l'École de Paris du management

Biomimetics: nature as a source of innovation

by

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Overview

Biomimetics (*bio* = life, *mimesis* = imitation) is an innovation strategy which consists of drawing inspiration from living organisms to make technologies and human societies more efficient. It has applications in the following sectors: energy, 'soft chemistry', high-performance eco-materials, and industrial ecology. In France, more than one hundred and seventy laboratories and eighty companies are active in biomimetics. In order to prolong the success of their approach beyond that of a few pioneering achievements, we have to create generic methodologies to make sure that those involved adopt them. The Senlis *Centre européen d'excellence en biomimétisme* (CEEBIOS: European Centre of excellence in biomimetics) intends to address these issues by decompartmentalising the disciplines involved, bringing fundamental research and industry closer together, making regions aware of these processes, and establishing training programmes. Its aim is to make France the pioneer in the development of biomimetics as the tool in the ecological transition to bring together biodiversity, innovation and the economic world.

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What is biomimetics?

Antonio Molina: Biomimetics (or biomimicry) consists of drawing inspiration from solutions which occur in nature, and developing industrial applications, the environmental and energy costs of which are largely inferior to those using traditional approaches.

If one compared the history of life on Earth which began 3.8 billion years ago with a journey from Paris to Marseille, the industrial period (which began two hundred years ago) would correspond to the last part of this journey. Nature has had time to develop solutions which are far more ingenious than those devised by man, and has also managed to do so by using far fewer means. Living organisms are essentially made up of four elements, carbon, hydrogen, oxygen and nitrogen, and they get their energy almost exclusively from the sun. To use a metaphor, man's industrial 'language' is more complex, but nature 'says' a great deal more with fewer words and an easier syntax.

Until now, the possibilities for man to be inspired by nature were limited because there were few means of analysis which allowed him to understand precisely the solutions which were invented by living organisms. However, over the past few years, there has been exponential growth in research and articles published in this field. For example, we have recently discovered the composition of ivy glue just one gram of which can support a weight of twenty tons. Applications from biomimetics are therefore currently multiplying rapidly.

Areas of application

Kalina Raskin: Let me comment on a few of the avenues which are currently being explored.

Energy

Questions related to energy are crucial for all living species. In the current context of global warming, they have taken on a new urgency especially those concerning the diversification of energy supply sources, the optimisation of consumption according to the seasons and times of the day, and energy storage.

Marc Fontecave, a professor at the Collège de France and the director of a laboratory at the Pierre et Marie Curie University, was inspired by hydrogenases, plant enzymes which have the capacity to separate hydrogen and oxygen from water using solar energy, in order to design an artificial photosynthesis process which produces hydrogen. He then grafted artificial enzymes onto very porous structures (initially carbon nanotubes).

The advantage of this method compared to the usual technologies is that the catalysts used are abundant and cheap. It has a small yield, but this is not a problem if one can multiply the number of surfaces used at a lower cost. Each leaf on a tree has a low energy yield, but all the leaves together make up a surface of several hectares which represents a considerable yield.

Materials

Antonio Molina: If our bones were dense rather than porous, it would be hard for us to move. We can reduce our energy consumption greatly by making the materials which help us to move lighter, for example by devising porous materials while making sure this hollow structure does not create weak areas.

Kalina Raskin: Some software designed to optimise structures (such as Autodesk used by engineers and architects) integrates algorithms which originate in the mathematical analysis of biological structures. The results often look very organic which is logical inasmuch as the rules of optimisation dictate that matter is concentrated where efforts are greatest, and where matter is essential, as is the case in nature. The next step will consist of adding characteristic gradients to these materials (which are still very homogeneous) which will enable them to be even more efficient despite using a smaller amount of material.

Antonio Molina: Some people have been inspired by spiders' webs to create reinforcement materials from a liquid state which makes it possible for them to adhere to the parts of the structure which needs strengthening without changing state.

Kalina Raskin: In two years, five companies (in Norway, Germany, the United States, and two in Japan) launched an artificial synthesis process made from spider silk for applications in the textile, medical and cosmetic sectors.

Antonio Molina: Another avenue is the use of agro-sourced material. Today, we know how to make practically all the polyesters - and also recently epoxy resins - from plants. This greatly simplifies the recycling process because when these materials are burned only the carbon dioxide and the energy captured by the plants used to produce them are released. The approach is even more interesting using industrial waste. For example, we work with a potato chip manufacturer who is trying to recycle the starch which is released when the potatoes are initially washed in water.

Another avenue includes the use of light as a source of energy. In the Mäder industrial group[1] , we have devised a process of polymerisation by ultraviolet rays which allows us to make composites without solvents or by means of evaporation, and using very little energy.

Green chemistry

Kalina Raskin: The principles of green chemistry put forward by the researchers Paul Anastas and John C. Warner in the 1990s are the same as those of life sciences. Thousands of chemical reactions are constantly taking place in our cells which are coordinated so that the organism can respond in the best possible way to the countless stimuli which it receives from its environment. Like the life sciences, green chemistry must first of all mobilise the four most abundant elements (carbon, hydrogen, oxygen and nitrogen), use solar energy, operate in environments where there is normal room temperature and pressure, favour water-based solutions, metabolic recycling, enzymatic catalysis, and produce molecules which ideally have no negative impact and are even biodegradable and metabolizable.

Some of the notable examples of green chemistry include the manufacture of glass at normal room temperature and pressure, developed by Jacques Livage and Clément Sanchez, professors at the Collège de France. They were inspired by the capacity of certain micro-algae, especially diatoms, to synthesise fine, glass shells. It may be possible to use this sol-gel process in the construction industry to protect historical buildings, in everyday objects for example to recoat the underside of electric irons, or even by chemists to embed active ingredients in a biologically neutral material and liberate them at the right time and place.

Another example of green chemistry is the use of living organisms to clean the soil. The method, which consists of cultivating plants which are 'hyperaccumulators' of heavy metals and grow in heavily polluted soils (such as on mining sites) in order to confine these metals, has existed for a long time, but until now we did not know what to do with the plants we collected. We generally tended to burn them which merely shifted the problem. A researcher, Claude Grison, invented a new discipline, the eco-catalysis, which consists of using these plants (which contain a great deal of metal) as natural catalysts to make new molecules with high-added value which are very difficult to synthesise using artificial processes.

Water

Water appeared on Earth 3.8 billion years ago, and living organisms spent 90 % of this time in water. Using the metaphor of the Paris-Marseille journey, the moment when living organisms ventured out of water corresponds

1. Antonio Molina, 'Revitaliser l'industrie grâce à l'innovation', Technological resources and innovation seminar, École de Paris du management, September 16th, 2015.

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