Bio-Inspired Design: Robotics, Prosthetics, Behaviors, and Materials

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Project Premise

As educators develop new teaching methods, the tools of biomimetic exploration prove increasingly germane.

Analysis of natural systems and animals, from mechanical, biological, and behavioral perspectives, can lead to design solutions that are truly sustainable:

Materially economical
Less energy consumptive
Dependant on cooperative behavior, and
Less impactful on the environment

Taking lessons from the most successful aspects of nature, such explorations can result in products and systems that empower humans.

Project 1: Bio-Inspired Prosthetics and Robotics

ANIMAL LOCOMOTION: TAKING STEPS TOWARD BIO-INSPIRED PROSTHETIC AND ROBOTIC DESIGN

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Abstract

Analysis of the locomotion of extremely efficient animals, studies of neural stimulation amongst amputees, and recent breakthroughs in tissue engineering have resulted in radical advancements in the field of human prosthetics. Closely related to and integral to prostheses, the field of robotics is currently taking inspiration from examination of animal mobility. Scientists and researchers who study the motion of such animals, often via high-speed motion tracking, are determining the biomechanical origins of running and energy efficiency.

In conjunction with biological analysis, such findings are driving the creation of prosthetic limbs that enhance human function beyond natural abilities. For example, double-amputee sprinter Oscar Pistorius was banned from the Beijing Olympics because his prosthetic legs (based up on the mechanics of a cheetah, the world's fastest land mammal) gave him a competitive advantage over the other runners.

This type of research ultimately lends human function the best mechanical qualities of the animal and engineering worlds. For instance, examining the intricacies of the running motion of highly energy-

Project 2: Bio-Behavioral Inspiration

In relating nature to design, classification and behavioral analysis facilitated our review of how biology can translate into product design.

We initially grouped organism behaviors and design outputs into categories based on the following:

Food

Housing

Self-Growth

Self-Preservation

Secondary Classification

We subsequently created the following categories to classify our findings:

Structural Optimization

Super Strength

Bottom Up Manufacturing

Environmental Response

Nutrient Extraction

Self-Patterning

Self-Organizing

RELATIONSHIPS IN BIO-INSPIRED DESIGN

Categorization of Phenomena

Organism

Bio-phenomena

Researcher

Possible Usage

Product/Material Example

Structural Optimization

Structure follows needs

Even Weight Distribution

Formal Efficiency

Organism	Kingfisher Bird
Bio-Phenomena	Tapered beak allows for low impact diving and streamlining through the air. Upon contact with water, Kingfishers barely splash and have a clean dive.
Researcher	*Japanese train designers*
Possible Usage	Perfect shape for aerodynamics, Streamlining of trains, planes, and other forms of transportation.
Product/Material Ex.	Forms of transportation, drilling, athletic gear

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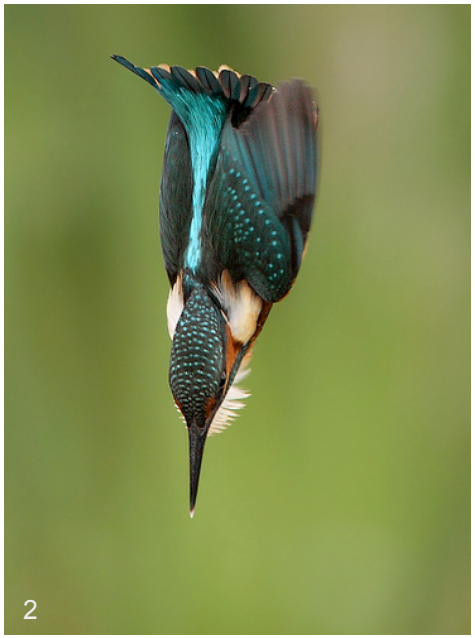
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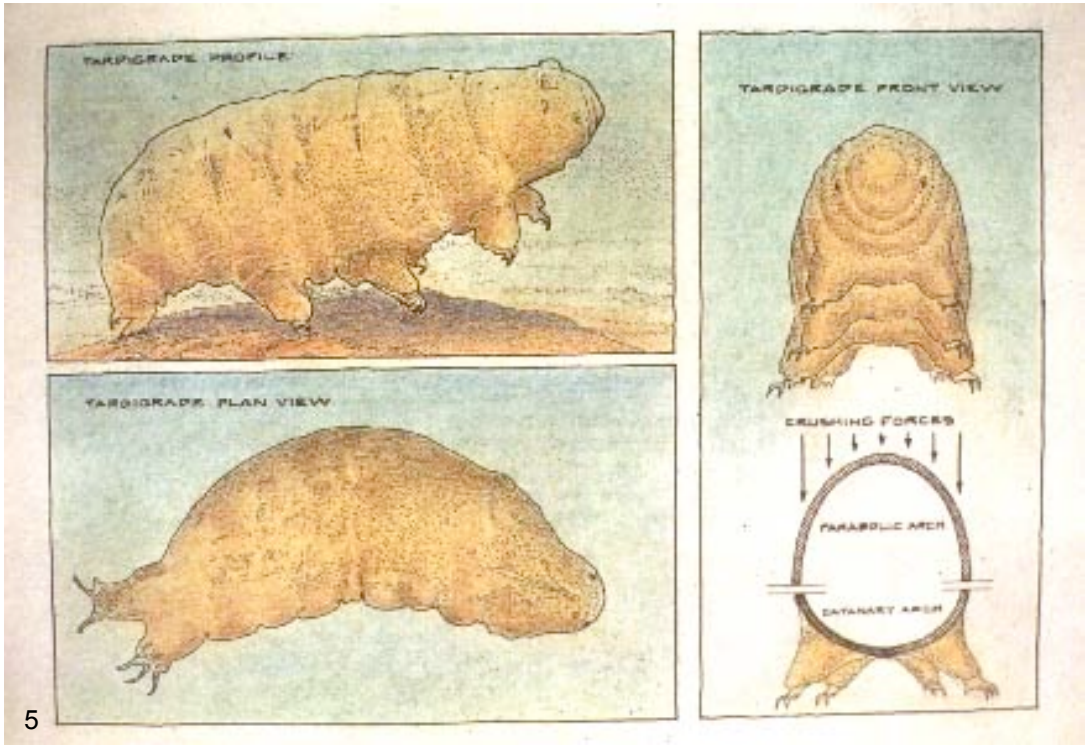
Organism	Tardigrade or “Water Bear”
Bio-Phenomena	Regenerative- can dry out (tun state) and become rejuvenated over long periods of time. Can travel to space through extreme hibernation.
Researcher	*Universities around the world- http://www.tardigrada.net/tardigradologists.htm*
Possible Usage	Extreme drying could be used to store vaccines
Product/Material Ex.	Could translate into cookware- due to survival of hot and cold temperatures, vaccines.



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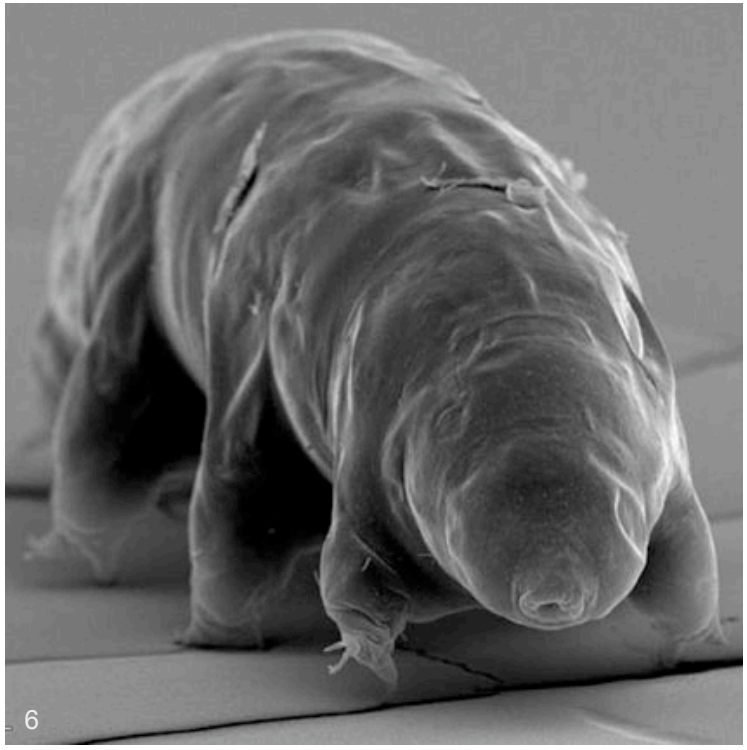

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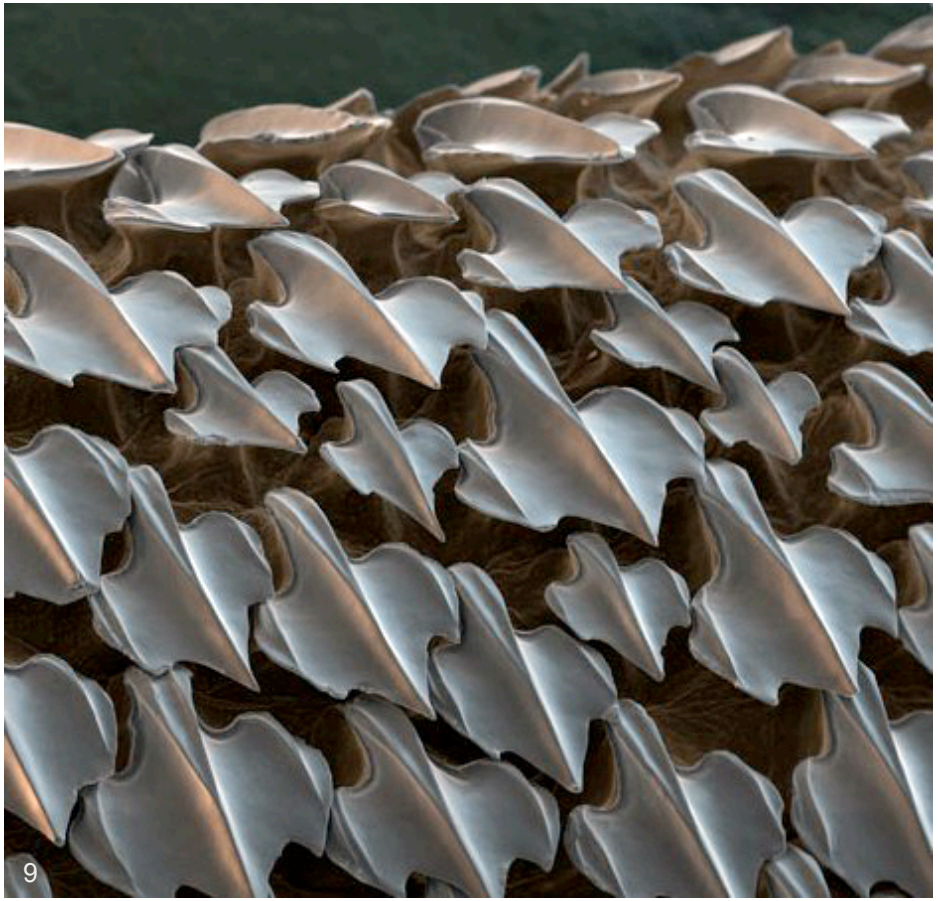
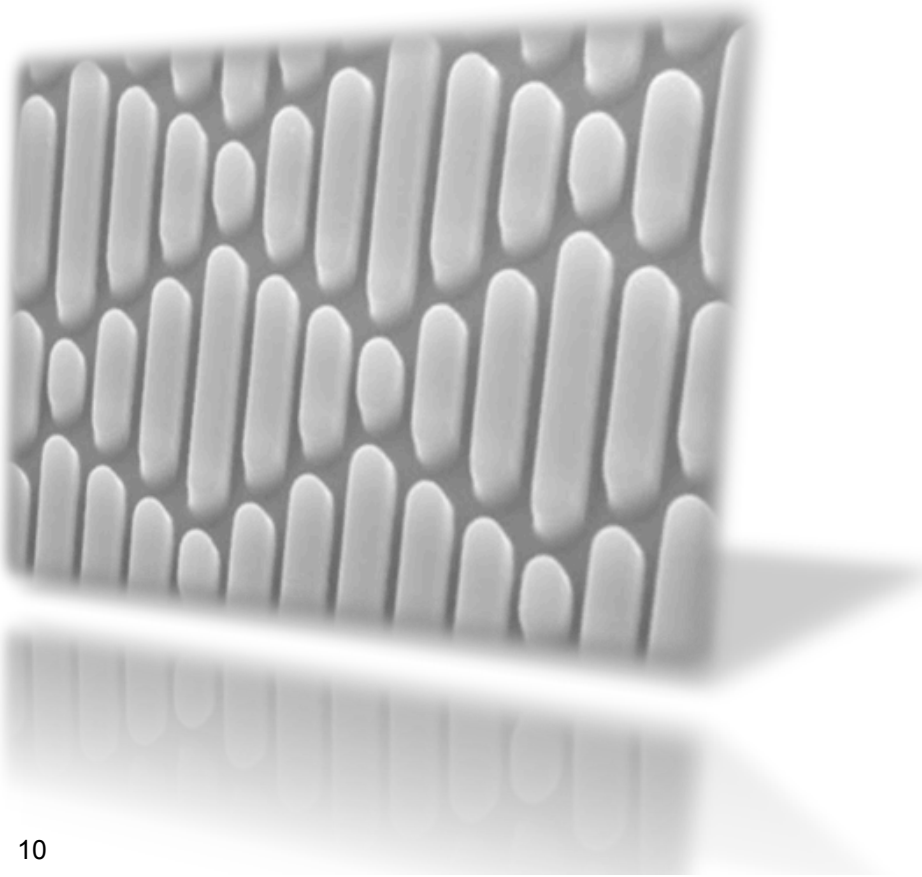
Organism	Parrot Fish
Bio-Phenomena	Strength- extremely fine, sharp teeth. Teeth are fused together and shaped like a beak. Able to crush coral (cause sand production). Additional teeth at the back of its throat for grinding.
Researcher	*American Museum of Natural History, U Exter, U California Davis (funded by US Environmental Protection Association)*
Possible Usage	The ability to grind coral helps contribute to underwater ecology- protects coral reefs.
Product/Material Ex.	Could translate into utensils, graters, best used to breakdown to other materials.

Organism	Shark Skin (Sharklet)
Bio-Phenomena	Tiny scales on shark's skin (known as denticles) prevent bacteria from growing due to their diamond patterning with tiny riblets
Researcher	*US Naval Researcher, Dr. Brennan*
Possible Usage	In "germy" areas to prevent spread of bacteria
Product/Material Ex.	Wall surfaces in hospitals





Super Strength

Perform under duress

High Strength to Weight ratio

Repetitive Structure

Organism	Spider (Spider Silk)
Bio-Phenomena	Spider silk- maintains web even after rain or dew. Can deal with stress. Elastic-like can be stretched up to 50% before breaking. Composite material- part crystalline, part-rubber based
Researcher	*University of Wyoming (funded by NSF), US Army, UC Santa Barbara, University of California*
Possible Usage	Strong flexible material has the ability to protect and flex. Weight for weight similar to steel.
Product/Material Ex.	Armor, vests, storage, hanging mechanisms, suspension cables for bridges, fiber optics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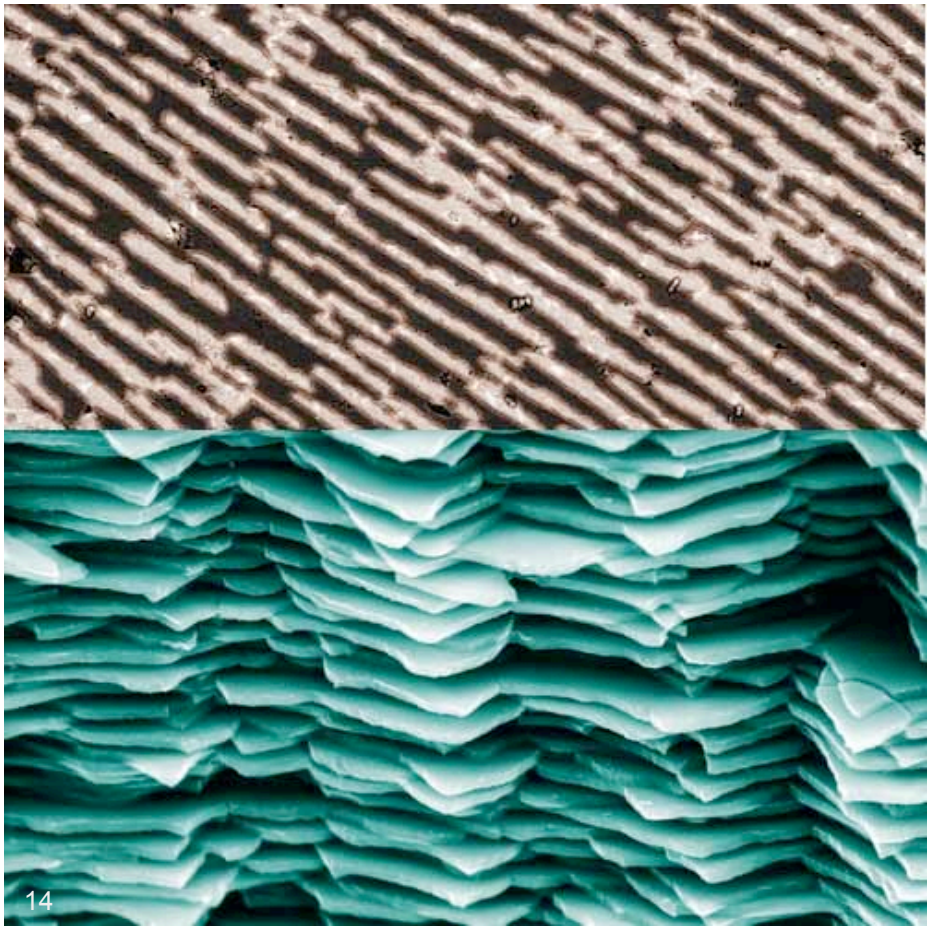
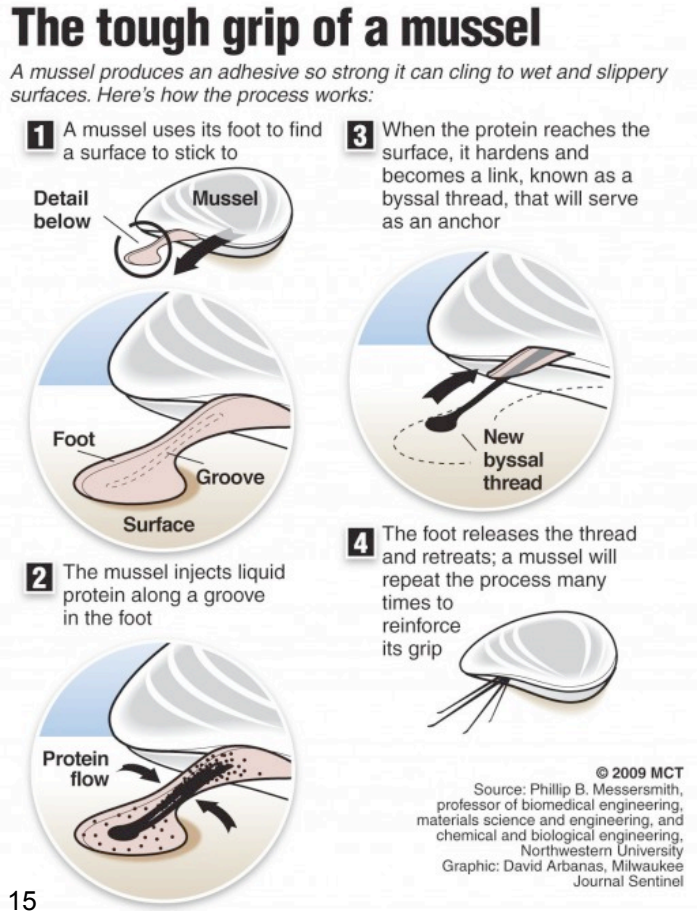
Organism	Abalone Shell (Nacre)
Bio-Phenomena	Brick work patterning of CaCo3 are held together by protein secreted by sea mollusks, super strength.
Researcher	*University of California, Dr. Vecchio; University of Michigan*
Possible Usage	Creating ceramics, durable composite materials
Product/Material Ex.	Medical applications- artificial bones, hard tissue; body armor; aircraft, automobiles



Organism	Mussels
Bio-Phenomena	Tiny filaments attach to surface, using a polyphenolic protein
Researcher	*Nerites in Wisconsin (Medhesive) , J. Herbert Waite is in the Departments of Molecular Cell & Developmental Biology and Chemistry & Biochemistry, University of California, Santa Barbara, Oregon State University, North Western University*
Possible Usage	Adhesives, durable structures, bonding agents, Wood glues, Bio-degradable adhesives
Product/Material Ex.	Bio-adhesives for sutures surgical sealants, auto dissolving solvents and anti-fouling paints



Bottom Up Manufacturing

Cyclical Building

Building through Deposition

Timed Degrading

Organism	Weaverbird Nest
Bio-Phenomena	Grass weaving and knotting. Weaverbirds learn to build well - mono material building.
Researcher	*Ohio Wesleyan University*
Possible Usage	As an ability to resist destruction and having no single area of stress and strain, weaving allows heavy loads to be held and even dispersion of weight.
Product/Material Ex.	Vases, bowls, coverings, upholstery

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Organism	Beaver Dams
Bio-Phenomena	Collection of logs, sticks and mud can turn rivers into calm ponds- able to withstand pressure of water
Researcher	*University of Alberta, University of Massachusetts*
Possible Usage	Filtration systems, architecture, flood control
Product/Material Ex.	Structures, vases, drains and stoppers

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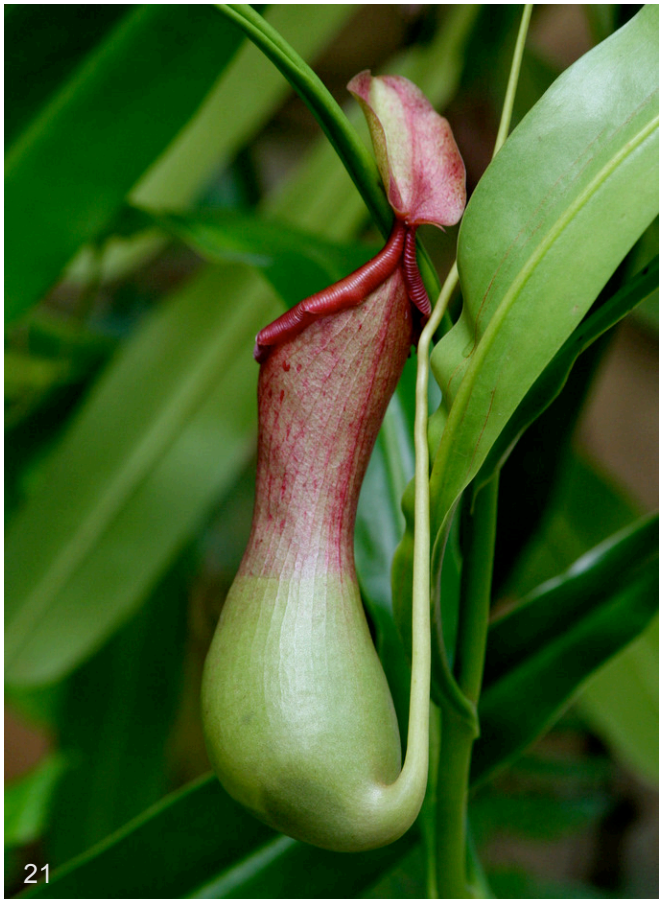
Environmental Response

Startled vs. Un-startled

Temperature-Based Reactions

Dormant vs. Activated

Organism	Pitcher Plants
Bio-Phenomena	Leaves with thin layer of waxy material to trap insects or rodents . Wax crystals on the inner walls collect on the feet of insects so they can no longer cling to walls.
Researcher	*University of Wyoming, US Army, UC Santa Barbara, University of California*
Possible Usage	Form for trapping- adhesive surface to trap or prevent movement- “pitfalls”
Product/Material Ex.	Vases, bug control, building materials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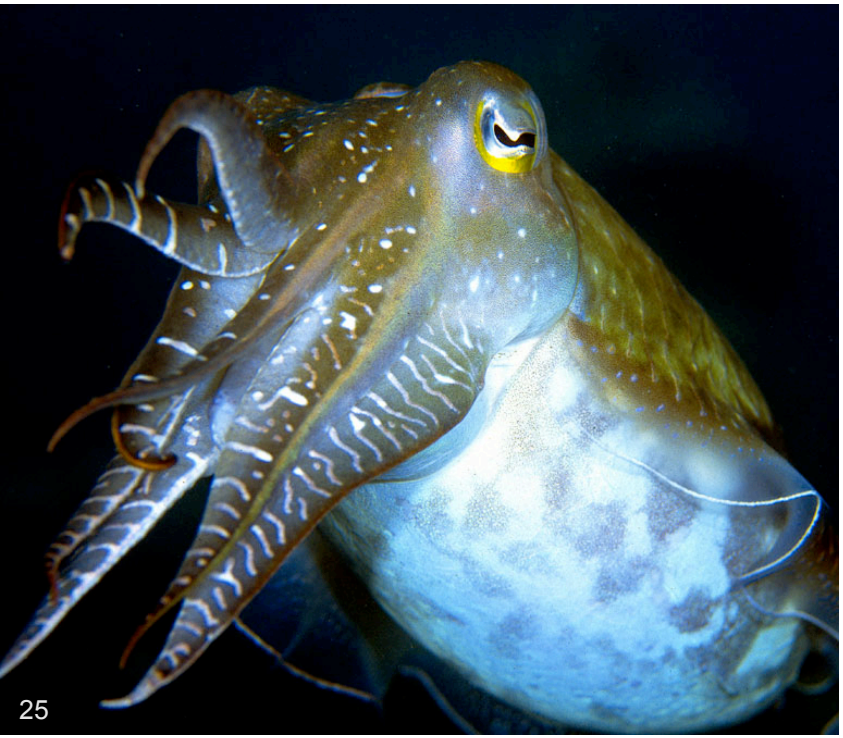
Organism	Pinecone
Bio-Phenomena	Opens petals when wet- closes petals when dry
Researcher	*Dr. Veronika Kapsali, the founder of MMT, British clothing companies*
Possible Usage	Pinecones act as if it is breathing due to reaction with humidity
Product/Material Ex.	Breathable fabric, ventilation systems

Organism	Cuttlefish
Bio-Phenomena	Change skin color in under a second to hide from predators. Camoflague.
Researcher	*MIT, Microsoft, Sun Chemical Corp., and Cornell University*
Possible Usage	Color changes could be translated into different lighting effects
Product/Material Ex.	LCD screens, fiber optics, OLEDs, LED



Nutrient Extraction

Filter Feeding

Separation while Cleaning

Passive Movement

Organism	Fiddler Crab
Bio-Phenomena	Stiff hair like structures allow fiddler crab to filter sand grains and small bacteria (spoon-shaped setae)
Researcher	*(Macnae 1968; Miller 1961; Ono 1965)." (Hogarth 1999:94-95)*
Possible Usage	Fiddler crabs absorb food through setae- small filters and hairs that prevent bad bacteria or sand from entering while eating.
Product/Material Ex.	Filtration systems

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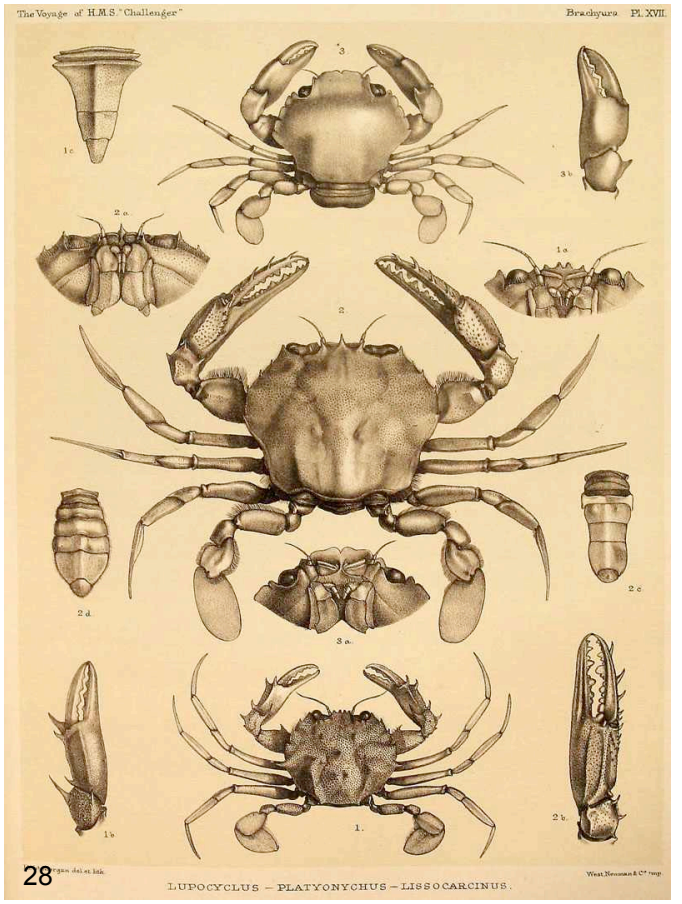

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Organism	Sea Anemone
Bio-Phenomena	Stalk maximizes feed position and allows top to bend its tentacles. Very stable base
Researcher	*Daphne Faunter, University California, Oxford University, California State*
Possible Usage	Soft neck allows for flexibility and rotational movement base on environmental needs
Product/Material Ex.	Wind turbines, tents

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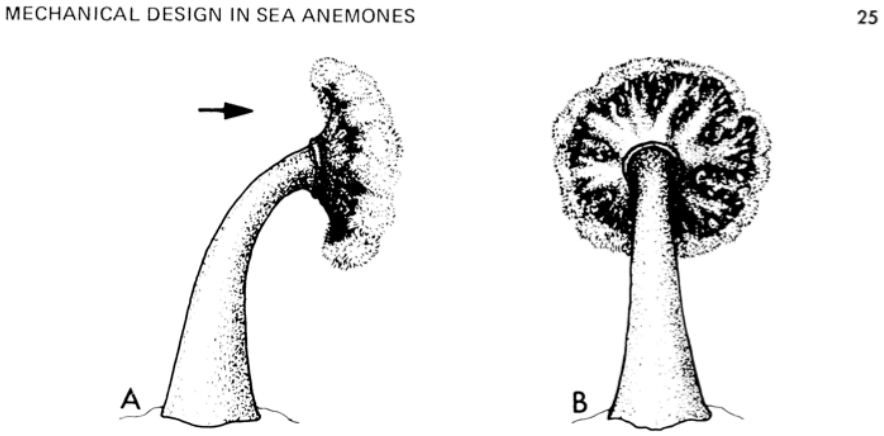

Figure 2. M. senile bent over in a tidal current. A. Side view (arrow indicates flow direction), and B. Rear view.

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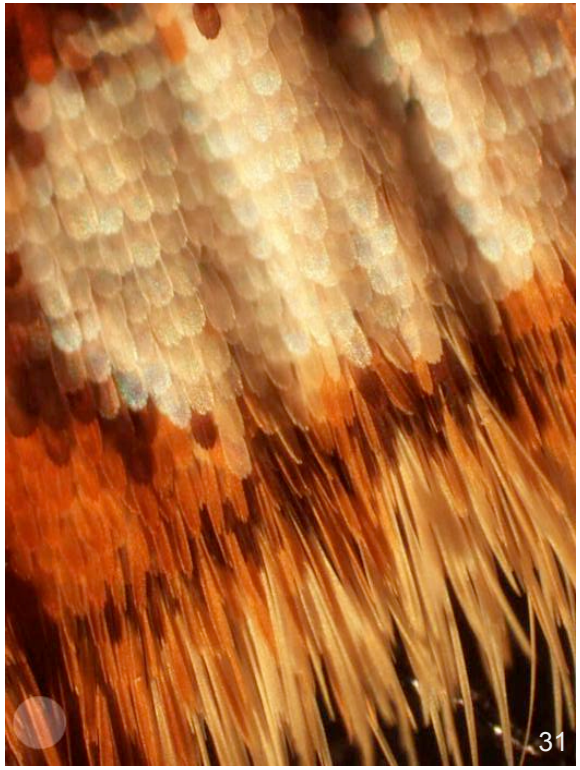
Self-Patterning

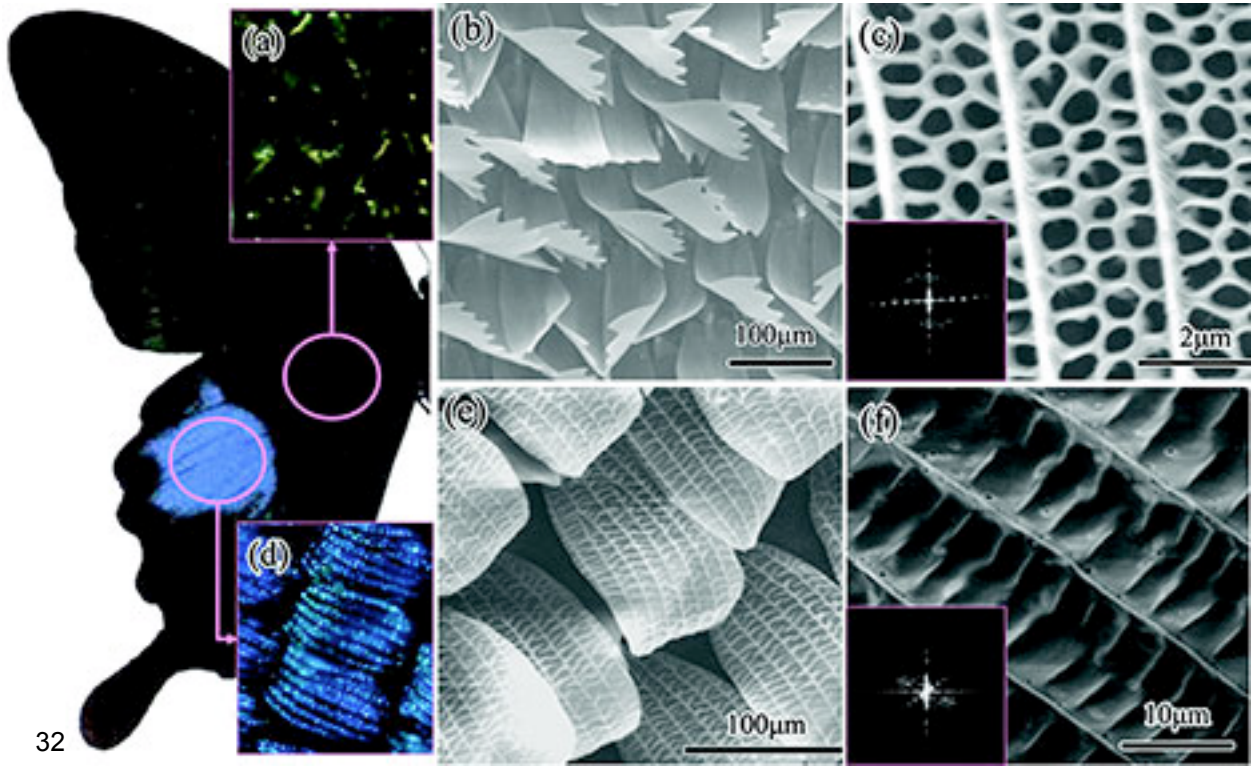
Combining identical elements

Large Structure/Tiny Parts

Self-Growth

Organism	Butterfly Wings
Bio-Phenomena	Iridescence in butterfly wings is caused by thousands of tiny overlapping scales that when sunlight penetrates these layers wavelengths blend together/cancel each other out
Researcher	*Gratzel (Michael Gratzel), General Electric (funded by DARPA), Qualcomm (Marisol screen), Penn State University, Materials Research Institute of the State University of Pennsylvania, Oregon State University*
Possible Usage	Color changes based on environment- scale pigmentation, light waves
Product/Material Ex.	Cosmetics, solar panels, car paint, optical computing, nano-sensors





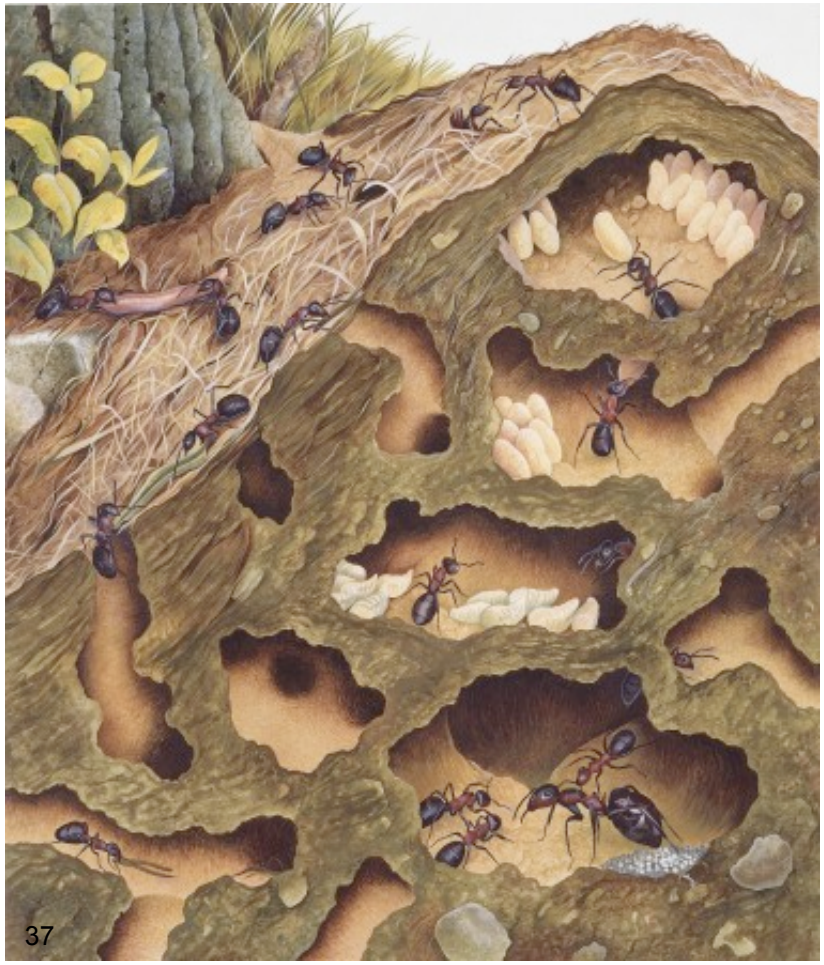
Self-Organizing

Community Preservation

Individual Roles

Networking

Biology	Ant Colonies
Bio-Investigation	Ants work together on a non-hierarchical system- there is no leader
Researcher	Northeaster University, University of California Santa Barbara
Manifestation	Always work together harmoniously towards the same goal, Creating networks and business models based on non-hierarchical behavior
Product Design	Airplane organization, phone systems



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Biology	Wheat Seed Dispersal
Bio-Investigation	Wheat seeds travel through air, when landing on ground have the ability to drill themselves into dirt
Researcher	*Department of Agricultural Botany, University College of Wales*
Manifestation	Self sustaining systems of life, growth
Product Design	Drilling tools, self planting farms, filtration

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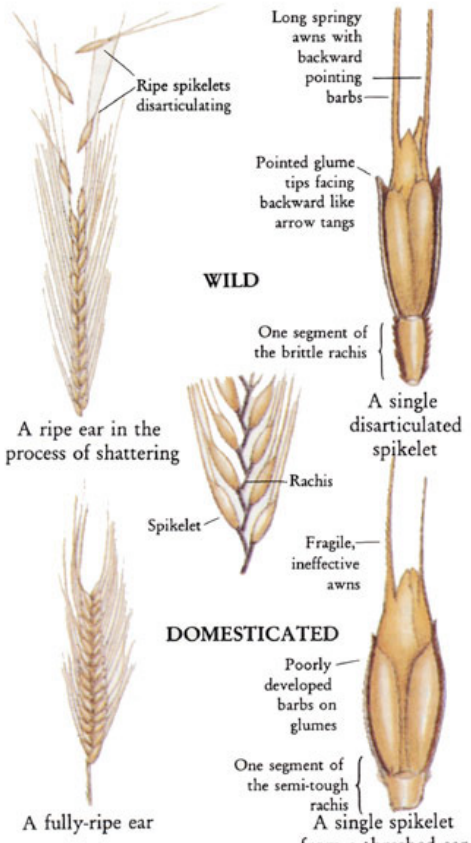

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