Technical Sciences
Academy of Romania
www.jesi.astr.ro

Journal of Engineering Sciences and Innovation
Volume 10, Issue 3 / 2025, pp. 327 - 346
http://doi.org/10.56958/jesi.2025.10.3.327

H. Inter – and Transdisciplinarity in Science and Technology

Received ***25 Apryl 2025*** *Accepted* ***16 September 2025***
Received in revised form ***4 August 2025***

Bionics - an essential solution to harmonizing society with nature and a case study

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Abstract. The paper proposes, in a somewhat novel approach, the consideration of bionics as an essential solution for harmonizing nature with society. Current investigation methods allow for the first time in the history of society to identify the particularities of the solutions used by nature to ensure the functioning of the various systems that make up its composition. Thus, it was found that in nature there are solutions of very high complexity, resulting from a refinement that lasted in some cases even millions of years, but also with a very high efficiency compared to the systems imagined and used in human society. The paper presents for the first time the directions that should be used to identify from the perspective of bionics, in a much more efficient manner compared to other approaches, the natural solutions useful for harmonizing the relationship between society and nature, namely: movement, orientation, energy production, constructions, interaction with the environment, metamorphosis, adaptation to the environment, each having several sub-directions that allow highlighting the most important natural solutions useful for solving the main problems of today's society. At the end of the paper, a case study is presented regarding a wasp mini-nest, which is described in detail and, for comparison, a form of yurt used by humans is presented, with a shape very similar to that of the described mini-nest.
Keywords: bionics, movement, orientation, constructions, case study.

1. Introduction

Bionics is the science that studies nature in order to identify useful solutions in solving technical problems of human society and even its improvement. In the first

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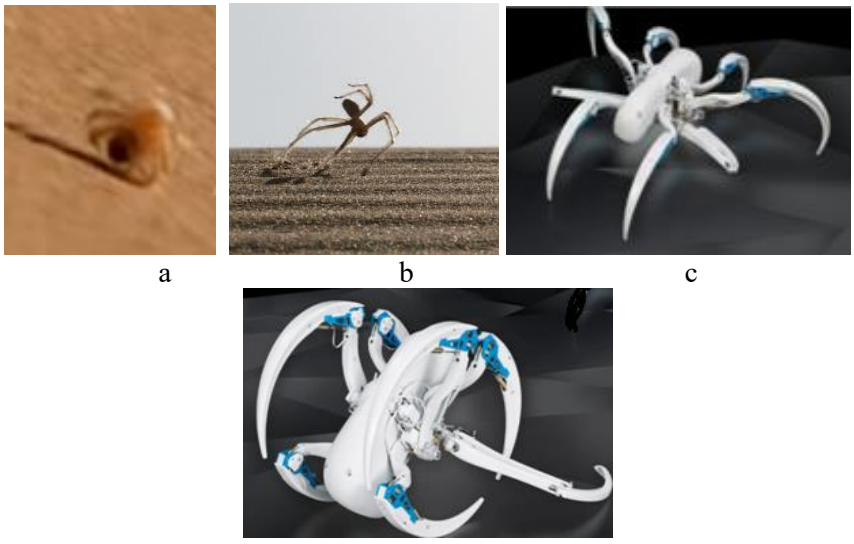
stage of the development of society from antiquity to the first industrial revolution - the end of the 18th century, which coincides with the invention of the steam engine, the discrepancies between the functioning of nature and society were reduced. However, after the onset of industrialization, a process began through which the achievements of society entered into an increasingly radical conflict with nature, a process that continues today. Furthermore, if this process continues, the imbalance between society and nature can lead to critical situations up to the level of even affecting the balance of nature, which is somewhat foreshadowed at present by the effects of global warming, certainly amplified by the activity of human society. As a result, a process of harmonizing technical solutions, but not only, with natural ones, must be started, in fact continued much more rapidly. This is only possible through detailed knowledge of natural solutions, which is, for the first time in human history, possible today with the appropriate means of investigation. This is where bionics comes in. But in order to transfer natural solutions into the activity of society, we must specify the main directions in which they should be implemented. Society was mainly modeled according to the types of interaction of man with the environment. The main interactions of man with the natural environment are materialized through: the use of the senses (sight, hearing, smell, taste, touch), movement and forced modification of the environment by addition (construction) or destruction (deforestation) so that the degree of relative comfort of man is as high as possible, that is, the greatest possible protection against hostile natural factors so that their control is also maximum. In order to identify natural solutions useful for harmonizing the relations between man-society and nature, we must specify the directions in which we must direct our attention. If we first consider the problem of movement, this implies movement and orientation. Movement means movement on the ground, underground, in water and in the air. In all these environments there are a lot of living things from which we can take over and adapt the solutions that they use in harmony with nature. Closely related to movement is orientation through appropriate means (vision but also other solutions such as echolocatiaon). The list continues with natural solutions for energy production, constructions, interactions with the environment, metamorphoses, adaptation to the environment, etc. Below are briefly presented some examples of the above and a case study for a mini-nest of a wasp family.

2. Movement

2.1. Movement on the ground (earth)

On the ground, movement can be done by crawling, rolling, rolling and jumping, jumping or walking. In nature, there are multiple variants for all these methods of movement. For crawling, the classic example is that of most snakes. Some hyper-redundant robots, including crawlers, have been built after this model. For movement by rolling, which requires less energy, there are fewer examples, but it is worth noting the wheel spider (*Carparachne aureoflava*), a hunting spider native

to the Namib Desert in South Africa, which escapes parasitic pompilid wasps by turning on its side and spinning on sand dunes at speeds of up to 44 rotations per second (15 km per hour: Fig. 1a[1]) - so in nature the wheel was invented long before humans. Another case is the acrobat spider (Cebrennus rechenbergi), which is found in the Erg Chebbi desert, on the edge of the Sahara. It can run like other spiders, but it can also move with a combined flight-jump and rolling sequence on the ground (Fig. 1b[2]). The reconfigurable robot *BionicWheelBot* was made by Festo (Fig. 1c and d[3]).



a b c d

Fig. 1. The wheel spider (a), the jumping spider (b)
and the reconfigurable robot BionicWheelBot (c and d).

The movement by jumping, already somewhat evoked, is specific to well-known creatures such as mammals (Kangaroo, but also types of antelopes and those related to them, which occasionally jump while running), birds, amphibians and a multitude of insects (for example, grasshoppers). Various robots have been created according to this movement model.
The movement by walking is characteristic of all creatures with two or four legs: birds, reptiles, mammals. This movement model is found in quadrupedal or bipedal robots (including humanoid robots).

2.2. Movement through water

Movement through water, in the aquatic environment, has led to the emergence of hydrodynamic forms and features that allow efficient movement in this environment. To date, there are few achievements inspired by hydrodynamic forms, the classic example being the submarine. The relative movement between the skin layers that allow the dolphin a much higher speed than in the absence of

this detail, as well as other solutions used by underwater creatures, are still awaiting their technical equivalents that, once achieved, will be able to revolutionize the movement of devices in liquid environments. Among the natural models that could inspire particularly interesting technical solutions are: the catfish, the sea turtle, some mammals, such as the seal, but also many other underwater or semi-aquatic creatures, which must be systematically analyzed and those of real interest identified. Below is an example of a car shape inspired by the shape of a fish (Fig. 2[4,5]).

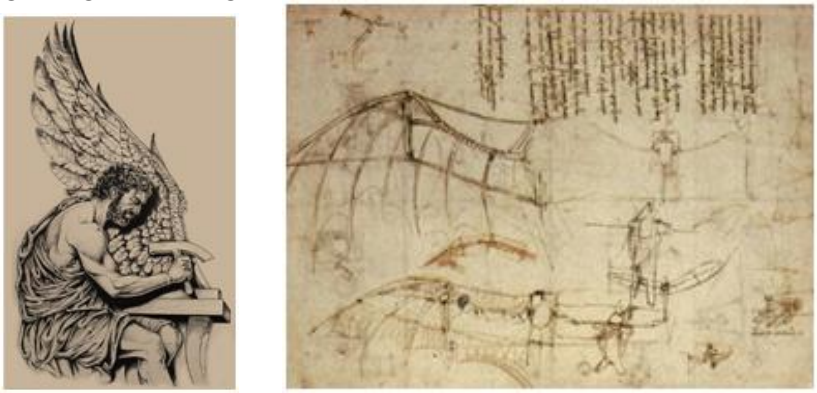
a b

Fig. 2. The natural model(a) and the resulting car design(b).

2.3. Movement through the air

The movement through the air has led to the most spectacular solutions, those found in birds, from aerodynamic shapes, practically ideal to detailed solutions such as wing tips and configurations. In this field, attempts to achieve technical solutions similar to natural ones date back to antiquity.

Birds have always been models for man's aspiration to fly and thus, since ancient times, attempts have been made to create wings similar to those of birds with which man could try to rise into the air. The classical attempts in antiquity by Daedalus, who made wings (Fig.3a[6]) for his son Icarus but also for himself, glued with wax, with which they even managed to fly (according to legend), and the wings imagined, during the Renaissance by Leonardo da Vinci (Fig.3b[7,8,9]).



a b

Fig. 3. Daedalus working on a wing (a) and Leonardo da Vinci's drawing of the wing imagined (b).

Even if currently the solutions applied to airplanes do not resemble much the wings of birds, there are attempts and surely in the future man will be able to fly, somewhat similar to birds, obviously with robotic wings, like those proposed by the FESTO company (Fig.4a[10, 11]). Such robotic birds can also be useful for studying birds themselves more closely, in their environment, an aspect not unimportant at all. On the other hand, many of the solutions found in birds have already been applied to the construction of airplanes, and it is enough to remember, in addition to the aerodynamic shape considered classic, the delta wing with variable geometry and the special configuration of the wing tips (winglet wing), a solution used not long ago (Fig.4b[12,13]).

a b

Fig. 4. FESTO robotic bird(a) and *winglet*-tipped airplane wing(b).

The *winglet* at the tip of an airplane's wing (similar to those on the wings of birds of prey, owls, condors) removes the large vortices caused by classic wingtips, which lead to high fuel consumption, and leads to the production of small vortices, thus considerably reducing drag and fuel consumption.

2.4. Moving through the basement

Some creatures have developed solutions that allow them to live underground and move around in it. Let's recall the case of the mole. Some of the solutions found for moving around underground are useful for building tunnels, but also for maintaining them as spaces that allow life.

3. Orientation

Orientation in nature has inspired and will inspire spectacular technical solutions. From the perspective of orientation, we consider the solutions through which different living things orient themselves in the environment in which they live for movement and interaction with other living things.

3.1. Orientation using sight-visual-optical sense

Most living things in nature have a visual system consisting of one or more eye-type sensors (an optical unit) that perceive light radiation from the white light spectrum reflected by the environment, and which are connected to the cerebral structure that processes the information and generates the visual image. In principle, there can be a single eye - a single visual unit, two eyes in most living things or even more eyes, as in the case of some crustaceans and insects. For example, the eye of a crab contains 3000 optical units, and that of a species of locust up to 30000 optical units (Fig. 5a[14]). A visual unit perceives the image from a certain area of the environment so that the visual area can be 180 degrees, or less, up to almost 360 degrees. The dragonfly has almost 360-degree vision, with a single blind spot behind it, so it can closely follow its prey without losing sight of it, while avoiding collisions with other insects in the swarm. The optical unit is specialized for the reception of a certain spectrum of light, which varies from one creature to another, as is visual acuity - vision at great distances. There is also the ability to see at night, or in low or very low light. Thus, eagles can see 4-5 times further than humans, have a visual field with their two eyes of 340 degrees (Fig. 5b[15]), can obtain much finer images (due to more cone cells on the retina) and can also see in ultraviolet light - they perceive ultraviolet radiation. For bionic engineers, the systematic study of the eyes is somewhat advanced, but the achievement of high-performance technical equivalences is still at the beginning. The systematic study of vision and the identification of its characteristics will undoubtedly lead to revolutionary technical solutions, which will allow the creation of optical devices that are much superior to those of today.

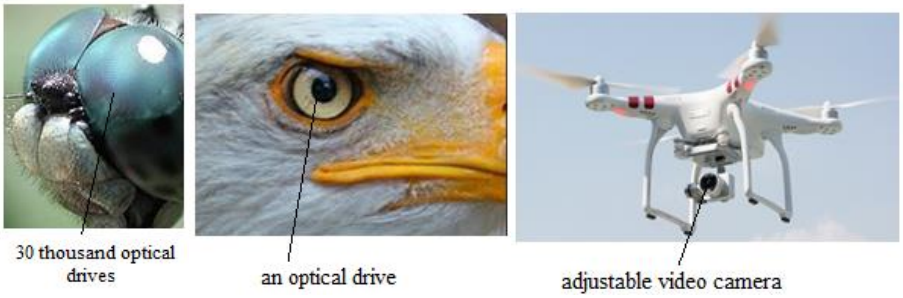


Fig.5. The multiple eye of the dragonfly (a), the eye of the eagle (b) and a drone with a steerable video camera (c).

Interesting peculiarities of vision are also found in underwater creatures, which see in liquid environments, with varying degrees of clarity. The technical solutions developed so far, besides the bionic eye[16], are limited to cameras, some of which are very high-performance, that equip drones (Fig.5c[17, 18]), airplanes and satellites. Using artificial intelligence, the conditions have been created for the received images to be processed and interpreted and based on them decisions to be

made, which is what humanoid robots do, but still at a simplistic level, which will certainly develop even faster in the coming period.

3.2. Ultrasonic orientation-echolocation

Ultrasonic orientation is found in air and water. In the air, the best-known creatures that use ultrasound are bats[19, 20]. They have a pharynx with strong muscles that allow a very high tension of the vocal cords, which are thin and tough. This results in high-frequency vibrations of up to 70,000 Hz, which cannot be heard by humans (the human auditory spectrum is between 16 and 20,000 Hz), but can be perceived by the bat's ears. When detecting a possible prey, an insect, the number of signals emitted reaches 250 per second and thus a real-time tracking of the prey is achieved, which has no escape (a bat can swallow up to 175 insects in 15 minutes, i.e. one every 5 seconds). The bat can reach the incredible speed of 96 km per hour. After this natural detection solution, *radar* was invented relatively recently (less than a hundred years ago). Current radars, which are based on electromagnetic waves and are useful over long distances, have proven ineffective over short distances, where the bat is particularly efficient, and as a result a detection system based on the natural solution must be developed. Recently, the bionic bat[21] has been created. In water, ultrasound is used for orientation by dolphins (considered very intelligent creatures), but also other underwater creatures. As a counterpart of radar for the aquatic environment, *sonar* was created, with which distances to various obstacles in the water, the underwater environment, can be measured.

3.3. Orientation by thermal radiation

Many creatures sense thermal radiation - infrared radiation transmitted by warm bodies. They can orient themselves by this radiation, as is the case with some species of snakes, in addition to the fact that their eyes, in many species, see in infrared - they perceive thermal radiation. The reptile has two holes on either side of its head, which are practically infrared ray detectors[22]. Obviously there are also creatures that do not have sight but can sense thermal radiation, such as the approach of a creature with a higher temperature than the environment.

3.4. Orientation by light radiation

In many plants, which do not have specialized organs for receiving white light, the ability to orient towards the main light source can be identified, the *sunflower* being a significant example. How plants perceive light and how they control their orientation towards light is still poorly understood. It is possible that a process at the molecular level - photosensitive molecules - generates an orientation impulse towards the main light source.

3.5. Orientation by smell according to olfactory sources

Smell is the sense by which the smell sensor identifies cells that have a specific odor and can be guided by the trail left by these cells in the environment, and the paths of these cells can be recognized over tens, hundreds, and even thousands of meters. The sense of smell in some predators is very fine and can detect the presence of the source of the odor at very long distances, even on the order of kilometers. For example, the polar bear, which lives in an extreme area, can smell prey even 30 km away and detect seals almost 1.6 km away and buried under 1 m of snow. Another example is the male silk moth that can discover a female by smell, up to 11 km away, selecting and detecting the substance called bombicol[22]. Maximum performances in the case of smell are achieved when a few molecules, or even the existence of a single molecule of a certain substance, are detected in an enclosure. The importance of this research also results from the awarding of the Nobel Prize in 2004 to scientists Linda B. Buck and Richard Axel for: The discovery of odorant receptors and the organization of the olfactory system[23]. However, the creation of an artificial odor sensor is still in its infancy, but future results will certainly be important.
A systematic research of all orientation solutions in nature will be able to identify other means, such as orientation according to the electromagnetic field lines of the terrestrial magnetic field or, why not, telepathic waves, some of which could have novel technical applications.

3.6. Orientation along the Earth's magnetic field lines

A classic example of orientation according to the lines of the Earth's magnetic field is that of migratory birds. They can move over very large distances, even from Antarctica to the Arctic and vice versa, as is the case of the *Arctic Chirchei - Sterna paradisaea* (a migration of over 70,000 km round trip[24]), living on a permanent day: six months of the northern polar day plus six months of the southern polar day - when the polar night comes the bird leaves for the pole where it is day. For orientation in this way, birds have tiny magnetite crystals in the muscles of the head or neck, which help them orient themselves according to the Earth's magnetic field and to position their flight direction when the sky is cloudy or raining and visibility is reduced. Even if they have a winding trajectory, following the coastline of the continents, the basic orientation is according to the Earth's magnetic field lines. The compass was the first instrument invented by humans for orientation along the lines of the Earth's magnetic field. Obviously, other devices can be imagined based on current knowledge, much superior to the period when the compass was invented.

3.7. Orientation by celestial bodies

It has already been proven that in the case of migratory birds, they orient themselves in certain phases of their journey by celestial bodies: the sun, the moon or the stars. The details of these orientation capabilities are still little known, but they have been successfully applied by humans for thousands of years.

4. Energy production

4.1. Mechanical energy

Nature is characterized by mechanical interactions. The use of mechanical energy is ubiquitous and ensures the performance of most activities in nature and in society. Among these, we have selected an extreme situation that refers to the *punching shrimp*. The impressive blow of the monk shrimp (*Stomatopod*) is due to a special feature - the crustacean has a "saddle" inside its limbs. The saddle-shaped structure is made up of two types of material, according to the study published in the journal *Science*: brittle bioceramics (similar to bones) and fibrous biopolymers. Ali Miserez, the leader of the study conducted by the Nanyang Technological University in Singapore, stated that "Ceramics can store energy if deformed, but it is so brittle that it would not be practical. But if compressed, it is very strong. It is stiffer than metal or polymer, so you can store a greater amount of energy than you could with other materials." The monk shrimp (Fig. 6[25]) typically grows to a length of 10 cm, but some specimens have been found as long as 38 cm. Its punch (the most powerful punch in the animal kingdom, in the direction of force F) can have a linear acceleration of 65 - 104 km/s. Experts estimate that humans could throw a ball into space if they had a similar ability.

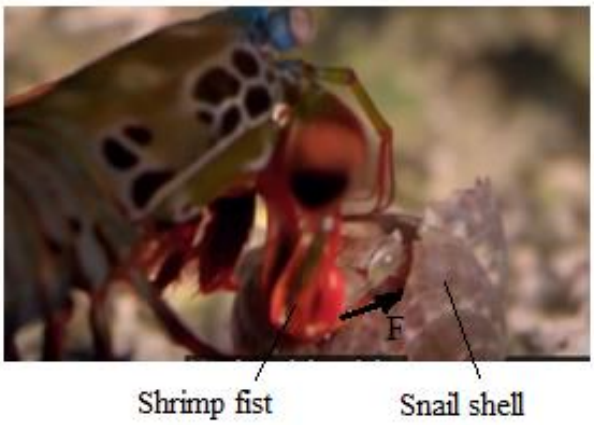


Fig. 6. The action of punching a snail by a mantis shrimp.
It is believed that this mechanism inside the powerful limbs of the mantis shrimp can be adapted in the field of microrobotics to create efficient energy springs.

4.2.Electrical energy

An example of an aquatic electricity generator is that of the electric eel (Electrophorus electricus)[26], which is equipped with three electrical organs: the main organ, the Hunter organ and the Sachs organ. The first two produce particularly powerful electrical discharges of up to 700 V, even 860 V. The Sachs organ produces weak impulses and is used in electrical probing of the environment and in communication. Here is a particularly interesting model of an electrical biogenerator for which a high-performance technical equivalent does not yet exist.

4.3. Radiant-light energy

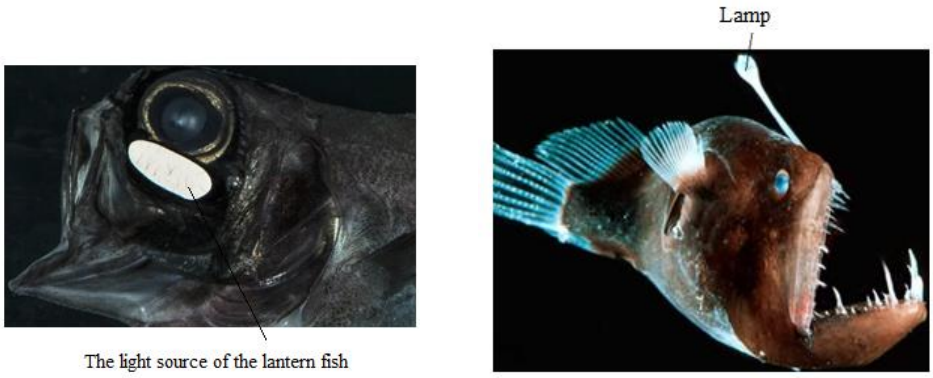
In addition to the classic example of the *firefly*, an insect found on the ground, in aquatic environments, a multitude of solutions can be identified in various living beings, a very small part of which have been used as models for the creation of bionic variants. Thus, the category of luminescent living beings[27] includes many species that live in deep-sea areas, but not only. An example is the jellyfish shown in Fig. 7[28]. Very important is that in many cases the efficiency of transforming chemical energy into light energy is even 98%[22], much higher than the efficiency of current solar panels which is somewhere around 20%.

Fig. 7. Transparent and luminescent jellyfis.

Another remarkable fact about this transparent and luminescent jellyfish is that it is practically immortal. When it ages, the cells in its body undergo a rejuvenation process, and the jellyfish thus reverts from the adult to the juvenile stage and resumes its life cycle.
Another example of the generation and use of light energy is found in the Lanternfish (Fig. 8a[29]), which have organs with luminous bacteria that they use to transmit light signals. These organs are called *photophores* and are found in several species, but the lanternfish seems to be the only creature that emits the

greatest amount of light. It uses these organs, which are located under the eyes, to distract predators or attract food with the help of light. At the same time, they also use light to communicate between fish of the same species, so that they can move in schools in the dark. The three photophores produce three types of light: red, orange and blue. While the blue light can be seen by most marine creatures, the red light is used to communicate during mating rituals, but it is not yet known what the orange light is used for. This creature decides when to "turn on" and "turn off" the light when it needs to. It can also emit light intermittently, like a traffic light. During the day, the lanternfish does not activate its light, so it tries to make itself invisible. Very interesting is that the intensity of the lanternfish's light source decreases as the brightness of the environment increases.

Another notable example is the *lampfish* (Fig. 8b[30]). The lampfish is about 23 centimeters in length. Its head is quite large, and its jaw is as large as its head. It has thin, recurved teeth to grip its prey. Its skin color turns red to black and it has a large number of narrow spines. The appendage is located near the snout and is known as the *illicium*. They have a hyoid barb that helps them to be easily distinguished from other species. They attract prey with their characteristic appendage, the lamp, after which they are named.



a b

Fig.8. Lanternfish(a) and lampfish(b).

Bioluminescence useful from a bionic perspective would be the creation of bioluminescent trees that could replace street lighting. It could also be used to create luminescent suits or tarpaulins that could be used to cover objects, etc.

4.4. Magnetic and electromagnetic energy

The magnetic energy that characterizes a magnetic field is characteristic of all living things through which biocurrents circulate, so they have a nervous system, which practically generates electromagnetic fields. There are also plants that create magnetic fields, which need to be studied much more deeply to find appropriate bionic solutions.

4.5. Thermal energy

All warm-blooded, *homeothermic* animals emit heat, with humans having a standard temperature of 37 degrees. Heat is produced as a result of chemical processes at the cellular level in the complex process of metabolism. There are also *poikilotherm* animals, in which the temperature varies depending on the temperature of the environment. The study of these animals could lead to the development of solutions for controlling temperature according to that of the external environment. A curiosity in this context is the Arctic squirrel that hibernates for eight months a year, at -3 degrees Celsius[31]. It is assumed that it prevents blood from freezing in the veins by removing particles on which water molecules could collect in the form of ice crystals. A closer study of this situation may lead to solutions for hibernation of the human body useful for long-term space travel.

4.6. Sonic energy

Living things emit sounds that are of great variety from the chirping of birds to the sounds produced by some whales, even considered a kind of songs, or other marine creatures. Sounds are produced by specialized organs, such as the vocal cords, and for propagation they need a supporting medium that can be gaseous, liquid or solid. From the perspective of bionics, the organs that produce sounds and their ability to generate sounds that can propagate over very long distances are of interest. Also of interest are the specialized organs that receive sounds, which in some cases can perceive infrasound, ultrasound, sounds with very low intensities or produced over very long distances. These organs are capable of detecting very weak vibrations of the gaseous or liquid environment. It was estimated at one time that a blue whale can generate a song that can be detected by another located at a distance of even 13,000 nautical miles[32]. The question is what intensity and how can such a sound be produced, especially in the aquatic environment, which propagates over a very long distance, and why is it not damped by the water after a relatively short distance, as would seem natural. It is believed that whales, especially solitary ones, can find themselves through these sounds. The careful study of the organs with which whales and other marine creatures produce sounds is of great interest in order to make some similar equipment more efficient than those currently known. It is of interest that the sounds are produced as vibrations of the air circulated through the lungs and a specific larynx, then transmitted to the water, even when the breathing holes are closed, which is not fully understood, without drowning occurring. It has also been found that at least two sounds can be emitted simultaneously. The techniques for emitting sounds by different creatures obviously must be connected with the science of *sonicity,* founded by the Romanian engineer Gogu Constantinescu.

4.7. Chemical energy

Chemical energy is omnipresent in nature. It is still a problem for society to find solutions to streamline the processes of transforming chemical energy into other forms of energy such as mechanical energy. To exemplify the importance and efficiency of the processes in which chemical energy intervenes, the example of photosynthesis is given in which light energy is transformed into chemical energy which is then the essential support of life. Moreover, in this case, oxygen is eliminated which is the gaseous element essential for maintaining life, the activity of most organisms on earth. The solutions currently used for transforming light energy into chemical energy still require major improvements, which will probably be achieved in the coming years. Obviously, it is desirable through bionics to reach a process similar to that of photosynthesis which would end, for example, with obtaining electrical energy, which is currently obtained with photovoltaic panels but at a too low efficiency, which would then be used on a large scale and represent the efficient solution for ensuring the functioning of society.

5. Interactions in nature

There are a multitude of interactions between living things, between plants, even plants and insects, which occur especially in the struggle for survival, for the acquisition of food. A systematization of these interactions from the perspective of bionics has not been achieved to date. And in this paper we will only present a single case, somewhat more special, namely that of the *archer fish*. This fish, being underwater, can observe an insect at a certain height and can project a jet of water in its direction, which, when hit, will fall near the fish that will swallow it. The curiosity in this case lies in the ability of the fish to correctly direct the water jet, taking into account the refraction of light when passing between the aquatic and gaseous medium (Fig.9[33]) and the Plateau–Rayleigh instability (the fish has a special way of spitting, to ensure that the back of the jet moves faster than the beginning and in this way, the jet is compressed into a smaller space, and its front part widens, an effect called the Plateau–Rayleigh instability, so that the fish hits with a force 5 times greater than the muscle of a vertebrate can generate), being among the most accurate marksmen, if not the most precise, even taking into account the gravitational attraction that curves the water jet. The fish estimates in a tenth of a second where the prey will fall in order to swallow it.

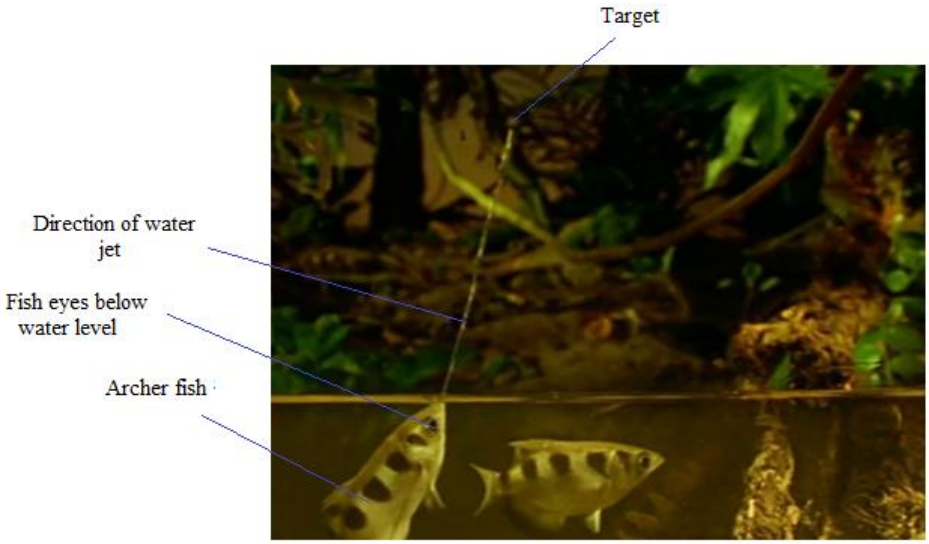


Fig. 9. Archer Fish in action.

Another peculiarity of archerfish is their significant ability to recognize human faces[34], which has recently been found, even though they lack the specialized part of their brain for this, present in creatures considered much more intelligent, such as monkeys.

6. Buildings

Practically all living things offer us models for construction. Certainly the most interesting are bird nests. Some of these are particularly complex and extremely resistant, which is why they have been used as models for various constructions, such as the *Bird's Nest* stadium, built for the Beijing Olympics (Fig. 10[35]).

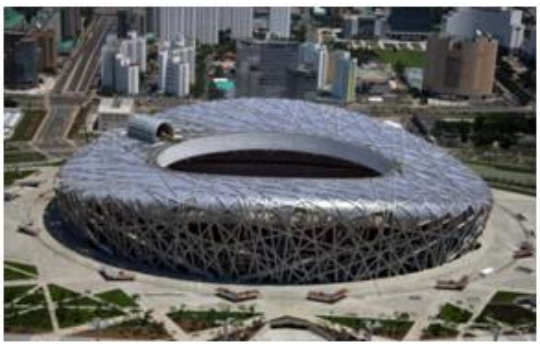


Fig.10. Bird's nest shaped stadium.

The beaver is a famous builder. It creates real ecological dams and underwater structures where it lives, controlling the circulation of water and humidity by ensuring an adequate air circuit. A careful study of its construction skills can lead to the identification of useful engineering solutions.
Insects make amazing constructions both in size, such as termite mounds, and in detail, such as the hexagonal prismatic boxes of bees and wasps. Wasps also make nests of special structures and shapes, as will be seen in the case study presented in the paper.
Many solutions found in plants can be and some have already been used, especially in architecture, in the design of the shape of buildings, but also in interior structures and equipment (however, the installations through which various fluids circulate are still far from the systems through which plant sap circulates). Obviously, the tallest buildings today, even the tallest over 800 meters (the *Burj Khalifa Tower* in Dubai), could not have been built if it had not been well known how some plants, from the fragile wheat stalk to the massive giant *Sequoia* trees, resist natural hazards such as winds, some very intense, especially with increasing height, and various weather conditions (rainstorms, snowstorms, etc.). An example of a bionic solution inspired by plants is shown in Fig. 11[36].

Fig. 11. Construction inspired by the fruit of a plant.

Symmetrical forms and arrangements according to perfect geometric shapes, whether flat or spatial, in nature are of enormous diversity, of which only a few have been used as models for various constructions, but the tendency is for the use of these models to expand. Obviously, *Bionics* is also closely related to *Sustainable Development* and can offer a clear perspective for the overall reconfiguration of society and ultimately the planet towards a new natural reality (Fig.12), friendlier and more favorable to constructive human activities

Fig. 12. Plant-inspired constructions.

An ingenious solution for temporary construction for, we can say, emergency situations are the rafts made by fire ants in Australia, from their bodies, to cross flooded areas (Fig. 13). After crossing, they are attached to a stem on which the swarm will move to a safe area[37].

Fig. 13. The raft built by fire ants (a) and mooring to a stem (b).

7. Metamorphosis

Metamorphosis according to the definition useful from the perspective of this study is: *the totality of biological transformations that some lower creatures undergo during their development from hatching from the egg to the adult phase*. As an example, the metamorphosis encountered in butterflies is given. Thus, inside the protective cocoon, the remarkable process of metamorphosis takes place, through which the caterpillar undergoes a complete transformation, decomposing its body and reassembling it in the form of a butterfly[38]. This process from a bionic perspective is very important and little known. In the future, metamorphosis could have multiple applications in the transformation of some products into completely different ones.

8. Adaptation to the environment

By environmental adaptation we understand the ability of living things to adapt to the characteristics of the environment in which they find themselves at a given

time, the most spectacular examples being that of the chameleon, the octopus and the cuttlefish. However, there are many other examples of living things that could become very difficult to identify in the environment in which they live, both terrestrial and aquatic. Adaptation to the environment is primarily through color, then through body shape, etc. The mechanism by which a living thing adapts to the environment is little known, it is usually only observed, and as a result a great challenge for bionics. Once understood, this mechanism could have spectacular applications such as in aviation, where there are already some achievements, but also in submarines, in changing the color of clothing, etc. The explanation for the ability to change color, for example in a chameleon, would be a layer of skin cells that contain nanocrystals floating in the cytoplasm. These microscopic crystals are positioned at relatively equal distances from each other within the cell, and this distance influences the wavelength of light that the cell reflects. The command to change this distance is given according to external factors perceived, such as the sight of another chameleon.[39, 40, 41] However, certain details remain to be deciphered to fully clarify this color-changing process.

9. Case study: mini hornet's nest

This case study describes a less typical wasp mini-nest. Wasps generally build complex honeycomb-shaped nests or relatively large quasi-spherical domes for large wasp colonies. In this case, it is an inverted bell-shaped mini-nest for a small number of wasps, a mini-colony. The nest is fixed with its base to the eaves of the roof (Fig. 14a: the outer dome has a diameter of 55 mm, and the height including the access channel of the intermediate dome is 70 mm). The nest has three domes, with somewhat concentric walls, the median one continuing with an access channel (Fig.14b: the interstice between the domes is 3mm and the access channel has a diameter of 10mm and a length of 20mm). In the nest, at the base, there is a single layer of alveoli in the form of hexagonal prisms with a 3mm laura, for a small number of larvae, probably 10 (Fig.14c).

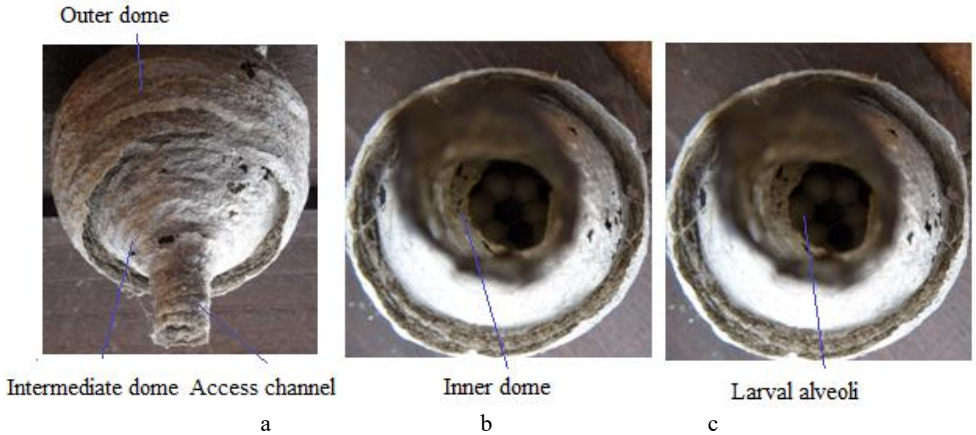


Fig. 14. General view of the nest (a), the inner dome (b) and the larval alveoli (c).

The walls of the domes and the alveoli are made of the specific material from which wasps build cellulose-based nests, similar to paper, with a thickness of 0.16-0.18 mm. The specific aspects of this case consist of the perfection of the shape of the three domes, of almost perfect symmetry and the existence of the access channel to the intermediate dome of a rarely encountered shape and made with great precision. Like other similar nests, but especially the one described, it is very similar to Mongolian yurts (Fig.15), which were perhaps made by inspiration after such a nest or more certainly based on similar creativity and logic. The role of the three concentric walls may be to maintain a relatively constant temperature inside, as well as for the eventual destruction of the outer wall, but there may be other reasons that can be identified through a deeper study, from which better solutions for yurts used by people may result.

Fig. 15. Mongolian yurt similar to a mini wasp nest.

10. Conclusions

Based on what is briefly presented in this paper, the following conclusions can be formulated:

-nature is the repository of solutions of a variety and complexity that only in recent years have been able to be highlighted thanks to the efficient means of investigation in all environments: terrestrial, aquatic and aerial;

-the solutions in nature, which surprisingly also cover aspects that not long ago were attributed only to human society, are the result of very long evolutions, often even millions of years, which brings them closer to perfection;

-the formulation of directions for systematization and analysis of the various aspects present in nature is essential to obtain results that, when used, can lead to efficient processes for solving some of society's problems;

-bionics is currently the essential scientific platform that can truly allow an increase in the degree of harmonization of society with nature and as a result it must be promoted and used intensively in the coming period.

-encouraging all research in the field of bionics must become a priority for all fields, especially engineering.

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