BIOTRAIL: ideas from nature

BIOTRAIL is a forest walk along the Saimaa shore near LUT University with the following information provided on the banners along the trail to inspire students' creativity:
(i) famous hook-and-loop fastener inspired by burdock in a dog's fur; (ii) beehives-inspired architecture; (iii) smart zero energy climate control systems based on the pinecone ability to open and close in response to humidity; (iv) bird-collision-protective glass based on the spiders' idea of UV-reflective silk; (v) quieter wind turbines inspired by the owl silent fly; (vi) painless medical needles based on the mosquito secrets; (vii) more energy efficient and brighter monitors based inspired by the iridescent male-duck head (structural coloration); (viii) combining elderly homes with kindergartens inspired by the symbiosis in lichens; (ix) more efficient solar panels inspired by leaves; and (x) shock-absorption systems based on the woodpecker head structures

Topic: **Environment and nature** (UN SDG 11 & 13)

Setting: Safe forest site with convenient path

Group size: 15 people max

Age group: 5+

Timeframe: 2 hours (incl. walking time between stops)

Special technologies and materials

- Banners placed on suitable parts of the trail and describing information about natural phenomena and technological and societal innovations interlinked in several cases of successful nature inspiration
- Smartphones with internet access (for scanning QR codes for videos and additional information; QR codes are provided on the banners)
- Comfortable tracking clothes and shoes

Learning goals:
Students discovered secret know-hows of Nature and found out how scientists and engineers have used them to solve real-world problems or come up with inventions

Source: This action was carried out by LUT (Finland); website: https://biotrail.org/

BIOTRAIL
Ideas from nature

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 770063

Preparation

To prepare the action, you need to prepare several info stands (banners), each describing some natural phenomenon that has been or can be a prototype for an innovation. The story of each banner should continue with a video presenting applications of these ideas into technology or science. You can place QR codes with access to each video on respective banner. Also, you can prepare question to the audience for each banner, e.g. How do you think what this natural phenomenon could potentially inspire? Therefore, the student can think and discuss before they are provided the answer by the facilitator.

Photo: Banner

Introduction (5 min)

It took 3.8 billion years of evolution for living organisms around us to become as they are. On that long way, they have been solving crucial issues of life and death, reproduction, adaptation and occupying new niches. Survived only successful ones.

Biomimetics (or biomimicry) is about nature inspired design, the transfer of ideas from biology to technology.

Question to the audience: What examples of biomimetics do you know?

Stop 1: Burdock to Velcro (5-7 min)

It is recommended to ask learners first what they think the object (burdock in this case) can be an inspiration for.

Burdock was an inspiration for famous Velcro. Once the dog of George de Mestral (which can be represented by a toy dog in instructor's hand) has caught some burdock seeds into its fur, a representation of how he has come up with an idea of the hook&loop fastener. More information about hooks and loops of burdock is given on the banner. Learners can also take time to discuss the case.


Photo: Burdock case

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Stop 2: Beehives-inspired architecture (5-7 minutes)

Ability of social animals to decentralized self-organizing behavior is known as swarm intelligence. Following simple interaction rules individual agents form complex intelligent behavior on the population level. Bees foraging behavior, first documented by Aristotle, is one of the examples of swarm intelligence.

Inspiration by bees lie in a hexagonal organization of their nectar storage that they create together. Such geometry provides a very efficient use of space. Architects around the world adopt this principal for their construction projects. Examples include the housing project in Israel, the apartment complex on Bahamas, and Chinese aquatic center.

Photo: Beehives-inspired architecture. Source: Archdaily

Stop 3: Pinecone climate control systems (5-7 minutes)

Questions to the audience: Do you see a pinecone around? Is it close or open? Why?

Scales of pinecones are self-opening when it is dry and closing otherwise. The cells are dead, so the mechanism is passive, no energy is needed to perform it, and the trick is in its structure. The scale functions as a bilayer with different orientation of cellulose microfibrils.

In sclerids (see the picture), the microfibrils are wound around the cell (high winding angle) allowing it to elongate when damp. Fibres have the microfibrils orientated along the cell (low winding angle) which resists elongation.

The ovuliferous scale therefore functions as a bilayer similar to a bimetallic strip, but responding to humidity instead of heat.

It can be used in architecture, e.g. for panels in building that can ensure climate control by keeping certain level of humidity in the room. Also, application in a textile design is possible – when it is humid, the fabric would get more "closed" and water-proof.

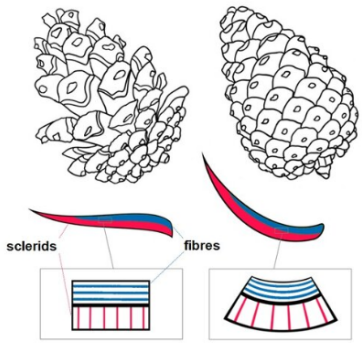

Photo: How pinecone opens. Source: biotrail.org

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Stop 4: Spider web for helping birds (5-7 minutes)

Questions to the audience: How tough should spider silk be to catch and keep preys? How do spiders avoid bird collision?

Spider silk is known to be as strong as steel. Its tensile strength is about 1,3 GPa (steel 0,5-2 GPa), while it is six times less dense than steel. If a spider made a silk strand around the Earth, it would weight just about 500 grams. In addition, spider silk is very stretchy; some types of it can be stretched five times of their relaxed length without breaking. Due to the combination of strength and ductility, spider silks are very tough and equivalent to synthetic fibers like Kevlar.

Orb-web spiders need to locate their webs in open space ensuring high flow of preys. But it also creates a risk of bird collision. To avoid that spiders invented UV-reflective silk, so the spider web becomes visible for birds (as well as butterflies and honeybees), but stays transparent for flies and other preys.

Glass manufacturers used this feature to create a bird protection glass – bird see it as an obstacle and do not end up colliding the glass but for human eye this glass is transparent (so as spider web).

Also, textile manufacturers actually learned some tricks from spiders. They recognize the potential of spider silk to replace some synthetic materials, like nylon. Adidas is about to launch a range of running shoes made of artificial spider silk and the NorthFace recently made its limited edition of moon parka made of the same material. The material is strong but light, stretchy and long lasting.

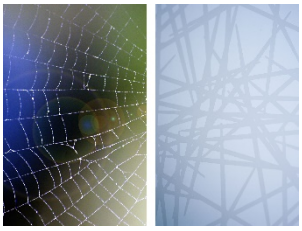

Photo: Bird protection glass. Source: Materialdistrict

Stop 5: Owl-inspired wind turbines (5-7 minutes)

Questions to the audience: Have you seen an owl? Have you ever heard its fly? Why is it so silent?

Owls hunt at night time. Being quiet allows them to approach preys unnoticeable and is crucial for successful hunting. Generally, the noise of bird flight comes from turbulences of the air rushing through the clapping wings. Owls have different feather design to reduce the sound.

The front feather of the wing has hooked structures breaking up the air flow. Moreover, each feather is fringed along the trailing edge, further damping the noise. This allows wings silently slide through the air.

In 2016, it inspired Siemens engineers to design wind turbine's blades that are cerated as owl wing's trailing edge fringe.

Photo: Owl-inspired low noise blades. Source: Power engineering

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Stop 6: Mosquito for surgery (5-7 minutes)

Questions to the audience: Is it itchy after mosquitos bite you? But is the bite itself painful? Why not?

Mosquito's mouth or proboscis is not just one needle. Actually, it contains six needles or stylets, each performing different functions while biting. Mosquito penetrates into the skin not by piercing it, but by sawing it. First, it uses two outer stylets, maxillae, with sharp teeth to saw through the skin. Then holding the tissue apart with mandibles, it pierces a vessel and sucks the blood out of it with the feeding needle. The last needle, hypopharynx, injects anti-coagulant into our blood to keep it flowing.

Researchers studied mosquito's proboscis (Kong & Wu, 2010) found out that the two maxillas work as variable frequency microsaw. This enables mosquito to penetrate the human skin with very low force (average of 16.5 μN).

Japanese scientists proposed mosquito principle for sharp and jagged needles for using in low-invasive medicine. It consists of central straight needle and two cutter jagged needles. The effectiveness of these needles was confirmed.

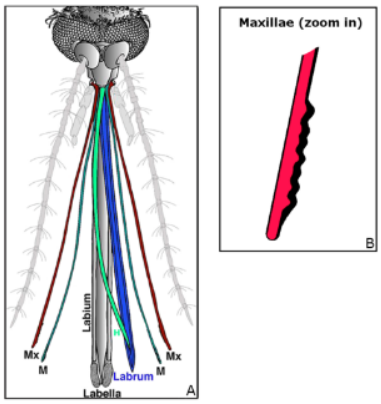

Photo: Mosquito's mouth. Source: biotrail.org

Stop 7: Male duck head monitor (5-7 minutes)

Questions: Have you noticed magnificent green-blue color of a male duck head? What is its secret?

Usually different colors appear from pigments that reflect light waves of particular length (color) and absorb all the others. However, colors can be produced from such optical phenomena as light interference and diffraction. A simple example is thin film interference that can be observed in soap bubbles. Resulting color is iridescent; it depends on the thickness and refractive index of the film, as well as the angle of light falling or observing.

Apart from thin films, the natural world uses various mechanisms to play with light, like diffraction gratings, selective mirrors, photonic crystals, crystal fibres and deformed matrices.

It is applied in practice in displays for smartphones and e-books. They utilise interference and diffraction of light to create actual colors. Main advantage of them is that they are visible in the sunlight.

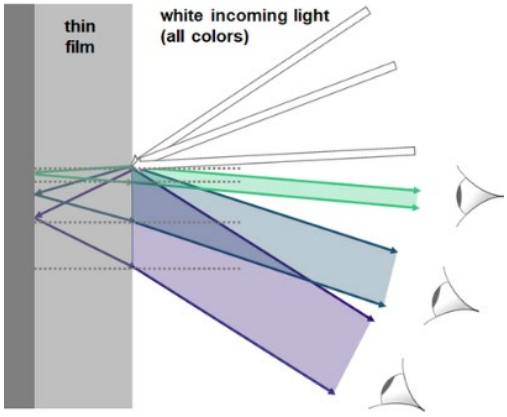

Photo: Diffraction of light. Source: biotrail.org

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Stop 8: Symbiosis (5-7 minutes)

Questions (If you do not have lichens, you can use example available in your area): Can you see some dry grayish plants on trees and stones around you? They are not plants…

It is lichens. Lichens are algae and fungi living together in symbiotic relationship and forming one composite organism. Fungi provide support for algae cells and protect them from drying out. Whereas algae photosynthesize and feed fungi. Together they obtain new properties as a living organism and occupy new niches, like surfaces of stones and trees.

Another example of symbiosis that grows in Finland is heath spotted orchid. When it is a small underground bulb, it only can grow in a symbiosis with fungi. However, when it becomes a mature flower with green photosynthesizing parts, it feeds the fungi back. Symbiotic relationships are also common among animals.

One of the examples of symbiosis is combining elderly homes with kindergartens. Elder people can socialize with children, which will make their time more interesting and less lonely. Children will benefit from socializing with “grandmas” and “grandpas”. It is a win-win situation.

Stop 9: Solar panels inspired by leaves (5-7 minutes)

Questions: Is it shady and cool in the forest even on a sunny day? Why?

Leaves evolved to sophisticated instruments of light capturing. Their disposition, called leaf mosaic, allows maximum exposure to direct sunlight with minimum loss of intervening space. Therefore, less light comes through tree crowns providing freshness in the shade of the forest.

Sunlight is used for photosynthesis taking place in tiny little green organelles called chloroplasts. They convert light, water and CO2 into sugars and, thus, are an important element of the plants feeding system.

Worldwide fight with CO2 emissions incentivizes scientists to develop new ways of carbon capture. The ability of trees and other green plants to absorb CO2 has been attracting researchers’ attention in search for the solution. Ideas of artificial photosynthesis emerge, but their implementation is still on a conceptual stage.

Working on polymers for solar panel cells, scientists from Princeton University noticed folds and wrinkles on the leaves that increase internal light scattering and introduced this principal into their solar cells. Their invention is 50% more efficient in electricity production than solar cell with a flat surface.

Other scientists from UK noticed the advantage of the unfolding tree leaves that they ultimately used in designing constructions for outer space where the structure should occupy as small amount of space in the rocket as possible but display a large surface when deployed.

Photo: Unfolding leaf and inspired construction. Source: SlideShare

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Stop 10: Woodpecker introduces shock-absorption (5-7 minutes)

Questions: Have you heard a woodpecker drumming a tree? Can you estimate the frequency?

Woodpeckers drum hard wooden surface of trees with average frequency of 20 Hz (20 times per second). Nature equipped their head with a shock absorbing system to avoid brain damage.

- Comparing to other birds woodpeckers have less space between the skull and the brain.
- Special spongy bone at the frontal part of the skull damps the stress force.
- So called hyoid bone that exceeds into tongue acts as a belt fastening the skull and redirecting the stress force into muscles.
- The asymmetric structure of the beak (the upper part is longer) further reduces the impact of drumming on the head.

Researchers from University of California studied woodpecker's head for developing a shock-absorptive system for micromachinery. Micromachines size is between 100 nano m to 100 micro m. For example, it can be an accelerometer that triggers air bag once a car stops suddenly.

So the researchers did a tomography of woodpecker's head and further studied it with a mechanical vibration model. As a result, they came up with a design for shock-absorbing system that contained analogies to woodpecker head, such as spongy and hyoid bones. New design was tested and shown less than 1% of failure rate compared to the conventional designs.

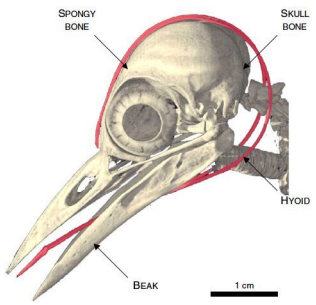

Photo: Woodpecker's skull. Source: JVEJournals

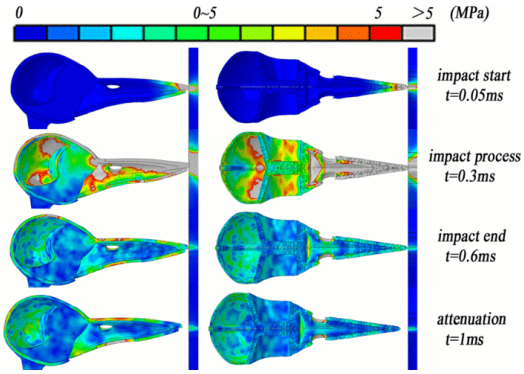

Photo: Impact response of woodpecker's head. Source: AIP

Conclusion (3 min)

Researchers from Stanford University conclude that evolution is not an inventor; it is just a tinker playing with what is already there and trying to come up with something better. It can be illustrated with an example of a finger bend system. Evolutionary, there was no need to animals to bend their fingers separately and there was one motor system that was receiving signals from brain to bend all fingers together. Later, this need appeared (for humans and apes). Instead of creating a completely new motor system, evolution decided to introduce a new one on the top of existing one: when you want to bend one finger the brain sends a signal to the first system to bend all fingers and immediately - to the second system to unbend other four fingers. **So, do not copy from the nature but be inspired by it and invent naturally!**

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