Biomimetics: nature as a source of innovation

by

Kalina Raskin
Managing director, CEEBIOS
(*Centre européen d'excellence en biomimétisme de Senlis*)

Antonio Molina
President,CEEBIOS

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.

Report by Élisabeth Bourguinat • Translation by Rachel Marlin

Seminar organised with help from the Directorate General for Enterprise (Ministry of the Economy) thanks to the sponsors of the École de Paris :

Algoé[1] • Carewan • Caisse des dépôts et consignations • Conseil régional d'Île-de-France • EDF • Else & Bang • ENGIE • FABERNOVEL • Fondation Roger Godino • Groupe BPCE • Groupe OCP • HRA Pharma[2] • IdVectoR[2] • IPAG Business School • La Fabrique de l'industrie • Mairie de Paris • MINES ParisTech • Ministère de l'Économie et des Finances – DGE • Renault-Nissan Consulting • RATP • SNCF • UIMM • VINCI • Ylios

1. for the Business Life seminar
2. for the Technological Resources and Innovation seminar

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.

to the moment when the traveller arrives at Aix. This recent event enables us to understand why living organisms are principally composed of water and have developed very sophisticated strategies to manage water such as purifying it, to salvaging it in arid environments, stocking it or transporting it.

Antonio Molina: There is a species of beetle which lives in the desert and whose shell curiously accelerates the condensation of fog. Its shell has both bumps whose surface is absorbent and grooves covered in hydrophobic wax. Early in the morning, when the desert is covered in fog, the beetle positions itself on top of a dune with its hindquarters raised. The fine drops of fog accumulate on the bumps and when they become too heavy they slide down the grooves into the beetle's mouth. Researchers are currently trying to imitate this process to create systems of salvaging water from the canvasses of tents used by NGOs in desert areas.

Kalina Raskin: The tardigrade is a microscopic animal capable of surviving for decades in extreme conditions of temperature (from 0°C to 150°C), pressure and dehydration. Its cells have developed conservation strategies of active ingredients which allow them to resume operating normally when all the conditions are in place. The pharmaceutical company Biomatrica was inspired by this conservation strategy to freeze-dry medicine and conserve it for a very long time even when there is no cold chain.

Information

A British study compared the strategies of problem resolution established by living organisms with those devised by man. *Homo sapiens* tends to devote a great deal of energy and matter by relying relatively little on information exchange whereas living organisms make a more restrained use of energy and matter and favour the exchange of information. This is why living organisms have a remarkable capacity to gather information using sensors, stock it in molecules, transmit it by chemical or electrical means, aggregate and analyse the data, and finally establish forms of group intelligence both with bees and in neurones and cellular automata, for example.

Information processing is undoubtedly one of the areas in which biomimetics has been prominent in the past forty years. With regard to some subjects, man is a long way behind nature in terms of sophistication, and cannot even attempt to imitate it. For example, between the olfactory sensors of some animals and those which man can produce artificially, the difference in performance can reach a factor of 105… This is why we train rats, for example, to detect the position of anti-personnel mines using their sense of smell, and they avoid being blown up because they are not heavy.

Nonetheless, there are industrial applications inspired by information processing used by living organisms. Nicolas Franceschini, a researcher at the University of Aix-Marseille, developed the first multifaceted eye inspired by insects. Ryad Benosman, a researcher at the Institut de la Vision, has devised image processing systems inspired by the human eye, and co-founded the Chronocam start-up which has just raised 15 million Euros to develop a technology of artificial vision. Patrick Pirim invented processors capable of imitating networks of neurones which process visual information downstream of the optical system.

Human systems

Living organisms can also inspire the design and organisation of human systems such as agriculture, the habitat and the economy.

In agriculture, biomimetics can take several forms such as agroforestry, agroecology or even permaculture. Farming which consists of cultivating the same plant in huge fields with large amounts of inputs has shown that it has limitations. We are now rediscovering ancient practices which consisted of planting several varieties simultaneously or successively in the same field. The progress of agronomy allows us to understand scientifically how these ecosystems work.

As far as the habitat is concerned, the concept of 'regenerative cities' has emerged. People no longer want to allow nature just to appear in urban environments; they want to reintegrate towns into the biosphere by deciding which ecosystemic services human infrastructures could give to nature, and by trying to make these services at least equivalent if not superior to those which made ecosystems disappear. After the 'low-energy' habitat, there was the ‘zero-impact’ habitat and then the ‘positive energy’ habitat. Now there is the ‘regenerative’ habitat, capable of playing an active role in the ecosystem.

The last field of examples of biomimetic processes involves the circular economy and economic flows, based on the model of exchanges of matter in ecosystems. In this field, we are still in the early stages rather than designing real models.

Biomimetics in Germany

When one discusses biomimetics with French people, they generally find the idea interesting and refreshing. Our German neighbours have grown used to adapting solutions found in nature for a long time. They have a considerable head start on us, both in terms of academic research and publishing patents and devising industrial applications.

The BIOKON (*Bionik-Kompetenznetz*) network, created in 2001 under the guidance of the German Ministry of Education and Research, received a grant of 8 million Euros over a six-year period to form an academic network, launch thematic workgroups, and finance research in order to demonstrate the importance of biomimetics to the industrial world. Subsequently, programmes similar to our ‘Investing for the Future’ programmes (PIA: *Programmes d’investissements d’avenir*) were launched using a total of 120 million Euros of public money. This led to the creation of about ten specialised networks based on the historic poles of expertise present in different regions.

The most important leader of these networks explained to me that the German federal state continues to support them because it has been shown that for one Euro of German public money the return on investment is nine Euros, regardless of whether it is a question of grants obtained because of projects which are part of European programmes, R&D projects with industry, or both.

This is how the SFB-TRR 141 (*Sonderforschungsbereich-Transregio:* Transregional collaborative research), which is jointly run by the universities of Stuttgart, Tübingen and Fribourg and focuses on research in order to understand biological structures applied to architecture, received a grant of 9 million Euros over a four-year period which is renewable twice. When this laboratory recruits PhD researchers, it hires them in groups of twenty!

Switzerland has followed the example of Germany. Two years ago, the Swiss national science body launched an inter-university project focusing on materials which are inspired by nature. This required an investment of 26 million Euros. There are also remarkable initiatives in the United States, China, and even Japan.

The creation of CEEBIOS

In France, the Centre européen d’excellence en biomimétisme (CEEBIOS: European Centre of excellence in biomimetics) opened its doors in 2013 on the former Ordener military site in Senlis. The project for CEEBIOS was initially piloted by Gilles Bœuf, president of the French Natural History museum. He was succeeded by Antonio Molina in 2015. Among the founding members were the city of Senlis, three competitivity clusters – Matikem (bio-based materials), Uptex (innovative textiles) and IAR (Industries and agro-resources) –, the French Natural History museum, and the Oise departmental Chamber of Commerce and Industry. CEEBIOS’ fundamental objective is to identify talent in biomimetics in France and align it with the industrial issues it could address.

Projects at Senlis

We have already launched five workgroups, each with its own topic. The first one was dedicated to a bio-inspired habitat which is one of the most popular topics with regards to biomimetics development in France and abroad, especially in Germany. In 2016, this group published a state-of-the-art subject in their field, drew up the technical specifications of the sustainable bio-inspired habitat, then identified and initiated research projects. Soon we are going to work on a project in conjunction with the French Natural History museum concerning the multi-functional layers for building renovation, which will be one of the most important issues in sustainable development in the coming decades.

The second workgroup is dedicated to bio-based materials with the aim of putting all those involved on the same level. This requires devising a state-of-the-art concept on a national and international scale, and identifying the important industrial issues.

The third is dedicated to agriculture and began in December 2016. Part of the 10-hectare Senlis site has been given over to both testing bio-inspired techniques and training. Because the Hauts-de-France region is largely agricultural, it is necessary to make farmers aware of alternative farming strategies.

The fourth workgroup is training-based. It includes representatives from about twenty French higher education institutions which want to develop training in biomimetics, on the initiative of students, educational managers or the heads of the institutions. Today there are a large variety of training programmes on offer, and we are trying to bring some sort of uniformity. Our aim is to set up courses which are jointly run by different establishments.

Finally, we hope that we will soon be able to launch a workgroup on information management in the life sciences. It so happens that the French Military Intelligence Directorate (DRM: *Direction du renseignement militaire*) will be setting up a centre dedicated to research and innovation in the intelligence field near Senlis in the near future which will be called the Intelligence Campus. It is very interested by biomimetic approaches especially the technology developed by the Chronocam start-up, notably broadband visual analysis.

Antonio Molina: We also intend to create a training centre at Senlis which is essential in order to promote biomimetics, and to build a laboratory of materials characterisation in co-operation with the French Natural History museum. This institution has one of the largest libraries of specimens and knowledge about living species in the world, but its function means it is too complex for users. We are currently working with the French National Institute for Research in Computer Science and Automation (INRIA: Institut national de recherche en informatique et en automatique) and Michel Authier from Mugeco to decide how to reorganise this mass of information in order to make it more accessible. Using this data base, we hope to be able to devise a platform for materials characterisation in the next two years.

Kalina Raskin: As well as the platform we intend to build at Senlis, we want to implement a standardised protocol to align the activities of materials characterisation carried out by the three competitivity clusters and the various research centres and universities in the Hauts-de-France region. In this way, we will be able to benefit from and capitalise on what already exists and devise standardised indicators regarding the performances of the different materials which will comparison easier. The data bases will be collected and centralised at Senlis, as will undoubtedly be the same for the biological samples.

A national network

Antonio Molina: Our initial objective was to invite researchers to Senlis to work on biomimetics projects, but we quickly realised that we would not have enough space on one site for this. Today our aim is to create a national hub of knowledge in the biomimetics field.

Kalina Raskin: We have already identified more than one hundred and seventy research laboratories in France. The list is probably not exhaustive because the term 'biomimetics' does not necessarily figure in research titles. Searching by key words only allows us to identify some of them. We have visited more than one-third of these laboratories which has enabled us to complete the census.

In terms of regional distribution, 37 % of these laboratories are in the Île-de-France region, 13 % in Auvergne-Rhône-Alpes, 9 % in Occitanie, and 8 % in Nouvelle-Aquitaine. The majority of research is focused on material sciences (24 % of the laboratories identified), information technologies and engineering of complex systems (18 %), bio-based chemistry and bioprocesses (16 %), and life sciences and tissue engineering (11 %).

We have also identified eighty French companies which have launched themselves into biomimetics. This is not very many by comparison with the national industrial context, but it is still a good start.

Antonio Molina: We want to develop our activities throughout France with specific themes for each region. For example, we have just signed an agreement with the Nouvelle-Aquitaine region for a programme based on marine biomimetics, and we have launched a workgroup in Biarritz. We are using the same approach in the PACA, Centre and Île-de-France regions.

Kalina Raskin: CEEBIOS' non-laboratory research is essential and includes the success of the Senlis site. Not only do we have to continue to map out the location of our research teams, but we also have to identify the key industry challenges we should work on, without neglecting fundamental research.

For the past two years, the Ministry of the Environment has granted us some funding for inter-regional work on coordinating our efforts with the aim of re-creating the same dynamic as that in Germany, and working even faster if possible. We want to make sure that the regional innovation or environmental agencies, the competitivity clusters and the SATTs (transfer technology companies) which ensure the interface between industry and academic research, are made aware of what biomimetics has to offer, and that these bodies commit themselves to activities in their fields which are part of regional strategies for innovation and are currently being finalised.

Financing

Antonio Molina: We still have to resolve the question of financing. In Germany, not only was the BIOKON network created twelve years before CEEBIOS, but it received a grant of 8 million Euros whereas CEEBIOS only received 20,000 Euros from the Ministry of the Environment in 2016. Even Switzerland invests more money in biomimetics than France. Nonetheless, we are convinced that the creation of jobs in the coming years will depend on our ability to innovate, and that a large part of future innovations will come from biomimetics. It is therefore imperative that we catch up quickly.

Kalina Raskin: CEEBIOS is a non-profit-making association with members which include (apart from the founders) major companies (Eiffage, Air Liquide, L'Oréal, Renault, ENGIE, Arcelor Mittal, etc.), SMEs, environmental consulting firms, and also local authorities (Hauts-de-France region, Nouvelle-Aquitaine region, Pays de l'Oise area), universities and higher education institutions (Compiègne Technological University, Pau and the Pays de l'Adour University, the École nationale supérieure des arts et industries textiles, and so on). It functions a little like a competitivity cluster and has three forms of financing: grants, contributions and services.

Initially, in 2013, CEEBIOS had a budget of 80,000 Euros, 70 % of which was financed by the city of Senlis. There was just one employee: me. The budget practically doubled every year due to the Hauts-de-France and Nouvelle-Aquitaine regional grant, as well as that of the Ministry of the Environment, contributions from companies, and finally sales from our services. The operational team now consists of five people, and the 2017 provisional budget is almost 400,000 Euros.

Unfortunately, for the moment, the multi-annual nature of public grants is not at all certain, and funding relies principally on private contributions. However, we do not think that it is the role of companies to structure the network, implement methodologies and supply support tools or even to develop characterisation platforms. Private individuals can indeed be stakeholders, and this is the case, but the Technology Readiness Levels (TRL) of research carried out by CEEBIOS are not high enough for private individuals to be able to finance them all by themselves. This is why we hope that the French government will invest in CEEBIOS or in a new configuration of CEEBIOS, and thereby make it a government project.

Discussion

The demonstrations

Question: *In his book* 'Pasteur: guerre et paix des microbes'*, Bruno Latour points out how important it is for scientists to organise biomimetic 'demonstrations'. Artificial intelligence remained a virtual concept for a long time until the day that AlphaGo, a programme developed by Google DeepMind, beat the world champion of the Go game, Lee Sedol. Are there already demonstrations which can help us to move from the stage where we consider that biomimetics is an 'interesting and refreshing' concept to one where we realise that it is essential?*

Kalina Raskin: Demonstrations have existed for a long time. Some of the most talked about inventions of biomimetics include velcro (a term coined from a combination of the French words for velvet (*velours*) and hooks (*crochets*)). In 1948, the Swiss George de Mestral took his inspiration for this invention when he noticed that burdock flowers were attached to the hairs of his dog. In 1974, Richard Whitcomb, a NASA engineer, was inspired by the way in which quills were situated at the ends of wings of certain birds, and he invented 'winglets', small vertical wings placed at the ends of aeroplane wings which help to increase their aerodynamics. In 1976, the German biologist Wilhelm Barthlott highlighted the extreme hydrophobia of lotus leaves which enables them to float to the surface of the water. This singularity was imitated in numerous industrial applications, notably in the field of paints and self-cleaning window panes.

Q.: *Why then does biomimetics not spread more quickly?*

K. R.: It is the amount of knowledge needed in order to understand and imitate living organisms. We have been studying spider's webs for fifteen years, but it is only in the last five years that we have come to understand the molecular structure. It is only now that we are able to make webs artificially, often resorting to modified bacteria because the technology does not yet exist to manufacture this type of product.

A. M.: The Matikem competitivity pole has just carried out a study on scientific parks and visited numerous sites in the world. The study showed that the success of a scientific park depends essentially on the fact that it is devoted to a precise theme, and manages to motivate a certain number of industrialists to take part in this same theme. In France, many scientific parks have had to give in to pressure from local authorities to optimise rent and tax revenue, and have welcomed companies which only had little or nothing to do with the theme of the park itself. There are, however, some success stories like Euralille which is exclusively dedicated to digital technologies.

Production costs

Q.: *Companies which are trying to manufacture artificial spider's webs are using biological technologies such as insects' cells, bacteria or yeast to make webs. Unfortunately, these technologies have very high costs. For biomimetic demonstrations to be complete and effective, production costs must be compatible with the market. In general, we turn to industries with high added value for this. This is why the sector which has resorted most to biomimetics over the past forty years is the pharmaceutical industry. Currently, two-thirds of molecules which it develops come from living organisms, notably through our understanding of the defence mechanisms of plants. Use of monoclonal antibodies has multiplied production costs by four, and the margins of the pharmaceutical industry have fallen from 90 to 60 %. Compared from where we started, this is still acceptable, but not all industries can afford such costs.*

Antonio Molina: It is a fact that bio-inspired technologies are very expensive when one just wants to substitute a biomimetics product with a traditional product, as, for example, when one wants to replace steel with a composite material. However, it is much less costly when one uses a truly biomimetic logic and one which has several uses. For example, at Mäder, we are in the process of developing the outsides of TGV trains made from composite materials which will represent a huge added value compared to surfaces made from steel because of the numerous additional advantages which they provide. Nature always makes several things at once. When we are inspired by this belief, we can create interesting economic models.

Characterisation platforms

K. R.: As far as I am concerned, the main drawback to the adoption of biomimetic processes is not industrial production costs, but costs of fundamental research necessary to highlight the properties of living organisms. The majority of bio-inspired products sold today began by chance. For example, someone observed the property of a living organism and dreamed up an industrial application, like the case of velcro.

If one wants to speed up the acceptance and adoption of bio-inspired approaches, one must start from the opposite direction, in other words one must begin with an industrial need and draw on solutions which have been invented by nature. This supposes that one has to identify the strategies in question. If we do not do this, industry will keep exploiting the fifteen or twenty important bio-inspired materials of which we already aware. Industry does not have the means to carry out fundamental research which would consist of studying thoroughly the functioning of an organism which is supposed to be worth imitating, while running the risk that after three or four years it may not satisfy one's expectations.

This thinking gave rise to the creation of a characterisation platform of plant materials. About fifty or one hundred particularly remarkable species were chosen, with help from the French Natural History museum, and a standardised research protocol was applied to them in order to form the most complete data base possible about interesting materials.

Why Germany?

Q.: *Why did the miracle take place in Germany and not elsewhere?*

K. R.: According to Thomas Speck, an important person in the development of biomimetics in Germany, it is the result of the political desires of one man, Jürgen Heidborn, a member of the German Ministry for Research, who convinced the government to give 2 million Euros over two years to create a network, and to provide additional sums if the results proved positive. The idea began some time ago in the United Kingdom, and also led to the creation of a network of five hundred researchers called the 'Biomimetics network for industrial sustainability' (BIONIS), but, because it lacked political support, it did not develop any further.

Q.: *You seem to suggest that the problem is not linked to the research stage, but to later stages, in other words particularly to demonstrations which included an economic dimension. How has Germany handled this question?*

A. M.: When you try to get funding for a prototype from the public authorities in France, you come up against European rules which state that it is impossible to receive more than 50 % of the budget in grants. The Germans overcame this difficulty by using a clever trick: 50 % of a project can be financed by the government and 50 % by the German Car Plan which also depends on state funding, but a different type of funding. The same is true in Belgium. An important industrialist in the oleaginous sector told me recently 'I have just built a large biomimetics demonstration in Dunkerque, but next time, I am going to build it on the other side of the frontier in Belgium.'

Lighting the spark

Q.: *Who initiated the project in Senlis?*

K. R.: It was one of the mayor's assistants who was a researcher at L'Oréal, a company which is very active in the biomimetics field. He knew that this sort of structure did not exist in France, and decided to 'light the spark' and managed to convince the city council. Simply announcing that the city of Senlis was going to create an area of 25,000 square metres and a park of 10 hectares dedicated to biomimetics aroused people's interest. In the process, the city of Senlis is already starting to benefit from a few economic spin-offs with the arrival of some companies in the park. We will see in the future whether the park will be completely occupied.

Presentation of the speakers

Antonio Molina: an engineering graduate, he is the president of the Mäder Group supervisory board, president of the Matikem competitivity pole, and president of CEEBIOS (*Centre européen d'excellence en biomimétisme*). He is a member of the steering committee of La Fabrique de l'industrie and the Rabot-Dutilleul strategic committee.

Kalina Raskin: a physical chemistry engineer and a doctor in biology. She first promoted biomimetics for responsible innovation in the Paris Région Entreprises agency where she developed tools to help to make eco-designs using biomimetics. She has taken part in the growth of CEEBIOS (*Centre européen d'excellence en biomimétisme*) since 2013, and became its CEO at the beginning of 2017. Her aim is to make France a pioneer in the development of biomimetics as an ecological transition tool reconciling biodiversity, innovation and the economic world.

Translation by Rachel Marlin (rjmarlin@gmail.com)