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InNature

LEARNING ACTIVITIES

Innovation in schools

Inspired by nature solutions

Co-funded by the
Erasmus+ Programme
of the European Union

INNOVATION IN SCHOOLS
INSPIRED BY NATURE SOLUTIONS

Content


InNature

[A] Philosophy of biomimicry

A1. Biomimicry : techno or life ?

SUMMARY

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.

Activity based on a presentation by Mr Alain Renaudin, NewCorp Conseil - France

LEARNING OBJECTIVES

Point out the genius of the living, its exploits but also our lack of knowledge of the common species that surround us.

ACTIVITY SEQUENCE

. observe, recognize and / or discover six species
(Bombyx - Black Swift - Fly - Ivy - balone - Sponge)
. recognize 6 brands of cars, manufactured products or road signs
What to conclude?

AGE RANGE

12-15

DURATION

Preparation :
10 min
ACTIVITY(IES) :
30 min

SUBJECT(S)

Connaissance du vivant

KEYWORDS

Biosphere
Technosphere
Awareness
Reconnecting with life

BACKGROUND for teachers

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.

Make an alliance with the living, the condition of our future
The living rehabilitates the long term and invites us to consider the interdependencies between humans and the dynamics of ecosystems, 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 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 Man is part of a complex whole on which he depends.

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.

ACTIVITY DETAILS for teachers (1/2)

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.

Six common species:

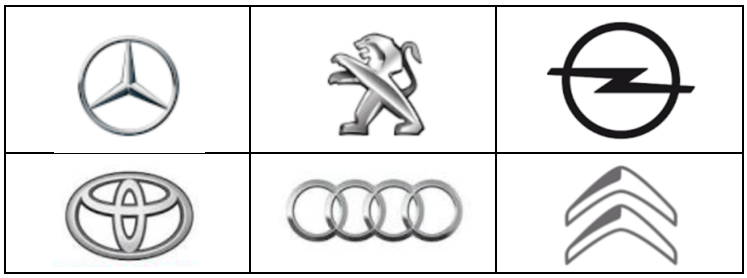
Butterfly – Bombyx The bombyx, a moth, detects the pheromones of its female up to 11 km away.	**Black Swift** The black swift, which lives most of its life in flight, peaks at speeds of up to 200 kph.	**Fly - Forcipomyia** This insect beats its wings at almost 1000 b/s (beats per second) thanks not to muscular effort but to a resonance phenomenon of its shell.
Ivy 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** Abalone is ten times stronger than conventional ceramics: hardness and resistance. However, it has the same composition as chalk: calcium carbonate ($CaCO_3$). It is the organisation of these atoms on a microscopic scale that gives it these properties of hardness and strength.	**Sponge - Éponge euplectella** The sponge is capable of making glass in water at room temperature, whereas humans need to heat to over 1000°C to make glass.

TOOLS & MATERIALS

Student Worksheets or PPT presentation

ACTIVITY DETAILS for teachers (2/2)

6 logos of famous international brands (like cars for example):



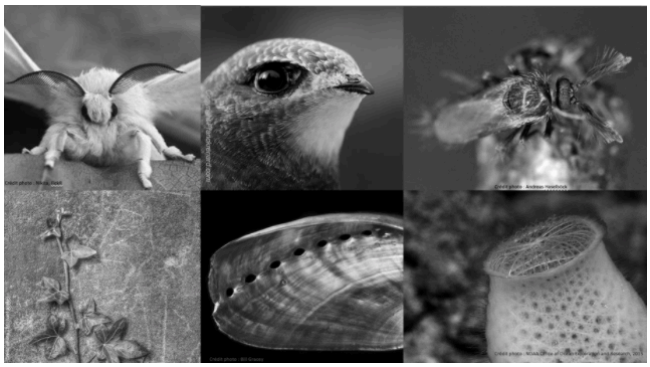
Mercedes – Peugeot – Opel – Toyota – Audi - Citroen

TOOLS & MATERIALS

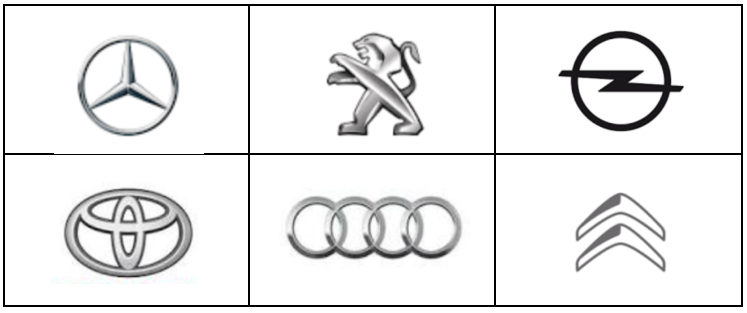
Student Worksheets or PPT presentation

STUDENT WORKSHEETS (1/2)

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



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



STUDENT WORKSHEETS (2/2)

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

[A] Philosophy of biomimicry

A2. To be inspired by nature, for what purposes?

SUMMARY

Nature inspires us: poems, songs, works of art, all kinds of inventions: airplane wings, artificial hands. Discuss these examples. Do they correspond to bio-inspiration? Biomimicry? Biomimetics? Bionics?
This activity encourages us to question the ethics of bio-inspired practices.

LEARNING OBJECTIVES

Define the concepts of biomimicry, bioinspiration, biomimetics and bionics Questioning the purposes of bio-inspired inventions, their sustainability

ACTIVITY SEQUENCE

. Differentiate the different levels of inspiration from nature, through examples: bio-inspiration, bionics, biomimicry.
. Understand the philosophical, ethical and sustainable dimension of biomimicry.
. To awaken a critical spirit about inventions inspired by nature and based on the principles of the living world.

AGE RANGE

to adapt according to age

DURATION

Preparation :
10 min
ACTIVITY(IES) :
45 or 2x 45 min

SUBJECT(S)

Ethics of the act of being inspired by living beings
Definitions: biomimicry, bioinspiration, bionics

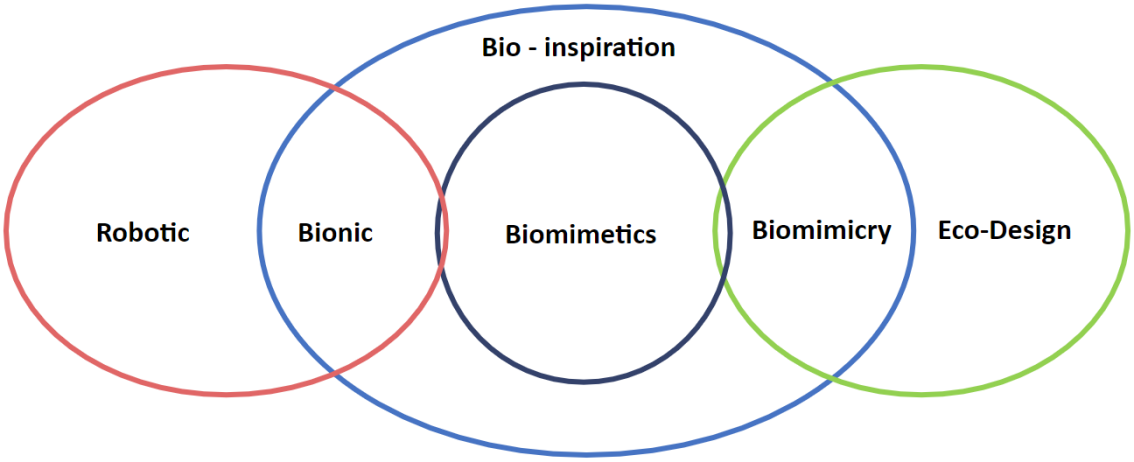
KEYWORDS

Biomimicry
Bioinspiration
Bionics
Ethics
Sustainability

A2. To be inspired by nature, for what purposes?

BACKGROUND for teachers

DEFINITIONS: Biomimicry, biomimetics, bioinspiration



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 ecodesign specifications (intersection with eco-design)

Biomimicry, biomimetics, bioinspiration, bionics: a standard concept

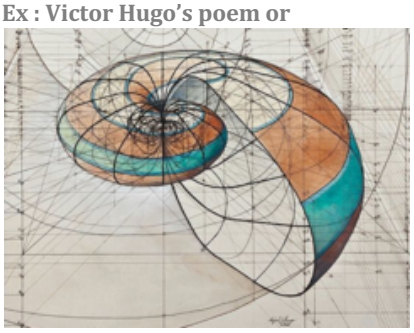
These terminologies are defined in ISO standards. The approach has been defined by the ISO TC 266 - ISO 18458 standard with related notions :
Bio-inspiration: a creative approach based on the observation of biological systems.
Biomimicry:
// Interdisciplinary cooperation of biology and technology or 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.
// 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.

ACTIVITY DETAILS for teachers (1/3)

. studying examples of inspiration, questioning their sustainability

On powerpoint for whole class discussion or n student sheet if group work

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

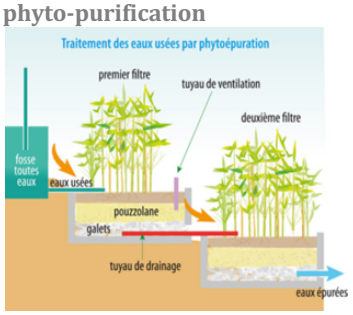


Pollinating Drone

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

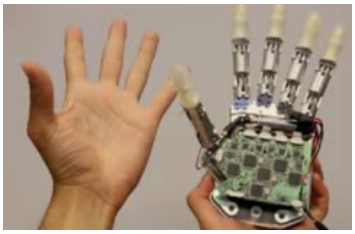
The velcro® imitates the many tiny burdock hooks that cling to the hair of animals and thus to the stitches of certain textiles. `

TOOLS & MATERIALS

Student Worksheets or PPT presentation
Video

ACTIVITY DETAILS for teachers (2/3)

Hand prosthesis



Fuselage of a TGV inspired by a kingfisher's beak

Shark skin / antibacterial coatings

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.

Building in bamboo

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.

TOOLS & MATERIALS

Student Worksheets or PPT presentation
Video

ACTIVITY DETAILS for teachers (3/3)

Elements of response...

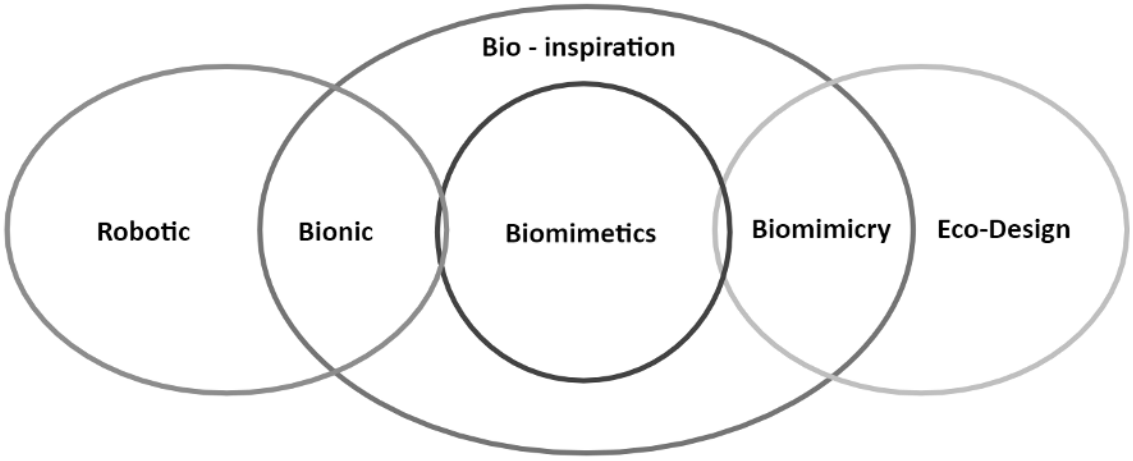
Poetry, song, artwork	*Bio-inspiration*
Pollinating drone	*Is a world without bees desirable? Can we really replace pollinators with drones?* *The debate is open ;-)*
Hand prosthesis	*Bionic hand*
Fuselage of a TGV	*More comfort for passengers (less noise)* *Gain in speed* *Gain in energy consumption* *Biomimicry or biomimicry: the debate is open*
Treatment of waste water by phyto-purification	*No chemicals, little artificial flooring...*
Velcro® / Bardane	*A beautiful invention to be able to glue/unglue endlessly.* *But synthetic velcro!*
Shark skin / anti-bacterial coating	*Helps to avoid the use of toxic products while supporting health* *Questions about the eco-design of these coatings? How long do they last? Material ? Place of manufacture ? Gluing ?*
Building in bamboo	*Use local, biodegradable resources* ⇨ *biomimicry*

TOOLS & MATERIALS

Student Worksheets or PPT presentation

A2. To be inspired by nature, for what purposes?

STUDENT WORKSHEETS (1/2)

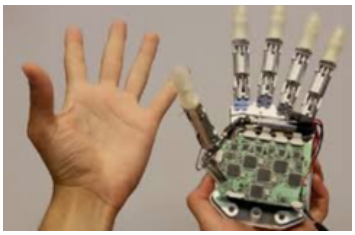


Definitions: bio-inspiration, biomimetics, biomimicry, bionic

STUDENT WORKSHEETS (2/2)

Q | Discuss these examples of inspiration. Do they involve biomimicry? Bionics? Bio-inspiration?

Hand prosthesis



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STUDENT WORKSHEETS (2/2)

Q | Discuss these examples of inspiration. Do they involve biomimicry? Bionics? Bio-inspiration?

Work of art : poetry,, music, song
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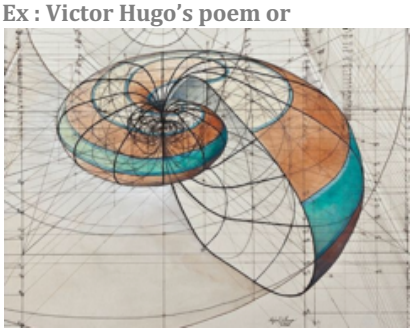
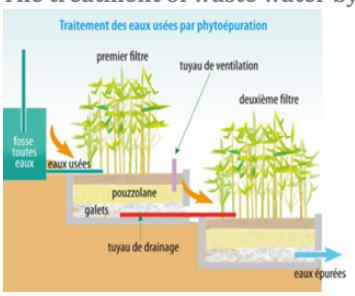


Pollinating Drone

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. `

A3. Overview Effect

SUMMARY

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 OneHome'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?

LEARNING OBJECTIVES

. discover the earth seen from the sky, in its entirety
. Understanding and experiencing the overview effect

ACTIVITY SEQUENCE

. Watch the video by OneHome with Jean-François Clervoy, French astronaut :
https://www.youtube.com/watch?v=YVQIF3tICG8
. Watch other videos on https://fr.onehome.org/ , take the time, listen, discuss, feel !

AGE RANGE

All ages

DURATION

Preparation :
10 min
ACTIVITY(IES) :
30 min

SUBJECT(S)

Unicity of life on Earth
Fragility of life
emotions

KEYWORDS

Overview effect
Fragility of life
The uniqueness of life on Earth

A3. Overview Effect

BACKGROUND for teachers

The overview effect

From Wikipedia, the free encyclopedia

Jump to navigationJump to search

The **overview effect** is a cognitive shift in awareness reported by some astronauts during spaceflight, often while viewing the Earth from outer space.[1][2][3][4][5][6]

It is the experience of seeing firsthand 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.[5]

The thing that really surprised me was that it [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, it's home, and it's fragile.

— *Michael Collins, Apollo 11*[7]

Astronauts Michael Collins, Ron Garan,[8] Rusty Schweikart,[5] Edgar Mitchell,[5] Tom Jones,[5] Scott Kelly,[9] James Irwin,[10] Mike Massimino,[11] André Kuipers,[12] Chris Hadfield,[13] Sally Ride, and Anne McClain[14] are all reported to have experienced the effect.[5]

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), (AIAA, 1998).[15][16]

In 2018, the Spacebuzz project was created so "children around the world can also get to experience the Overview Effect."[17] It was announced in a press release on December 20 by astronaut André Kuipers on the European Space Agency's (ESA) website.[18] Spacebuzz 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. Spacebuzz is a project started by the Overview Effect Foundation backed by ESA and the Netherlands Space Office.[17].

In late 2019 it was reported that researchers at the University of Missouri aimed to reproduce the experience, with an isolation tank, half a tonne of Epsom salts, and a waterproof VR headset.[19]

In August 2020 anthropologist Deana L. Weibel introduced the parallel term "ultraview effect," a subjective response of intense awe some astronauts have experienced viewing large "starfields" while in space, and discussed the impact of the overview effect and the ultraview effect on astronauts' religious beliefs.

STUDENT WORKSHEETS (1/1)

**Q | 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?**

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

[A] Philosophy of biomimicry

A4. Video Nature = Futur! “Biomimicry, life as a model”

SUMMARY

Video and chat : Nature = Futur ! (In French)
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.

LEARNING OBJECTIVES

Understanding biomimicry, its ethics and approach

ACTIVITY SEQUENCE

. watch (and translate?) the video "Nature = future! »
https://www.youtube.com/watch?v=K5HRCM55hKY&list=PLe1IbGdQIhaz0iZuRMeqlFTwfsVKSWobe
"Biomimicry, the living as a model".

. discuss the messages contained in the video

AGE RANGE

All ages, chat tand questions to adapt

DURATION

Preparation :
20
ACTIVITY(IES) :
45 min

SUBJECT(S)

Biomimicry : definition, understanding

KEYWORDS

Biomimicry
Ethics
sustainabiliy

BACKGROUND for teachers (1/2)

Transcript of the video

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 a

BACKGROUND for teachers (2/2)

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, we need different sensibilities.
This biomimicry, it 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.

A4. Video Nature = Futur! “Biomimicry, life as a model”

ACTIVITY DETAILS for teachers

Warning! this video is in French on Youtube. Possibility to activate the English subtitles.

With the audio transcription, the teacher will be able to develop or take up the points that seem important to him or her in order to open a discussion with the students.

The teacher will also have the opportunity to view other videos from the InNAture series available on YouTube.
https://www.youtube.com/channel/UCghmtdCHpMUYkVxg3nC9dlw

Some of these videos are translated into English. For others, it is possible to activate subtitles in YouTube.

TOOLS & MATERIALS

Video :
https://www.youtube.com/watch?v=K5HRCM55hKY&list=PLe1IbGdQIhaz0iZuRMeqlFTwfsVKSWobe

A4. Video Nature = Futur! “Biomimicry, life as a model”

STUDENT WORKSHEETS

Watch the video, listen carefully (option: take notes)

Q | When did life appear on Earth?

Q | Which crises invite us to rethink our modes of production and consumption (3)?

Q | Is the living economy based on abundance or scarcity?

Q | Why is it interesting that nature manufactures at room temperature and pressure?

Q | Why is biomimicry described as a multidisciplinary approach?

[A] Philosophy of biomimicry

A5. From planetary boundaries to biomimicry

SUMMARY

The planetary limits are the thresholds that humanity must not exceed so as not to compromise the favorable 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.

LEARNING OBJECTIVES

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

ACTIVITY SEQUENCE

.1. planetary limits (more or less detailed according to time)
.2. principles of life and biomimicry

AGE RANGE

12-15 years
(simplify for younger people)

DURATION

Preparation :
45 min
ACTIVITY(IES) :
45 min or 2x45 min

SUBJECT(S)

Planetary boundaries
Life principles

KEYWORDS

Biosphere
Technosphere
Awareness
Reconnecting with life

BACKGROUND for teachers (1/4)

Statement :

. Decrease in resources produced by ecosystems
. Increase in the population and its consumption

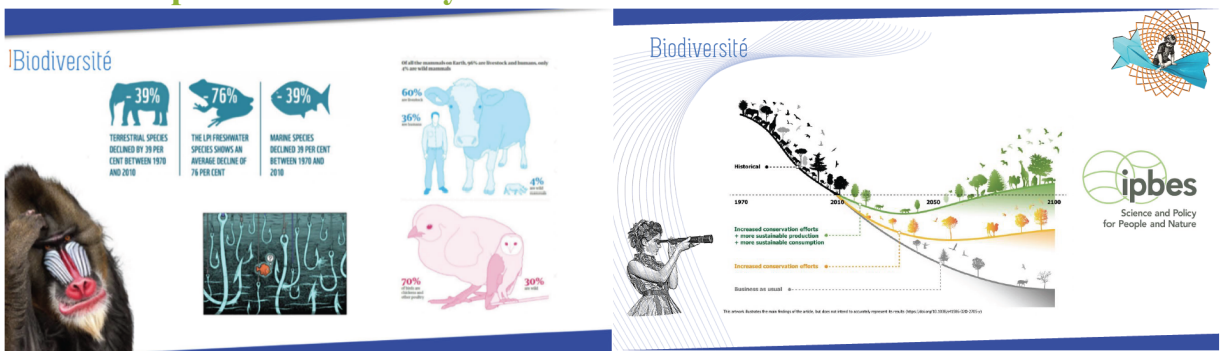
Ex1: drinking water resources are limited on a global scale

On Earth, 97.5% of water is salty and contained in the oceans. Only 2.5% is fresh water, or about 35.2 million billion cubic meters.
Of this amount of water
. 68.7% is found in glaciers
. 30.1% is in the water tables
. 0.8% in permafrost
. 0.4% in the surface and in the atmosphere.
All in all, **less than 1% of the water on Earth is fresh, liquid water**.

Ex2: climate deregulation:

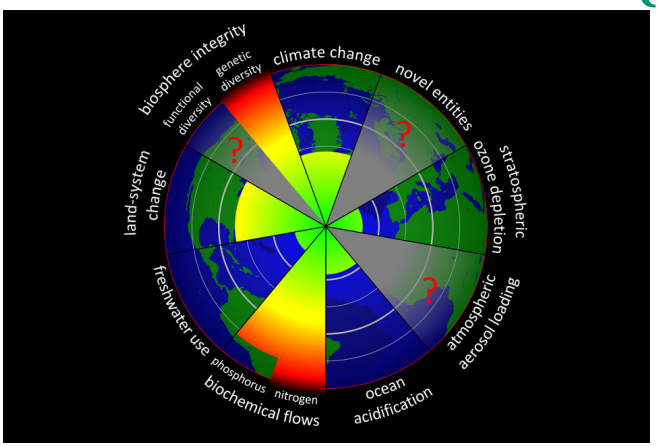
Temperature anomalies arranged by country from 1900 – 2016
https://www.youtube.com/watch?v=K4Ra2HR27pQ

Ex3: Collapse of biodiversity



Source : Tarik Chekchak, Pikaïa

BACKGROUND for teachers (2/4)



Planetary boundaries

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."[1] 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.[2][1]

Source : wikipedia

In a sustainable society, nature is not subject to a systematic increase:

. The concentration of substances extracted from the earth's crust
. The concentration of substances produced by the company
. Its degradation by physical means

And in this society: people are not subject to conditions that systematically diminish their ability to provide for themselves.

BACKGROUND for teachers (3/4)

Our planet: the earth

The 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. They 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, neither 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 we humans are also part of the Earth's ecosystem.

BACKGROUND for teachers (4/4)

THE PRINCIPLES OF LIFE for the youngest ones

Becoming a biomimetician means wanting to respond to a question or a need with an answer or a solution that
. is compatible with the Earth and the rest of living things
. is inspired by the living, both in its technical process and, above all, its functioning.

The invention :
. does not produce waste, or waste that can be recycled or reused
. uses local and abundant resources
. consumes renewable energy
. creates respectful links between humans and with the rest of the living world
. does not degrade the Earth's ecosystem but improves it
. uses just the right amount of resources for its manufacture and operation
. can be used for something else when it is no longer needed

THE PRINCIPLES OF LIVING for older people

Six operating principles are key to guide the development projects of territories, businesses and organisations:
. Nature works in cycles: the constituent elements of ecosystems are linked by cyclical exchanges of matter and energy. In particular, nature recycles everything it produces: each waste produced by one species will be recycled as raw material by another.
. Nature optimises the use of resources and means: it is effective, efficient and avoids losses and waste.
. Nature favours the use of local resources: it favours local interactions and is sourced locally.
. Nature uses mostly flow energy (mainly solar energy) and no or very little resource or stock energy such as fossil fuels.
. Nature is based on dynamic and interconnected balances: the constituent elements of ecosystems are multifunctional, fulfil key functions and are essential for the conservation of all processes. They function, interact and are interconnected.

Nature is constantly innovating in the service of resilience and diversity: it uses constraints as opportunities.

A5. From planetary boundaries to biomimicry

ACTIVITY DETAILS for teachers

The objective of this activity is to introduce the notion of planetary limits, to understand why humanity has everything to gain from reinventing itself, from changing paradigm.
Biomimicry is a possible answer to steer these more desirable futures, to invent new ways of living, producing and consuming, in balance with the living.

TOOLS & MATERIALS

Student Worksheets or PPT presentation

.1. Discover the 9 planetary boundaries:

.2. Discover the life principles:

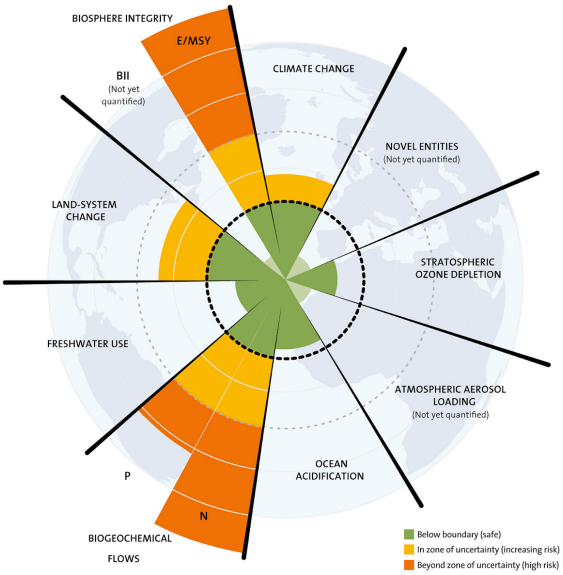
Six operating principles are key to guide the development projects of territories, businesses and organisations:

- 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

.3. Link with biomimicry

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.

STUDENT WORKSHEETS (1/2)



Q | What are the sizes that exceed the planetary limits?

Q | The living is ingenious. Man 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?

[B] Biomimicry: examples

B1. Kingfisher and Shinkansen

SUMMARY

The Shinkansen is a Japanese high-speed train that connects two cities by passing through numerous tunnels. The engineers were inspired by the beak of the kingfisher to design the profile of the train.
Gain: power consumption, speed and passenger comfort.

LEARNING OBJECTIVES

Observe nature, understand how the anatomy of a species is adapted to its way of life. Address the notion of transposition to technology

ACTIVITY SEQUENCE

Observe and describe the kingfisher: its anatomy and its way of fishing.
Think about the reasons that led the engineers to choose this model to design the profile of the train?
Bonus: Draw the profile of the kingfisher

AGE RANGE

All ages
Chat to adapt according to age

DURATION

Preparation :
10 min
ACTIVITY(IES) :
45 min

SUBJECT(S)

Observe nature
Biomimicry method
Transposition to technology
Speed and power consumption

KEYWORDS

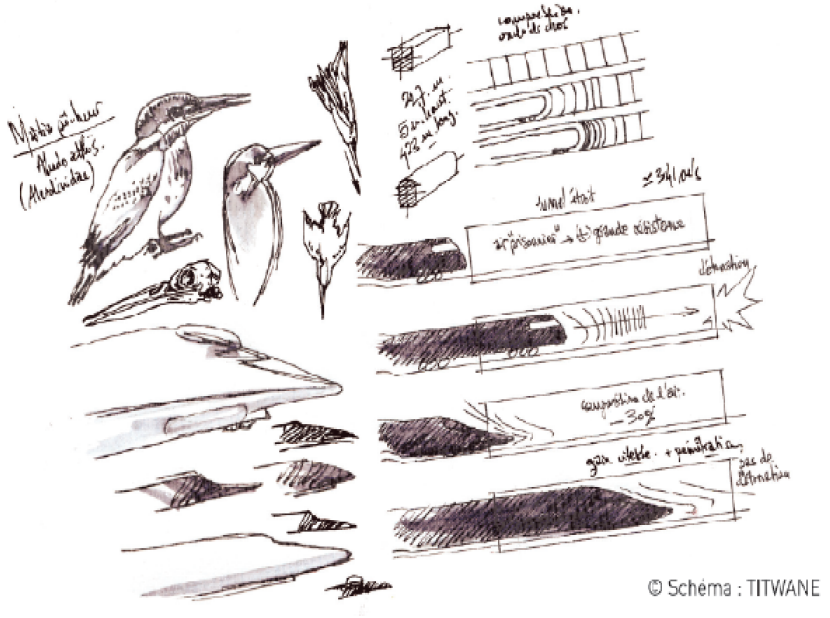
Biologic model / profile
Transposition

[B] Biomimicry: examples

B1. Kingfisher and Shinkansen

BACKGROUND for teachers

Drawing inspiration from the profile of a kingfisher to profile a train



Observe: these birds (about 90 species) feed on the fish they catch when they dive into the water.

Understanding :
The bird's profile is adapted to its hunting strategy: its long, slender beak cushions the transition between air and water, allowing it to enter the water without splashing or waves. Its streamlined shape allows it to hunt with limited disturbance due to aerodynamic and hydrodynamic drag, allowing it to lose less speed and not alert its prey when it enters the water.
Its eyes are protected by a bony pasque attached to the prefrontal bone of the skull.
Its feathers store the air that facilitates the ascent, thanks to Archimedes' thrust.

Did you know that?
Kingfishers are the champions of the transition from a not very dense environment (air) to a very dense environment (water).

Strategies and functions
. mode of locomotion by beaten flight
. energy efficiency (recovery of energy for use in propulsion)
. Aerodynamic profile of the nozzle
. Quick dive and underwater swimming

Field of application: transport

Innovation inspired by the kingfisher
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 engineers turned to a champion of the rapid transition between two environments with different densities: the kingfisher. They thus imitated the shape of its beak and head for an astonishing result: with a power consumption of -15%, the train went from a maximum speed of 210 to 320 km/h, reducing the problems of slowing down and noise pollution in the tunnels along the

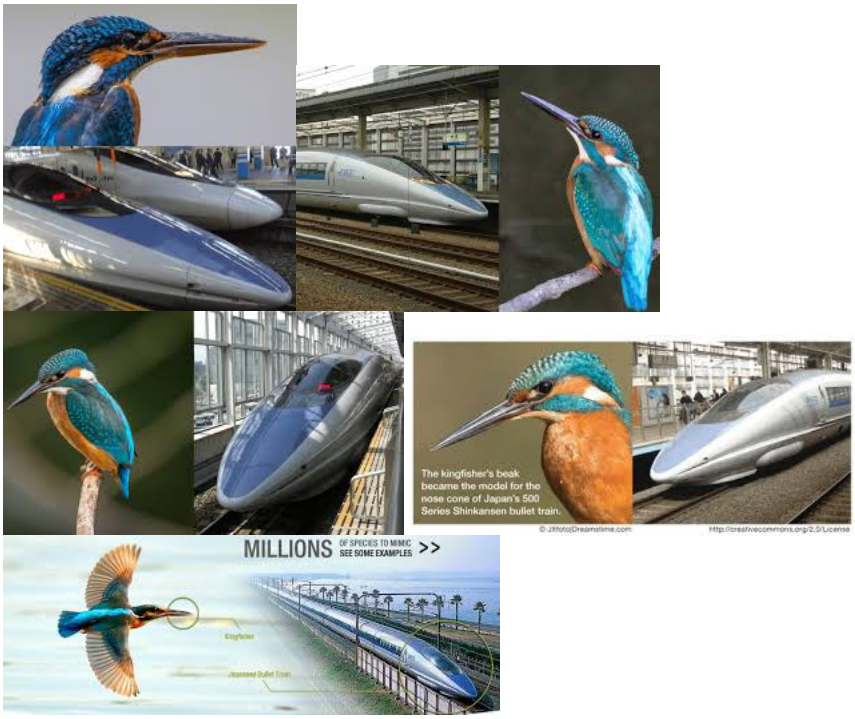
B1. Kingfisher and Shinkansen

ACTIVITY DETAILS for teachers

The objective of this activity is to invite students to understand why engineers would have turned to the biological model of the kingfisher to design the front of a train.
This train has the specificity of passing through many tunnels. These changes in environment (more or less dense) can be compared to the kingfisher's dives, which go from air to water at high speed, minimising shock and splashes.

TOOLS & MATERIALS

Student Worksheets or PPT presentation
Slow motion video (2 min)



Slow motion video of a kingfisher : (2 min)
https://www.youtube.com/watch?v=xX9J-lVUQd0

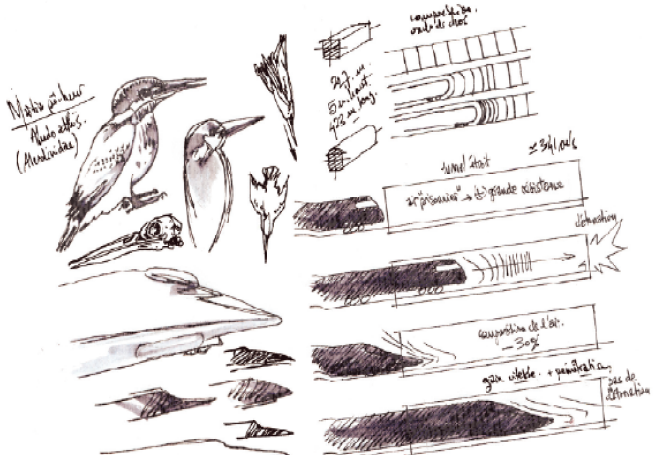
Learn more about the kingfisher : (50 min documentary)
https://www.youtube.com/watch?v=KQ5JYNx7kKg

B1. Kingfisher and Shinkansen

STUDENT WORKSHEETS

Q | 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?
Hint: On its journey, the train passes through many tunnels.

Q | Based on the following drawings, can you draw a profile of a kingfisher and a shinkansen train?



[B] Biomimicry: examples

B2. Coral and cement

SUMMARY

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)

LEARNING OBJECTIVES

. Understanding the **carbon cycle**, the accumulation of CO_2 in the atmosphere
. Study the **manufacture of cement** (with CO_2 emissions and energy consumption)
. Study the composition of the coral skeleton: $CaCO_3$
. Making cement by imitating coral: to capture CO_2

ACTIVITY SEQUENCE

. study: the production of limestone by nature (the coral)
. study the industrial production of cement (limestone)
. compare and open up to an innovative start-up

AGE RANGE

14-16
a lighter version can be offered to the youngest

DURATION

Preparation :
10 min
ACTIVITY(IES) :
45 min or 2x45 min

SUBJECT(S)

. concept of carbon cycle and carbon sink
. cement manufacturing making the coral limestone skeleton

KEYWORDS

Coral
CO2 sink, carbon cycle
calcium carbonate
cement production

B2. Coral and cement

BACKGROUND for teachers (1/2)

What is coral?

Coral is an animal of the cnidarian family living in the form of polyps. 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.

Strong points

. CO_2-based solid rigid material
. product at room temperature
. raw materials available locally and in abundance
. recycles CO_2 instead of producing it

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.

© Schéma : Laurence BERTHEL

B2. Coral and cement

BACKGROUND for teachers (2/2)

Nature makes its own materials...

Cement (and the carbon cycle)

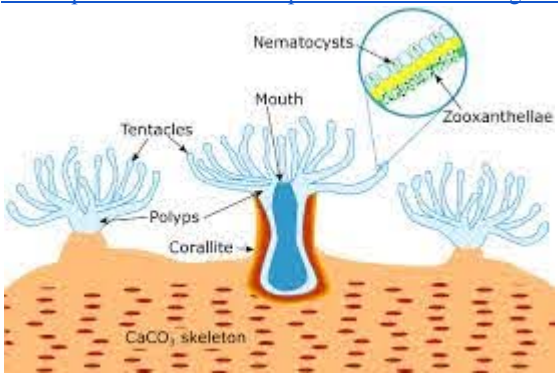
Throughout the history of our planet, enormous quantities of carbon have been sequestered in limestone, sediments and hydrocarbons by the activity of the living world; shellfish have used it to make their shells and trees have transformed it into woody material. One solution to the problem of carbon dioxide (CO2) 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.

At least that is what the Australian John Harrison, who uses the term "geomimicry",70 believes. He described processes and technologies that mimic geological processes. His firm TecEco develops technologies that allow for the sequestration of excess CO_2 and waste in the built environment. And when a building has reached the end of its useful life, it can be demolished and used as a raw material to make new cement, hence potentially recyclable cities. The common barnacle lives in the (intertidal) tidal balancing zone. To avoid being constantly displaced by the waves, it secretes an ultra-fast setting underwater cement which is one of the most powerful natural binding materials known. Coral also produces a type of calcium carbonate cement ($CaCO_3$) from carbon dioxide (CO_2). By studying the process used by coral to produce this "cement", scientists have created eco-cement, a new type of material that absorbs CO_2 from the air as it dries and into which waste products (e.g. ashes) can be incorporated. These new cements therefore contribute both to recycling waste and to transforming our buildings into gigantic carbon sinks.

Video

Listen to 1'30 of the video :

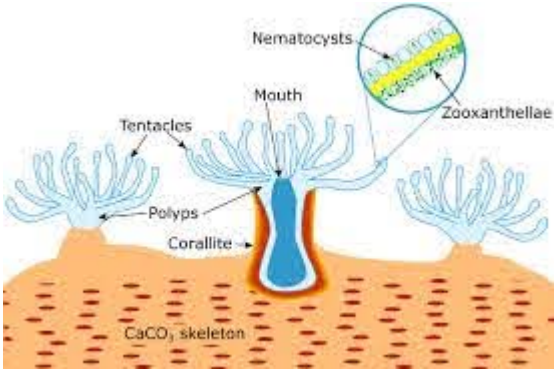
5 exemples de biomimétisme pour combattre le changement climatique | Architecture Energie Ecologie



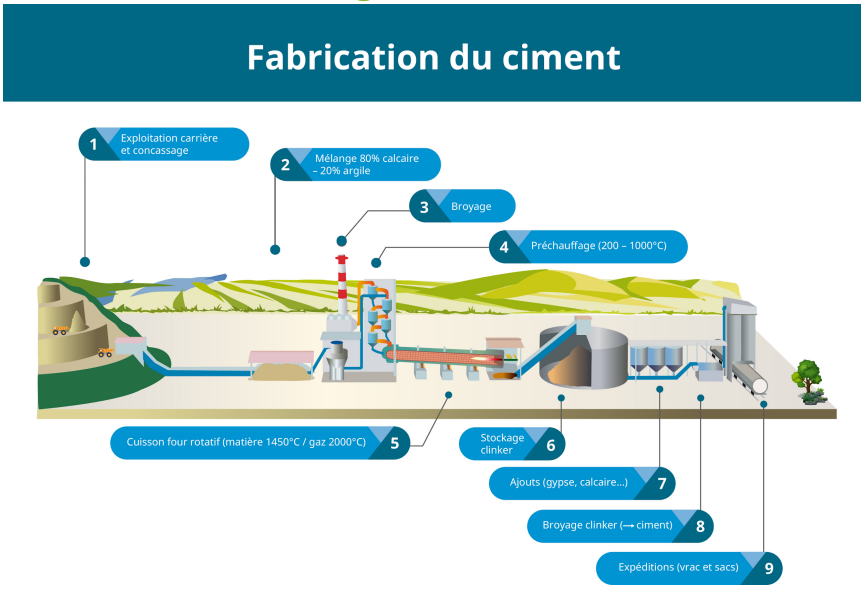
B2. Coral and cement

ACTIVITY DETAILS for teachers

Coral's anatomy



Cement manufacturing



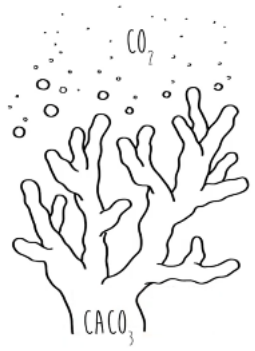
TOOLS & MATERIALS

Student Worksheets or PPT presentation

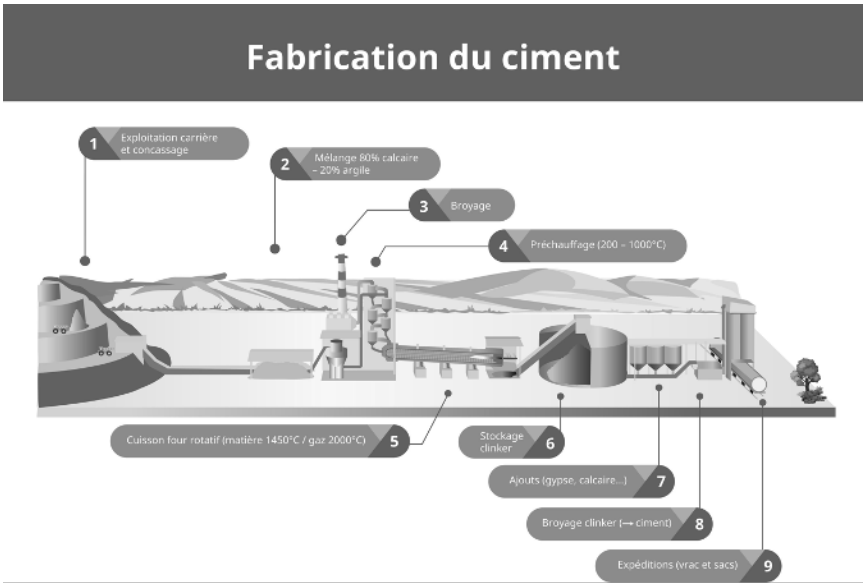
B2. Coral and cement

STUDENT WORKSHEETS (1/2)

Q | Coral sequesters CO_2 to make its calcareous skeleton ($CaCO_3$). Dessiner l'anatomie de cet animal.



Q | Industrialists, in order to manufacture cement (which is in fact limestone) emit CO2. The process requires a great rise in temperature (even two!). Briefly describe these steps.



[B] Biomimicry: examples

B3. Bite like a mosquito

SUMMARY

The ability of mosquitoes to bite painlessly is due to the diameter of their proboscis (20 micrometers to less than one micrometer at the tip) and their conical shape. Without equaling it, biomedical needles are inspired by this thinness.

LEARNING OBJECTIVES

Point out the genius of the living, its exploits but also our lack of knowledge of the common species that surround us.
Observe a mosquito's bite
Understanding the biomimetic process

ACTIVITY SEQUENCE

https://www.youtube.com/watch?v=rD8SmacBUcU
. Video: observation of a mosquito bite
. draw the anatomy of a mosquito and its proboscis
. Understanding the principle of the bio-inspired needle

Bonus : video of a mosquito's bite under the skin
https://youtu.be/MbXSPacvuak

AGE RANGE

all

DURATION

Preparation :
10 min
ACTIVITY(IES) :
45 min

SUBJECT(S)

Drawing inspiration from a mosquito bite to develop a needle

KEYWORDS

Mosquito
bite
needle

biomimicry

B3. Bite like a mosquito

BACKGROUND for teachers (1/3)

The mosquito: a model for the medical sector

.

Observe: The mosquito bites its prey painlessly.

Understand: A mosquito bite is painless, it is the aftermath that annoys the world! This can be explained by the special structure of the mouth parts. In the mosquito, the proboscis (or proboscis) is made up of 6 styluses protected by a sheath and each one has a precise function: incision, injection of anticoagulant, blood sampling.
In order to make penetration into the skin easy, the mosquito has developed a few tricks. On the one hand, it reduces the effective length of its styluses (or fascicles) to prevent them from twisting, and on the other hand, it uses another guide structure (the labium) to facilitate the delicate insertion.
In short, this beautiful engineering inspires researchers to design high-performance, painless hypodermic needles for injections or blood sampling, but also for the development of microelectrodes placed on the surface of the brain or deeper to stimulate certain areas in the event of disease (Parkinson's for example). It is then vital that the insertion of these microelectrodes is done as gently as possible, in order to avoid any trauma and the inflammatory reactions that result!

Did you know that?
Thanks to the delicacy of her proboscis, the female mosquito can bite the epidermis of her host in complete tranquillity. Because this bite is painless (what scratches you is the insect's anticoagulant saliva), the mosquito is often already gone when you react

B3. Bite like a mosquito

BACKGROUND for teachers (2/3)

Field of application: medical

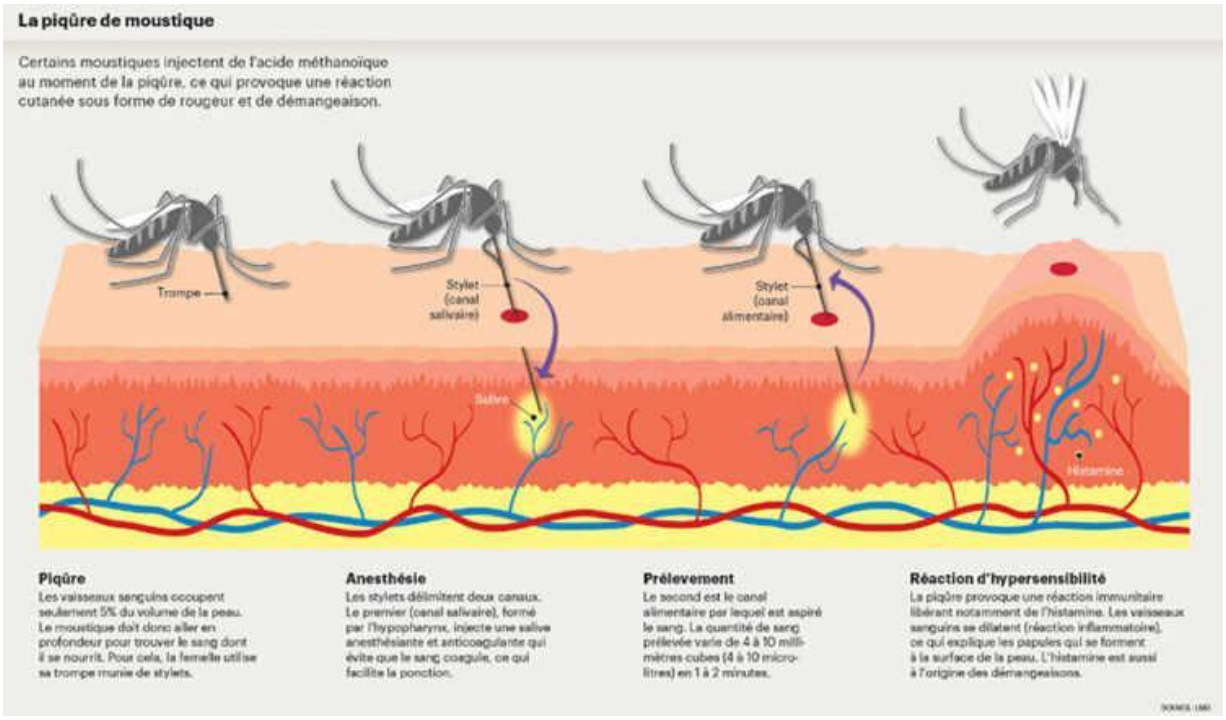
Mosquito inspired innovation

The ability of mosquitoes to bite painlessly is due to the diameter of their proboscis (from 20 micrometres to less than one micrometre at the tip) and their conical shape. Biomedical needles are unrivalled in this fineness.

The conical shape, with a refining of the diameter as one approaches the tip, allows better flow of the liquid for injections, especially insulin.

In 2005, the new NANOPASS 33G needles, made of titanium, were launched on the market and sold millions of units.This needle with a diameter of just 0.2 mm costs 5% more than a conventional hypodermic needle. An even thinner model will be launched in 2012.

Further information :



BACKGROUND for teachers (2/3)

Wikipedia :
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.

A crazy video of a mosquito bite filmed under a microscope, under the skin
https://youtu.be/MbXSPacvuak

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. »

Analyze how mosquitoes bite

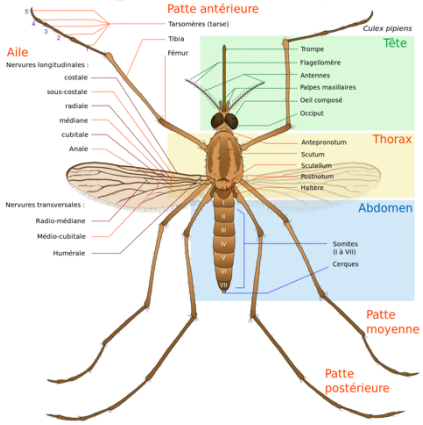
So far, they have not developed a prototype of this needle. What they have done is take a closer look at the components that allow the mosquito to bite people without causing them discomfort. Mosquitoes use a combination of four substances. These include the use of a saliva-based numbing agent during 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.

[B] Biomimicry: examples

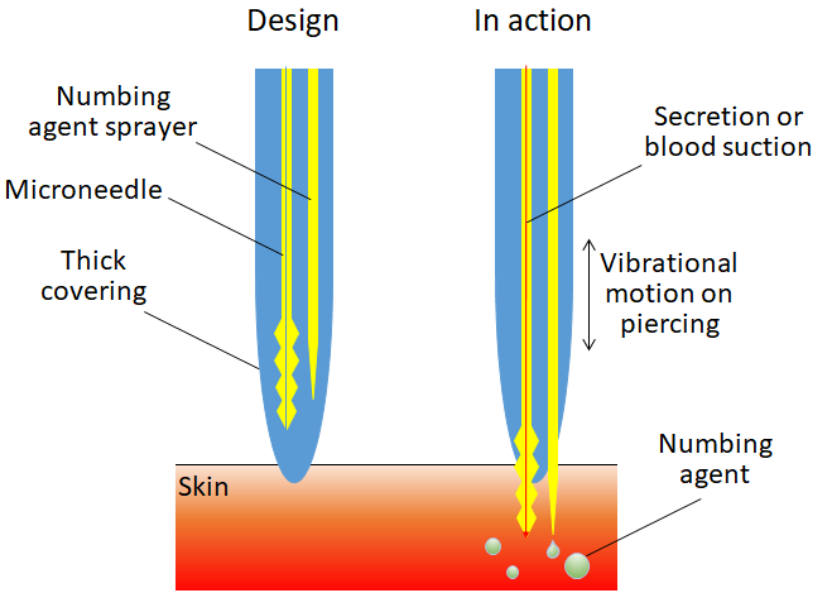
B3. Bite like a mosquito

ACTIVITY DETAILS for teachers

1. Mosquito anatomy



2. Mosquito inspired medical needle



TOOLS & MATERIALS

Student Worksheets or PPT presentation

B3. Bite like a mosquito

STUDENT WORKSHEETS

Q | Watch the surprising video of a mosquito biting.

Q | Draw a mosquito, indicating where the labium and the fascicle are located.

Q | 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?

[B] Biomimicry: examples

B4. Colorful like a morpho butterfly

SUMMARY

The intense color of the morpho is not a pigment like for other butterflies but an optical effect on a microscopic scale, the surface of it is covered with keratin scales (like nails or human hair) partially transparent and structured in such a way as to reflect only certain colors (often blue). without this structuring at the scale micrometric, the wings would be brown or gray.
This diffration phenomenon allows the morpho to self-regulate its temperature to 40 ° C, which could allow the photovoltaic panels not to heat up too much, at the risk of losing efficiency.

LEARNING OBJECTIVES

. work on the different scales . diffraction principle . simple concept of the operation of a photovoltaic panel and efficiency

ACTIVITY SEQUENCE

. understand the **multifunctionality** of nature: the morpho wing generates **color**, is **self-cleaning**, **hydrophobic** and able to thermally **self-regulate**
. Represent the **multi-scale structure** (wing: cm, scales: 100 µm, striations: µm, lamellae: nm).
. understand the **transposition** to the **photovoltaic panel**

AGE RANGE

14-16
a lighter version can be offered to the youngest

DURATION

Preparation :
20 min
ACTIVITY(IES) :
45 min

SUBJECT(S)

Connaissance du vivant

KEYWORDS

Biosphere
Technosphere
Awareness
Reconnecting with life

B4. Colorful like a morpho butterfly

BACKGROUND for teachers

The morpho butterfly

The morpho of the tropical forests of Central and South America has wings with blue reflections but also sometimes white or iridescent red. This allows the evil to be visible in the shade of the rainforest, attracting females.

The intense colour of the morpho is not due to a pigment as with other butterflies but an optical effect. On a microscopic scale, its surface is covered with keratin scales (like human nails or hair) that are partially transparent and structured to reflect only certain colours (often blue). Without this structuring on a micrometric scale, the wings would be brown or grey.

Strong points :

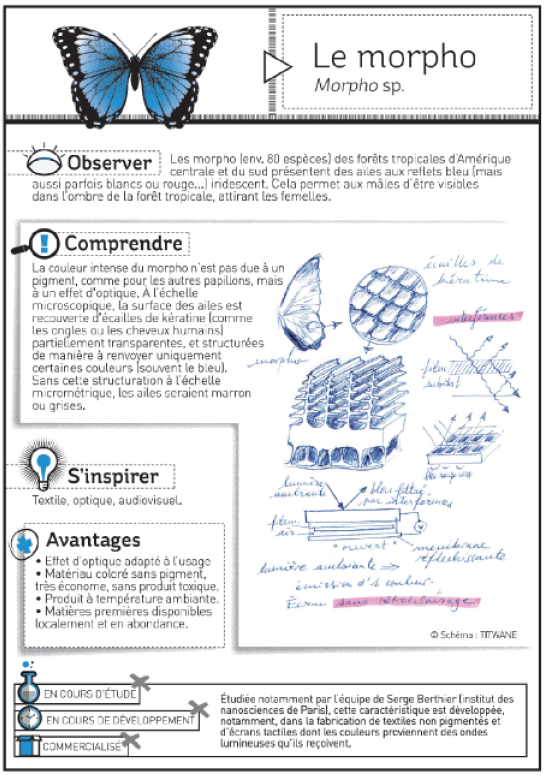
. Optical effect

. pigment-free, very economical, toxic-free coloured materials

. product at room temperature

. raw materials available locally and in abundance

This colouring can be developed in the manufacture of unpigmented textiles and touch screen textiles, whose colours come from the light waves they receive.



The solar butterfly

Video : Nature = Futur! (in French)

https://www.youtube.com/watch?v=j625EAuCb2M

The wonderful butterfly

(source : Moana Lebel)

The study and understanding of the optical properties of butterfly wings is inspiring to researchers, as butterflies are masters of photonics. The clever tricks they have developed to manipulate light with their wings are on a par with our most advanced optical technologies. Have you ever held a butterfly and observed a fine dust or powder on your fingers? This dust consists of scales. Butterfly wings 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 wing, 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

B4. Colorful like a morpho butterfly

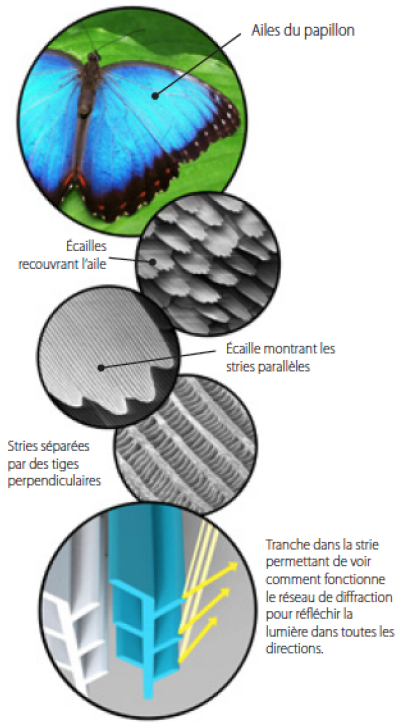
BACKGROUND for teachers (2/2)

The wonderful butterfly (continued)

Scales covering the wing the pigments absorb light at certain wavelengths and enhance the strong reflexivity of the wing in blue. The scales are generally quite different in shape, structure and optical properties in iridescent species. In blue Morphos, while the outer scales are transparent, to allow light to reach the lower layer, the outer scales are both structural and pigmentary; structural, to generate colour in the manner of a diffraction grating (streaks), and pigmentary, to absorb other radiation and enhance the strong reflexivity of the wing in blue. The interference of the reflected waves produces the iridescence of the blues.
and the shimmering greens of the Morphos. Butterfly wings are a fine example of a multi-scale, multi-functional structure. Nature is thrifty, using very few elements of the periodic table. Moreover, she develops few devices that fulfil only one function. For example, butterflies use iridescence to attract their partners and discourage predators. In addition to producing colour, Morpho's photonic structures perform other vital functions for their bodies, such as body protection, self-cleaning, via their high hydrophobicity, and thermal regulation because we have seen that butterfly wings also act as a collector of energy from the sun to keep warm. Understanding the optical properties of butterfly wings has greatly enriched photonics. And as these wings have a multifunctional structure, it is not surprising that they can inspire applications in many other fields. Iridescence is reproduced in textiles, varnishes and paints, and to prevent the reproduction of banknotes. Photonic crystals are also used in computers, mobile phones, lasers and even in printing.

Fabrics

The multi-scale structure evoked for the wings of the Morpho also exists in the fabrics. A standard fabric is made of interlaced threads, and each thread is spun from about 60 strands. There is therefore an analogy between strands and streaks, threads and scales, fabric and wings. The researchers were inspired by butterfly wings to make shimmering, colourful fabrics without dyes or pigments. They coated the thread-forming strands with a structure of thin layers, imitating the evenly layered structure of the striations on the scales of the Morphos. This technique provides various ranges of iridescent structural colours. At Merck, a pigment sold under the name Silica Flex consists of tiny glass scales coated with a thin layer of titanium oxide (10 to 100 nanometers thick). At such thicknesses, the titanium oxide makes the top layer transparent, allowing light to reach the glass layer. The light is reflected slightly offset by the top and bottom layers and the interference between the reflected and out-of-phase rays creates iridescence. Iridescence is produced as in the case of soap bubbles or oil stains. This effect is particularly spectacular on a curved surface, such as the fold of a garment, where the angle of observation constantly varies with the movements of the wearer.



Structure à cinq niveaux d'une aile de papillon

[B] Biomimicry: examples

B4. Colorful like a morpho butterfly

ACTIVITY DETAILS for teachers

Observe

The morpho (8 species) from the tropical forests of Central and South America has wings with blue reflections, but also sometimes white or indescribable red. This allows the males to be visible in the shade of the rainforest, attracting the females.

Understand

The intense colour of the morpho is not due to a pigment but to an optical effect.
On a microscopic scale, the surface of the wings is covered with keratin scales, like human nails or hair, partially transparent and structured to reflect only certain colours (often blue). Without this structuring on a micrometric scale, the wings would be brown or grey.
Getting inspired: textile, optical, audivisual

Advantage

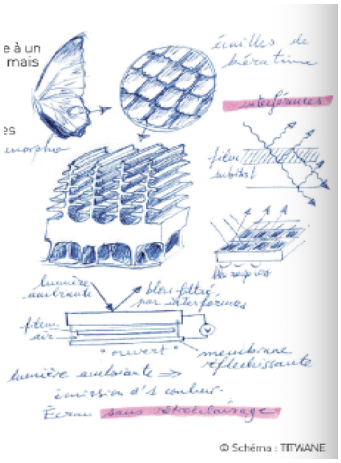
. optical effect adapted to the use
. pigment-free coloured material, very economical and free of toxic products
. product at room temperature
. raw materials available locally and in abundance

Studied by Serge Berthier's team at the Institute of Nanosciences in Paris, the characteristic of morpho is developed in the manufacture of non-pigmented textiles and touch screens.

TOOLS & MATERIALS

Student Worksheets or PPT presentation
Video Nature = Futur!
"The solar butterfly" (in French)

https://www.youtube.com/watch?v=j625EAuCb2M



© Schéma : TITWANE

B4. Colorful like a morpho butterfly

STUDENT WORKSHEETS (1/2)

Q | What is a morpho? Where does its blue colour come from? Is it due to a pigment?

Q | Why has morpho developed this colour?

Q | Watch the video Nature=Future! about the sun butterfly. Why is the researcher Serge Berthier interested in this butterfly? How could we be inspired by it?

[B] Biomimicry: examples

B5-B6-B7-B8. Fly like a raptor

SUMMARY

Large-scale birds curl the feathers from the tips of their wings in certain phases of flight. Inspired by these primary flight feathers, the winglets reduce the wingspan and therefore the friction forces while keeping a sufficient wing surface for flight. Gain of 3 to 4% in autonomy.

LEARNING OBJECTIVES

. Anatomy: wings
. History
. Physics : aerodynamics

ACTIVITY SEQUENCE

B5. Discover and draw the anatomy of a bird: the wing
B6. History: the desire to fly, from Léonard de Vinci to Airbus
B7. Winglets and aerodynamics
B8. Experience: lift of a wing according to its profile

AGE RANGE

.[all ages for activities B5, B6, B8.
Activity B7 : [15-16 years]

DURATION

Preparation :
10 min for B5 and B6
30 min for B7 and B8
ACTIVITY(IES) :
45 min

SUBJECT(S)

KEYWORDS

Flight
Rapace
Anatomy
Plane
Wing
winglets

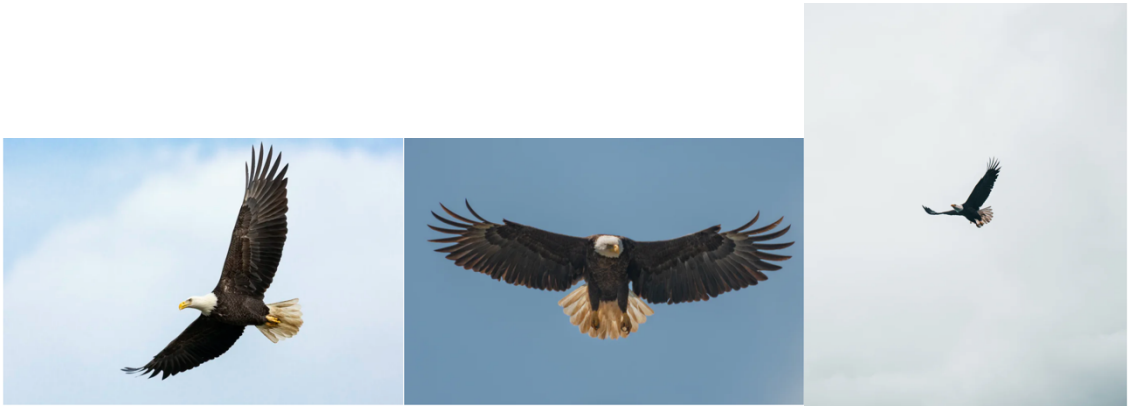
B5-B6-B7-B8. Fly like a raptor

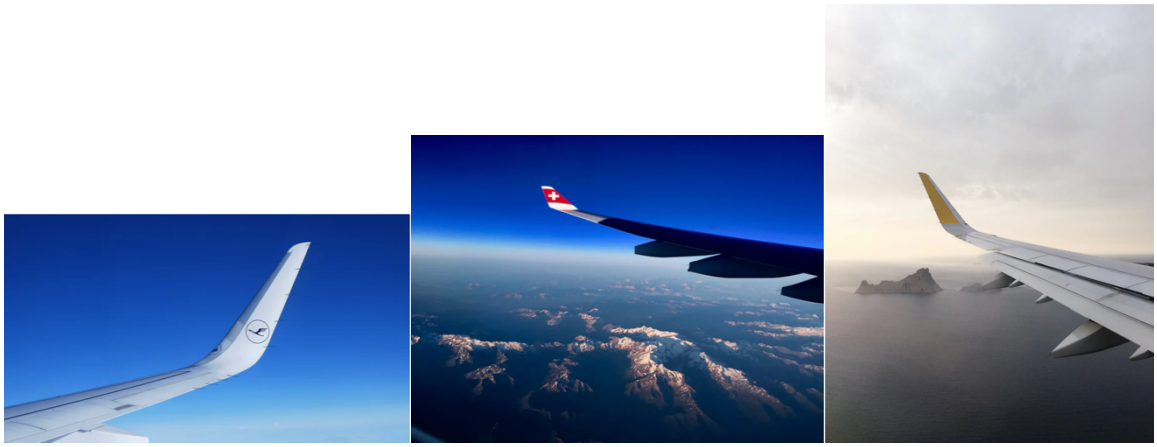
BACKGROUND for teachers

Flying like a bird

An eagle in full flight, what a magnificent sight! The bird hovers, suddenly rising towards the sky when it catches a stream of warm air, then descends again in search of prey. It is precisely by observing the flight of large birds of prey that researchers have noticed that the feathers at the tips of their wings are curved. These feathers, the remiges, can also spread out to allow air to pass through.

Inspired by this shape, engineers added vertical wings to the wing tips of aeroplanes.
The result: their flight is more efficient! Equipped with winglets, the plane flies faster and needs **4% less fuel to cover the same distance.**





BACKGROUND for teachers (1/7)

Flying like a bird

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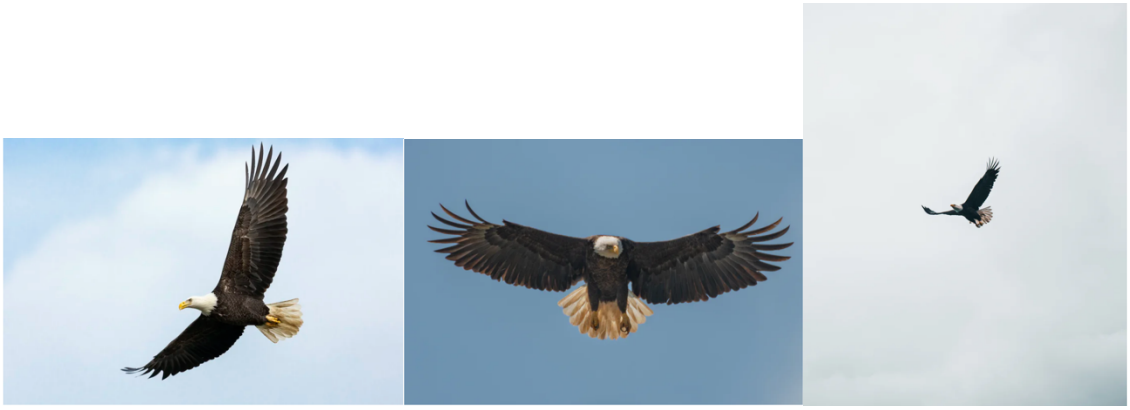

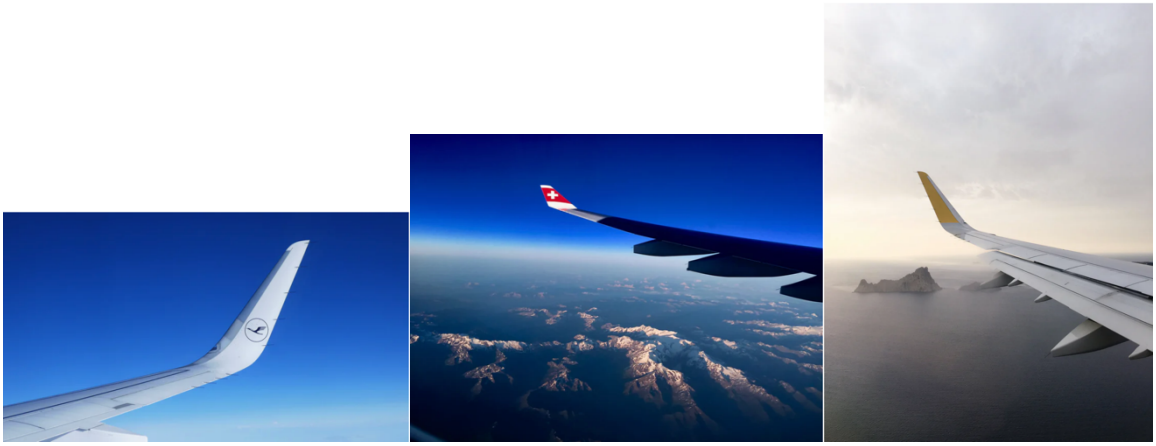

BACKGROUND for teachers (2/7)

Less oil

With this solution, we consume a little **less oil** (fossil energy).
Oil: an oily liquid that comes from the very long decomposition of micro-organisms that decomposed at the bottom of the oceans several million years ago. When oil or gas burns, it releases greenhouse gases that warm the atmosphere and are partly responsible for climate change. In addition, other compounds of these gases, when combined with water, can form **acid rain**, which has a destructive effect on flora and fauna.
Source : Bio-inspired! The living world gives us ideas (Cité des sciences et de l'industrie, Nathan)

Winglets: definition

Winglet: A substantially vertical winglet located at the wingtips of an aircraft that allows a gain in efficiency of a few percent by reducing the drag induced by lift without increasing the eagle's wingspan.
This English word is still the most widely used, although French equivalents penne or "*ailerette*" have been proposed.

Winglets: principle

The winglet aims to recover some of the vortex energy induced by the pressure difference between the top and bottom of the wing. At the tip of the wing, the flow from the lower surface in relative overpressure tends to pass over the upper surface (for an aeroplane wing or a helicopter main rotor blade, it is the upper surface (the one directed on the lift side) in relative depression, generating a marginal vortex. This not only increases the drag of the aircraft but also causes turbulence behind the aircraft that persists over long distances. It is particularly dangerous to enter this vortex behind a wide-bodied aircraft, which leads to minimal separation times and distances in the management of aircraft movements.
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. 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 of the order of a few percent and varies with the incidence (efficiency will be zero or even negative at high speed); the figure of 2% could be taken as an average value.

Tourbillon, created by the passage of an aeroplane, revealed by red smoke.

BACKGROUND for teachers (3/7)

Vultures can also give us aerodynamic lessons. Variations in air pressure at the tips of aircraft wings create vortices, the marginal vortices, which affect flight performance. These vortices cause a turbulent flow that persists for long distances behind the aircraft. It is particularly dangerous to enter the vortices produced by a jumbo jet. This is why air traffic controllers leave a minimum separation time and distance between take-offs. Observation of vultures reveals that when 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, this trick saves 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 aeroplanes. 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.
(book Moana Lebel)

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. Autonomy has increased by 3.5% compared to the 747-400D which has the same wingspan. We find the same gains in energy efficiency on the Airbus models.

Airbus has developed winglets and Sharklets wing tips 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 by 3 metres, 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 on many jet aircraft to obtain the benefits of higher effective aspect ratio: reduce the distance to take off and land at secondary airports, increase flight altitude to increase ground speed.
In addition to the installation of winglets on new aircraft, there is a retrofit market for installing winglets on older aircraft. The winglet has become popular for business aircraft; only Dassault has (temporarily) resisted this trend. Cessna recently announced a partnership with Winglet Technology to test elliptical winglets, with the aim of increasing range and payload.

BACKGROUND for teachers (4/7)

HISTORY

Aeronautic is a sector that has historically been very bio-inspired, for reasons that are easy to understand: man has always dreamed of flying like a bird.
15th century: Leonardo da Vinci lays the foundations of aeronautics
His fertile mind bubbling with ideas, his insatiable curiosity deployed 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 learns and understands the world has led him to doodle a lot. Everything he observed and analysed, his reflections, thoughts, ideas, projects with diagrams and drawings have been carefully recorded in notebooks that he carries everywhere with him! For a long time, these manuscripts were scattered around the world, some of them lost, but thousands of pages eventually resurfaced a few hundred years after his death



Leonardo da Vinci lays the foundations of aeronautics

Man has always been fascinated by flight and flying by itself is a well-anchored dream that has long led to failure! Driven by his curiosity and strong scientific spirit, Leonardo da Vinci is no exception to the rule: he is literally fascinated by the idea of man's flight and he will draw countless plans, with detailed comments and explanations, to build machines. A study of these documents shows that the inventor had already laid the foundations of aeronautics.

Leonardo da Vinci's manuscript on the study of the flight of birds

It started, as the scientific approach requires, with a large observation phase: birds are the model par excellence and are an incredible source of small details to be observed. In short, from the manuscripts, we understand that Leonardo studied the beating of the wings, the way the bird stays in balance, gains altitude by being facing the wind and the way a change of direction is made!
His interest and knowledge of anatomy and mechanics (study of movements and forces) helped him a lot. He then puts down on paper, drawings of mechanical wings or flying machines, diagrams with notes and details to explain a shape but also the dynamics and mechanisms and how to operate them. There are worms, levers, pulleys, gears...
Manuscript of a flying machine (1488)
By observing birds in this way, Leonardo da Vinci sought to break through the physical laws that allow them to fly. He thus dissected the notions of lift and drag:
- Lift is the force that counteracts weight for sustentation: it is created by the difference in pressure between the top and bottom of a wing,
- drag is the force of resistance to penetration into the air when a body is in motion. Drag must be compensated for by propulsion.

BACKGROUND for teachers (5/7)

HISTORY (continued)

Thus, he understands that the up and down flapping of the wing does not contribute to lift but to propulsion. He had understood that these two forces were a function of the surface of the object (therefore its shape) and the speed of air circulation around it (in fact it is even the speed of air in a square).
Although the machines he had thought of were never able to "take off" for lack of sufficient propulsion, the foundations of the physical principles of aeronautics have been laid... and it must be said that current research on design and materials (both on the aircraft and the engines) is focused on the fine 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 very strong development in this sector, to improve shapes, surfaces, or even the material structures of devices.

Our ancestors were already imitating nature

Over the centuries, inventors have been inspired by the shapes existing in nature to innovate. Among them: Leonardo da Vinci (1452-1519) showed that he was not only an extraordinary scientist but also 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 and 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!

Wings :

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:

- 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.
- tectors: have no direct role in the flight (primary, large, median, small, scapular)

BACKGROUND for teachers (6/7)

WINGS: anatomy

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.

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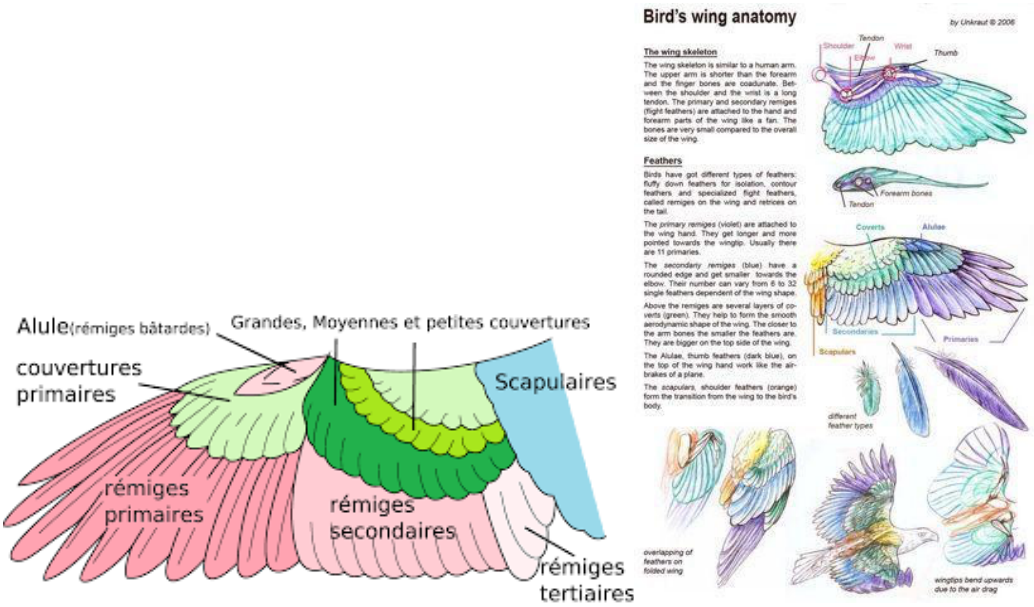
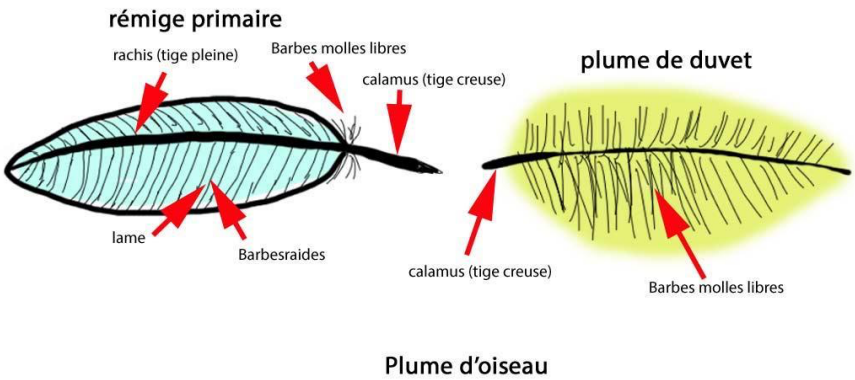




Plume d'oiseau

BACKGROUND for teachers (7/7)

Learn More…

Aerodynamic forces

Lifting, pushing or pulling, weight, drag
Flight mechanics
Bernouilli, relative wind, air resistance...

Bird aerodynamics

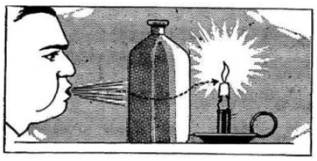
Birds are vertebrates whose bones make up 10% of their body mass. They have hollow bones (just like crocodiles, which on the other hand do not have the ability to fly), which allows them to be as light as possible and therefore reduce their body mass. They are both strong but very light.

Skeleton and muscles of the bird

The bird's beak is an extension of their skull which, if it were heavier, would prevent them from flying and might obscure their sight, this characteristic contributes to the lightness of their skeleton.
The wing bones are therefore 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.

Aerodynamic experiments

https://youtu.be/vUySZyArt70



Experience: lift and aerodynamics

https://lesneuronesatomiques.com/tools/experience-en-lien-avec-laerodynamisme-et-la-portance/

Wing Lift Experiment : https://www.youtube.com/watch?v=qRIPjQwqxwY

Ressources :

Aeronews : When Airbus is inspired by the wings of the albatross: free movements at the wing tips.
https://www.youtube.com/watch?v=rpCybl7VFng&feature=youtu.be

[B] Biomimicry: examples

B5-B6-B7-B8. Fly like a raptor

ACTIVITY DETAILS for teachers

B5 : [History] The urge to fly

For all ages: retrace the history of the first inspirations to fly: from Leonardo da Vinci and Clement Ader to the winglets of the greatest commercial aircraft manufacturers.

Compare the shape of an aeroplane to the morphology of a bird (raptor).
What are the similarities?

TOOLS & MATERIALS

Student Worksheets or PPT presentation

B6: [Anatomy] The desire to fly

For the youngest: drawing wings, feathers, observing and drawing nature.
Explain briefly that winglets reduce the vortices at the wingtips .
For visuals: on ppt presentation or slides.

_

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

TOOLS & MATERIALS

Student Worksheets or PPT presentation

B7: [Aerodynamics] Winglets

Principle of winglets and gains

TOOLS & MATERIALS

Student Worksheets or PPT presentation

B8: [Experiment] The lift of a wing

For all ages: experiences / bearing capacity

TOOLS & MATERIALS

Student Worksheets or PPT presentation

STUDENT WORKSHEETS

[HISTORY] THE URGE TO FLY, FROM LÉONARD DE VINCI TO AIRBUS

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

B6. Fly like a raptor

STUDENT WORKSHEETS

[ANATOMY] THE DESIRE TO FLY

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

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

B7. Fly like a raptor

STUDENT WORKSHEETS

[AERODYNAMICS] WINGLETS: PRINCIPLE AND GAINS

Q | Describe the shape of raptors' wings and the shape of aeroplane wings.

Q | 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%).

STUDENT WORKSHEETS

[EXPERIMENT] THE LIFT OF A WING

Q | To test the link between aerodynamics and lift, organise a series of experiments. You have at your disposal: string, paper, tape, a hairdryer, metal tripods.

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

2. Manipulate!

3. Conclusion?

[B] Biomimicry: examples

B9. Shine like a cat's eye

SUMMARY

Cats, like all felines, have highly developed night vision. When it encounters a light source (the headlights of a car, for example), their eyes shine in the night. The cat has a retinal membrane lining the tapetum lucidum. Like a mirror, it reflects light and makes it pass through the retina a second time. Its eyes need 6 times less light than humans.

LEARNING OBJECTIVES

. 1. Discover and draw the anatomy of an eye
. 2. Analysing the analogy between the cat's eye and the road reflector

ACTIVITY SEQUENCE

. observe the anatomy of the cat's eye, draw it

AGE RANGE

All ages

DURATION

Preparation :
10 min
ACTIVITY(IES) :
45 min

SUBJECT(S)

Biology : cat's eye
Physics : optics

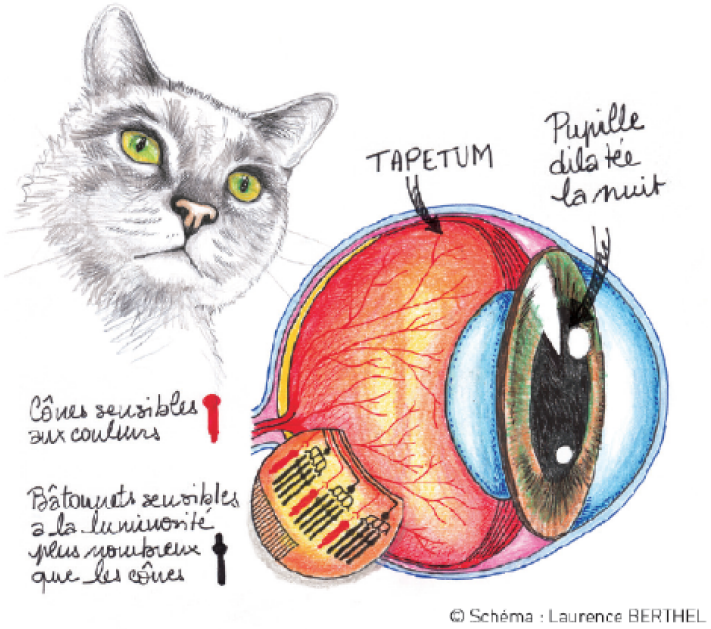
KEYWORDS

Anatomy cat's eye
reflection

B9. Shine like a cat's eye

BACKGROUND for teachers (1/2)

Anatomy: cat's eye



THE CAT

Felines have highly developed night vision. When they encounter a light source, the headlights of a car for example, 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.
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.
Inspiration: car headlights, lamps, optics adapted for night vision...
In 1924, the French company SECA Marchal marketed electric car headlights with a reflective coating on the reflector, which significantly increased the brightness of the headlights.

B9. Shine like a cat's eye

BACKGROUND for teachers (2/2)

Living at night

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.




, such as ns, raccoons, deer, dogs or cats, display this phenomenon improperly eyes". T urnal animals superior night vision. Retro-reflective devices used in white li ective strips on clothing, bicycles, sports shoes, etc. work on the petum lu s that are equipped with them. One evening in 1933, while driving home, the English inventor Percy Shaw illuminated the eyes of a cat on the side of the road, and from this was born the retroreflective device aptly named "cat's eye".

In contrast, the eyes of moths have a cornea with nanometric bumps arranged in hexagons to form a "super-black" light-absorbing surface. Because the structures in this eye collect as much light as possible without reflecting it, moths can see their predators in the dark, but have difficulty spotting them.

A big problem with photovoltaic solar panels is that silicon reflects 35-40% of light, which can no longer be converted into electricity. By researching the eye structure of moths, Peng Jiang and his colleagues have developed an anti-reflection coating containing nanometric 'nipples' that reflect less than 2% of light, a major efficiency gain. This centrifugal deposition process is easy to carry out and inexpensive. It could be used to improve the design of LEDs and liquid crystal displays (LCDs).

The coating inspired by the cornea of moths could also be used on the lenses of telescopes and cameras, and on windows and dashboards to eliminate the reflection and glare produced by the sun's rays.

While some animals deploy strategies to make the best use of natural light or produce their own, others engage their other senses that do not use light.

[B] Biomimicry: examples

B9. Shine like a cat's eye

ACTIVITY DETAILS for teachers

Living at night

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.

The cat's night vision

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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.

The inspiration

In 1924, the French company SECA Marchal marketed electric car headlights with a reflective coating on the reflector, significantly increasing the brightness of the headlights..

TOOLS & MATERIALS

Student Worksheets or PPT presentation

B9. Shine like a cat's eye

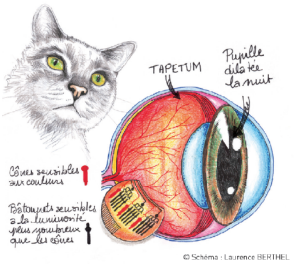
STUDENT WORKSHEETS

Q | What are the three main strategies developed by living beings to find their bearings, hunt or communicate at night?

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

Q | 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.
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.

Anatomy: Represents a cat's eye, with its cones, sticks, tapetum and pupil.



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

[C] Biomimicry : strategies and functions of living organisms

C1-C2-C3. Living strategies to attach

SUMMARY

To adhere to a wide variety of dry and wet surfaces, living organisms have developed different structures and strategies at the atomic and molecular levels. This will inspire the industry for which glue is often a problem (performance, toxicity).

LEARNING OBJECTIVES

. observing the strategies developed by living beings to attach (themselves)

. study the possibility of transposing the strategies of the living organisms

ACTIVITY SEQUENCE

AGE RANGE

.[all ages]
Chat to adapt

DURATION

Preparation :
10 min
ACTIVITY(IES) :
45 min

SUBJECT(S)

Biology : strategies to attach

KEYWORDS

Organisms
stratagies
Functions
Adhere

BACKGROUND for teachers (1/5)

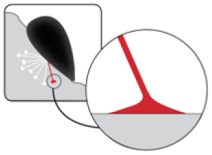
How to attach, to adhere?

Living organisms do not always have an easy life and often they have had to learn to "hang on", literally, to survive. To adhere to a wide variety of dry or wet surfaces, they have developed different structures and strategies at the atomic and molecular levels. In industry, glue is a product that too often poses toxicity and performance problems. With their new tools for observation at the nanometre scale, scientists have sought to understand nature's technological tricks, and some have even managed to combine them.

The snail

Snails leave a sticky deposit when they move around. The snail's mucus acts both as an adhesive and a lubricant for its gliding. It is this techno-gloss that allows snails to crawl on walls and ceilings without falling off. At rest, the snail's mucus is a solid gel containing long proteins. When it wants to move, the snail contracts the back of its foot and exerts a thrust that breaks the bonds between the proteins, destroying the structure of the glue. Then, the area where the foot contracts undulates.
forward a little like a bump under a carpet that is slid outwards. As soon as the contraction stops, the gooey material re-forms, holding the snail securely in place.

Les moules s'accrochent aux rochers à l'aide d'un ensemble de fibres filamenteuses qu'on appelle « byssus ».
Tiré de Nature's Techno Tricks



Mussels

Mussels can withstand currents, wave action and the pull of predators by clinging to rocks with a set of filamentous fibres called byssus. These filaments form the beard that we
remove before eating a mussel. The byssus is both rigid and elastic, attaching the mussel to the rock while acting as a shock absorber.
If you examine a byssus closely, you will see dozens of filaments the size of a human hair. To make these filaments, the mould first draws a vacuum in a small crack in a rock, much like you would with a suction cup.
It then deposits a sticky liquid foam in the hole, which it then pumps with its foot to form the filaments. The marine adhesive proteins (MAPs) found in the byssal tissue of blue mussels contain several unique amino acids. One of them, 3,4-dihydroxyphenylalanine (DOPA), plays a key role in the mollusc's powerful adhesive properties. Mussels have a strong affinity for solid surfaces, even when wet. With the help of their byssus, they are able to adhere to a
astonishing variety of surfaces, including teflon, steel and glass. They can even climb onto the hulls of ships and be transported over very long distances across the oceans.

BACKGROUND for teachers (2/5)

PureBond Technology

Conventional plywood contains formaldehyde. This organic compound is a toxic agent (can impair cell function), carcinogenic (can cause cancer) and mutagenic (can alter genes). In order to prevent hazards to human health and the environment, the wood products industry must therefore turn to alternative solutions. Kaichang Li, a researcher at the Oregon State University College of Forestry, has drawn inspiration from the composition of the proteins of the blue mussel byssus to develop a biodegradable, resistant and formaldehyde-free glue for the plywood industry. This system, known as PureBond, is an exclusive product of Columbia Forest Products. Soy protein contains amino acids similar to those found in Marine Adhesive Protein (MAPs), but contains other amino acids that are not found in MAPs. Dr. Li found the means of blocking these extra soy acids to better mimic the adhesive proteins of the byssal tissue of mussels. During the manufacture of plywood, a hybrid resin is heated with the soy proteins, which blocks the unwanted acids, and the resulting adhesive is injected into the wood fibres. The result is a product with the strength and durability of conventional plywood containing formaldehyde.

Geckos

Forget Spiderman, geckos are nature's most formidable climbers. Like snails, they have an incredible ability to stick to surfaces, climb vertical walls and walk upside down on the ceiling, but they use a completely different strategy. It is said that Aristotle observed geckos in action in the 4th century BC, but their ability as gravity defying climbers remained a mystery until the present century when biologists and other scientists unlocked the molecular secret of the gecko. Scientists now know that these little lizards can do all this because they use the forces of van der Waals9. Long before 1873, when the Dutch physicist Johannes van der Waals discovered a low-intensity electrostatic interaction between atoms or molecules and surfaces, geckos were already using intermolecular forces. These forces can only be well understood within the framework of quantum physics. They are responsible for properties that can sometimes be completely new and surprising, such as creating adhesion to a surface. The van der Waals forces only work at very, very small distances, in the nanometre range. Each gecko's leg has a flat cushion densely covered with microscopically fine hair called setulas or setae. Each setele is divided into hundreds of flexible tips called spatulae or spatulae. The spatulae are made of keratin, the same protein found in human hair. As the geckos climb, the spatulae momentarily rearrange the electrons on the surface they are climbing, creating the adhesive forces of van der Waals. Geckos defy gravity by using not glue, but fine hair! They use this fabulous trick to glue and unstick their
legs in the manner of Post-it tights.

BACKGROUND for teachers (3/5)

The geckskin

Lhe large-scale production of a material imitating the gecko's setulas posed major technical problems, in particular because of the fragility of their synthetic equivalents. So a team of researchers, consisting of a biologist, Duncan Irschick, a chemical engineer, Al Crosby, and graduate students from Amherst University in Massachusetts, developed an adhesive surface also inspired by the gecko's leg, but considering it in all its complexity (interacting tendons, bone, skin and setulae), which allowed them to use common materials rather than working at the nanometre level. Their adhesive, called "geckskin", is essentially composed of a very common polymer and a rigid fabric such as Kevlar or carbon fibre.
A geckskin piece the size of a business card placed on a smooth surface, such as glass, can withstand more than 300 kilograms, can be detached without leaving any residue and can be reused. Can you imagine? Being able to glue a TV set, a computer
or a medical device on the wall and remove it without leaving a trace? No wonder this spectacular innovation inspired the fertile minds of science fiction, who made Tom Cruise climb Dubai's Burj Khalifa skyscraper by putting on "getskin" gloves in the film Mission Impossible 4: Ghost Protocol. Who knows, these gloves may soon be a reality...

The geckel

Other scientists have developed "geckel" glue, which combines the remarkable adhesive properties of geckos and moulds to create a material that can adhere to both dry and wet surfaces. This new material contains a fibrous silicone coating, imitating the spatulas of geckos, and a polymer similar to the marine adhesive proteins of mussels. Professor Phillip Messersmith, who helped create the geckel at Northwestern University near Chicago, hopes that the material can be used to make waterproof bandages that will stick to the skin of bathers and can be painlessly peeled off like Post-it tights.

The sea knife (solen)

The sea knife, or solen, is an elongated bivalve mollusc that sinks into mud or sand to anchor and take shelter. It digs by liquefying the soil around it, much like an earthquake does in the presence of underground water.
The knife transforms its surrounding environment into a kind of slurry that resembles quicksand. It does this by contracting and expanding its shell to create a vacuum that forces the sand to flow like a fluid and allows water to infiltrate. Thanks to this strategy, which reduces friction during drilling, the small mollusc is ten times more efficient and faster than the best industrial excavators.
At MIT, Peko Hosoi (her again!) and engineer Amos Winter have created RoboClam11, a robot that mimics the way the sea knife digs in the Atlantic. It is made up of two parts that can move closer and further apart like an accordion. RoboClam is developed in partnership with Bluefin Robotics, which manufactures small autonomous submersible vehicles for research and oceanographic data collection. One of these underwater robots, the Bluefin-21, has been used to try to find MH370, the Malaysian plane that disappeared in 2014. The challenge in anchoring these small vehicles lies in the limited space and energy available. RoboClam offers an anchoring system that is compact, reversible and energy efficient. Other possible applications for RoboClam include the controlled explosion of buried underwater mines, with the robot being able to dig close to the mine and reach the detonator. It could also be extremely useful to communication companies that need to install underwater cables in shallower and therefore less navigable waters.

BACKGROUND for teachers (4/5)

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!

BACKGROUND for teachers (5/5)

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astonishing variety of surfaces, including teflon, steel and glass. They can even climb onto the hulls of ships and be transported over very long distances across the oceans.

ACTIVITY DETAILS for teachers

C1: How does the gecko hang on?
for older children

Study the strategy deployed by the Gecko (van der Valls' forces) to adhere to all smooth walls.

–

C2: The Velcro is inspired by a plant
for younger students

Study the strategy deployed by the bardane to adhere to dog hair.
To understand how Velcro works.
Does Velcro(R) meet all the criteria for biomimicry?

C3: Adhere, without toxic glue
for all students

Look for examples of living organisms that have deployed strategies to hold on
Look for everyday examples of manufactured objects that involve the adhesion of two or more pieces. What about the life cycle analysis of these objects? Are they made with local and abundant resources? Are they recyclable? Are they reusable? Have they been manufactured at room temperature and pressure? Etc...

TOOLS & MATERIALS

Student Worksheets or PPT presentation

STUDENT WORKSHEET

How does the gecko hang on?

Q | We admire the gecko, so much its movements on the walls and ceiling are disconcerting. How can an animal of this size (about 20 centimetres) do as well as a tiny fly? Thanks to its remarkable fingers (see figure 1), whose structure is an effective adhesive.

Do some research on the internet to find out how the gecko manages to attach itself to vertical surfaces, despite its relatively heavy weight.
And to go further, try to understand how the gecko can adhere infinitely, as opposed to all the adhesive tapes that are not indefinitely replaceable.

STUDENT WORKSHEETS

VELCRO© AND BURDOCK

Q | Velcro© was invented by an engineer who observed burdock seeds hanging on his dog's hair. Can you draw, in zoom mode, the two sides of a Velcro strip and explain in a few words the principle of adhesion?

Q | 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.

STUDENT WORKSHEETS

ADHERE, WITHOUT TOXIC GLUE

Q | Observe nature and cite examples of living organisms (at least 3) that have developed a strategy for sticking, sticking, attaching.

Q |What about the life cycle analysis of these organisms? Are they made with local and abundant resources? Are they recyclable? Are they reusable? Have they been manufactured at room temperature and pressure? Etc

Q | Glue is certainly the most common way to glue two objects together. What do you think of glue? Is it made from local and abundant resources? Recyclable? Made at room temperature and pressure?

[C] Biomimicry : strategies and functions of living organisms

C4-C8. Living strategies to protect themselves from heat and cold

SUMMARY

Living organisms are ingenious at protecting themselves from heat and cold. An overview of these strategies...

LEARNING OBJECTIVES

. observe and understand the strategies of living beings to protect themselves from heat and cold

ACTIVITY SEQUENCE

C4. Approach : PROTECTING AGAINST HEAT AND COLD
C5. PROTECTING AGAINST HEAT
C6. PROTECTING AGAINST COLD
C7. The termite mound, a model of natural air conditioning
C8. EXPERIENCE : TERMITE MOUND

AGE RANGE

All ages

DURATION

Preparation :
10 min
ACTIVITY(IES) :
45 min

SUBJECT(S)

Strategies deployed by living beings to protect themselves from heat and cold

KEYWORDS

Strategies
Protection
heat
cold
termite mound

BACKGROUND for teachers (1/6)

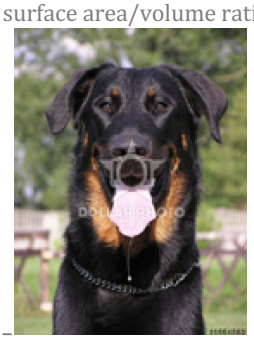
Source : Moana Lebel

[Protect]
Maintaining physical integrity

To stay alive and healthy, animals must adapt some of their physico-chemical parameters according to the situation (temperature, salt level in the blood, etc.). They must also feed, quench their thirst, hydrate themselves and filter toxic products, protect and defend themselves against environmental or predator attacks and take care of themselves when the strategies of prevention have not been successful. Here again, living beings offer us a variety of strategies and structures that can inspire us.

Regulating your temperature

Heat transfer is subject to the principles of thermodynamics. Broadly speaking, these tell us that when there is a difference (or gradient) in temperature between two media, heat passes spontaneously from the hottest to the coldest. However, in a very large number of species, known as homeotherms, it is essential to maintain a relatively constant body temperature that is independent of environmental fluctuations. Thermoregulation, or temperature control, therefore involves the laws of thermodynamics as well as a very large number of physiological and behavioural functions. In order for its temperature to remain constant, any heat production in an animal's body must be compensated for by heat loss. There are three ways of losing heat: 1) by radiation; 2) by conduction, when there is direct material contact between the animal and its environment; and 3) by convection, if there is renewal of the fluid (air, water) around the animal. The two main factors influencing the passage of calories through the skin, skin tissue and subcutaneous fat are thermal insulation and the surface area/volume ratio, i.e. the smaller the surface area of the animal is in relation to its volume, the less heat is lost.



Fight against heat.

If the outside temperature is higher than body temperature, the animal cannot dissipate heat by the above means; it must do so by evaporating water. In this case, the two main heat control strategies are perspiration, which is predominant. in large species, and the acceleration of respiratory movements in smaller species, such as a dog panting in hot weather. Thermoregulation is indeed one of the functions of the respiratory system. As breathing involves humidifying the inspired air, an increase in ventilation flow increases water evaporation.

BACKGROUND for teachers (2/6)

Fight against the cold.

When the animal has to fight the cold, there are two possible strategies: reduce heat loss or produce more internal heat. It can slow down its heat loss through physiological, anatomical or behavioural adaptations. Physiological adaptations involve processes of dilation or constriction of the cutaneous capillary vessels, the organisation of heat exchanges between arteries and veins, the reduction of blood flow in the different structures acting as radiators (horns, ears, tail...) or blood redistribution at the level of the limbs, especially at the extremities which have a surface/volume ratio favouring energy losses. Anatomical adaptations concern insulation and the surface/volume ratio. In animals that have to maintain a constant body temperature (homeotherms), the two insulation systems that are systematically used are fur or plumage and subcutaneous fat. The latter is highly insulating and has the advantage of being better adapted to the aquatic environment, as fur or plumage is insulating in that it retains more or less air. On the other hand, they have the advantage of being light and of being able to make a quick thickness adjustment by controlling the erection of the hair or feathers. Finally, the behavioural adaptations are diverse. One thinks of seasonal migrations in birds, groupings in large colonies in mammals, or the wearing of clothing in humans. As for the increase in heat production
internal, it is either of mechanical origin (shivering) or of metabolic origin (increase in general metabolism) through the use of hormones, such as adrenaline. But the opposite strategy also exists, that of hibernation. It consists of
On the contrary, to slow down the general metabolism to very low levels which puts the animal in a state of regulated hypothermia allowing it to save its energy during the winter. Whereas in savannahs or tropical deserts the climate is hot and arid, in northern ecosystems the temperature drops below freezing in winter and the ground freezes. Living organisms have had to adapt to the special and sometimes difficult conditions of their environment. Some animals with very strict thermal requirements are restricted in their movements. Others, which can withstand great variations, have acquired a great deal of freedom of movement. Some people migrate, of course, but others stay behind and have developed all sorts of innovative strategies and techniques to survive.

The camel and the dromedary

Camels and dromedaries are the only mammals that are able to vary their body temperature according to the ambient temperature; they can easily tolerate a variation of 6°C in their internal temperature. They are therefore not strictly speaking homeotherms, just like mammals that hibernate with a dramatic drop in their internal temperature. The dromedary is particularly well adapted to the extreme heat and dryness of its habitat. Its long legs keep its body away from the burning ground. Its thick coat
light-coloured reflects the sun's rays during the day and protects it from the cold at night. Its body temperature drops to 34 °C at night and rises to 40 °C during the day, activating perspiration. Sweat wets his hair and forms a moist, refreshing layer of air against his skin. When the sun hits hard, the cunning dromedary stands directly in front of it, minimising the area exposed to the rays. The dromedary is a prime candidate to inspire thermoregulation of electronic devices and industrial machinery

BACKGROUND for teachers (3/6)

Elephants

Elephants have the smallest surface area/volume ratio of all land mammals, making them the most difficult to evacuate heat. Moreover, the poor pachyderm has no sweat glands. It takes up the challenge of cooling itself through a combination of behaviours such as swimming, beating its ears and spraying water with its proboscis. They also lose heat through radiation, because the hotter a body is, the more energy it loses through radiation and convection.
when the wind, or the movement of his ears, renews the air around him. But the elephant has another way, surprising to say the least, to cool down. While the hairs are generally insulating and retain heat, those of the pachyderm help to evacuate it. Engineers at Princeton University in New Jersey have studied the principles of fluid mechanics involved in its heat loss by convection. They found that the elephant's scattered hairs facilitate heat transfer with the ambient air. There is therefore a critical point below which the density of hair switches from an insulating to a cooling function. The main author of the research, Conor Myhrvold, is not surprised that the role of something so small on such a large animal may have escaped the attention of researchers. Using a thermal camera, biologists at the Vienna University of Veterinary Medicine discovered that the elephant's body and its large earlobes are dotted with highly vascularised "hot spots" that facilitate heat loss. The size of these "heat windows" increases with the ambient air temperature and the weight of the animal. By concentrating close to the surface of these areas, the elephant's skin blood flow can fine-tune its heat dissipation. The latter type of thermoregulation could be put to good use by creating "highly vascularised hot spots", i.e. small specialised areas in strategic locations on buildings, computers, cellular phones and clothing, where heat could escape. Several industry sectors are interested in this.

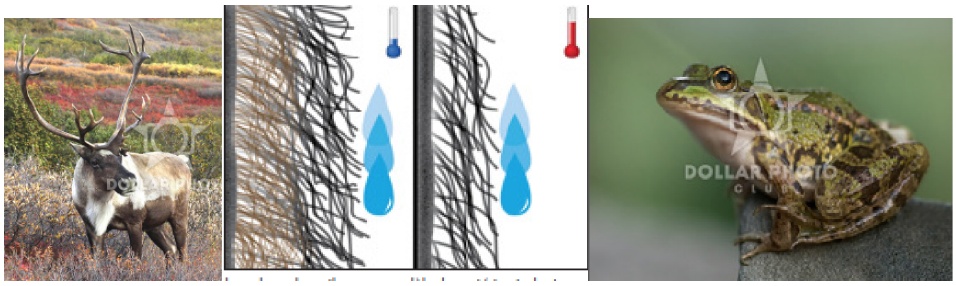
Butterflies

Only birds and mammals are true homeotherms, as they have an internal heat source and their temperature is regulated. But butterflies are also experts in air conditioning. As with all insects, their body temperature is variable and adapts to the ambient temperature; they are very sensitive to climatic conditions. Requirements and tolerances vary greatly from species to species. However, in order to evolve normally, they all have to maintain a temperature inside their thorax comparable to that of mammals. They must therefore find a way to regulate their temperature in order to remain active in an environment where the ambient air undergoes significant variations.
At rest and during takeoff, butterflies must maintain an appreciable body temperature, while in flight they must dissipate their heat. The regulation mechanisms are mainly physiological and behavioural. While before taking flight moths vibrate their wings, which stimulates the metabolic (endothermic) production of heat (physiological mechanism), day butterflies expose themselves to the sun (behavioural mechanism) by spreading their wings flat so as to capture more or less solar radiation, although some species do this by keeping their wings closed and turning sideways.
The size, colour and structure of the butterflies' beautiful wings contribute to their thermoregulation. For example, in colder regions, most species are dark in colour and their bodies are covered with hair to better absorb and control the sun's rays.
retain heat. Butterfly wings are covered with scales that act as tiny solar collectors. At the University of Shanghai, Professor Di Zhang and his team have taken inspiration from these natural nanostructures to make photovoltaic cells that are more efficient and less expensive than traditional silicon cells. The manufacturing process for these bio-inspired photovoltaic cells is simpler and cheaper, and could be used to make other products, such as electronics chips , dissipating heat better.

BACKGROUND for teachers (4/6)

Caribou

The majority of land mammals in northern environments, such as muskoxen, arctic foxes or caribou, and aquatic environments, such as beavers and muskrats, are particularly well protected from the cold by their fur. The insulating qualities of their coat depend on its characteristics: density, length and structure of the hair. During the winter, the warm coat of the caribou has two types of hair: the upper layer, exposed directly to the cold, is made up of long, thick, hollow, water-repellent hair (jar hair), while the lower layer is made up of a very dense down of fine, woolly hair sheltering small pockets of air (wadding hair). By preventing water from penetrating the coat (water-repellent hair) and reducing insulation due to air pockets, and by preventing air circulation out of the animal's down, this double-layered coat greatly reduces heat loss.
Caribou have developed a thermoregulation system that is well adapted to the changing seasons since they moult during the summer; they shed their wadding hair and their jar hair becomes much shorter. In this way, they are well protected against the rigours of winter, without overheating during the summer months. The caribou's fur could inspire the manufacture of insulating materials for pipes or walls, insulating textiles or clothing, or blankets to protect engines in cold climates.



Amphibians

Amphibians in northern ecosystems survive the cold by hibernating underground, in the mud of ponds and lakes, under leaf litter, or protected by an insulating blanket of snow. Knowing that the freezing temperature of water is 0°C, the ability of their bodies to stay above this temperature is vital. This is because freezing water expands and could cause their cells to burst. When it comes to hibernation, anurans from cold regions (like Quebec in January!) have more than one trick up their sleeve. The wood frog (Rana sylvatica), for example, manages to survive to
temperatures as low as -7°C by lowering its metabolism until it comes to a complete stop. She then shows no sign of life; her heart and brain stop working and she stops breathing. But she is not dead! She will wake up in the spring with the increase in room temperature. But how can she achieve such a feat? When the temperature reaches the freezing point, the water withdraws from her vital organs and accumulates in her abdomen. In addition, the frog is protected by a natural antifreeze, sugar. Glucose lowers the freezing point of the cells and, even though nearly 65% of the water in its body is frozen, the inside of the cells remains liquid. The level of sugar then present in the frog would be enough to induce a diabetic coma in humans, but unlike the highly toxic chemicals contained in man-made antifreeze, glucose is harmless. This phenomenon is of great interest to medical researchers, especially those interested in the global scourge of diabetes. They are trying to understand why the frog's body is not affected by such a high concentration of sugar. In addition, imagine the interest in organ transplants if they could be frozen and thawed as easily as the wood frog does!

BACKGROUND for teachers (5/6)

The Morio butterfly

The Morio (Nymphalis antiopa) is a fairly abundant species in Eurasia and North America. It is the first butterfly that can be seen in Quebec when spring arrives. It hides under the bark of trees or in dead stumps to spend the winter and wakes up in February or March. It is one of the only species that overwinters as a butterfly, most other species will overwinter as eggs, larvae (caterpillars) or pupae. This is also one of the reasons why it reaches record longevity, 10 to 11 months compared to other species that only live for a few days in winged form. This is remarkable!
For its hibernation, the Morio uses a process similar to that of the wood frog by gradually lowering its metabolism and then producing an antifreeze substance, glycerol. Knowing that the product generally used in automotive coolant, ethylene glycol, is extremely toxic, antifreeze manufacturers are turning to glycerol to find a more environmentally friendly solution.


The polar bear

Polar bears are among the coldest animals in the world, so they must be well protected against hypothermia. Their morphology (e.g. small ears, surface/volume ratio, short tail, minimizing heat loss), thick layer of fat and several other physiological, anatomical and behavioural adaptations contribute to their thermoregulation. Of course, its abundant coat also has a major role to play in maintaining its body temperature.
As in the caribou, the polar bear's fur consists of a layer of long, stiff hair, under which is a dense, woolly down. Visible light is reflected from the inner walls of the long, hollow, transparent hair, which gives the polar bear its whitish colouration. These long hollow hairs also have insulating properties because of the air they contain. The hollow fibres used to make winter coats, duvets and ultra-light and very warm sleeping bags are made from the same principle. Katie's Design was therefore inspired by the polar bear's heat-retaining hair to design a kind of "skin" for thermos flasks, which often tend to lose their heat too quickly. For a long time it was believed that the bear's hollow hairs
Polar fleece acted like an optical fibre, directing the sun's rays to its black skin to warm the animal. But recent studies have shown that this is not the case. Research by physicist Daniel W. Koon of St. Lawrence University in upstate New York has shown that light radiation penetrates shallowly into the bear's fleece. According to him, it is rather the keratin in the hair that absorbs UV rays.
For her part, physicist Priscilla Simonis43 from the University of Namur in Belgium, wondered how, with just 5 centimetres of fur, the polar bear manages to regulate its body temperature so well. She modelled the animal's fur, firstly as if it absorbed all the solar rays hitting it (black body phenomenon). Then, in a second step, she simulated the hairs as grey bodies, i.e. opaque bodies that partially reflect the heat emitted by the animal's body. The result? According to the researcher, "... the improvement in thermal insulation was drastic: about 100 times better than in the previous case. This is the secret of the excellent insulation of the polar bear's fur. It is not based - as everyone believes - on a layer of air trapped in the fur, but on the diffusion of heat through the fur. This is because the infrared rays from the skin at 37°C are reflected from hair to hair many times, reducing the loss to the outside. "The situation with the camel's thick, light-coloured fur is similar, but it works in the opposite direction. While it's 50°C outside, the animal keeps its internal temperature of 35°C. "It's a good idea to keep the temperature inside. "The multi-directional heat diffusion in the hair insulates it from the outside.
Priscilla Simonis wonders why our building insulation materials are so inefficient compared to the few centimetres of fur of the polar bear, which can maintain its body temperature at 37°C when it is -40°C or -50°C outside. She believes that her research may lead to the development of new types of ultra-thin insulation that can be used in construction, but also lead to a new generation of snowsuits, sleeping bags and survival equipment.

BACKGROUND for teachers (6/6)

Termites

African termites of the genus Macroterms live in environments where the temperature variation between day and night can reach more than 40°C. In order to survive and to ensure the renewal of the Termitomyces fungi that predigest their food (a fungus lives in fairly strict thermal conditions), termites must maintain their nests at an acceptable temperature. The ingenious termite nest aeration system regulates the temperature of the nest.
Architect Mick Pearce and engineers from Arup were inspired by the termite nest ventilation system in the design of the Eastgate office building and shopping centre in Harare, Zimbabwe. The integration of this incredibly efficient natural process reduced air conditioning energy consumption by 90% compared to conventional buildings of the same size. The absence of air conditioning and heating systems saved $3.5 million over a 20-year period, which is certainly not negligible from a financial point of view. Pearce believed that termite mounds used constant soil temperature and natural wind induced ventilation as a means of thermoregulation. So he designed a building where fresh night air is pushed into a box between the first and second floors using fans, and distributed during the day through grates. Warm air is evacuated by means of a chimney effect, if necessary assisted by low-speed fans. But now two researchers, J. Scott Turner and Rupert C. Soar, have cast doubt on how the functioning of a termite mound is understood.
For them, the termite mound behaves more like a lung that breathes in and out in a kind of beating. Beyond biomimicry, they say, they want to build a "living edifice" and not simply "inspired by the living". Does this mean that strategies developed from an imperfect understanding of the organism being studied are not valid? Mick Pearce proved the opposite, and so much the better if new scientific knowledge allows him to improve his future achievements.
All this tends to demonstrate that living things are much more complex than they appear. The fact that to this day there is still no 100% satisfactory explanation for the lift of an aeroplane or bird wing, and yet we continue to fly, illustrates one of the main characteristics of science; a theory is always open to improvement. It can be completed, improved or even questioned. But imitating a living being according to the last recognized explanation, even if a better explanation may come along later, almost always bears fruit, whether it is a thermos flue or a new generation of ultra-thin insulation, a building without air conditioners or a "living" building.

These examples on thermoregulation offers us an excellent opportunity to show how biomimicry is a powerful tool for innovation. Two of the classic examples mentioned by the promoters of the discipline have inspired remarkable applications, despite the fact that the understanding of the principles put forward by the imitated organisms was not perfect. The new knowledge will undoubtedly enable us to go even further. These two examples come from polar bears and termites. We are living in an era where scientific knowledge is exploding, thanks in particular to the power and perfection of observation and data processing tools. So it should come as no surprise that biomimicry is evolving at the same pace as discoveries in nanosciences, and the better understanding of the living world that the new tools make possible.

[C] Biomimicry : strategies and functions of living organisms

C4-C8. Living strategies to protect themselves from heat and cold

ACTIVITY DETAILS for teachers

C4: Protecting against heat and cold

For all ages: look for examples in nature of living organisms that need to protect themselves from heat or cold. Describe their strategies...

TOOLS & MATERIALS

Student Worksheets or PPT presentation

C5: Protecting against the cold

Caribou, polar bear, amphibian, edelweiss... living organisms use their ingenuity to fight against the cold. An overview of strategies for dealing with low temperatures.

TOOLS & MATERIALS

Student Worksheets or PPT presentation

C6: Protecting against heat

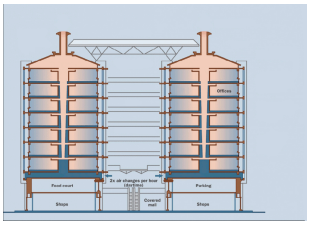
Elephant, dog, butterfly, dromedary, termites... living organisms use their ingenuity to fight against heat... An overview of strategies for dealing with high temperatures.

TOOLS & MATERIALS

Student Worksheets or PPT presentation

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

Termites deploy a clever strategy to cope with very high temperature amplitudes. Architects were inspired by this principle in the design of a building: the Eastgate Center in Zimbabwe. The result is a building that is 90% autonomous and 35% less energy consuming than other buildings in the country.



TOOLS & MATERIALS

Video (in English)
https://youtu.be/620omdSZzBs

C8: Experiment: The termite mound, a model of natural air conditioning

Termites deploy a clever strategy to cope with very high temperature amplitudes. Architects have been inspired by this principle when designing a building...
https://biomimetismetpemaimo.wordpress.com/experience/
https://www.youtube.com/watch?v=qbKppQwfc2o
https://www.youtube.com/watch?v=TU7ay12bCNs

TOOLS & MATERIALS

Pipes
Thermometer
Food colouring

C4. Living strategies to protect themselves from heat and cold

STUDENT WORKSHEETS

PROTECTING AGAINST HEAT AND COLD

Q | Observe nature. Which species have the capacity to protect themselves from the extreme cold? From intense heat? Can you name at least three of each?

Q | How does the dog regulate its temperature when it's hot? And the elephant?

Q | How does the penguin fight against the cold? And the polar bear?

STUDENT WORKSHEETS

PROTECTING AGAINST COLD

Caribou, polar bear, amphibian, edelweiss... living organisms use their ingenuity to fight against the cold. An overview of strategies for dealing with low temperatures.

Q | In your opinion, how do caribou, polar bears and amphibians protect themselves from the cold? (each organism develops its own strategy)

Q | Complete your answers by looking for information from your teachers, in books or on the internet.

C6. Living strategies to protect themselves from heat and cold

STUDENT WORKSHEETS

PROTECTING AGAINST HEAT

Q | Choose an animal that must fight the heat for its survival. Do you have any idea how it regulates its temperature?

Q | Elephant, dog, butterfly, dromedary, termites... living organisms use their ingenuity to fight against heat... Look on the internet or with your teacher for specific information on heat management strategies used by these animals.

C7. Living strategies to protect themselves from heat and cold

STUDENT WORKSHEETS

THE TERMITE MOUND, A MODEL OF NATURAL AIR CONDITIONING

Q | Watch the video (in English) https://youtu.be/620omdSZzBs

Q | 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.

C8. Living strategies to protect themselves from heat and cold

STUDENT WORKSHEETS

EXPERIENCE : TERMITE MOUND

Q | After completing Activity C7, imagine an experiment that might allow you to highlight hot and cold draughts. 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 of course get help from your teacher)

Q | Now it's your turn to experiment! Write down your comments here.

[C] Biomimicry : strategies and functions of living organisms

C9-C11. Zoom on the leaf and its multiple functions

SUMMARY

The sheet is an example of multifunctionality. It captures solar energy, the carbone. It serves as a resource for other living species. It is self-repairing. It serves as a habitat for other species. It provides shade. It regulates temperature and humidity. It can be transparent...

LEARNING OBJECTIVES

. observe the living #multifunction
. study an example: the leaf

ACTIVITY SEQUENCE

The study of the sheet can be organised as an overview session of all the features of the sheet.
An activity on artificial photosynthesis can be organised with older students.

AGE RANGE

To adapt

DURATION

Preparation :
10 min
ACTIVITY(IES) :
1x45 min : multifonctionnality
1x45 min : photosynthesis

SUBJECT(S)

The leaf, an example of the multifunctionality of living
Artificial photosynthesis

KEYWORDS

Leaf
Multifonction
Solar Energy

BACKGROUND for teachers (1/4)

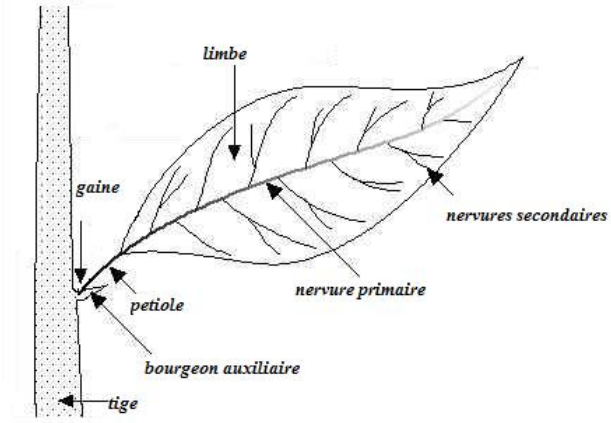
THE LEAF

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.

http://feuille-automne.blogspot.com/p/introduction-est-divisee-en-saisons-le.html

BACKGROUND for teachers (2/4)

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, ...), or -their sometimes toxic compositions.
- 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.

BACKGROUND for teachers (3/4)

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.

LeafCoverage

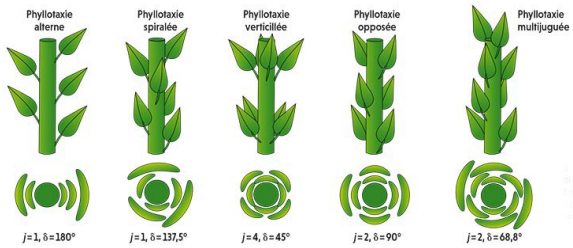
Order of ideas of numbers of leaves in large trees :
Large apple trees have 50 to 100,000 leaves,
birch trees 200,000 on average,
A mature oak can bear 250,000 leaves
700,000 mature oaks - placed side by side, these 700,000 leaves would cover a surface area of 700 m2.
Some American elms have up to 5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

It is estimated that all the leaves of the world's trees produce by photosynthesis 65,000 to 80,000 million m3 of dry matter per year, which corresponds to two thirds of the world's terrestrial plant

BACKGROUND for teachers (4/4)

Optimisation of sheet coverage

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.

C9-C11. Zoom on the leaf and its multiple functions

ACTIVITY DETAILS for teachers

C9. Observation & nature : the leaf

If it is possible to go out in the forest or in a park: collect leaves, describe them, think together about all their functions.
If it is not possible to go for a walk in the forest, compensate with photographs or videos of nature, the forest, etc.

C10. The multifunctionality of the leaf

Note the functions of a leaf.
To question the mono-functionality of manufactured products

C11. Artificial photosynthesis

To understand the principle of "natural" photosynthesis.
Compare the environmental impact of a leaf and a photovoltaic panel

TOOLS & MATERIALS

Stroll outside if possible: observe and collect various leaves

TOOLS & MATERIALS

Students worksheet or PPT slides

STUDENT WORKSHEETS

OBSERVATION & NATURE : THE LEAF

Q | Après votre promenade en forêt, notez ici ce que vous avez au sujet des feuilles : leurs fonctions, leurs cycles…

C10. Zoom on the leaf and its multiple functions

STUDENT WORKSHEETS

THE MULTIFUNCTIONALITY OF A LEAF

Q | Notez les nombreuses fonctions d'une feuille

Q | Les produits manufactures sont-ils aussi multifonctionnels ? Fabriqués à partir de ressources locales et abondantes ? Servent-ils de ressources pour d'autres usages ?

C11. Zoom on the leaf and its multiple functions

STUDENT WORKSHEETS

ARTIFICIAL PHOTOSYNTHESIS

Q | What is photosynthesis?

Q | Photovoltaic panels, like the foil, capture solar energy. The foil stores this energy in chemical form. The photovoltaic panel transforms it into electrical energy.
Solar energy is often considered "green" energy. What do you think about it? How and with what are solar panels made?

[D] Biomimicry: the principles of living

D1-2. The tree / the building : observation and inspiration

SUMMARY

A forest is an ecosystem capable of regenerating itself, providing services such as feeding other organisms, filtering water and purifying the air.
The building and the city of the future can draw inspiration from ecosystems to become regenerative itself...

LEARNING OBJECTIVES

. Understanding the regenerative aspect of living things, ecosystem services
. Consider applying them to the building, to the city

ACTIVITY SEQUENCE

. Observing the functioning of an ecosystem such as a forest.
. Compare the functioning of a city

AGE RANGE

All ages (to adapt)

DURATION

Preparation :
30 min
ACTIVITY(IES) :
45 min

SUBJECT(S)

Ecosystem services
Bio-inpired cities

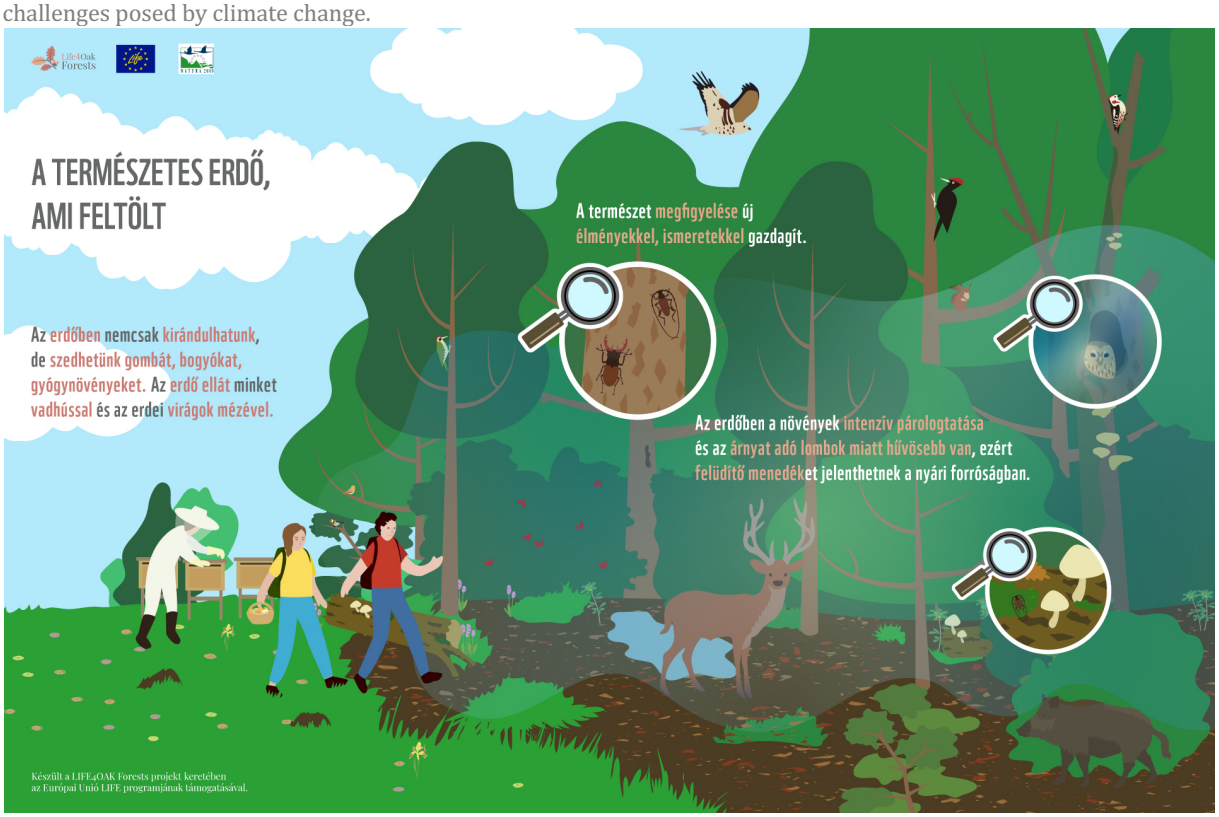
KEYWORDS

Principles of the living
Ecosystem
Ecosystem services
Forest
Building
City, regenerative city

BACKGROUND for teachers (1/4)

Forest / ecosystemic services

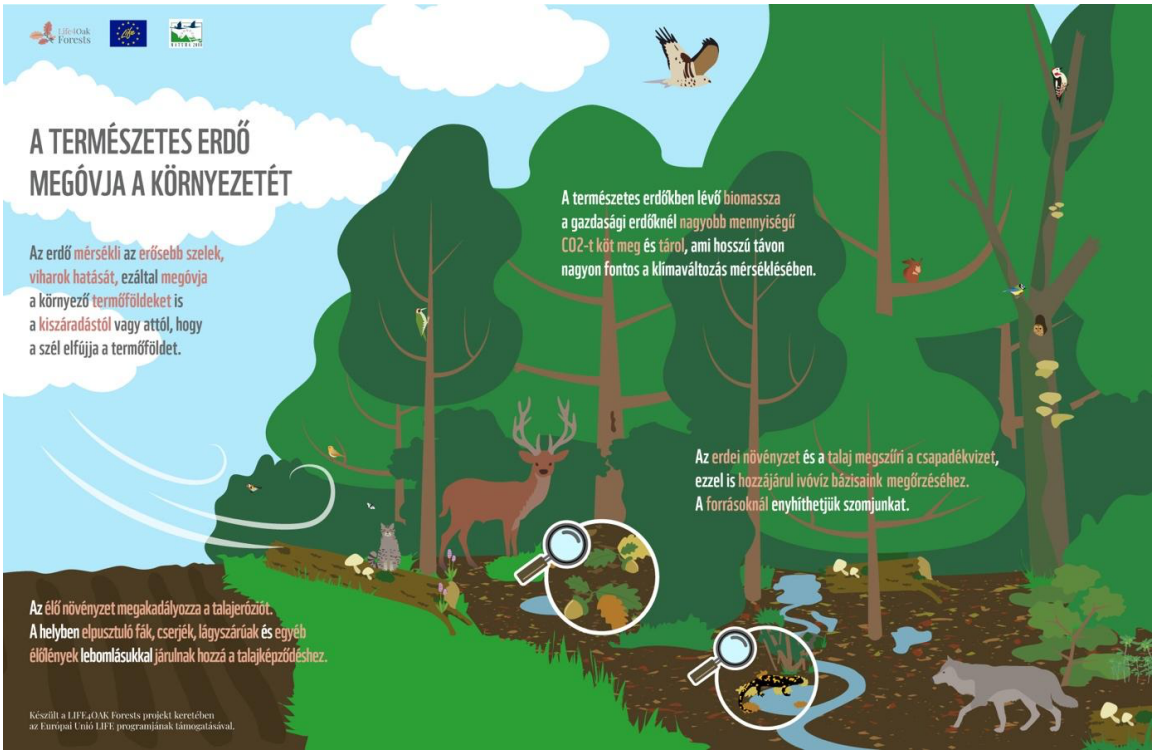
Natural forests give us much more than we think: herbs, edible fruits and mushrooms, diverse flora and fauna and refreshing refuge in the summer heat.
Our natural forests also play an important role in the functioning of their environment. They protect the surrounding farmlands from dehydration and strong 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 whi
ch 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.

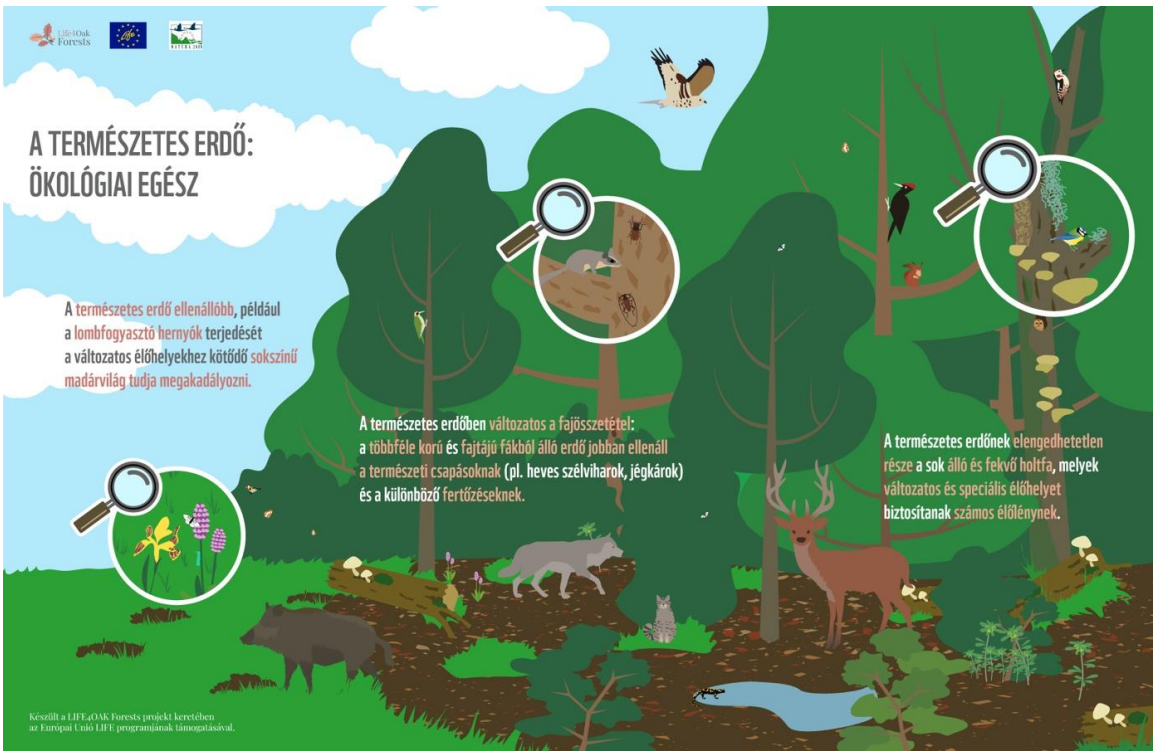


[D] Biomimicry: the principles of living

D1-2. The tree / the building : observation and inspiration

BACKGROUND for teachers (2/4)





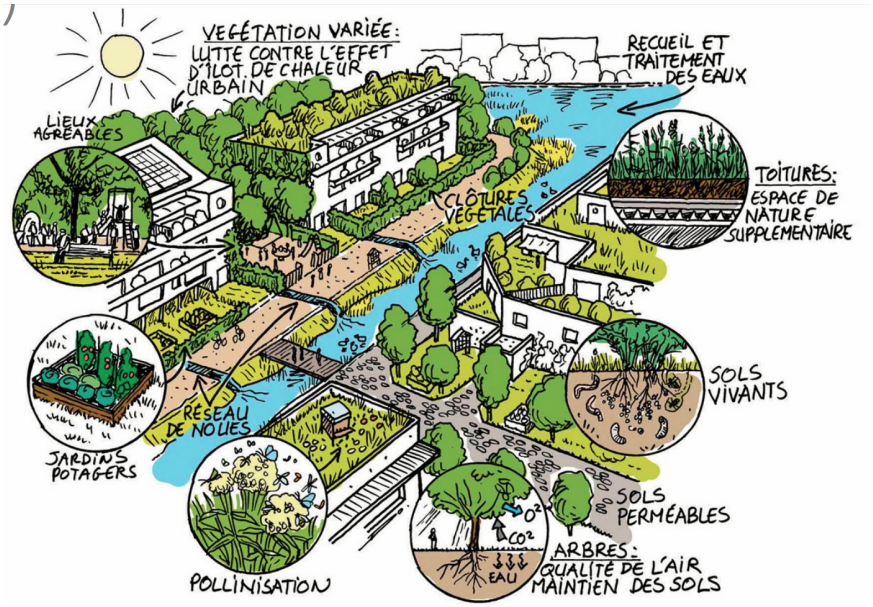
[D] Biomimicry: the principles of living

D1-2. The tree / the building : observation and inspiration

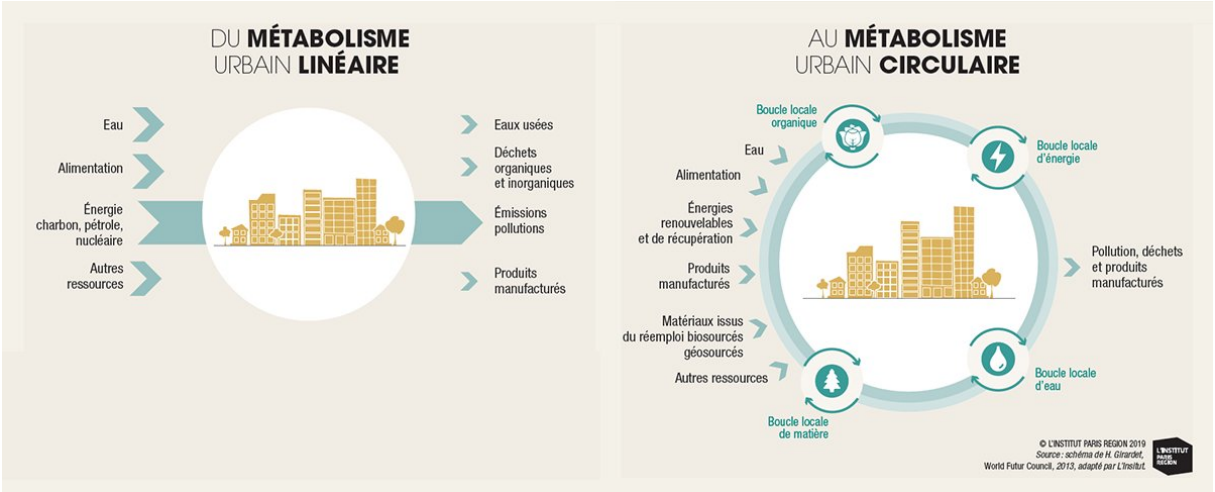
BACKGROUND for teachers (3/4)

The nature in the city contributes to :

- the fight against pollution (air, soil, water...)
- fight against heat islands
- flood control
- provision of socio-cultural services (green areas, shared gardens, etc.)



More broadly, the perspective is that of a regenerative city: able to produce biodiversity, energy and food, recycle waste, store carbon and purify air and water. A city capable of constituting itself as a privileged support for reinventing the symbiotic relationships between living beings.



BACKGROUND for teachers (4/4)

What model for a living city?

À lire en français : https://theconversation.com/quel-modele-pour-une-ville-vraiment-vivante-136335

Rethinking the city inspired by nature (by NOBATEK/INEF4)

Tomorrow, buildings, neighbourhoods and cities will be designed or renovated to integrate into their environment, optimising their resources, reducing their energy consumption and waste production... Incredible source of inspiration, nature leads us to imagine a city with a positive impact on the environment, producing its own materials, energy, water... Many solutions already exist to move towards this model of "regenerative" city.

Nature as an example for the city

More and more architects and town planners are no longer looking at nature as a space to be protected but as a model to be followed. In a process of bio-inspiration, they see the city as an ecosystem capable of bringing together biodiversity and the human way of life. They are inspired by the life cycle of living beings and imagine a "regenerative" city, a city that reduces the pressure it exerts on the environment to the point of positively transforming its impact by providing some of its own services such as the production of food, energy...

Towards "regenerative" town planning

Inspired by the strategies of living beings, the city of tomorrow will integrate ecosystem services provided by nature today: purifying air and water, providing food and fresh water, generating energy, producing its materials... Moving towards the model of the generative city thus implies improving the energy performance of buildings, increasing the solidity of structures or the quality of materials and making them easily modifiable and dismountable, producing renewable energy, treating and recycling waste as much as possible: water, organic matter, building materials. The city of tomorrow will also focus on local food with urban agriculture, on soft traffic and on bio-sourced materials. It will study the morphology of buildings to optimise solar gain such as plants and natural ventilation such as termite mounds. Its footprint will be restricted to promote the penetration of rainwater into the soil, to feed the water tables, to collect rainwater on roofs and treat it with phyto-purification... The city of tomorrow will also be greener. Vegetation refreshes the atmosphere, reduces urban heat islands, creates a greater variety of flora and fauna, allows the soil to be more permeable, resulting in less drought and flooding.

The key words of the sustainable city: water, vegetation, transport, building, circular economy, energy...

The sustainable city: a response to climate change

Building the "regenerative" city would go as far as mitigating the very causes of climate change and biodiversity loss, while making the built environment more adaptable to climate change. In a bio-inspired city, nature is less stressed and regenerates better: healthier ecosystems provide humans with services that cannot be provided by the built environment and are more adaptable to climate change. In the same way, the city imitates nature and develops its capacity to adapt to change. It becomes more resilient.

[D] Biomimicry: the principles of living

D1-2. The tree / the building : observation and inspiration

ACTIVITY DETAILS for teachers

D1. A tree: observation & inspiration

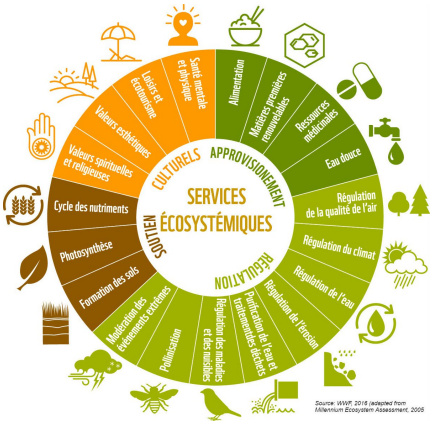
In the forest, observe nature and more particularly a tree. Think of all the services it can render to other organisms, the symbioses it can form...

TOOLS & MATERIALS

Nature walks
Illustration of ecosystem services

D2. Ecosystem services / nature walks

Walking in nature and observing. Identify the services provided by nature, by a forest.
. supply: food, raw materials, fresh water .
Regulation: air quality, climate, erosion, pollination...
Support: soil formation, nutrient cycling...
Cultural: mental and physical health, recreation and ecotourism



TOOLS & MATERIALS

Student Worksheets or PPT presentation

D3. The city of the future, a bio-inspired, regenerative city

Imagining the city of the future, a regenerative city....

STUDENT WORKSHEETS (1/2)

A TREE: OBSERVATION AND INSPIRATION

Q | Take a walk in the forest. Observe the trees. Choose one in particular. Take the time to observe it. Think of all the services it provides to the organisms around it. It's up to you!

STUDENT WORKSHEETS (1/2)

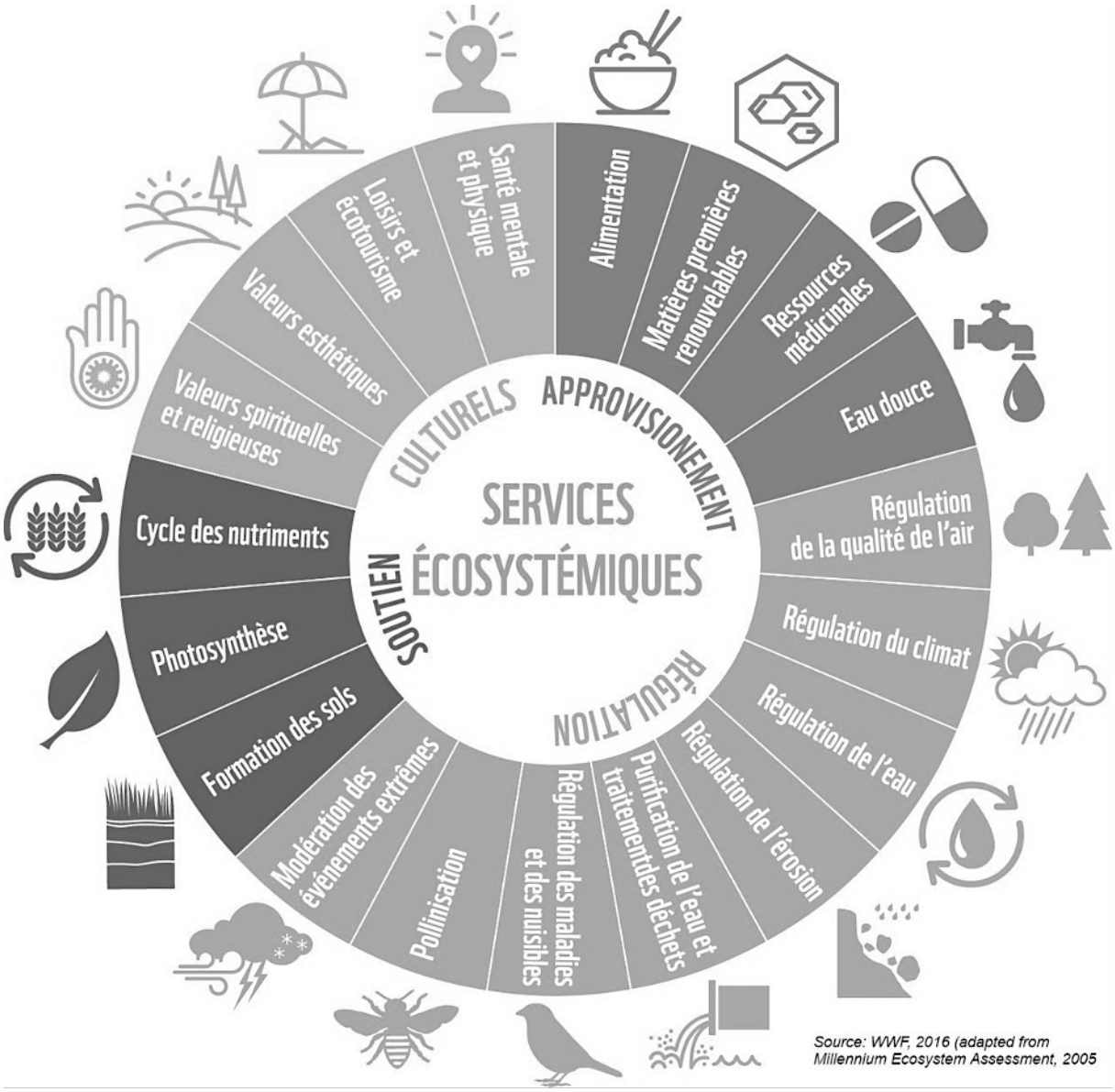
ECOSYSTEM SERVICES / NATURE WALKS

Q | Stroll in the forest, in nature... Observe and let your teacher guide you to identify the services provided by nature.
These services are called: ecosystem services. List them...

Q | Do you think that a building (a house, a block of flats) or a town renders the same services to its environment?

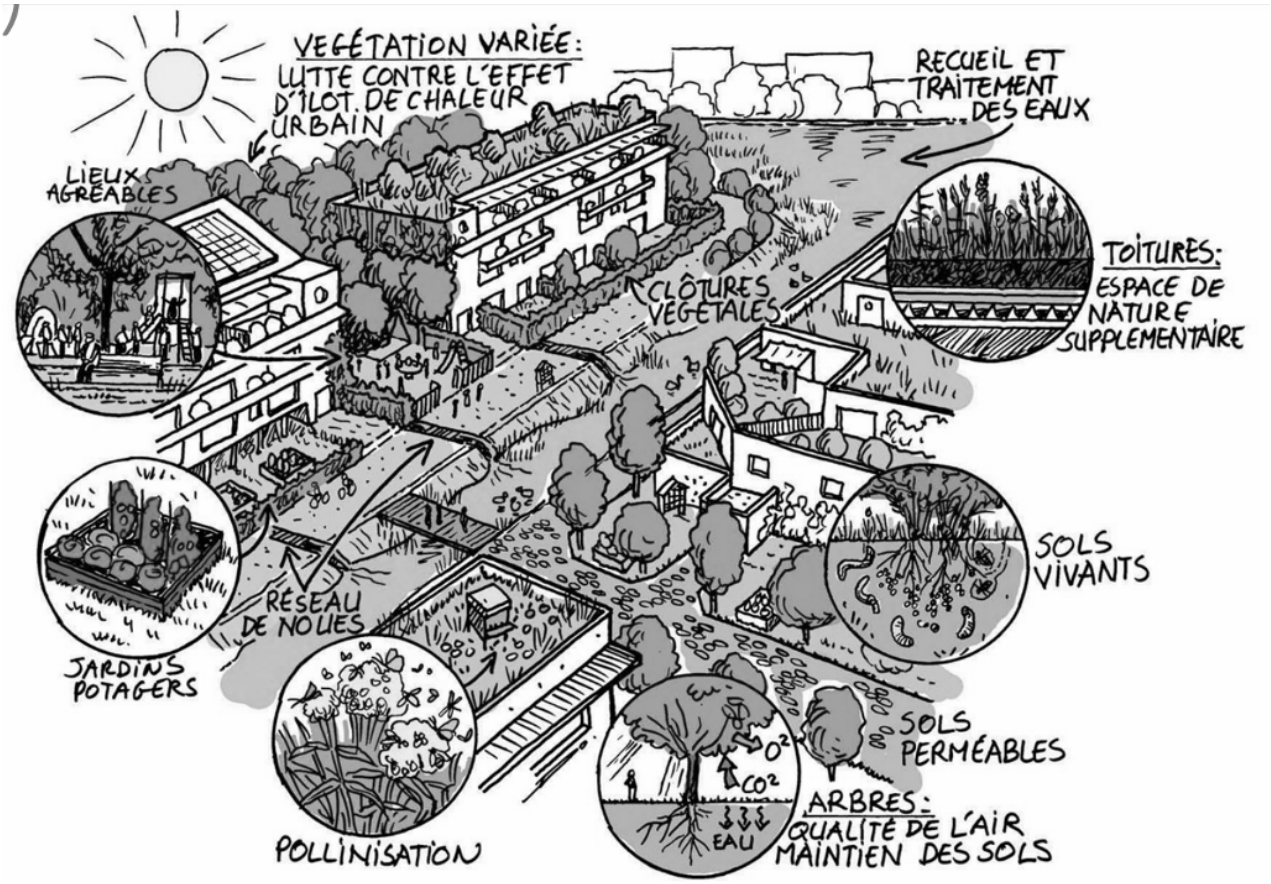
Q | Some architects and town planners reinvent the city, thinking it regenerative. What about you? How do you imagine the building of the future? The city of the future?

STUDENT WORKSHEETS (2/2)



STUDENT WORKSHEETS (1/2)

THE CITY OF THE FUTURE, A BIO-INSPIRED AND REGENERATIVE CITY



Q | Some architects and town planners reinvent the city, thinking it regenerative. What about you? How do you imagine the building of the future? The city of the future?

STUDENT WORKSHEETS (2/2)

THE CITY OF THE FUTURE, A BIO-INSPIRED, REGENERATIVE CITY

Q | Read this text. What do you think?

Rethinking the city inspired by nature (by NOBATEK/INEF4)

Tomorrow, buildings, neighbourhoods and cities will be designed or renovated to integrate into their environment, optimising their resources, reducing their energy consumption and waste production... Incredible source of inspiration, nature leads us to imagine a city with a positive impact on the environment, producing its own materials, energy, water... Many solutions already exist to move towards this model of "regenerative" city.

Nature as an example for the city

More and more architects and town planners are no longer looking at nature as a space to be protected but as a model to be followed. In a process of bio-inspiration, they see the city as an ecosystem capable of bringing together biodiversity and the human way of life. They are inspired by the life cycle of living beings and imagine a "regenerative" city, a city that reduces the pressure it exerts on the environment to the point of positively transforming its impact by providing some of its own services such as the production of food, energy...

Towards "regenerative" town planning

Inspired by the strategies of living beings, the city of tomorrow will integrate ecosystem services provided by nature today: purifying air and water, providing food and fresh water, generating energy, producing its materials... Moving towards the model of the generative city thus implies improving the energy performance of buildings, increasing the solidity of structures or the quality of materials and making them easily modifiable and dismountable, producing renewable energy, treating and recycling waste as much as possible: water, organic matter, building materials. The city of tomorrow will also focus on local food with urban agriculture, on soft traffic and on bio-sourced materials. It will study the morphology of buildings to optimise solar gain such as plants and natural ventilation such as termite mounds. Its footprint will be restricted to promote the penetration of rainwater into the soil, to feed the water tables, to collect rainwater on roofs and treat it with phyto-purification... The city of tomorrow will also be greener. Vegetation refreshes the atmosphere, reduces urban heat islands, creates a greater variety of flora and fauna, allows the soil to be more permeable, resulting in less drought and flooding.

The key words of the sustainable city: water, vegetation, transport, building, circular economy, energy...

The sustainable city: a response to climate change

Building the "regenerative" city would go as far as mitigating the very causes of climate change and biodiversity loss, while making the built environment more adaptable to climate change. In a bio-inspired city, nature is less stressed and regenerates better: healthier ecosystems provide humans with services that cannot be provided by the built environment and are more adaptable to climate change. In the same way, the city imitates nature and develops its capacity to adapt to change. It becomes more resilient.

[E] Biomimicry: methodology

E1-E2. In the shoes of a biomimetician

SUMMARY

For this activity, the objective is to put oneself in the shoes of a biomimetician and move forward, step by step, to solve a problem by taking inspiration from nature:
1. Analysing the problem
2. Express in simple words
3. Looking for a model in nature
4. To identify the reasons why this model addresses the problem
5. Transpose

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

LEARNING OBJECTIVES

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

ACTIVITY SEQUENCE

. study an example of biomimicry, step by step (the shinkansen)
. Do the same for one or two other examples (problem of swimming faster or making plywood without toxic glue).
. Ensuring the ethical and sustainable nature of the invention

AGE RANGE

All ages

DURATION

Preparation :
30 min
ACTIVITY(IES) :
45 min

SUBJECT(S)

Understanding the biomimetician's approach, from observation to transposition

KEYWORDS

Biomimetician
Methods
Multidisciplinarity
Transposition

BACKGROUND for teachers (1/2)

1st approach to biomimicry

. at the interface between biology and engineering sciences
. marvels at the beauty, diversity and genius of nature
. is aware of the finiteness of the Earth, the planetary limits and the fragile balance of life

At the interface between biology and engineering sciences, the biomimetician :

- **analyses the problem, the challenge to be solved:**
  - ex 1: how to ensure that high-speed trains can pass through a large number of tunnels without hindrance.
  - ex2: swim faster
  - ex3: making plywood with a less toxic glue
- **he expresses it with simple words, detaching himself from the context**
  - ex1 : facilitate the transition from one medium to a denser medium at high speed
  - ex2 : slip in the water
  - ex3 : finding a way to make particles adhere to each other
- **seeks in nature the model, form, function, organisation from which it can draw inspiration**
  - ex1 : the kingfisher - air > water
  - ex2 : Shark
  - ex3 : the mussel
- **identify the reasons for the model's performance**
  - ex1 : the kingfisher dives into the water (denser than air) at high speed, without injury and without splashing so as not to frighten its prey (the fish). The shape of its beak and head optimises its passage through the water.
  - ex2 : The shark's solid skin is made up of superimposed tooth-like scales covered with tiny grooves. This structure allows the water to be channelled so that it slides as close as possible to the body, limiting friction. The shark can swim faster and with less effort.
  - ex3 : The mussel clings to a support to avoid being swept away by the waves. To fix itself firmly, it produces small adhesive filaments: the byssus. They stick so well that they even withstand storms!

- **it transposes the strategy of the living to solve its problem (form, function, organisation)**
  - ex1 : design of the train profile imitating the beak and head of the kingfisher
  - ex2 : micrometric structure of the material in grooves, facilitating the circulation of fluids, limiting friction (varnish to be applied on boats or aeroplanes to consume less energy)

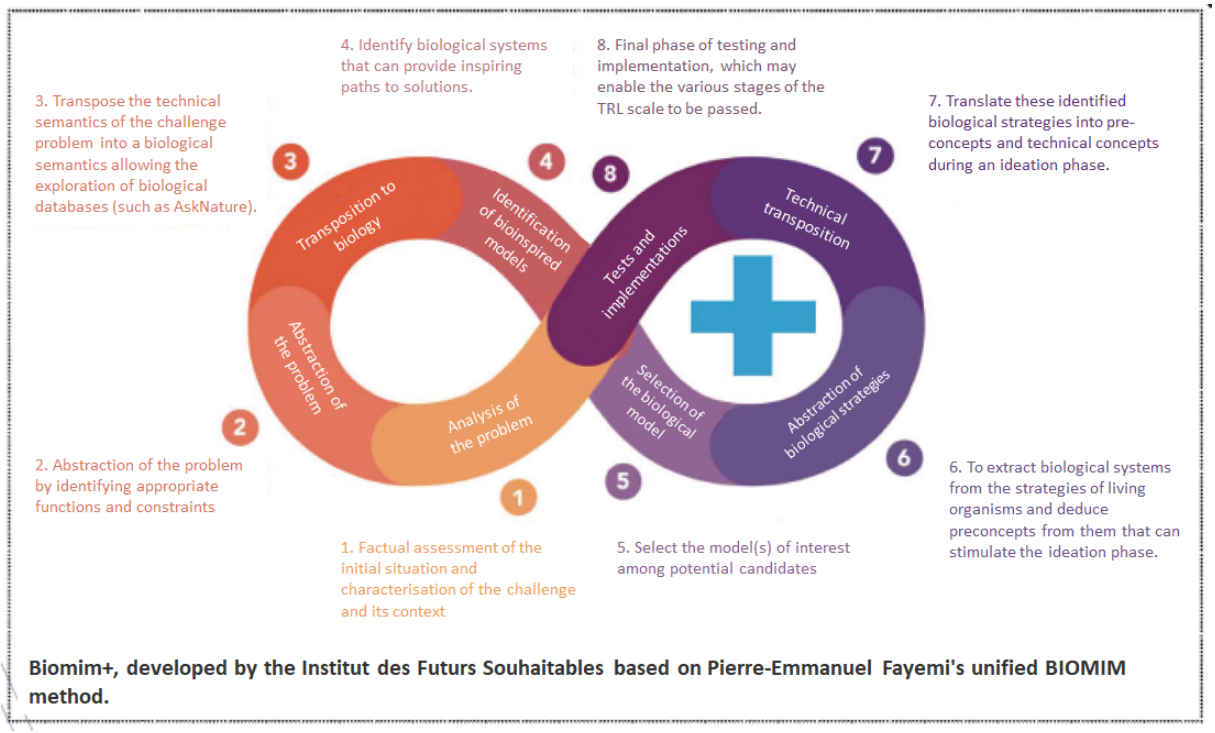
Becoming a biomimetician means wanting to solve a question or respond to a need in a certain way:
1/ that is compatible with the Earth and the rest of the living world.
2/ which is inspired by the living, both in its technical process and above all in its functioning.

But how do you know if the technique, object or organisation you invent is respectful of the living?
By ticking as many boxes as possible in this little memo:
- ☐ **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**
- ☐ **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**
- ☐ **use just the right resources**

BACKGROUND for teachers (2/2)

For the most expert : Biomimetic eco-design method

Biomim+, developed by the Institut des Futurs Souhaitables based on Pierre-Emmanuel Fayemi's unified BIOMIM method.



Biomim+, developed by the Institut des Futurs Souhaitables based on Pierre-Emmanuel Fayemi's unified BIOMIM method.

1. Factual assessment of the initial situation and characterisation of the challenge and its context
2. Abstraction of the problem by identifying appropriate functions and constraints
3. Transpose the functional "business" semantics of the challenge problem into a biological semantics allowing the exploration of biological databases.
4. To identify biological systems that can provide inspiring pathways to solutions.
5. Select the model(s) of interest among potential candidates
6. To extract from biological systems strategies of the living or to deduce pre-concepts capable of stimulating the ideation phase.
7. Translate these identified biological strategies into pre-concepts and "business" concepts during an ideation phase
8. Final phase of testing and implementation, enabling the various stages of the TRL (Technology readiness level) to be passed, if necessary.

ACTIVITY DETAILS for teachers

E1. In the shoes of a biomimetician: step by step

For this activity, the objective is to put oneself in the shoes of a biomimetician and move forward, step by step, to solve a problem by taking inspiration from nature:

1. Analysing the problem
2. Express in simple words
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4. To identify the reasons why this model addresses the problem
5. Transpose

E1. In the shoes of a biomimetician: ethics & sustainibility

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

TOOLS & MATERIALS

Student Worksheets or PPT presentation

E1. In the shoes of a biomimetician: step by step

STUDENT WORKSHEETS

. a biomimetician works at the interface between biology and engineering sciences
. marvels at the beauty, diversity and genius of nature
. is aware of the finiteness of the Earth, the planetary limits and the fragile balance of life

Q | Read this example : The biomimetician :

1. **analyses the problem, the challenge to be solved:**

how to ensure that high-speed trains can pass through a large number of tunnels without hindrance.

2. **he expresses it with simple words, detaching himself from the context**

facilitate the transition from one medium to a denser medium at high speed

3. **seeks in nature the model, form, function, organisation from which it can draw inspiration**

the kingfisher - air > water

4. **identify the reasons for the model's performance**

the kingfisher dives into the water (denser than air) at high speed, without injury and without splashing so as not to frighten its prey (the fish). The shape of its beak and head optimises its passage through the water.

5. **it transposes the strategy of the living to solve its problem (form, function, organisation)**

design of the train profile imitating the beak and head of the kingfisher

Q | Try to state the same 5 steps to solve the problem: "how to swim faster"

Q | Try to state the same 5 steps to solve the problem: "making plywood with a less toxic glue"

E2. In the shoes of a biomimetician: ethics & sustainability

STUDENT WORKSHEETS

. Becoming a biomimetician means wanting to solve a question or respond to a need in a certain way:
1/ that is compatible with the Earth and the rest of the living world.
2/ which is inspired by the living, both in its technical process and above all in its functioning.

But how do you know if the technique, object or organisation you invent is respectful of the living?
By ticking as many boxes as possible in this little memo:

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