*

1. Draw a bird's wing, showing primary, secondary and tertiary remiges and scapulars.

2. Compare bird and plane on the different phases of flight: take-off, flight, and landing. Feel free to make drawings.

**References, link, bibliography:**

The Anatomy of Flight

Einhard Bezzel “Birds” Multico Oficyna wydawnicza 2010 PL

Przemysław Busse “A small zoological dictionary. Birds" Wiedza Powszechna Publishing House 1990 PL

Bird wing

# Topic: Biomimicry: examples

Title of activity: B6: History: The desire to fly, from Leonard de Vinci to Airbus

**Level of difficulty: easy-moderate-difficult**

Materials / equipment:

*Video:* The history of aviation in 11 incredible objects

**Theoretical background of the activity:**

Aeronautics is a sector that has historically been bio-inspired. For this reason, it is easy to understand. Man has always dreamed of flying like a bird.

15th century: Leonardo da Vinci created the foundations of aeronautics. His creative mind bubbling with ideas and his insatiable curiosity worked in so many fields. His thirst for innovation, his creativity have been revealed to us by all the manuscripts that have come down to us. His quest for perfection, in the way he learned and understood the world, has led him to doodle a lot. His reflections, thoughts, ideas, projects with diagrams and drawings have been carefully recorded in notebooks that he carried everywhere with him! For a long time after his death, these manuscripts were scattered all around the world. Some of them lost, but thousands of pages eventually reappeared a few hundred years after his death.

Leonardo da Vinci laid the foundations of aeronautics, Laid by his curiosity and a scientific personality made the foundations of aeronautics. For ages, he was fascinated by the possibility of flight, which resulted in countless plans with detailed comments and explanations to build flying machines. A study of these documents shows that he was one of the first people who had laid the foundations of aeronautics.

Leonardo da Vinci's manuscript on the study of the flight of birds. According to the scientific approach, it started with an observation: birds are the model and an incredible source of knowledge in this field, so he used it. From the manuscripts, we understand that Leonardo studied the beating of the wings, the way the bird stays in balance, gains altitude. During his observations, he considered the impact of the wind on the way a change of direction in flight! His knowledge of anatomy and mechanics (the study of movements and forces) supported his work. Then, he wrote down drawings of mechanical wings or flying machines, diagrams with detailed notes.

In the Manuscript of a flying machine (1488), Leonardo da Vinci described his observations and conclusions:

- Lift, caused by the difference in pressure between the top and the bottom of a wing, is the force counteracting weight for sustentation.
- Drag is the force of resistance to penetration into the air when a body is in motion. It must be compensated by propulsion.

He noticed that flapping of the wing does not contribute to lift but to propulsion. He understood that these two forces were a function of the surface of the object. The shape and speed of air circulation around it have tremendous importance. Although his flying machine was unable to take off, he formed the basic principles of aeronautics. It must be said that current research on design and materials (both on the aircraft and the engines) is focused on both optimisation of lift and the minimisation of drag.

Clément Ader's plane III (1897) is, for example, very inspired by the bat's wing.

Bio-inspiration remains an approach in developments of this sector, improvement of shapes, surfaces, or even the material structures of devices. Over the centuries, our ancestors were already imitating nature. They have been inspired by the shapes existing in nature. Among them: Leonardo da Vinci (1452-1519) showed his genius not only as an extraordinary scientist but also as a champion of biomimicry. His motto? "Go and take lessons in nature, that's where our future is". To draw his ornithopter, with which he hoped that a human could fly with the strength of his arms, Leonardo da Vinci carefully observed the flight of birds, bats and dragonflies. Nothing escaped him: neither the shape of the wings, nor the function and arrangement of the feathers, nor the sequence of movements for taking off, flying nor landing. Leonardo da Vinci's various projects for flying machines remained in the form of sketches and plans: the manufacturing materials that existed at the time were too heavy. No human would have had the muscles to fly a prototype.

Source: Bioinspired!

Winglets: discovery of the winglet in 1974 at NASA

The winglet was developed at the NASA research centre in Langley (USA) in 1974 by the American aerodynamicist Richard Whitcomb, also known for his work on area law and supercritical wing profiles. Whitcomb published his work on winglets in 1976.

Boeing and first winglets

Boeing announced in 1985 a new version of the B-747, the 747-400 with increased range and cargo capacity. The wing of this model had an increased wingspan and the fitting of winglets. We find the same gains in energy efficiency on the Airbus models. Airbus has developed winglets and Sharklets wingtips for its Airbus ranges. Directly inspired by the curved tips of raptors' wings, the winglets have increased the lift of the A380 wings and reduced the size of the wings, keeping the wingspan within the possible limits of today's airports. The "sharklets", additionally inspired by shark fins, improve stability and reduce fuel consumption by up to 3.5%, representing an annual CO2 reduction of around 700 tonnes per aircraft (Airbus, 2012).

Business aviation

Winglets have been used in many jet aircraft to obtain the benefits of a higher effective aspect ratio: reducing the distance to take off and landing at secondary airports and increasing flight altitude.

Not only can it be installed on new planes but on the older ones as well. The winglet has been used on business aircraft; only Dassault has temporarily resisted this trend. Cessna recently announced a partnership with Winglet Technology to test elliptical winglets.

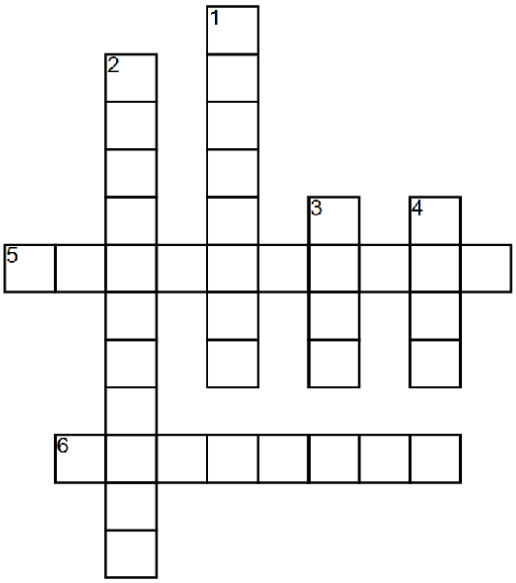
## Activity one

Man has always dreamed of flying in the air. Trace, in the form of a chronological frieze, the main events in aviation.

As an inspiration watch the video: The history of aviation in 11 incredible objects

## Activity two

Fill in the crossword.




**Across**

**5.** The practice of making technological and industrial design copy natural processes

**6.** Discovered by NASA scientist.

**Down**

**1.** Which activity of birds contributes to their propulsion?

**2.** Which species of animals did Leonardo da Vinci carefully observe ?

**3.** It is caused by the difference in pressure between the top and the bottom of a wing, is the force counteracting weight for sustentation.

**4.** It is the force of resistance to penetration into the air when a body is in motion. It must be compensated by propulsion.

## References, link, bibliography:

The history of aviation in 11 incredible objects

Thermal Engineering

# Topic: Biomimicry: examples

## Title of activity: B7 Fly like a raptor

**Level of difficulty: easy-moderate-difficult**

**Materials / equipment:** *Students' worksheet, The presentation "Winglets and birds wings."*

**Theoretical background of the activity:**

**Winglets: definition**

Winglet: A substantially vertical winglet located at the wingtips of an aircraft reduces fuel consumption and increases in flight range. It works by reduction of the drag of the wing induced by lift. Winglets also have a great influence on the effective elongation of the wings. They make the flight more comfortable as they help to dampen vibrations. Improving performances of airplanes, they shorten the run-up of the planes and decrease the level of the noise during take-off and landing. This English word is still the most widely used, although French equivalents penne or "ailerette" have been proposed. Scientists of Wroclaw Technical University explain winglets are lurking in birds' life. Although birds do not bend the wings upwards, they outstretch feathers on the tips.

**Winglets: principle**

Overcoming gravity enables flying in the air. For overcoming that force a lifting force is responsible. But it could not occur if not for the special structure of wings. Especially shaped wings cause that the air flows around them with different lengths. At the top, it has a longer path than at the bottom. At the end of the wing surface, the air flowing over them from above and below meets simultaneously. Because it has different lengths to cover, the top one moves faster, and the bottom one moves slower. The difference in velocity between the air flowing over the top of the wing and that one flowing over the bottom causes pressure differences. The slower it goes, the lower its pressure. So the air from the bottom of the wing lifts a plane upwards. The pressure difference between the upper and lower surfaces of the wing is called a lifting force. There is only one problem, the wing does not have an infinite length. The air with higher pressure from the bottom of the wing curls upwards at the tip of the wing, causing air vortices called edge vortices to form at the wing tip. Thus, the induced resistance increases. One way of counteracting this effect is to lengthen the wing. However, a higher aspect ratio (at the same surface area) causes an increase in the bending forces of the wing and an increase in its thickness, thus increasing its mass. The other solution should be applied. To overcome edge vortices, there is a need of either more engine power during the flight or the installation of diffusers of these vortices, i.e. winglets. Correctly positioned, the winglet can recover some of the energy from the vortex. This has the effect of increasing the effective aspect ratio of the wing and reducing the drag induced by lift, without increasing the wingspan. A winglet receiving oblique airflow can straighten the airflow and develop slightly forward lateral lift, which can cancel out its own drag. The gain in efficiency is a few percent.

**Bird aerodynamics**

Birds are vertebrates whose bones make up 10% of their body mass. They have hollow bones, which allows them to reduce their body mass. They are both strong but very light. The bird's beak is an extension of their skull which, if it were heavier, would prevent them from flying and deteriorate their sight. These characteristics contribute to the lightness of their skeleton. The wing bones are adapted to flight and are similar to the arms of a human. The muscles of birds make up 40% of their weight and produce heat that warms them up. The muscles on the legs allow the birds to propel themselves, while those on the rib cage allow them to flap their wings and stay in the air. The bird's bone is mainly hollow to allow it to be lighter and thus to perform better in flight.

Activity one

1. Describe the shape of raptors' wings and the shape of aeroplane wings.

   (Write the answer below)

2. Look for information (from your teacher, on the internet...) to explain why these winglets improve the flight efficiency of aircraft (reduction in fuel consumption of about 4%).

   (Write the answer below)

References, link, bibliography:

Thermal Engineering

# Topic: Biomimicry: examples

Title of activity: B8: Experience: lift of a wing according to its profile

**Level of difficulty: easy-moderate-difficult**

**Materials / equipment:**

*String*

*Paper*

*Tape*

*Hairdryer*

*Metal tripods*

**Theoretical background of the activity:**

Overcoming gravity enables flying in the air. A lifting force is responsible for overcoming that force. But it could not occur if it was not for the special structure of wings. Specially shaped wings result in the flow of air around them. At the top, it has a longer path than at the bottom. At the end of the wing surface, the air flowing over them from above and below meets simultaneously. Because it has different lengths to cover, the top one moves faster, and the bottom one moves more slowly. The difference in velocity between the air flowing over the top of the wing and that one flowing over the bottom causes pressure differences. The slower it goes, the lower its pressure. So the air from the bottom of the wing lifts a plane upwards. The pressure difference between the upper and lower surfaces of the wing is called a lifting force.

Vultures can give us aerodynamic lessons. Variations in air pressure at the tips of aircraft wings create marginal vortices, which affect flight performance. This causes a turbulent flow that persists for long distances behind the plane. It is particularly dangerous to enter the vortices produced by a jumbo jet. Due to this fact, air traffic controllers leave a minimum separation time and distance between take-offs. Observation of vultures reveals that while they fly they open their remiges, the large feathers at the tips of their wings, just as when you open your fingers. Aeronautical engineers and biologists have understood that by reducing the resistance exerted by the vortices that is a possibility to save energy during flight, both for an aircraft and for the vulture. This is why upward-pointing structures called winglets, invented in 1974 by NASA engineer Richard Whitcomb, can be seen at the tips of the wings of planes. But usually, there is only one point per wing. By continuing to draw inspiration from vulture flight technology, airlines could further reduce their energy consumption and impact on the environment.

**Activity 1**

To test the link between aerodynamics and lift, organise a series of experiments.

You have at your disposal: string, paper, tape, a hairdryer, and metal tripods.

1. **Describe the experiences (you can make a drawing)**

2. **Manipulate!**

3. **Write conclusions below.**

**References, link, bibliography:**

TPE: le vol de l'avion-1ère expérience

# Topic: Biomimicry: examples

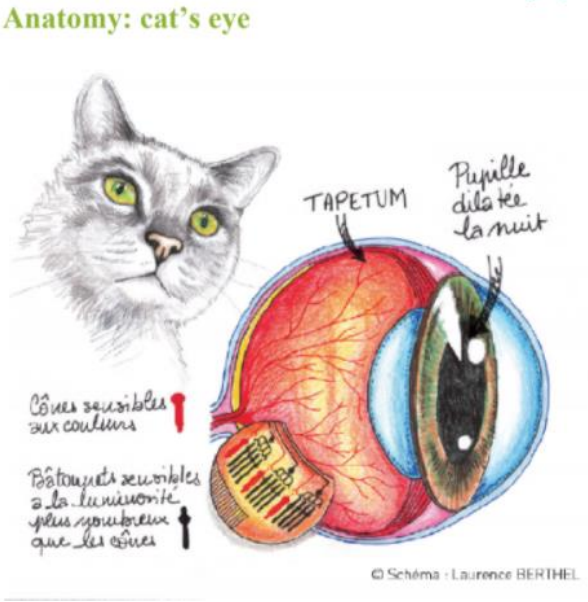
Title of activity: B9: Shine like a cat's eye

**Level of difficulty:** easy-moderate-difficult

**Materials / equipment:** *The presentation "Cats eyes as an example of Biomimicry", The Video* All about Cats Eyes (Are We There Yet: Guide to Roads)

**Theoretical background of the activity:**

Felines have highly developed night vision. When they encounter a light source, such as the headlights of a car, their eyes shine in the night. Cats, like all felines, have a membrane lining the retina, the tapetum lucidum. Like a mirror, it reflects the light and makes it pass through the retina a second time. Its eyes need six times less light than those of humans. The retina, the eye's most concentrated nerve, has two main types of cells i.e. rods and cones. Rod cells enable cats to see in low light conditions such as a night light. Comparing the number of rod cells in the human and cat's eye, there are 6-8 times more in the case of felines. Moreover, rod cells allow cats to feel the motion in the dark to a greater extent than a human's eye. Felines have a large number of rods but very few cones. Cones are the main factor that gives cats the ability to perceive and distinguish colours. Cat eyes have three types of cones that can determine the combination of red, blue and green. It absorbs mainly green light and very little blue and red. Felines see their environment in shades of grey, but they detect movement very well. Living beings have adopted three main strategies for finding their bearings, hunting or communicating at night: maximising the little natural light present, producing their own light (bioluminescence) or appealing to other senses that do not use light. Have you ever noticed that many animals suddenly exposed to light betray their presence with eyes that become extremely bright in the dark? Moths, on the other hand, can easily go unnoticed thanks to their very poorly reflecting corneas. In the dark, some amplify the light they receive, others collect as much light as possible without reflecting it, and still, others exploit wavelengths invisible to us. In most nocturnal animals, a special reflective layer, called tapetum lucidum (shiny carpet), acts as a mirror that reflects light that has passed through the retina without being absorbed. When light is directed at the eyes of an animal with a tapetum lucidum, the pupil appears to glow. Even a flashlight can produce this visible glow.



1. What are the three main strategies developed by living beings to find their bearings, hunt or communicate.

2. The cat is famous for its good night vision. What do you notice when it crosses the headlights of a car?

3. The cat, like all felines, has a membrane lining the retina, the tapetum lucidum. Like a mirror, it reflects light and makes it pass through the retina a second time. Its eyes need six times less light than those of humans.

4. Which object was inspired by the cat's eye (hint: we come across it on the roads)

References, link, bibliography:

All about Cats Eyes (Are We There Yet: Guide to Roads)

Cat Eyes: Anatomy, Function and Vision

Zintegrowana Platforma Edukacyjna

# Topic: Biomimicry: strategies and functions of living organisms

## Title of activity: C1. How does the gecko hang on?

**Level of difficulty: easy-moderate difficulty**

**Materials / equipment:**

*Books, software, presentations, etc. to be used in class in order to allow the accomplishment of tasks and activities.*

**Theoretical background of the activity:**

The "gecko" is a small lizard (gecko) whose ability to "climb" the walls (and walk on the ceiling) and intelligence fascinate biologists and physicists. This adherence has been studied and, in part, explained by numerous works. At the centre of the ability to cling to the gecko spiderman are its specialized pads, located on the toes of the reptiles, composed of several setae (structures similar to bristles or hair) at the tip of which there are small structures called spatulas, each less than a micron wide. This allows attractive forces called van der Waals interactions to emerge between the adhesive bristles and the surface. A single spatula shows very weak molecular forces, however, when coupled in the thousands of thousands in the setae, the attraction becomes very strong. These forces are so strong that they not only support the weight of the gecko, but also for highly robust humans - up to 133 kg can be sustained by the adhesion forces between the gecko's fingers and the surface. However, a recent publication shows that the animal is so agile, it's because its feet are greasy!

Adhesive soles of the gecko are a hobby of biomimetic specialists, a discipline that draws inspiration from nature to develop new tools and materials. This is the very example of a technology transfer, almost out of the wild to the laboratory. The study published in Interface magazine, of the Royal Society, by a team from the University Of Akron, Ohio (USA), could well lift the last veil on an increasingly better understood phenomenon. Many studies have tried to explain this exceptional adhesion: undone and renewed up to twenty times per second, with each step of the reptile. All demonstrated that cunning, "the trick" resides in the forest of microscopic hair, the setula's, which cover the back of their paws. Each hair will, in fact, interact on a nanometric scale with the support, being able to support a fraction (very small) of the lizard's weight, thanks to the Van-der-Waals forces, responsible for the attraction between molecules. The accumulated action of millions of hairs will allow the animal to perform its acrobatics. What's more, a single finger is sufficient for the gecko to remain suspended from the ceiling. The discovery of this small secretion profoundly alters the theoretical models of "dry" adhesion. The principle, integrated with existing research, will refine the development of biomimetic materials, making them even closer to the natural example and, therefore, with greater performance.

## Main Activities

1. Find out what Biomimetics is by watching short videos.
2. Asking the question "Would you like to be like Spiderman?"
3. View video
4. Conduct targeted research that leads students to see how Gecko manages to scale walls defying gravity.
5. Research whether the Gecko can serve as an inspiration to the Human Being by creating new technologies.

**References, link, bibliography:**

Smart materials (1 of 5): Gecko Adhesive fit for Spiderman

Em Pauta - Novidades

Patented Gecko-inspired Technology | Setex Technologies

Gecko-clinging-ability-wet-surfaces-might-inspire-water-resistant-adhesive-tape

Robert_full_learning_from_the_geckos_tail

Ford usa biomimética para pesquisar novas soluções na produção de veículos

Biomimetismo extremo: Ouvido animal inspira olho artificial

Rhaco;

# Topic: Biomimicry: strategies and functions of living organisms

## Title of activity: C2: Velcro© and burdock

**Level of difficulty: Scale: easy-moderate-difficult**

**Materials / equipment:**

*Worksheets - Activity one, Activity two*

*The presentation – Velcro© and burdock*

*Video –* Inventing with Plants!

*Yarn gloves. Floorball. Floorball with Velcro. Magnifier. Velcro tape. Colourful toy designer, Velcro, burdock.*

**Learning Objective:**

- Interpret the concept of biomimicry.
- Explain the influence of nature on our life.
- Describe the structure of burdock.
- Study the strategy deployed by the bardane to adhere to dog hair.
- Explains how Velcro works.
- Explain whether Velcro (R) meets all biomimicry criteria.

**Theoretical background of the activity:**

Everybody knows Velcro, the quick fastening system for clothing. Better known as “scratch”, the Velcro tape is an invention by the Swiss engineer George de Mestral. But did you know that this invention is a clever imitation of nature and more precisely of the fruit of the Burdock?

The story goes that in 1941, on his return from a hunting trip to the Alps, George de Mestral had to remove a lot of burdock fruit hanging on his clothes and in the hair of his dog. Burdock (Arctium lappa) is a wild plant that has fruits that cling to the hair of animals, allowing the seeds to spread. George de Mestral had the idea of observing the Burdock fruit under a microscope, and he noticed that the spines of the fruit end in deformable hooks. These hooks get caught in the hairs and looped tissues and return to their original shape when pulled out of a support. This observation gives him the idea of creating a type of quick-release fastener for clothing. After several years of development, he achieves the desired result with a soft cotton strip and a polyester strip with hooks. He named his invention Velcro, an apocope of the words “velvet” and “hook”, and filed patents in the early 1950s (registration of the trademark in 1952), and industrial production of Velcro was launched right away!

### Activity 1

Find a partner. Put on the glove. Try to catch the ball with one hand. You catch different balls. Students exchange places. After activity, answer the question below.

**Which ball was easier to catch? Why?**

### Activity 2

**Part One:** Looking at the video: How Does Velcro Work? | Design Squad answer the question below. **How does Velcro work?**

**Part Two:** Explore both sides of the Velcro tape with a magnifying glass. Velcro© was invented by an engineer who observed burdock seeds hanging on his dogs hair. Draw, in zoom mode, the two sides of a Velcro strip and explain in a few words the principle of adhesion below.

**References, link, bibliography:**

Inventing with Plants!

How Does Velcro Work? | Design Squad

Burdock Thistle | Kids Answers

# Topic: Biomimicry: strategies and functions of living organisms

## Title of activity: C3: Adhere without toxic glue

**Lesson Duration: 55 minutes**

**Level of difficulty: easy-moderate-difficult**

**Students' age: all ages**

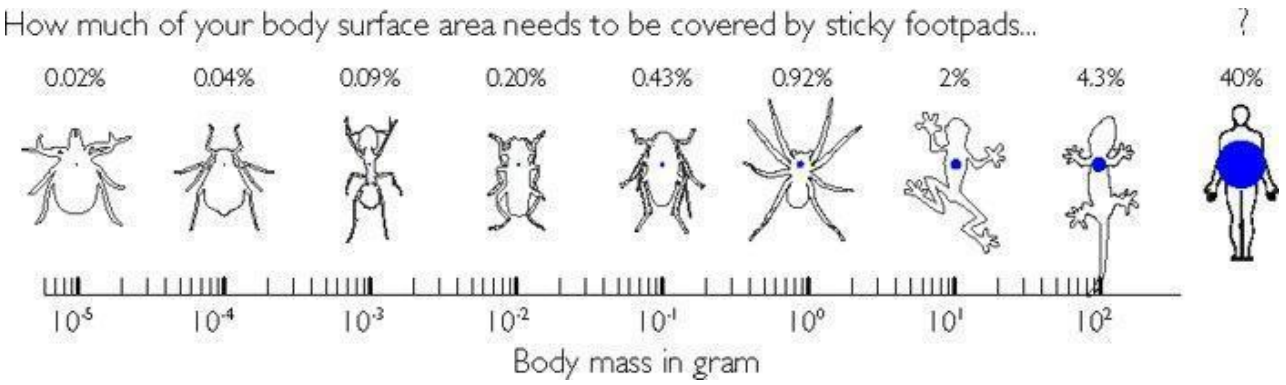
**Materials / equipment:** *Presentation*, *YouTube video* Why a Geckos Feet Can Stick to Almost Anything

**Theoretical background of the activity:**

Geckos are officially the largest animals capable of sticking to smooth walls. Spider-Man's ability to scale vertical walls may help the web-slinger catch the bad guys in comic books, but he could never pull this trick off in reality. A new study by zoologists at the University of Cambridge has found that geckos are the largest animals capable of sticking to smooth vertical surfaces – an ability that requires increasingly larger adhesive foot pads as a percentage of overall body surface as animals themselves become bigger.

Geckos run up walls and scurry across ceilings with the help of tiny rows of hairs on their feet. The hairs, known as setae, generate a multitude of weak attractions between molecules on the two surfaces that add up to a secure foothold. Moreover, making and breaking the bonds that hold individual setae to a surface is easy. So, unlike glue or tape, a gecko's sticky feet attach and detach effortlessly, a trait envied by mechanical engineers.

Scientists have recreated gecko-like adhesion using silicones, plastics, carbon nanotubes, and other materials—but they've run into a scaling problem: The stickiness diminishes when the size of the adhesive exceeds a few square centimetres, severely limiting its practical applications.



1. Observe nature and give examples of living organisms (at least two) that have the ability to stick themselves?

2. Look at everyday examples of manufactured objects that involve the adhesion of two or more pieces. Are these objects recyclable or reusable? How have they been manufactured?

3. Glue is certainly the most common way to stick objects together. What do you think of glue? With what resources is that made?

4. What are these called?

References, link, bibliography:

Why a Geckos Feet Can Stick to Almost Anything

New research investigates the physics of sticky gecko feet

Gecko-inspired adhesives allow people to climb walls

# Topic: Biomimicry: strategies and functions of living organisms

## Title of activity: C4: Protecting against heat and cold

**Level of difficulty: easy-moderate difficulty**

**Students' age: 9-11 years**

**Materials / equipment:**

*Presentation*

*YouTube video* How Do Animals Survive in the Arctic? 🐻‍❄️ - Animals for Kids - Educational Video

**Theoretical background of the activity:**

Wildlife can succumb to frostbite and hypothermia, just like people and pets. Avoiding the cold is important for preserving life or limb (or, in the opossum's case, tail) and the opportunity to reproduce. These biological imperatives mean that wildlife must be able to feel cold in order to try to avoid the damaging effects of its extremes. Animal species have their own equivalent to what human beings experience as that unpleasant biting mixed with a pins-and-needles sensation that urges us to warm up soon or suffer the consequences. In fact, the nervous system mechanisms for sensing a range of temperatures are pretty much the same among all vertebrates.

One winter challenge for warm-blooded animals, or endotherms, as they're scientifically known, is to maintain their internal body temperature in cold conditions. Interestingly though, temperature-sensing thresholds can vary depending on physiology. For instance, a cold-blooded — that is, ectothermic — frog will sense cold starting at a lower temperature compared to a mouse. Recent research shows that hibernating mammals, like the thirteen-lined ground squirrel, don't sense the cold until lower temperatures than endotherms that don't hibernate.

Polar bears (Ursus maritimus) are not just one of the most beautiful animals in the world. They are also extremely interesting from a scientific perspective, as these bears live in the Arctic Circle and thus, are adapted to survive in one of the most extreme climates in the world. Have you ever wondered how polar bears survive the cold of the Arctic Ocean? Scientists have spent many years researching how polar bears maintain their body heat and how their fur works. Polar bears belong to the same genus as black and brown bears, which means they're more closely related to these species. Out of all habitats, their favourite is the sea ice on the Arctic Circle, where there are many small archipelagos. As mentioned earlier, polar bears are carnivores, and they have 42 impressive teeth to prove it. When they rise to the land, it's usually to hunt. Their most common prey includes the different seals of the Northern Hemisphere, belugas and young walruses.

Main activities

1. By observing nature, which species have the ability to protect themselves from the extreme to intense heat? Can you name at least three of each?

   (Write answers below)

2. How does the penguin fight against cold?

   (Write answer below)

3. Which animals can survive extreme cold?

   (Write answers below)

References, link, bibliography:

How Do Animals Survive in the Arctic? 🐻‍❄️ - Animals for Kids - Educational Video

How Do Animals Survive the Cold? Antifreeze and Fur Are Just the Beginning

Adaptation in Animals: Polar Bear, Penguins, Tropical Animals, Video, Q&A

# Topic: Biomimicry: strategies and functions of living organisms

## Title of activity: C5. Protecting against cold

**Level of difficulty:** easy-moderate-difficult

**Materials / equipment:** *Video watching YouTube, Computer for research and produce*

**Theoretical background of the activity** Biomimicry 101 - Examples of How We Copied Nature

**Main activities:**

We aim at recognizing the uniqueness of animals' characteristics that inspire the construction of lots of the things that we use in our daily life. Students must be able to research for animals that are an inspiration for man, regarding their abilities to protect themselves against heat or cold. An oral presentation will be asked as a final product by following a worksheet with guidelines on the animal students researched.

**Activity 1:** Visualizing and understanding the message in the video Biomimicry for Young Children - Animals in Snow

**Activity 2:** Class divided in small groups:

- finds out the definition of Biomimicry
- Identifies the animals mentioned in the video
- identify what did the animals mentioned inspired to build/construct
- Short Presentation to the class of the findings – moment for dialogue/discussion about the importance of nature as an inspiration.

**Activity 3:** In groups do research about other animals that protect themselves from cold, how they do it and how it inspired man to create similar situations. Each group presents their research to the class.

**References, link, bibliography:**

11 awesome technologies Inspired by animals'

Biomimicry 101 - Examples of How We Copied Nature

# Topic: Biomimicry: strategies and functions of living organisms

## Title of activity: C6. Protecting against heat

**Level of difficulty:** easy-moderate-difficult

**Materials / equipment:** *Video watching YouTube, Computer for research and produce*

**Theoretical background of the activity:** Biomimicry 101 - Examples Of How We Copied Nature

**Main activities**

We aim at recognizing the uniqueness of animals' characteristics that inspire the construction of lots of the things that we use in our daily life. Students must be able to research for animals that are an inspiration for man, regarding their abilities to protect themselves against heat. An oral presentation will be asked as a final product by following a worksheet with guidelines on the animal students researched.

**Activity 1:** Visualizing and understanding the message in the video

See How Termites Inspired a Building That Can Cool Itself | Decoder

**Activity 2:** Class divided in small groups:

- finds out the definition of Biomimicry
- Identifies the animals mentioned in the video
- Short Presentation to the class of the findings – moment for dialogue/discussion about the importance of nature as an inspiration

**Activity 3:** In groups do research about other animals that protect themselves from cold, how they do it and how it inspired man to create similar situations. Each group presents their research to the class.

**References, link, bibliography:**

11 awesome technologies Inspired by animals

# Topic: Biomimicry: strategies and functions of living organisms

## Title of activity: C7: The termite mound, a model of natural air conditioning

**Level of difficulty: easy-moderate-difficult**

**Students' age: 9-11 years**

**Materials / equipment:** See How Termites Inspired a Building That Can Cool Itself | Decoder

**Theoretical background of the activity:**

We humans like to congratulate ourselves for our ingenuity. Yet nature's passive designs often outperform our expensive, energy-hungry technologies. And while engineers and architects can improve their designs by mimicking the natural world, nature always has another lesson to teach. That has certainly been the case for termites and air conditioning.
The story begins in 1992, when Zimbabwean architect Mick Pearce received a commission to build Eastgate Centre, a two-building office complex and shopping mall, in the country's capital city of Harare. Pearce, however, wanted to do more than just build a new building. He wanted to eliminate the huge heating and cooling plants a 340,000 square feet development typically needed. Pearce had grown up in Zimbabwe and was familiar with termite chimneys. They raised six to 30 feet above termite nests and were strong enough for elephants to use to scratch their flanks. Below the chimneys, the termites farmed fungi for food. While the termites relied on the soil's thermal storage capacity to help keep temperatures stable. "The termite nest was warmer than the outside, particularly at night," Pearce said in an interview. "You get air rising out the chimney, and that pulls air in from the holes they go out to forage. That's how they breathe."

Termite-inspired Eastgate Centre in Harare, Zimbabwe, uses convection cooling to remove hot air through chimneys located on the top of the building.

Main activities:

Activity 1

Have a look at the video

See How Termites Inspired a Building That Can Cool Itself | Decoder

And answer the questions below.

1. Could the future of air conditioning be found inside termite mounds?

   (Answer below)

2. Termite mound air conditioning is solar, not wind. Can you explain why?

   (Answer below)

3. How do termite mounds regulate temperature?

   (Answer below)

## Activity 2

Draw, using the right colours, a termite mound and the natural currents of hot and cold air that explain the ingenious thermoregulation principle put in place by termites.

References, link, bibliography:

See How Termites Inspired a Building That Can Cool Itself | Decoder

Termite Mounds Inspire Energy Neutral Buildings

What Termites Can Teach Us About Cooling Our Buildings (Published 2019)

# Topic: Biomimicry: strategies and functions of living organisms

## Title of activity: C8: Experience: Termite mound

**Level of difficulty: easy-moderate-difficult**

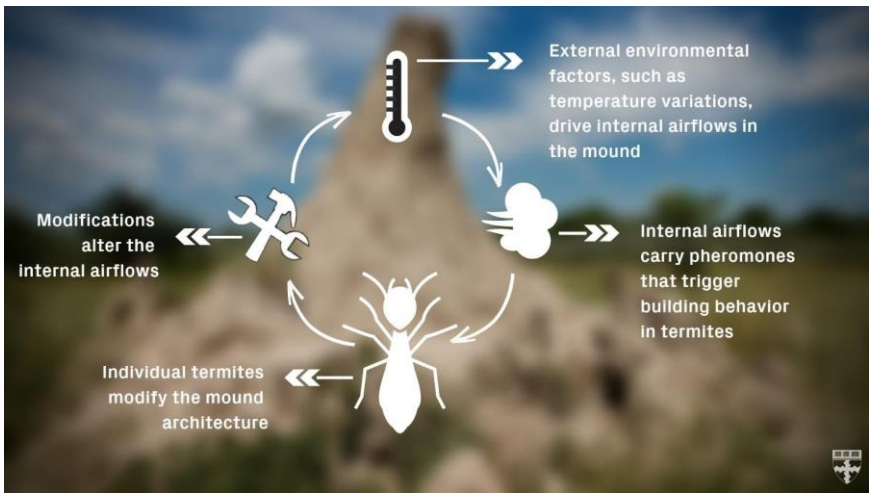
**Students' age: 9-11 years**

**Materials / equipment:** *Newspaper, masking tape or string, flour or glue mixture, paints, wooden beads, paper towel roll, scissors and sponges.*

**Theoretical background of the activity:**

Termites live in Africa, Australia and South America. The mounds sometimes have a diameter of 30 metres (98ft). Most of the mounds are in well drained areas. Termite mounds usually outlive the colonies themselves and if the inner tunnels of the nest are exposed, it is usually a dead mound. Sometimes other colonies of the same or different species occupy a mound after the original builders.

The structure of the mound can be very complicated. Inside the mound is an extensive system of tunnels and conduits that serve as a ventilation system for the underground nest. The mound is built above the subterranean nest. The nest itself is a spherical structure consisting of numerous gallery chambers. The magnetic termites' mounds are created tall, thin and wedge-shaped, and are usually oriented north-south.




Changes in airflow carry information-containing odours to termites inside the mound. These information clouds — made up of pheromones and metabolic gases such as carbon dioxide — tell termites where to adjust the mound. If, for instance, one section of the mound is too warm, that temperature change will trigger a change in air flow, which will carry construction-cues to nearby workers. The termites will follow their senses to that section and adjust the mound to reduce temperature. That change in temperature will change the air flow and the termites will change their behaviour.

**Activity 1:** Answer following questions (class discussion + research)

1. **Do termites build mounds like ants?**

   **(Answer below)**

2. **Do termites bite humans?**

   **(Answer below)**

**Activity 2:** Drawing

**What does a termite nest look like?**

**Activity 3** (After completing Activity C7)

**Imagine an experiment that might allow you to highlight hot and cold droughts.**

**You have at your disposal: water, U-shaped tubes, containers that can hold water and a water-soluble food colouring agent.**

**Draw the assembly that you could set up (you can ask your teacher for help!)**

**References, link, bibliography:**

Termite mounds in Namibia inspire energy-efficient buildings

Termite Mound with Termites | Termites, Insects theme, Crafts

# Topic: Biomimicry: strategies and functions of living organisms

## Title of activity: C9: Observation & nature: the leaf

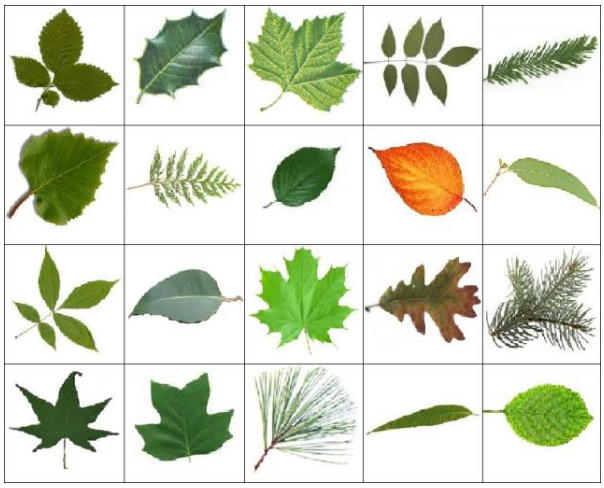
**Lesson Duration: 45 min**

**Level of difficulty: easy-moderate-difficult**

**Students' age: 11**

**Materials / equipment:** *Worksheet, The presentation – Observation & nature: the leaf, Visual material – laminated tree leaf cards*

**Theoretical backgrounds:**



Variety of leaf shapes - simple or compound - solid or cut.

**LIST OF LEAF FUNCTIONS:** Hydrophobia - to allow water to drain off, Photosynthesis - to capture the sun's energy, Oxygen production, Ombrage, Temperature control, Protection against herbivores - by their spatial organisation, their structures (thorns, needles, teeth, ...), Amino acid synthesis, Nutrient uptake, Defence against drought (thorns, or succulents), Stores water (succulents), Spin for hanging and climbing plants, Float for aquatic plants, Optimal organisation for better sun exposure

**Hydrophophy Float Defences -** Thermoregulation and hydroregulation by the leaves, which have become very small and allow a thin layer of air to remain around the cactus.

**Main activities:** Watching presentation **Observation & nature: the leaf** and discussing! What do you see in the pictures? What do you think about it?

**Activity 1:** Go outside to the park or the forest or look at the teacher distributing visual material – laminated tree leaf cards. Let's explore them! **Draw on the worksheet what elements do you see on the leaves! What functions do you recognise?**

**Activity 2: Based on the following drawings, draw your idea of biomimicry using functions of leaf or elements on a leaf!**

**References, link, bibliography:**

When Architecture Mimics Nature

PHOTOS: Beautiful Times Eureka Pavilion Mimics the Structure of a Leaf

Biomimicry of Palm Tree Leaves Form and Pattern on Building Form

La Palme Jumeirah à Dubai, un incontournable selon le site EXPEDIA

Azerbaijan unveils design of Country Pavilion and breaks ground for Expo 2020 Dubai

# Topic: Biomimicry: strategies and functions of living organisms

## Title of activity: C10: Zoom on the leaf and its multiple functions

**Level of difficulty: easy-moderate-difficult**

**Materials / equipment:**

*Worksheet*

*The presentation – Zoom on the leaf and its multiple functions*

*Pen, magnifier, compass, projector, calculator on solar panels, garden lighting lamp on solar panels*

**Theoretical background of the activity:**

1. The leaf of the plant avoids wetting or dirt - the so-called "lotus effect".
2. Hair on the leaves retains moisture in the plant leaf during dry climates and does not allow it to evaporate
3. A layer of wax on the leaves of the plant does not allow moisture to evaporate.
4. Shiny leaves reflect sunlight.
5. The edges of the leaves of the plant are serrated, which leads to more intensive photosynthesis and transpiration (resulting in a decrease in leaf temperature), resulting in condensation of water vapor and dew droplets on the edges.
6. Aromatic oils and poisons on the leaves of the plant repel herbivores.
7. The leaves have a vein through which nutrients move.

## Activity 1

Watch a teacher's presentation and a film about the process of photosynthesis in plant leaves.

## Activity 2

Go to the park and find 3 different tree leaves. Get acquainted with the information about the tree leaf. Carry out the research and write it down in a worksheet.

**1. At the top of each box, enter the name of the appropriate tree page.**

| _____ | _____ | _____ |
|---|---|---|
| | | |

**2. Read the information given on the tree leave and record the information sequence number that corresponds to each leave.**

**3. What are common features of leaves?**

**(Answer below)**

**4. What are different features of leaves?**

**(Answer below)**

Find one tree. Use a compass to determine the north and south direction of the tree. Pay attention to the location of tree branches on the north and south sides.

**1. On which side of the sky does the tree have more branches?**

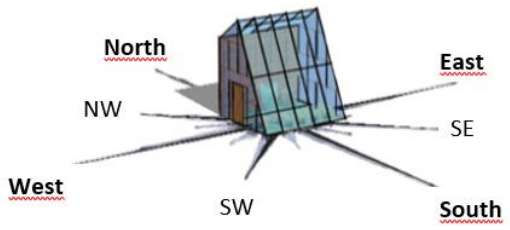
**(Answer below)**

**2. Write your opinion, why are there more branches on the south side?**

**(Answer below)**

### Activity 4

Look at the picture and substantiate their construction idea. Link the idea to the location of the tree branches, the sides of the sky and the functions of the leaves.






Read information about solar panels, make conclusions.

In Latvia, the autonomous system works best from spring to October - when the most sunlight is received. During this time, all the necessary electricity could be provided by solar panels, not only covering consumption during the day, but charging the batteries for the night. Solar panels are installed on the side of the roof facing south, southeast or southwest. This ensures the best access to light for solar panels. In the geographical location of Latvia, the most suitable positioning angle for solar panels is 39–41 degrees to the horizon. The appropriate angle can be adjusted and obtained with solar mounting systems. It is important that the selected area is not overshadowed by trees or other buildings.

**References, link, bibliography:**


Ing dep

Piedra Decorativa Con Luz Led Solar Para Jardín, Lámparas - $ 532.34

Kalkulators Milan, 14 ciparu displejs

An Architect's House That Melds Traditional Japanese And Ukrainian Ethos In A Modern Shell

Saules baterijas – mājokļa apgādei ar elektrību. Padomi uzstādīšanā

Lapas — Vikipēdija

# Topic: Biomimicry: strategies and functions of living organisms

## Title of activity: C11. Artificial Photosynthesis – reality or fiction?

**Level of difficulty:** easy-moderate-difficult

**Materials / equipment:** *Books, software, presentations, etc. to be used in class in order to allow the accomplishment of tasks and activities.*

**Theoretical background of the activity:**

Advancements in artificial photosynthesis have the potential to radically transform how societies convert and use energy. Scientific progress on artificial photosynthesis (AP) research—defined as using technology, notably synthetic biology and nanotechnology to capture light, transport electrons, split water and store hydrogen has the potential to radically transform for the better how societies convert and use energy. New technology has the long-term potential to so radically transform the planet towards sustainability as artificial photosynthesis engineered (alone or together with other technologies) in more efficient form as an 'off-grid' zero-carbon energy solution into all our structures (i.e. buildings, roads, vehicles)'. In Interface Focus by Sovacool & Gross (2015) the discovery of this small secretion profoundly alters the theoretical models of "dry" adhesion. The principle, integrated with existing research, will refine the development of biomimetic materials, making them even closer to the natural example and, therefore, with greater performance.

**Main Activities:**

1. Remind what photosynthesis is/The process
2. View video
3. The importance of Photosynthesis for our planet /critical thinking
4. Asking the question "Do you think it is possible to reproduce Photosynthesis?"
5. View video and take notes on what they understand by answering the questions (Definition of artificial photosynthesis, what is it used for? Is it reality or fiction?)

**References, link, bibliography:**

Photosynthesis

Photosynthesis | Photosynthesis in plants | Photosynthesis - Biology basics for children | elearnin

Artificial Photosynthesis | Adam Hill | TEDxStLawrenceU

The social acceptance of artificial photosynthesis: towards a conceptual framework | Interface Focus

A-LEAF: exploring artificial photosynthesis | Shaping Europe's digital future

Fotossíntese artificial: um futuro próximo - Brasil

# Topic: Biomimicry: the principles of living

## Title of activity: D1: The tree / the building: observation and inspiration

**Level of difficulty:** easy-moderate-difficult

**Students' age:** 10-12

**Materials / equipment:**

*Worksheet*

*The presentation – **The tree / the building: observation and inspiration***

*Coloured pencils (felt-tip pens, crayons, etc.)*

*Comfortable clothing for a little physical activity*

**Theoretical background of the activity:**

Natural forests give us much more than we think: herbs, edible fruits and mushrooms, diverse flora and fauna and refreshing refuge in the summer heat.

Our natural forests also play an important role in the functioning of their environment. They protect the surrounding farmlands from dehydration and strong winds, contribute to the conservation of our drinking water bases, and sequester and store carbon dioxide. In addition, they provide habitat for far more plant and animal species than cultivated forests. It is made up of trees of different sizes, ages and species, many of them are fallen, rotting dead wood in which a lot of special species find refuge. This diversity makes natural forests healthy, which are more successful in tackling the challenges posed by climate change.

A TREE: OBSERVATION AND INSPIRATION

## Main activities

### Activity 1

After listening to the sounds of the forest, answer the questions!

1. What did you hear?

2. What else could you hear besides the birdsong?

3. What did these sounds remind you of?

4. What can you compare?

**Activity 2**

Take some notes! Let's look at the roots, stem, and foliage! Listen to the roar of the trees! Look for which tree has been chosen as the home! Let's see what grows on the trees. Think and write for each tree organ, what it does, why he is needed. What can the forest give us? How to help preserve the environment in which we live?

**Activity 4**

Think and feel like a Tree! Draw Your City in the Future!

**References, link, bibliography:**

Build a Tree - A Sharing Nature Game

Quel modèle pour une ville vraiment vivante ?

Meža skaņas, atslābinošs troksnis: putni širp un dzied, kukaiņi un koki (sounds of forest)

Dreaming of the future cities

# Topic: Biomimicry: the principles of living

## Title of activity: D2.1: Photovoltaic sheets

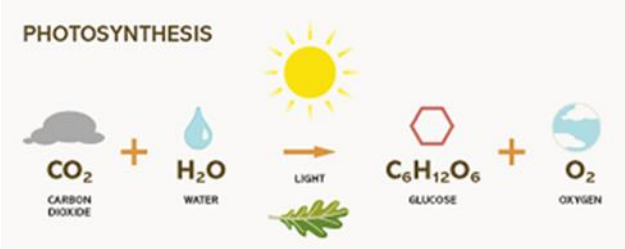
**Level of difficulty: easy-moderate-difficult**

**Materials / equipment:** *Resource document*, *Computer*, *Writing material*

**Theoretical background of the activity:**

Problems to solve: How does a photovoltaic panel look like a plant leaf? What are the advantages and disadvantages of using photovoltaic panels? Are there alternatives?

Plants are powerful allies in the fight against global warming as they absorb large amounts of carbon dioxide ($CO_2$) which reduces global warming. In addition to the essential role of synthesizing practically all the energy used on the planet. The plant leaf is at the centre of the photosynthesis process:




Photosynthesis chemical equation | OregonForests

Leaves are the organs of the plant that capture solar energy to produce sugar. During photosynthesis, leaf pigments capture solar energy and convert it into chemical energy in sugar molecules. The photosynthesis process uses light to combine carbon dioxide with water to produce sugar and oxygen. Part of the glucose is used as energy that is used by various vital processes. The extra glucose can be combined to form large starch molecules and be stored in the roots. These molecules are broken down into sugar and used when the plant needs more energy than is currently available.

The anatomy of the leaf is highly specialized for the absorption of light. The outermost layer, that is, the epidermis, is usually transparent to visible light and the individual cells are often convex. The convex structure of the cells of the epidermis allows them to act as a lens, redirecting and focusing the incident light to the chloroplasts that are adjacent to the side walls of the cells of the parenchyma. This is common among herbaceous plants and especially in tropical species that grow within forests (understory), where light levels are very low.

The energy flow captured by photosynthesis (on a planetary scale) is about 100 terawatts: which is about 10 times greater than the world's energy consumption (integrated in one year). This means that just under a thousandth of the energy received by the Earth is captured by photosynthesis and provides virtually all the energy in the biosphere.

**Photovoltaic panels**

Through photovoltaic solar energy it is possible to produce electricity by converting a part of the sun's rays using a photovoltaic cell. Schematically, an incident light photon can, under certain circumstances, set an electron in motion, producing an electrical current.

Photovoltaic panels can be used for small-scale domestic purposes (e.g. on roofs) or for large-scale industrial energy production.

## Activity 1

Watch the video: Disadvantages and Advantages of Solar Energy

1. Write the main advantages and disadvantages of using photovoltaic panels for energy production.

2. How does Nature manage to produce energy from the sun? Do you know any examples? Write them down.

## Activity 2

Look at different leaves


1. Explain how a photovoltaic panel resembles a plant leaf, with regard to: Importance of sunlight for its operation and energy transfers and transformations.

**Activity 3**

Watch the following video: Artificial Leaf Technology Could One Day Power Our World

1. **The video talks about artificial photosynthesis. Explain in your own words what this technology consists of.**

   **(Answer below)**

2. **It indicates the advantages of this energy production technology in relation to the use of photovoltaic panels.**

   **(Answer below)**

**References, link, bibliography:**

Disadvantages and Advantages of Solar Energy

Artificial Leaf Technology Could One Day Power Our World

# Topic: Biomimicry: the principles of living

## Title of activity: D2.2 Ecosystem services

**Level of difficulty: easy-moderate-difficult**

**Materials / equipment:**

*Computer*

*Aquarium with freshwater for mussels and freshwater mussels*

*Tray*

*Splash of water*

*Tweezers*

*Cleaning paper*

*Activity guide/worksheet*

**Theoretical background of the activity:**

Freshwater mussels: excellent river cleaners by answering the question - Why can freshwater mussels help fight water pollution?

This activity aims to:

- Relate the characteristics (body shape, covering, locomotion organs) of different animals with the environment where they live.
- Characterize some of the existing biodiversity at local, regional and national level, presenting examples of relationships between flora and fauna in different habitats.
- Know the concept of Biomimetics and relate to sustainability.
- Relate the characteristics of freshwater mussels with the environment where they live

## Activity 1

Start by watching the video: Mexilhões de água doce

## Activity 2

### Reading I - What is the type of mussel coating?

The mussel is an invertebrate animal. The lining of invertebrate animals is the epidermis. The epidermis of invertebrates can be covered by a cuticle, present an exoskeleton with chitin or limestone salts, or be protected by a shell.

Invertebrate - animal that does not have a vertebral column and that for the most part does not have an internal skeleton.

Chitin - substance produced by the epidermis of invertebrates.

The shells can be univalves, when made up of a single piece, such as, for example, the whelk, or bivalves when made up of two articulated pieces, such as, for example, the mussel.

| | |
|---|---|
|  |  |
| Shell univalve<br>Búzio | Shell bivalve<br>Mussel from fresh water |

Figure 1 - Shells are limestone structures segregated by the epidermis and grow with the animal. Protection is the main function of this type of coating.

**Based on the material that you just have read answer the following questions**

1. Indicate the type of coating of the freshwater mussel.
2. Give an example of two other animals with a bivalve shell
3. Based on the text you read, it identifies the function of the shell
4. Identify the habitat of the freshwater mussel
5. Give two examples of other living things that you can find in a river.

**(Answer below)**

## Reading II - How do freshwater mussels eat?

Like fish, mussels also have gills. The gills of the mussels help to filter the water. Mussels are fed by filtering water through a system of lashes. They absorb water, use microorganisms and nutrients (nitrogen or phosphorus) as food and release the water back into the river, but now cleaner than it was when it first entered the mussel.

Vocabulary:

Gills - respiratory organs of animals with gill breathe.

Eyelashes - very thin filaments.

Microorganisms - are organisms that can only be seen under a microscope.

**Based on the material that you just have read answer the following questions**

1. What mussels feed on?
2. Explains how mussels are fed.
3. What is the function of gills in mussels?
4. The high concentrations of the mentioned nutrients, in rivers and estuaries, can lead to the formation of authentic algae forests.
5. Formulate a hypothesis that explains what could happen to aquatic life in those places, if it does.

**(Answer below)**

## Reading III - How was it discovered that freshwater mussels have the ability to filter river water?

In an estuary, next to an industrial zone in the United States, a group of scientists placed a species of raft, six meters by six meters, lined with mussels. The following spring the raft was removed and the molluscs were analysed. The scientists concluded that they were healthy and that they had a lot of nitrogen, which indicated that they removed nitrogen from the water. The scientists also estimated that a raft of mussels had the capacity to remove up to 60 kilograms of nitrogen and about 150 particles such as dust and soot, over a year.

Vocabulary:

Estuary - is a transitional aquatic environment between a river and the sea.

**Based on the material that you just have read answer the following questions**

1. Explain what scientists did to discover that freshwater mussels have the ability to filter river water.
2. What substances do mussels filter from the river water?
3. Why can freshwater mussels help us fight water pollution?

**(Answer below)**

**Activity 3 - Assignment**

In the place where you live you can find several rivers. In this context, what I propose is that you carry out a field activity, specifically, a visit to the river that exists in your locality. Before leaving, you must select all the material you will need and use. During the visit, fill out a habitat characterization form (you can and should use the model form of your Students' book!). You must also photograph some living beings that you find in the river. Do not forget to prepare an activity report, following the suggestions of Terra à Vista! Support Materials. Finally, prepare a presentation to disseminate the information collected to the class and on the school's website.

References, link, bibliography:

The hidden strengths of freshwater mussels

Mussels | Department of Environmental Protection

# Topic: Biomimicry: the principles of living

## Title of activity: D.3.1 The city of the future, a bio-inspired and regenerative city

**Level of difficulty: easy-moderate-difficult**

**Materials / equipment:**

*Video YouTube: One Earth*

*Video YouTube: "City of the Future" Is Copenhagen the World's Most Sustainable City?*

*Using Menti.com (App) for sharing ideas*

**Theoretical background of the activity:**

This activity aims to motivate students for the learning process regarding the Observation of our Planet and the importance of changing our attitude towards our daily life actions in the construction of a better future, while protecting our unique Planet earth.

We aim at recognizing the uniqueness of our Planet Earth in our Galaxy, its features of its uniqueness and alert our students for what is happening to the Planet by the hand of Mankind.

Students must be able to recognize the wrong Mankind is doing to the Planet by exploring its Natural resources, and harming our atmosphere, water and land. They must be able to understand that we must look into our Planet, nature, Biodiversity and see how we can do better to survive and live-in unison with Nature.

This activity is an introduction/ motivation to a project on "Making my city a city of the Future" that will take on a different path of work, where students study and prepare a presentation of their work.

## Main Activities

1. Visualizing and understanding the message in the video “One Earth”

2. Students take notes on what they learn from the visualization of the video

3. Oral activity: sharing their opinion on what the video enhances

4. Using the Mentimeter App to share their opinion by answering the question: “What is a city of the future?”

5. Discussion of ideas and identifying the main characteristic and visualizing a video “A City of the Future” as an inspiration for the next task.

6. Using Mentimeter App to answer the question: “How can Loureiro be a city of the future?”

7. Discussion and identifying the main characteristics of a city of the future

8. Students decide on the groups to work with and the guidelines of the project “Making my city, a city of the future”.

**References, link, bibliography:**

This is what the future's sustainable cities could look like

# Topic: Biomimicry: the principles of living

## Activity: D.3.2 The city of the future, a bio-inspired and regenerative city - A sustainable and ecological house

**Level of difficulty: easy-moderate-difficult**

**Materials / equipment:**

*Students' book computer, internet*

*Activity support theory:*

*Thermal conductivity - good materials and bad heat conductors.*

*Renewable and non-renewable energies.*

*More ecological and self-sufficient equipment to use in homes.*

**Main activities**

**Activity 1**

Explore the meaning of sustainable and ecological house by watching the video:

15 Eco Friendly and Sustainable Houses | Green Living

**Activity 2**

Visualize an image that describes all the materials and equipment that a house should have to be considered self-sufficient and ecological. Discuss about it in class.

### Activity 3

Watch the video What Material Conducts Heat Best Science Experiment

1. What materials are there in nature that could be bad conductors of heat? Think about the homes of some animals that live in nature.

### Activity 4

Watch the video is cork a good insulator of heat?

1. Discuss in class the possible characteristics of materials that the students are suggesting (for example cork, hence the usefulness in the insulation of houses).

### Activity 5

1. Search the internet for other materials and techniques that are used in the construction of houses in order to reduce energy losses.
2. Synthesis, in the daily notebook, of the most common and advantageous materials in terms of energy for the construction of the most efficient houses.
3. Remember and apply the concepts already discussed about renewable and non-renewable energy.
4. Analyse and debate the advantages of using renewable energy, in ecological terms, compared to non-renewable energy, mostly used in our homes.
5. Answer several questions, according to the guidelines of the script, in order to verify which materials, equipment and technical details of the construction of your houses.
6. Prepare a reflection where you present proposals for change and improvement so that your home would be more self-sufficient and ecological. It can be in text, design or models.

References, Links, Bibliography:

How do solar panels work? - Richard Komp

# Topic: Biomimicry: methodology

## Title of activity: E1: In the shoes of a biomimetician: different steps

**Level of difficulty: easy-moderate-difficult**

**Students' age: 9-11 years**

**Materials / equipment:**

*PowerPoint presentation titled 'E1: In the shoes of a biomimetician: different steps*

*Paper, pencils and colours*

*YouTube Video Why This Train Is The Envy Of The World: The Shinkansen Story*

*YouTube Video The world is poorly designed. But copying nature helps.*

**Theoretical background:**

A biomimetician is a person who provides solutions or pathways by being getting inspiration from nature.

Biomimetics, a name coined by Otto Schmitt in the 1950s for the transfer of ideas and analogues from biology to technology.

Biomimicry is rapidly transforming life on earth. Biomimics study nature's most successful ideas over the past 3.5 million years and adapt them for human use. The results are revolutionizing how materials are invented and how we compute, heal ourselves, repair the environment, and feed the world.

The kingfisher is a bird that dives into water to catch its prey. It has a long, narrow pointed beak that allows it to enter the water while barely making a splash. The beak steadily increases in diameter from the tip to the head, which helps reduce impact when the bird hits the water. The engineers looked to nature to re-design the bullet train. They noticed how kingfisher birds are able to slice through the air and dive into the water to catch prey while barely making a splash. They then re-designed the front end of the train to mimic the shape of the kingfisher's beak. Not only did this help to reduce noise and eliminate tunnel booms, it also allowed the train to travel 10% faster using 15% less electricity.

In 1941, Swiss engineer and inventor George de Mestral was intrigued by the burdock burrs that kept sticking to his dog's fur as they passed by the unique plants. What resulted from George de Mestral's routine hike in 1941 is perhaps the most well-known example of biomimicry in history, Velcro.

**Activity 1:** Answer following questions (class discussion + research)

1. **How has technology been influenced by nature?**

2. **What inventions are inspired by nature? List 6 of them.**

3. **What was Velcro inspired by?**

**Activity 2:** Illustrate the similarities between the kingfisher and the Shinkansen bullet train.

**References, link, bibliography:**


Why This Train Is The Envy Of The World: The Shinkansen Story

The world is poorly designed. But copying nature helps.

Biomimicry: 9 Ways Engineers Have Been Inspired by Nature

Design Inspired by Nature

(PDF) Innovation inspired by nature: Biomimicry

High Speed Train Inspired by the Kingfisher — Innovation — AskNature

Papo de Paisagista - Pergunte à natureza - Casa de Valentina | Árvores e arbustos, Engenheiro biomédico, Protozoários

Teaching #KS3 design?

# Topic: Biomimicry methodology

## Title of activity: E2. In the shoes of a biomimetician. Ethics and sustainability

**Level of difficulty: easy-moderate-difficult**

**Materials / equipment:**

*PPT presentation and Student Worksheet*

**Theoretical background of the activity:**

The biomimetician must always ask himself questions about the "meaning" of his invention, its ethics and its sustainability [1].

The first important step is to realize what Nature is and the key characteristics of natural processes expressed as the Nature's laws, strategies and principles described by [2]:

Nature runs on sunlight.

Nature uses only the energy it needs.

Nature fits form to function.

Nature recycles everything.

Nature rewards cooperation.

Nature banks on diversity.

Nature demands local expertise.

Nature curbs excesses from within.

Nature taps the power of limits.

In this sense, we have to understand that the concept of following Nature in a sustainable manner may come to dominate and replace that of protecting Nature. If Nature's services can be reproduced artificially, then we may conclude that there is little reason to protect Nature and Biomimicry would become "*the ultimate ally for 'weak sustainability*" [3].

Based on the aforementioned concerns, future research and future generations have to answer the following questions [4]:

(i) How should we understand the supplementarily of biomimicry in practice, and what are the consequences of Biomimicry innovations that are better embedded in, and in harmony with, the ecosystems of planet earth?

(ii) How should nature be conceptualized and integrated in concrete biomimetic designs?

(iii) What is the ontological status of the supplementarily of technology if it is not natural in the strict sense of the word?

(iv) To what extent is the ethics of biomimicry derived from nature or imposed on nature?

**Activity 1:** Work in small groups

1. Study an example of biomimicry step by step

2. Do the same for one or two other examples

3. Ensure the ethical and sustainable nature of the invention

**Activity 2:** Discussion in a class

Becoming a biomimetician means wanting to solve a question or respond to a need in a certain way that is compatible with the Earth and the rest of the living world, and which is inspired by the living, both in its technical process and above all in its functioning. But how do we know if the technique, object or organisation we invent is respectful of the living?

1. **Chose, check discuss and tick as many boxes as possible below:**

- can be used for something else when it is no longer needed
- does not produce waste or waste that can be recycled or reused
- uses local and abundant resources and consumes renewable energy
- creates respectful links between humans and the rest of the living world
- does not degrade the Earth's ecosystem, but improves it

2. **Do you believe the above considerations are important or not? Write what you think below.**

**References, link, bibliography:**

[1] Online repository of resources, https://asknature.org/

[2] Dicks H. (2015): The Philosophy of Biomimicry, Philos. Technol.

[3] Dicks H. (2017): Environmental Ethics and Biomimetic Ethics: Nature as Object of Ethics and Nature as Source of Ethics, J. Agric. Environm. Ethics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