

BIOMIMETISM IN ENGINEERING

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<https://lmfteus.wordpress.com>

Plan

1. Definition of biomimetism
2. History
3. Applications
 - a. Inspiration by form
 - b. Inspiration by processes
4. Conclusion

DEFINITION

« **Bio** » from greek « *bios* » = **Life**

« **Mimetism** » from greek « *mimeisthai* » = **Mimic**

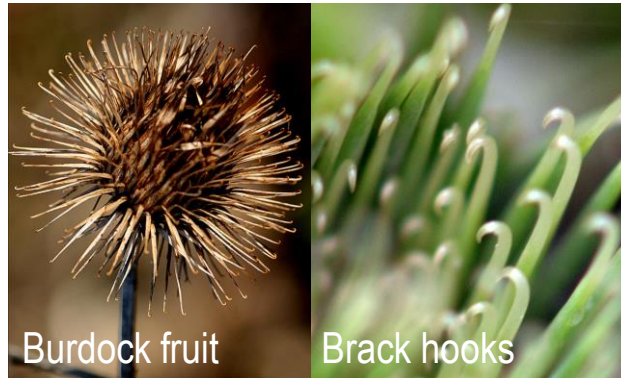
- Term born in 1969 from the biophysician american Otto Schmitt (Int. Biophys. Cong., Boston).
- Biomimetism is inspired by **forms**, **processes** and **systems** from nature in order to create, build and organize ... in an efficient way.
- Paradigm shift: we do not ask what we can take from nature but rather what we can learn from nature.
« Man commands nature by obeying her » (F. Bacon)
- 3.8 billions of year of experience in R&D !

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WELL-KNOWN EXAMPLES

- ❑ flying squirrels ↔ base jump;
- ❑ caterpillars ↔ heavy vehicles, tanks...;
- ❑ barbed wire invented by Louis Jannin (1865) and called bramble wire;
- ❑ retroreflective strips on the roads ↔ cat's eye (tapetum lucidum)...
- ❑ Echolocation of bats / dolphins ↔ radar, sonar technologies



VELCRO (VELours-CROchets)



George de Mestral (1948)

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INSPIRING NATURE

Whatever the problem, nature has already the solution :

- its main source of energy is solar energy
- it uses only the amount of energy required, not more
- it adapts form to the function
- it throws nothing away but recycles everything
- it bets on diversity and complementarities and looks for cooperation
- it works with local expertises

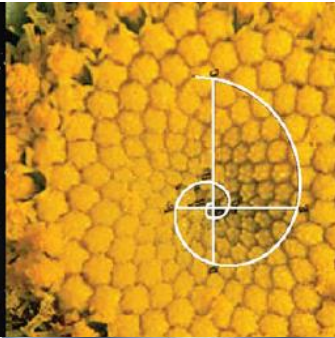
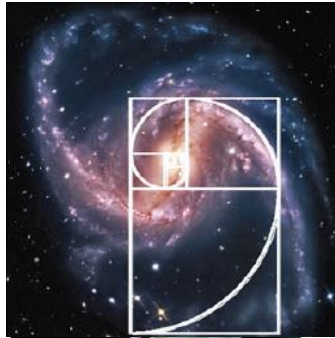
How be inspired by these base principles to improve our behaviors and processes, in order to reduce our environmental impact?

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OPTIMAL FORMS

- Spirals: galaxies, hurricanes, shells, cochlea, sunflowers...
→ to minimize the amount of materials, energy, while guaranteeing an important solidity.
- Scale invariance (fractal form): broccolis, trees, lungs...

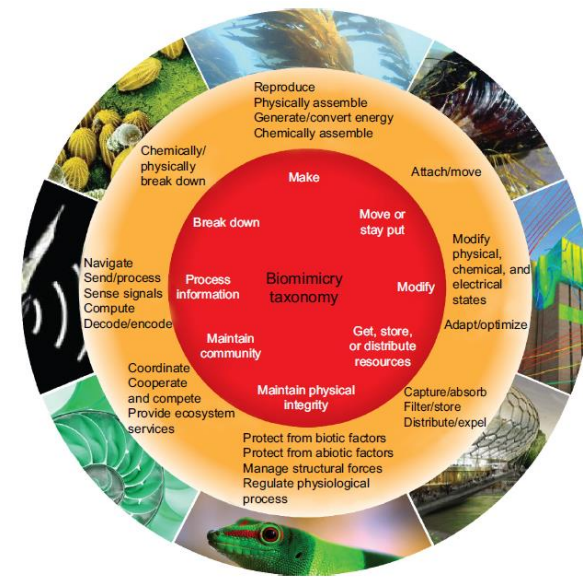
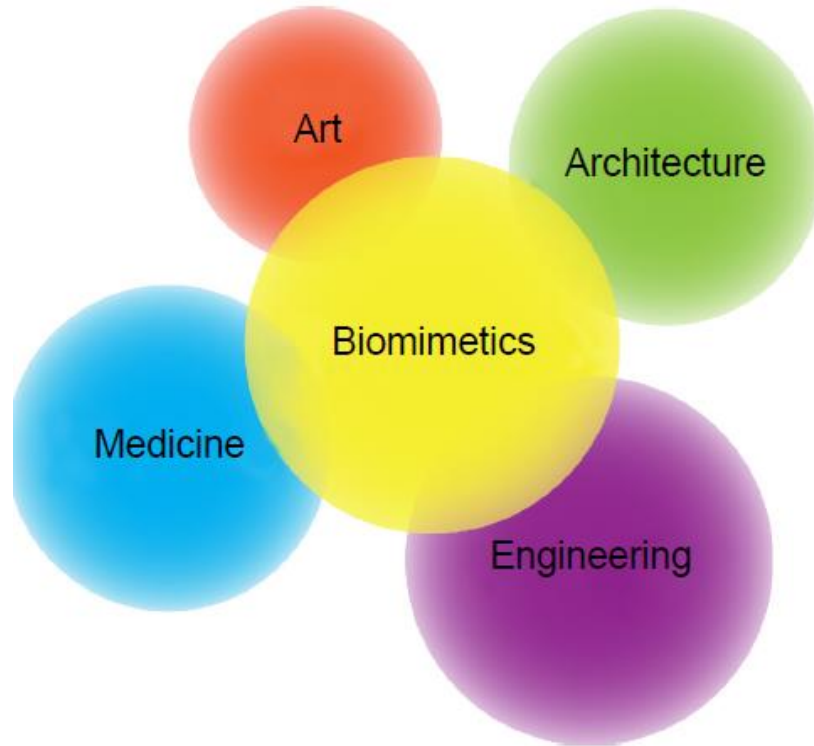


Ripley and Bhushan (2016)

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TAXONOMY



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ADAPTABILITY WITH TIME

Fauna and flora adapt over time to their environment to achieve an optimum.



Driven by inner "need"

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FOUNDING FATHER ?

*« Even if human genius uses different instruments to achieve the same result as nature, it will never produce an invention more beautiful, easier to realize and more economical than that of nature, because **in natural creations, nothing is missing and nothing is superfluous.** »*

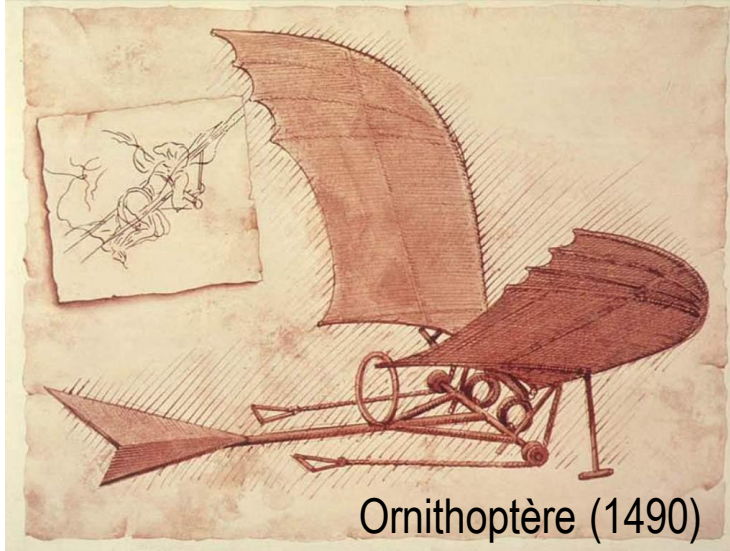
Leonardo da Vinci (1452-1519)

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ORIGIN: LEONARDO DA VINCI (1452-1519)

In 1505-1506, he wrote the *Codex on bird flights*. He produced more than 500 drawings on the flight mechanics.



Ornithoptère (1490)



Floating shoes

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AERODYNAMICS



« L'Éole » of Clément Ader (1890)
inspired by indian fruit bat



Otto Lilienthal inspired by the stork
flight (end of 19th century)

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GROWING DISCIPLINE

- Conceptualized by Janine Benyus in 1997 in « Biomimicry ». She then created in 2010 the compagny Biomimicry 3.8.
- Booming in the scientific community in the USA and China in the fields of chemistry, materials, engineering and biology.
- Economist Lynn Reaser claims that "biomimicry will account for US\$1.0 trillion (US\$1 trillion) in gross domestic product (GDP) by 2025 in the United States."
- Québec: creation of the Biomimetism Institute in 2009 (Moana Lebel, <https://biomimetisme.ca/>) and Biomimetech.
- France: organize conferences on biomimetism, with a chart and a label (Les Notes scientifiques de l'Office n° 27, déc. 2021).
- Germany: federal plan *Hightech strategy 2025*, which paves the way towards a one-billion funding (in €) over a ten-year period.

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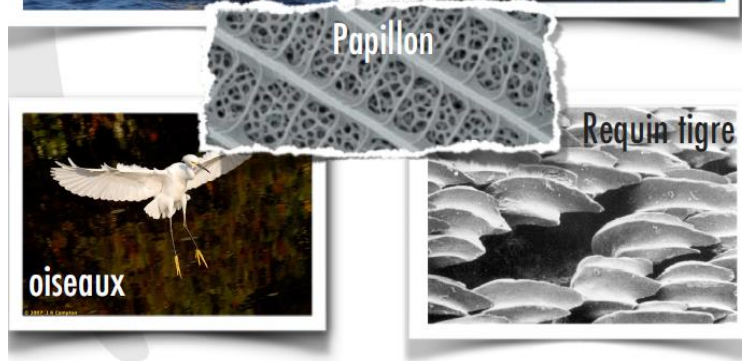


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RUGOSITIES

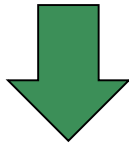
- Rough surfaces are more common than smooth ones;
- Rugosities improve the aerodynamic performances.



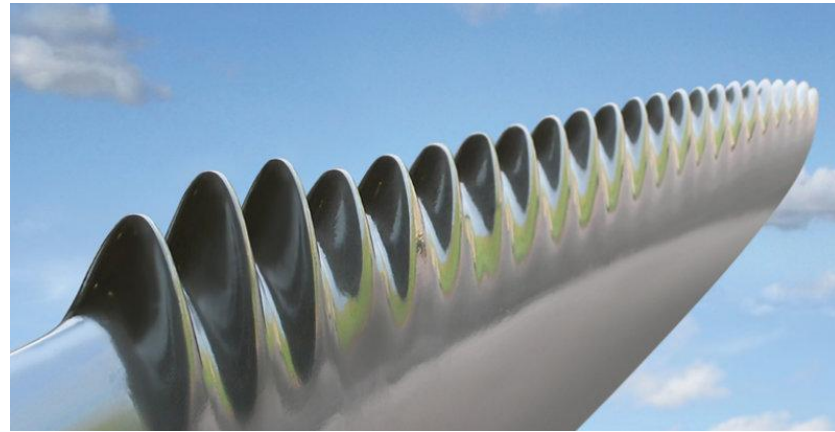
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HUMPBACK WHALES



Wind turbine of
Whalepower (Toronto)
[https://whalepowercorp.w
ordpress.com/](https://whalepowercorp.wordpress.com/)



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WIND TURBINE 2



Inspired by maple seed falling and kingfisher, the PowerCone from Biome Renewables (Canada) is a turbine retrofit that channels incoming wind onto the blades to address root leakage.

- The position is optimized based on the turbine type to keep the flow attached;
 - The length is designed to locate this secondary flow effect at rotor locations where separation is most problematic (reduced vibrations),
-
- 51% peak aerodynamic efficiency.
 - More than 6% increase to annual energy production.

<https://www.biome-renewables.com/powercone>

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OWLS AND FANS



Owls are able to approach their prey silently at high speed by managing turbulence and trailing edge vortices.



Unique
bionic profile

FE2owlet from Ziehl-Abegg is an efficient, low-noise fan that has winglets on the blade tips and serrated edges to reduce noise and save energy.

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SHARK SKIN

Shark skin is abrasive to the touch... due to micro-scales (similar to teeth). The small furrows allow water to circulate better on the skin - reduced friction.



- ❑ Riblet's effect: The reproduction of this structure is widely used to create diving suits, boat hulls and even aircraft coatings (noise reduction, reduced energy consumption).
- ❑ Rostami et al. (Biomaterials Advances 134, 2022) demonstrated the benefit of sharkskin coating to reduce bacterial biofilm formation for drug delivery systems.

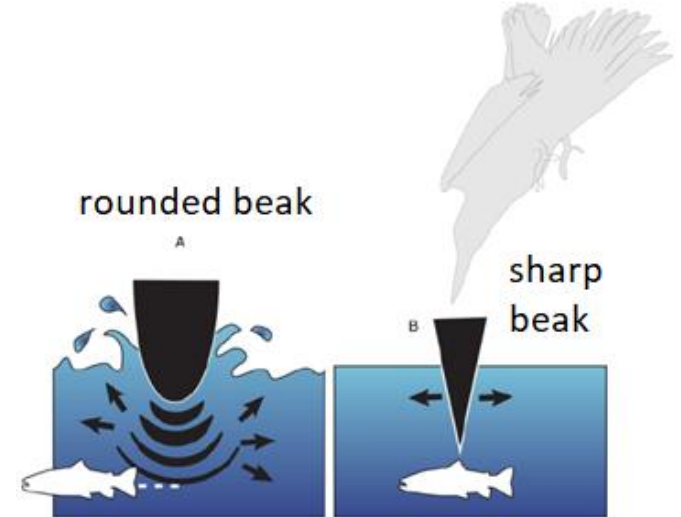


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WHEN KINGFISHER INSPIRES TRAINS

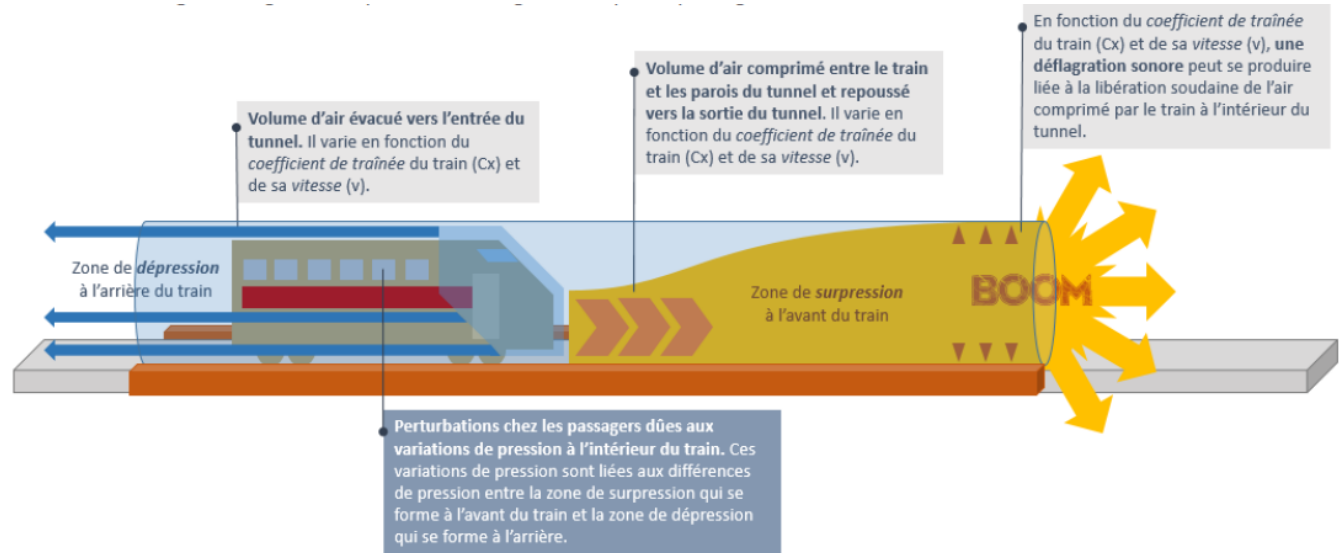
Air/water passage while maintaining a maximum speed (minimizes friction)



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WHEN KINGFISHER INSPIRES TRAINS



- Japan has around 11,000 tunnels whose 3 out the 10 longest ones worldwide;
- The entry and exit of a train in a tunnel generate shock waves, perturbate the train velocity, induce uncomfortable noise ...

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BASILISK LIZARD

Basilisk lizard can walk on water due to :

- Its low mass;
- Its high contact surface;
- Its high frequency walking.



« Liquid mountaineering » = hydrophobic shoes developed by the company Hi-Tec.



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WATER CIRCULATOR



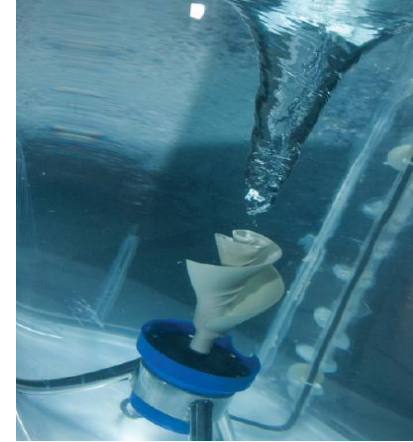
Nautilus shell

+



Calla lily flower

=

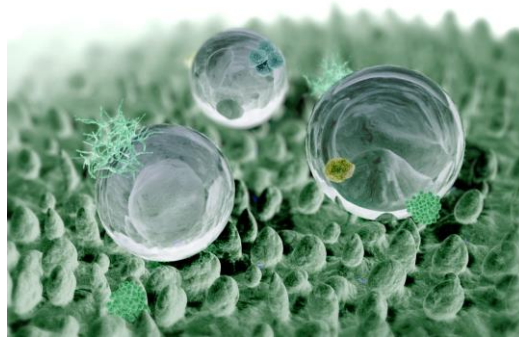


- ❑ Lily Impeller designed by Jay Harman (PAX Scientific)
- ❑ Reduction of the energy consumption by 10 to 85 % compared to conventional rotors, with up to 75% less noise.

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LOTUS EFFECT



Superhydrophobic phenomenon due to nanometric rugosities (minimizing the contact surface).



Applications:

- Waterproof clothes;
- Windshield;
- Coatings on wind turbines, in heat exchangers... to prevent from ice formation...

2022 Ray of Hope Prize finalists

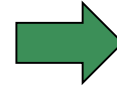


Direct Laser Interference Patterning (DLIP)

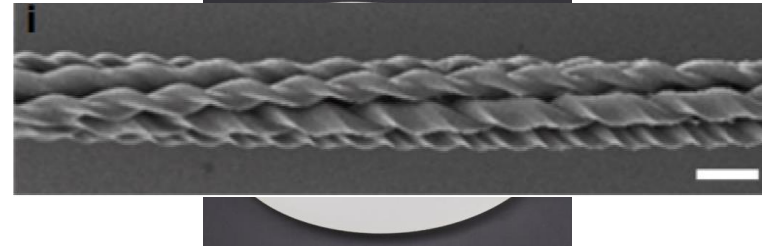
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SPIDER WEB



2. The Silk (Germany) has a modified DNA of a bacterium to produce a huge amount of resistant silk. Döcker, (2019), developed flexible fibers with this process, for water textiles, medical products...



Two interesting properties:

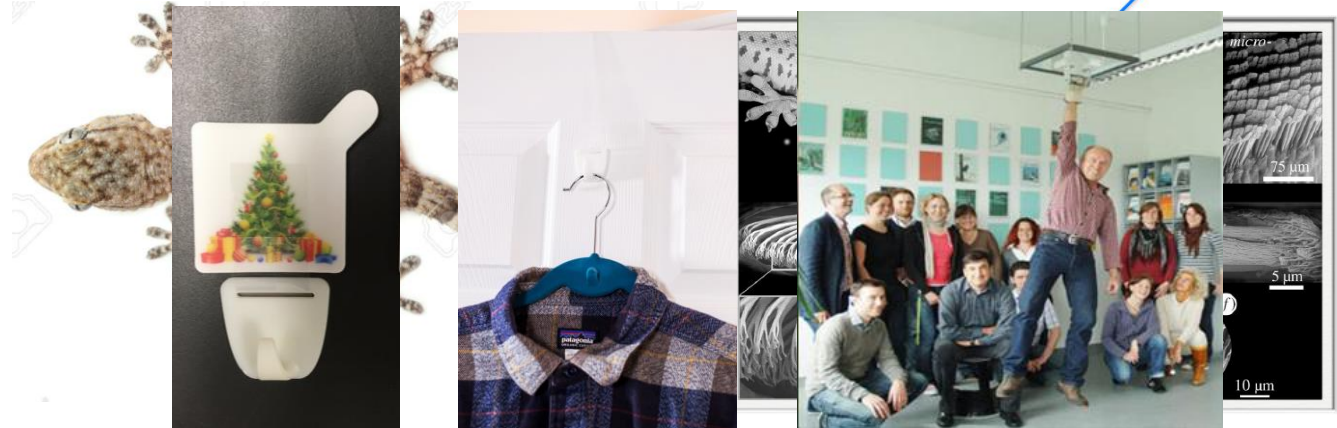
1. Highly resistant (1000 MPa in traction)
2. Holds water well

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GECKO THE SUPER ADHESIVE

Biomimetic surface: geckskin



- ❑ Extremely fast: several m/s;
- ❑ Exceptional adherence on any surface and under water;
- ❑ It weights 50 g but can resist to a traction of 20 N (40 times its weight!!);
- ❑ 600 times more adhesive than the best manufacturing one and reversible.

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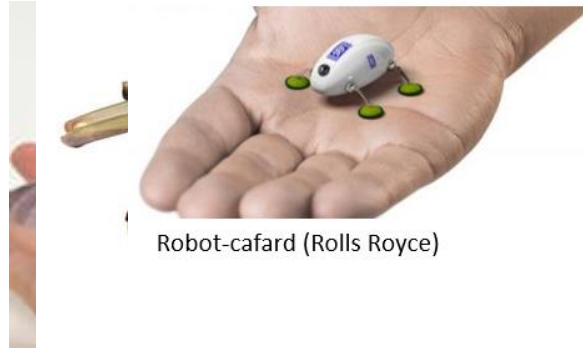
ROBOTICS

Objective 1: Mimicking nature to observe while being unnoticed

Objective 2: Automating tasks in unreachable places

Objective 3: Reducing the energy consumption of processes

Objective 4: Replacing human for difficult tasks



Robot-cafard (Rolls Royce)



StickyBot, robot-gecko
(S. Kim, Stanford, 2005)



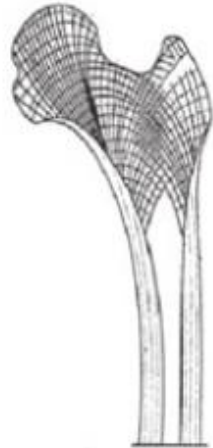
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ARCHITECTURE



« The architect of the future will build by imitating nature, because it is the most rational, sustainable and economical method » Antonio Gaudi



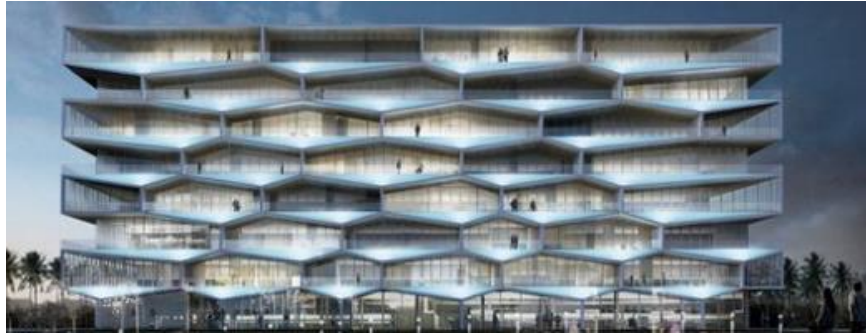
Eiffel tower in Paris (Eiffel, 1889)

- Inspired by force diagrams of some bones like femur to reinforce its solidity while minimizing its mass.

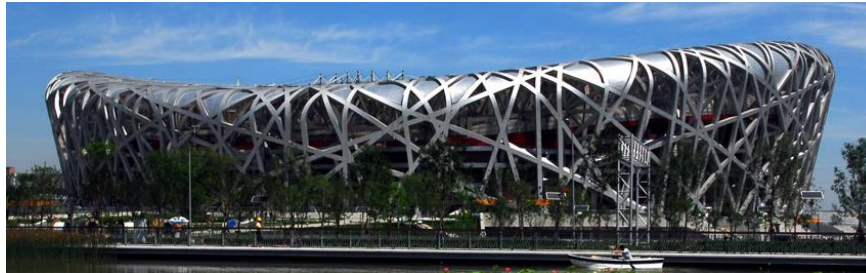
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Residential building in Bahamas by Shigeru Ban, inspired by honeycomb.



Bird nest, national stadium in Beijing, 2008



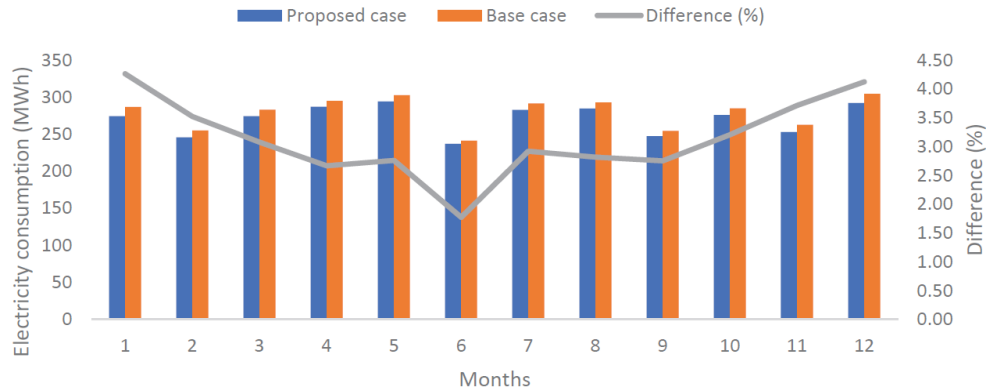
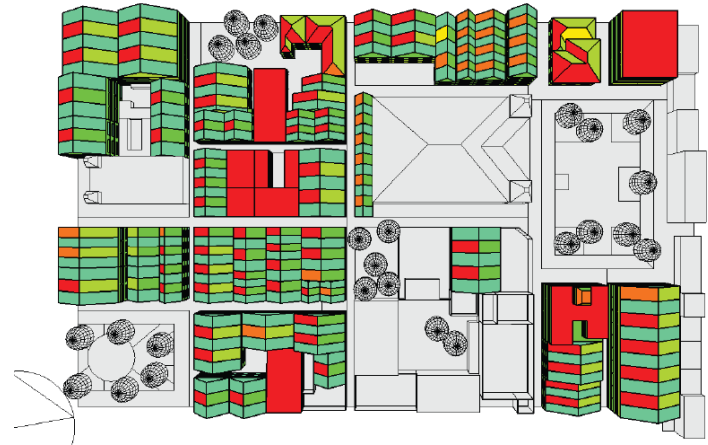
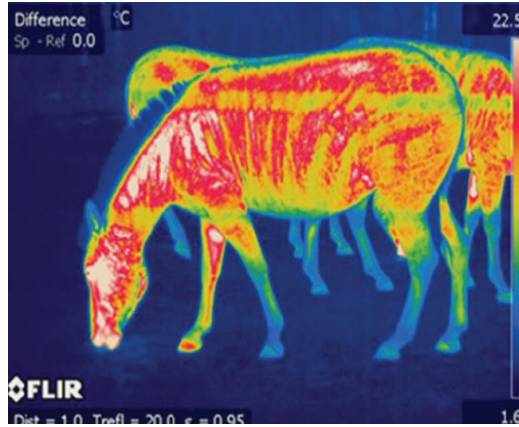
Eden project of greenhouse in Cornwall (UK) by Michael Pawlin inspired by a pollen seed.

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Zebra-stripes strategy (Austin et al., Biomimetics 7, 2022)

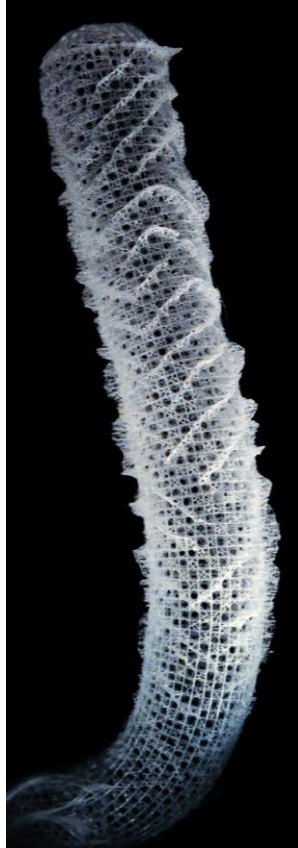


Cooling needs in Tropical climate

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SYNTHETIZE GLASS AS A SPONGE



A species of sponge (« Euplectella Aspergillum ») in the Pacific ocean (up to -5000 m).

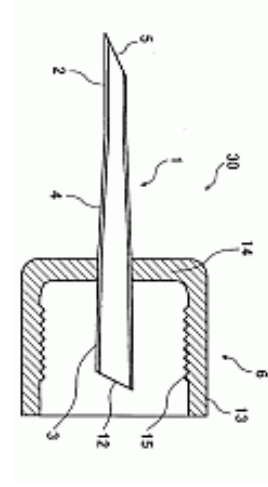
- Build a very solid and flexible fiberglass skeleton;
- Exceptional optical properties.



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PAINLESS NEEDLE

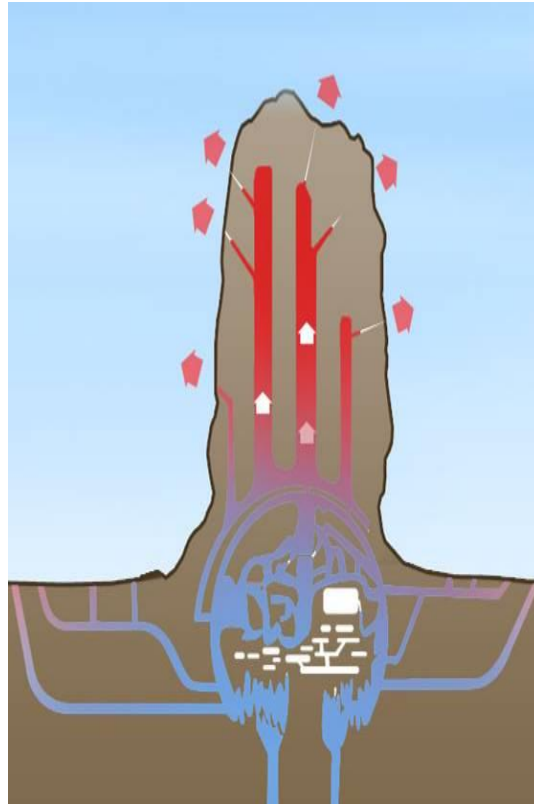


Nanopass 33 (2005, Japan),
PCT/JP2003/008781

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TERMITE MOUNDS



- Inside a termite mound, temperature (23°C) and absolute humidity are constant.
- The building of a termite mound (with controlled air inlets and chimneys) is a good example of passive air-conditioning.

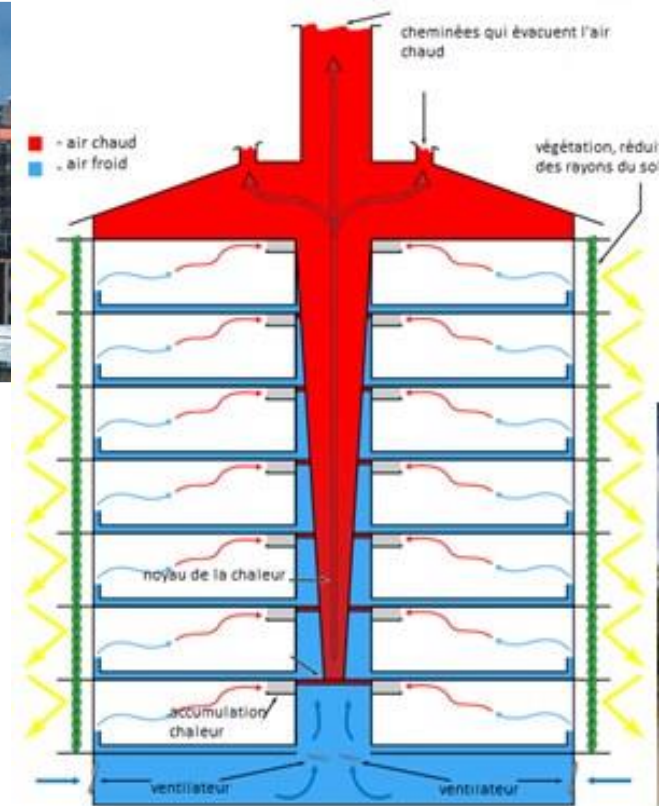
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PASSIVE AIR-CONDITIONING



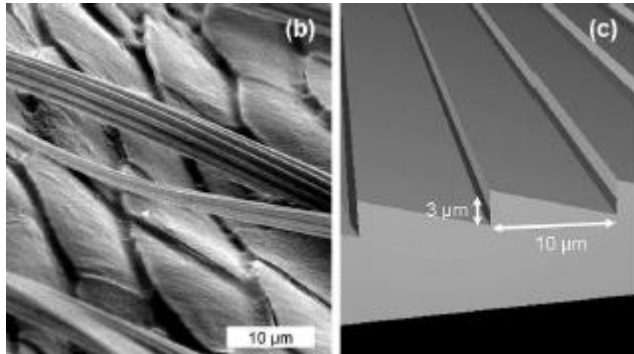
The Eastgate Center (Harare, Zimbabwe), by the architect Mick Pearce, uses only 10% of the total energy consumed by buildings of the same size, though outdoor temperatures reaching 45°C.



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FIREFLY



- Luminol = substance to detect bloodstains at crime scenes;
- High performance LED (+50% of energy efficiency): patent by prof. V. Aimez from Uds.



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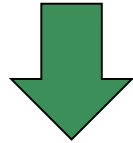
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CARBON DIOXIDE AS CEMENT

Coral reef

(800 years, 800 P_{atm})

CO₂ + sea water = calcium carbonate



50% cement + 50% calcium carbonate =
new cement
(company Calera)

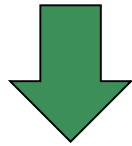


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LOCUST NAVIGATION

Neurological system allowing them to move in swarms following certain rules.



Has inspired people working in Artificial Intelligence and especially engineers at the origin of the Google car.



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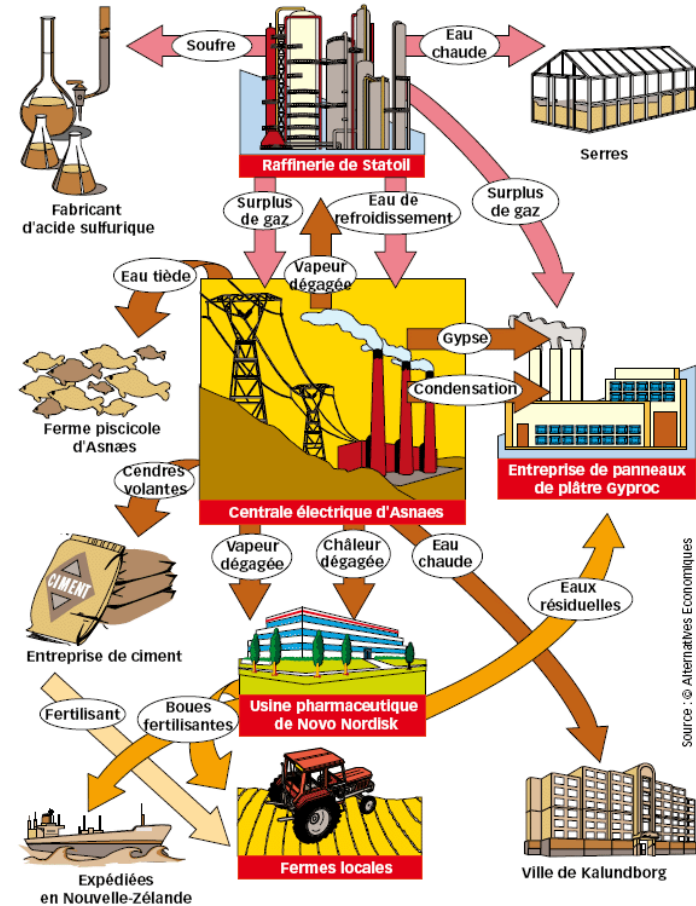
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INDUSTRIAL SYMBIOSIS



Kalundborg (Denmark)

- Any output (industrial waste, vapor, energy, CO₂...) of a company is used as an input for another;
- Many ongoing projects in Quebec industrial zones (aluminum smelter...).



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CONCLUSION

- Biomimetism, a solution to limit « the era of consequences » (Churchill)...
- ... but also for a better esthetic.
- Many possible applications in various fields:
 - Materials,
 - Robotics,
 - Building engineering,
 - Industrial processes....
- **Biggest challenge:** *changing our lifestyles and reorganizing our societies to limit our energy consumption and our environmental impact.*

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