

Biomimicry

Design Inspired By Nature

Bios = life
Mimesis = to imitate

What is Biomimicry?

Biomimicry Examples

Biomimicry Potential

Biomimicry Design
Process

Why Biomimicry?

What is Biomimicry: define biomimicry

Biomimicry Examples: Biomimetic examples already in existence

Biomimicry Potential: Biomimetic examples that would be beneficial to humanity but haven't been fully figured out yet

Biomimicry Design Process: Steps to take when designing a biomimetic product

Why Biomimicry: Why should we apply these practices? What are the benefits?

What is Biomimicry?

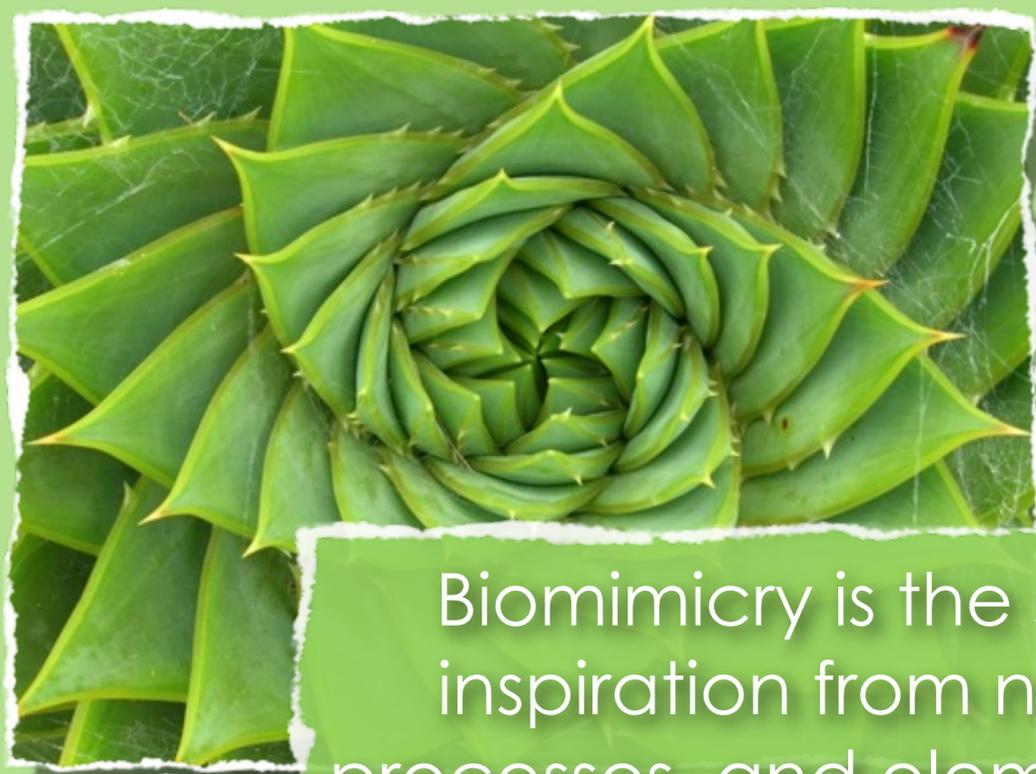
Biomimicry Examples

Biomimicry Potential

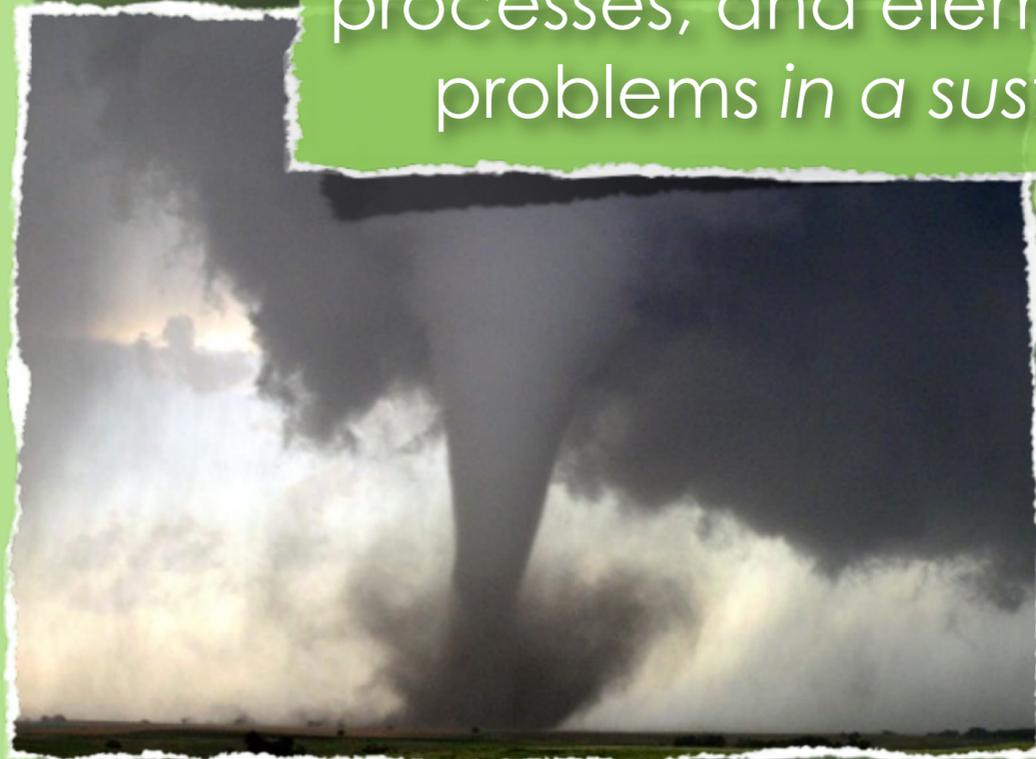


Biomimicry Design
Process

Why Biomimicry?



Biomimicry is the science of taking inspiration from nature, its systems, processes, and elements to solve design problems *in a sustainable manner*.



This is the San Diego Zoo's definition of biomimicry. In a sustainable manner (my own emphasis) is italicized to emphasize the point that we cannot just steal ideas from nature without appreciating the source of this inspiration. We must have green design along every step of the process from ideation to production. This includes closed-loop systems (elimination of waste), green chemistry, green packaging, etc.

<http://www.sandiegozoo.org/biomimicry>

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Biomimicry Examples

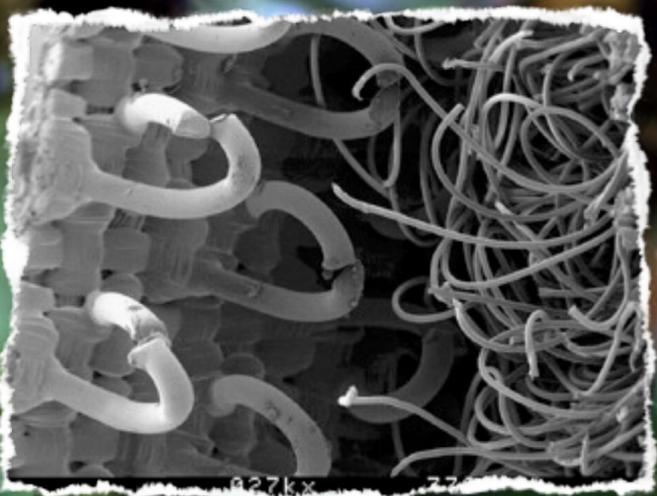
Biomimicry Potential



Biomimicry Design
Process

Why Biomimicry?

FASTENING



Swiss engineer/inventor walking his dog in a field and noticed burrs sticking to the dog's fur. Took the burrs home and looked at the structure under microscope and designed biomimetic fastener(Velcro) with interlocking hook and loop material. The hook mimics the burr while the loop mimics the fur.

<http://www.velcro.com/>

<http://brainz.org/15-coolest-cases-biomimicry/>



ARCHITECTURE



Termites thermoregulate by opening/closing vents and manipulating air currents inside the mound. They open vents near the bottom to let in cool air, while hot air rises and exits vents at the top.

The Eastgate Centre, a shopping and apartment center in Zimbabwe, does the same thing. There are chimneys on the roof and open vents at ground level. Air enters building and is either cooled or heated depending on internal temperature. At night, the building cools. As the day begins and people move around, the building heats up. Hot air exits out chimneys and is replaced by cooler incoming air.

By designing the building in this efficient manner the builders were able to save costs because no air conditioning system had to be installed. The lower energy bill continues to save the owners money and as a result, the tenants are charged less rent.

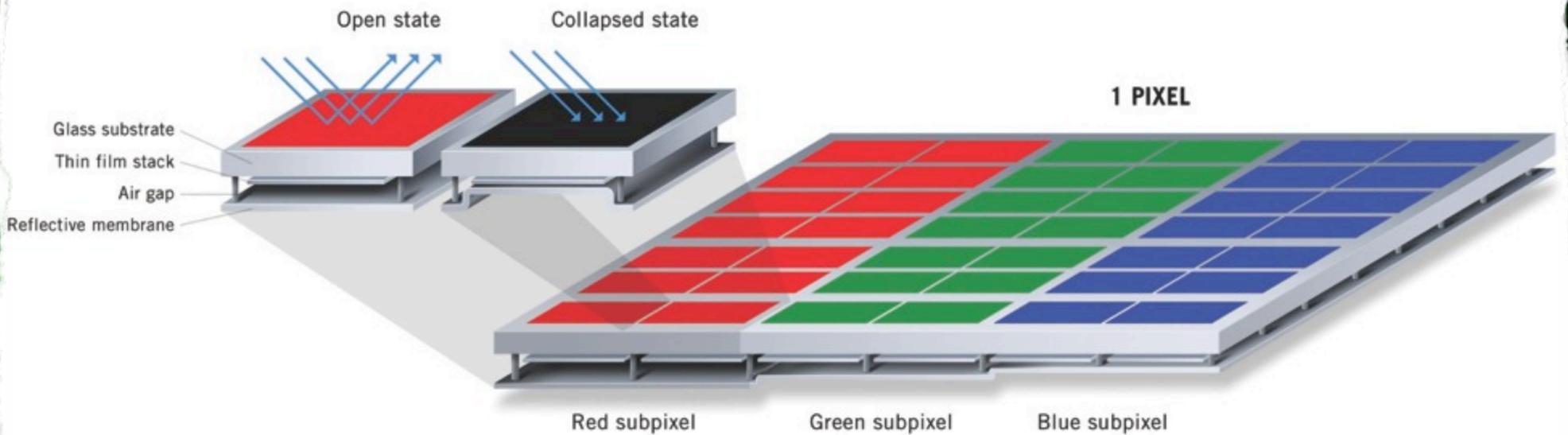
<http://www.inhabitat.com/2007/12/10/building-modelled-on-termites-eastgate-centre-in-zimbabwe/>

<http://brainz.org/15-coolest-cases-biomimicry/>

COLOR WITHOUT PIGMENT



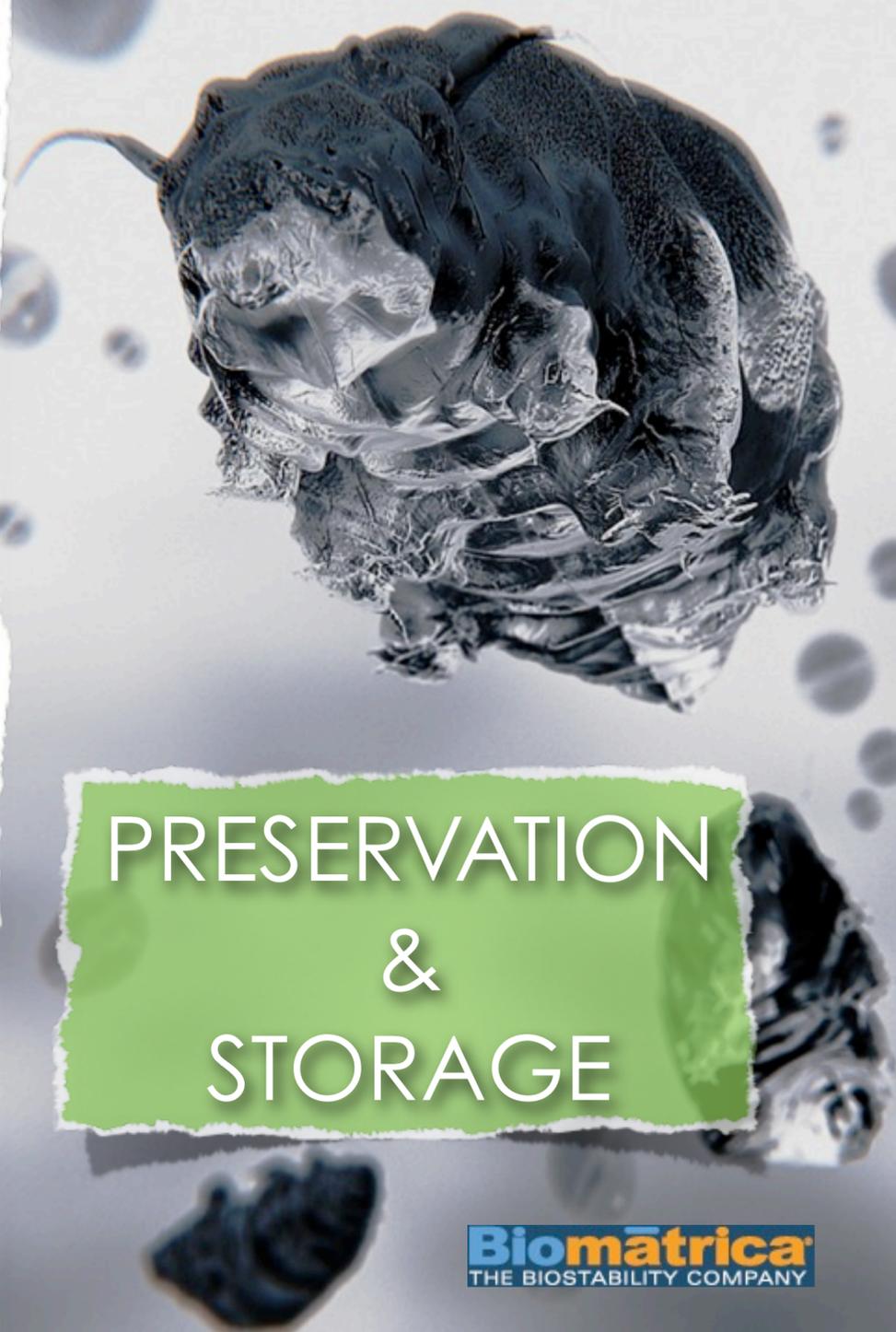
RED SUBPIXEL DETAIL



There is no pigment in the morpho butterfly's wings. The microstructure of the wings takes in ambient light and reflects it back at a different wavelength to produce the blue color. This process also occurs in peacock feathers. Qualcomm's Mirasol technology mimics this structure to create their handheld displays. Each pixel can be modified to increase or decrease the amount of light let in to preferentially reflect specific wavelengths of light. The display uses available sunlight to illuminate the screen and create colors. As a result it can easily be viewed in full sunlight, unlike current displays, which are difficult to view outdoors. There is one small LED light for night time viewing.

Qualcomm approached this problem in true biomimicry fashion. They looked at current technologies and saw that the trend was to make stonger and stronger batteries. Then they spoke to consumers and found out that what customers wanted was a device that lasted longer without as much charging. After gathering this information Qualcomm stepped back and broke the problem down to the functional level: what customers wanted was more usage time between charges. Instead of following the norm and making a stronger battery, Qualcomm designed a display screen, inspired by nature, with increased efficiency, therefore reducing drain on the battery. Their technology also reduces pressure on landfills, allowing customers to hold on to their batteries longer.

<http://www.mirasoldisplays.com/>



PRESERVATION & STORAGE

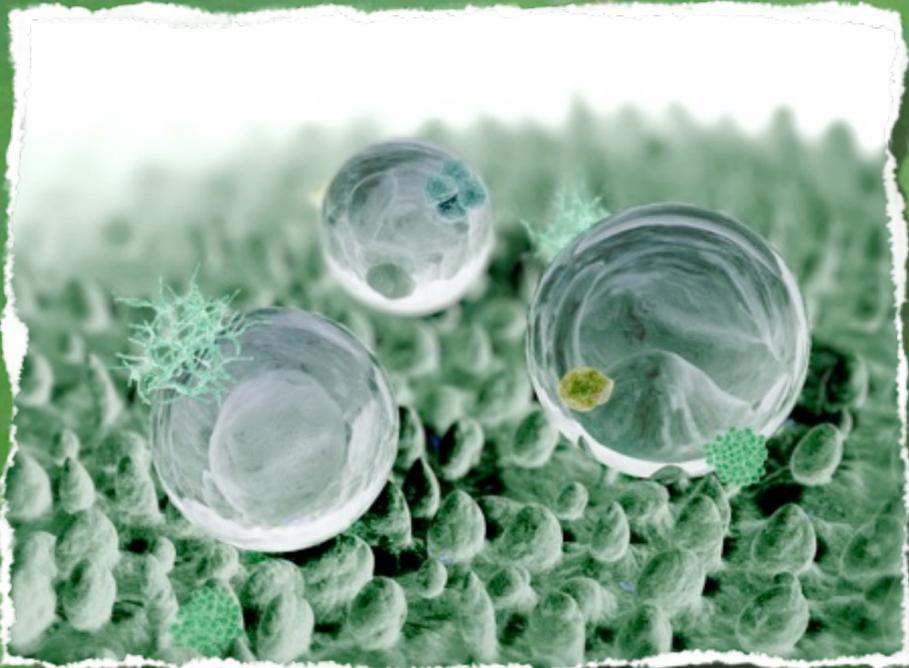
Biomātrica
THE BIOSTABILITY COMPANY



The tardigrade (water bear) undergoes a process called anhydrobiosis: it can remove all water from its body and live in an arrested metabolic state for 150 yrs. Add a drop of water and it completely reanimates. Biomātrica, a San Diego based company, has figured out how to replicate this process and has applied it to DNA and RNA storage. Samples can be stored on shelves at room temperature. This is a significant energy saver when applied to DNA storage systems such as right here at the Institute for Conservation Research. Right around the corner there is a -80 degree Celcius Freezer Room: there are 14 freezers. Each one costs \$1000 in energy alone per year. These freezers must be on at all times, with backup generators necessary in case of failure. There is a serious risk of degradation of samples, should the freezers climb in temperature. Mimicking the abilities of the tardigrade reduces energy and maintenance costs. It also decreases the amount of storage space needed to store DNA/RNA samples. Imagine the energy and money savings if all DNA/RNA storage was switched to this process.

Biomātrica is currently working on perfecting this application for whole cell systems. Huge implications for the Frozen Zoo.

<http://www.biomātrica.com/>



WATERPROOFING & SELF-CLEANING

The leaves of the lotus plant are waterproof and self cleaning. The microstructure forms an array of tiny bumps that create a hydrophobic surface. As the droplets roll off, they collect dirt particles and clean the leaf. Stocoat Lotusan is a paint mimicking the lotus leaf microstructure that is used to paint building exteriors. The building is then cleaned by rainfall. This minimizes water usage and reduces maintenance costs. Imagine applying this to car exteriors. You would never have to wash your car.

http://www.stocorp.com/index.php/component/option,com_catalog2/Itemid,196/catID,43/catLevel,5/lang,en/productID,34/subCatID,44/subCatIDBP,44/subCatIDnext,0/

http://www.paintpro.net/Articles/PP705/PP705_ProductProfiles.cfm

WATERPROOF ADHESIVES



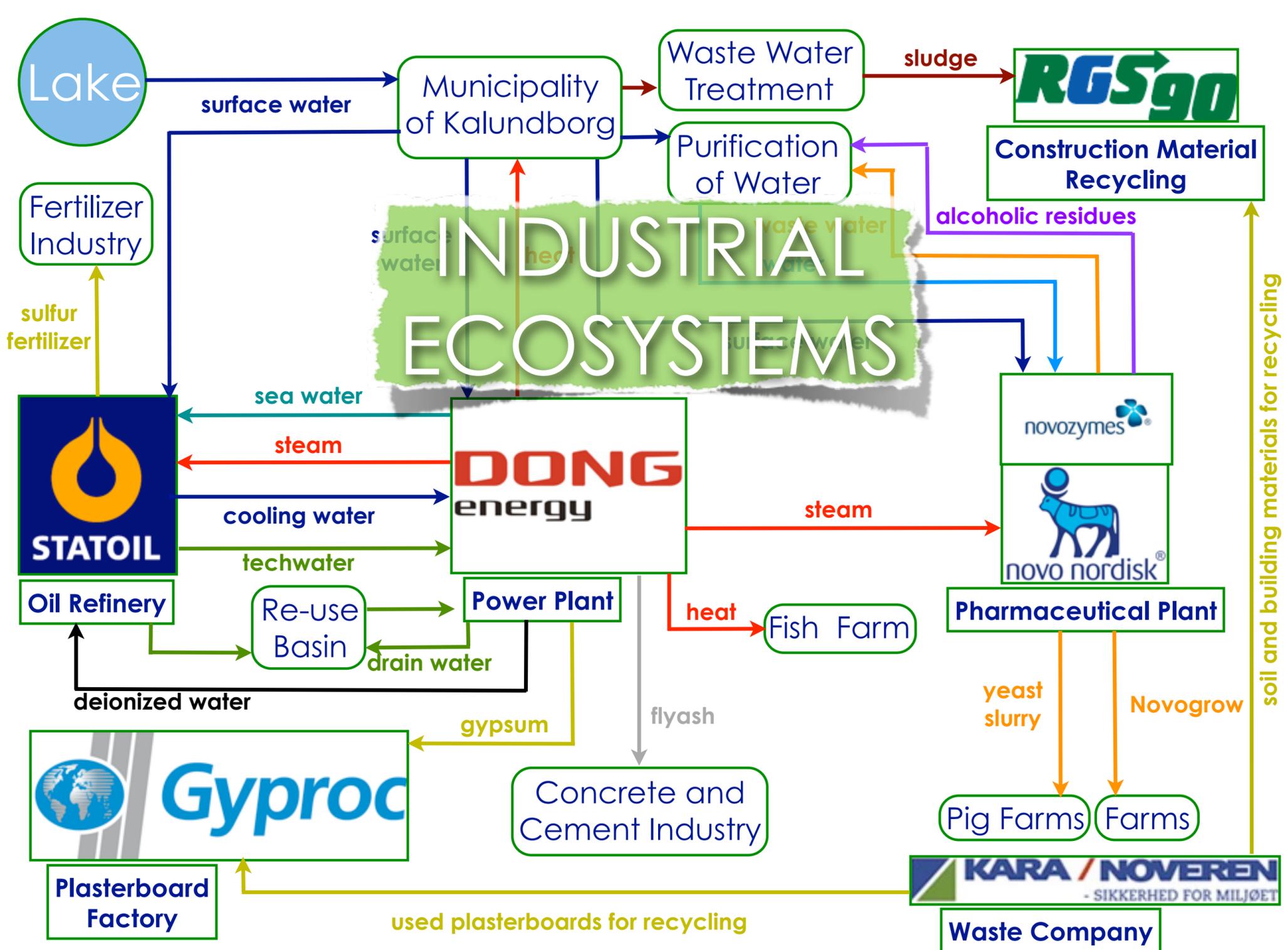
PureBond.
FORMALDEHYDE-FREE HARDWOOD PLYWOOD

Mussels form byssal threads underwater. It is necessary for these threads to be strong so that the mussel can attach itself to substrates in the rocky intertidal (must withstand constant wave disturbance.)

Widely applicable for use in waterproof adhesives.

Scientists, inspired by the mussel, have been able to manipulate soy proteins to behave like byssal threads to make plywood glue without urea-formaldehyde (a known carcinogen). Called Purebond. Doesn't cost any more than current adhesives yet outperforms them in waterproofing and heating tests.

<http://www.columbiaforestproducts.com/PureBond.aspx>



The town of Kalundborg, Denmark can be considered an industrial ecosystem. The companies in this ecosystem realized they could make a profit selling their production by-products, which they would otherwise be dumping into the environment. Each industry in this system provides resources to one or more industries in Kalundborg. All products are environmentally and financially sustainable.

Example: the power plant produces 10% of Denmark's energy and excess heat goes to heating the city of Kalundborg and to sterilize treated waste water.

Kalundborg has a population of 20,000.

Next challenge: apply this to industries that are not built in the same location.

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Biomimicry Design
Process

Why Biomimicry?



STRENGTH & FLEXIBILITY

Spider silk is sometimes referred to as the “Holy Grail” of biomaterials. Pound for pound it is 3 times stronger than steel yet still maintains flexibility. It is also fully biodegradable, unlike steel. Huge applications: special interest of US Military.

ENERGY



Plants can do photosynthesis. Our best solar cells are 30% effective at harvesting sunlight. Photosynthesis is 95% effective. What if we could design solar panels based on the reactions of photosynthesis. This could allow us to gain energy from the sun and also sequester carbon dioxide.

SUPER ADHESIVES



Geckos can stick to almost any surface due to the microstructure of their toes. There are tiny hairs that subdivide into even smaller hairs. This serves to increase surface area contact with the substrate in order to form many bonds (Van der Waals). These weak interactions add up to a strong adhesive force that can support multiple times the gecko's weight. Gecko Tape has been manufactured but only resulted in a single-use tape. Gecko setae can regenerate whereas synthetic ones cannot.

STRUCTURAL STABILITY



The hexagon is the ideal support shape in nature. Circles do not work because there are gaps between adjacent circles. Triangles and squares do not work because they stack in even rows. Hexagons have staggered stacking and thus dissipate forces effectively. Resilient Technologies has made tires that mimic this structure in nature. Their tires are not filled with air and thus cannot pop. So far this technology has been applied to military vehicles. There is no need to change a spare tire and expose soldiers to danger. The technology has the potential to be applied in non-military vehicles as well. This could be the end of flat tires.

<http://resilienttech.com/>

<http://eetamgr.blogspot.com/2009/09/biomimicry-creates-new-tires.html>



COLOR CHANGE



Chameleons have the well-known ability to change color. They do this by chromatophore (pigment containing cells) expansion. Scientists are looking at this process as inspiration for paint that can change color and have thermoregulatory properties. It would be a light color in the summertime and turn darker to absorb heat during the winter.

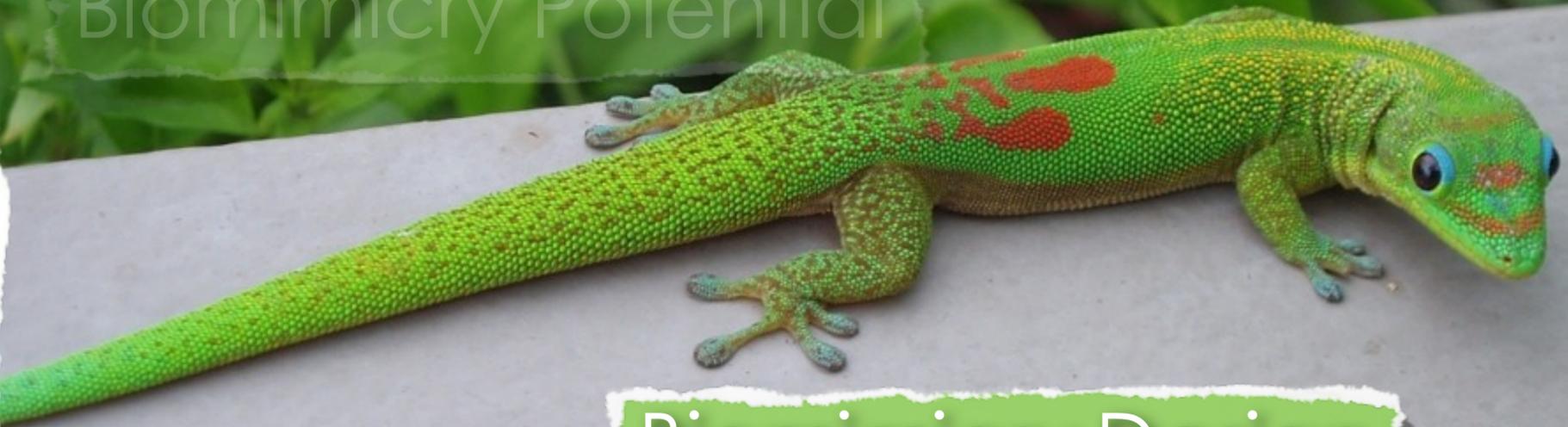


These are just some examples of nature's designs. There are many more that have already been discovered and millions of more with their secrets waiting to be unlocked.

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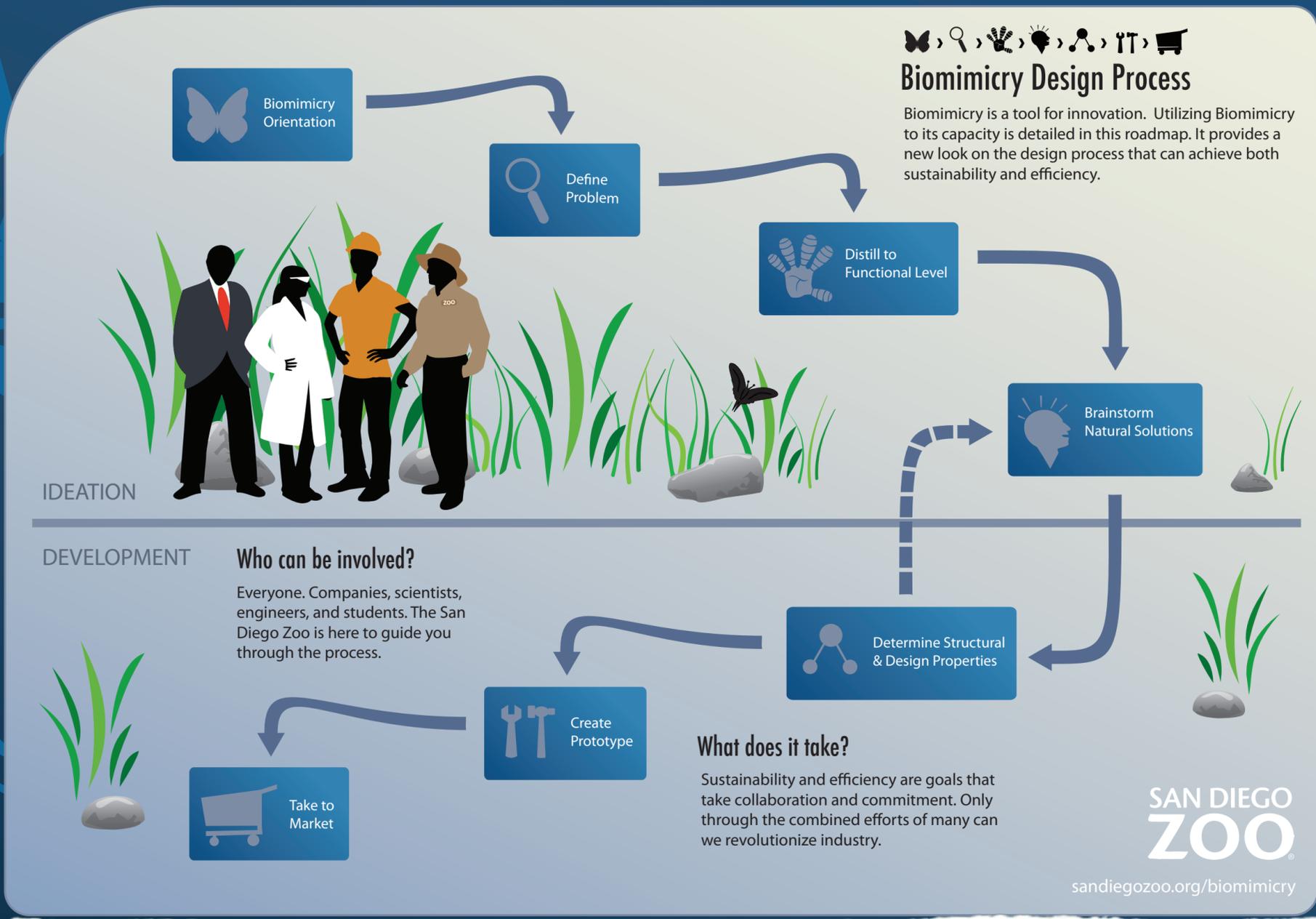


Biomimicry Design
Process

Why Biomimicry?

BIOMIMICRY

NATURE'S SOLUTIONS TO DESIGN CHALLENGES



IDEATION: Biomimicry brainstorming, defining the problem and paralleling natural example

DEVELOPMENT: implementing natural solution to the design challenge. Important to implement sustainability in every step of the production process. Create conditions conducive to life.

BIOMIMICRY

NATURE'S SOLUTIONS TO DESIGN CHALLENGES



Biomimicry Orientation: getting to know biomimicry through introductory materials and biomimetic activities that help to “flip the switch.”

BIOMIMICRY

NATURE'S SOLUTIONS TO DESIGN CHALLENGES



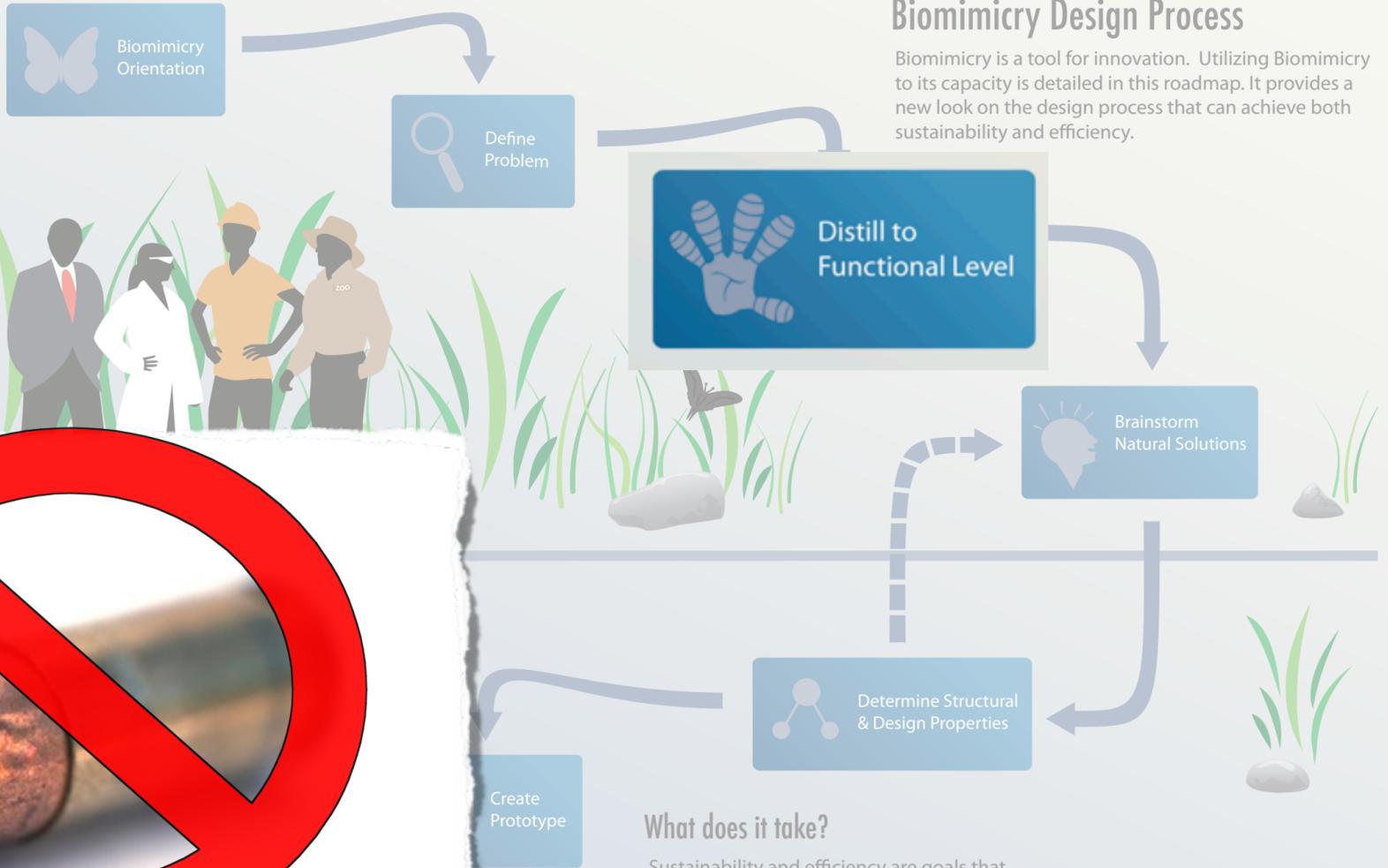
Define the problem: the bullet train in Japan was initially designed to mimic the shape of a bullet. It was effective at gaining high speeds but incurred a problem when entering and exiting tunnels. Would build up a pressure wave and emit a “song boom” upon exiting. Unpleasant for anyone on the train, nearby the tunnel, and any wildlife in the area.

BIOMIMICRY

NATURE'S SOLUTIONS TO DESIGN CHALLENGES

Biomimicry Design Process

Biomimicry is a tool for innovation. Utilizing Biomimicry to its capacity is detailed in this roadmap. It provides a new look on the design process that can achieve both sustainability and efficiency.



What does it take?

Sustainability and efficiency are goals that take collaboration and commitment. Only through the combined efforts of many can we revolutionize industry.

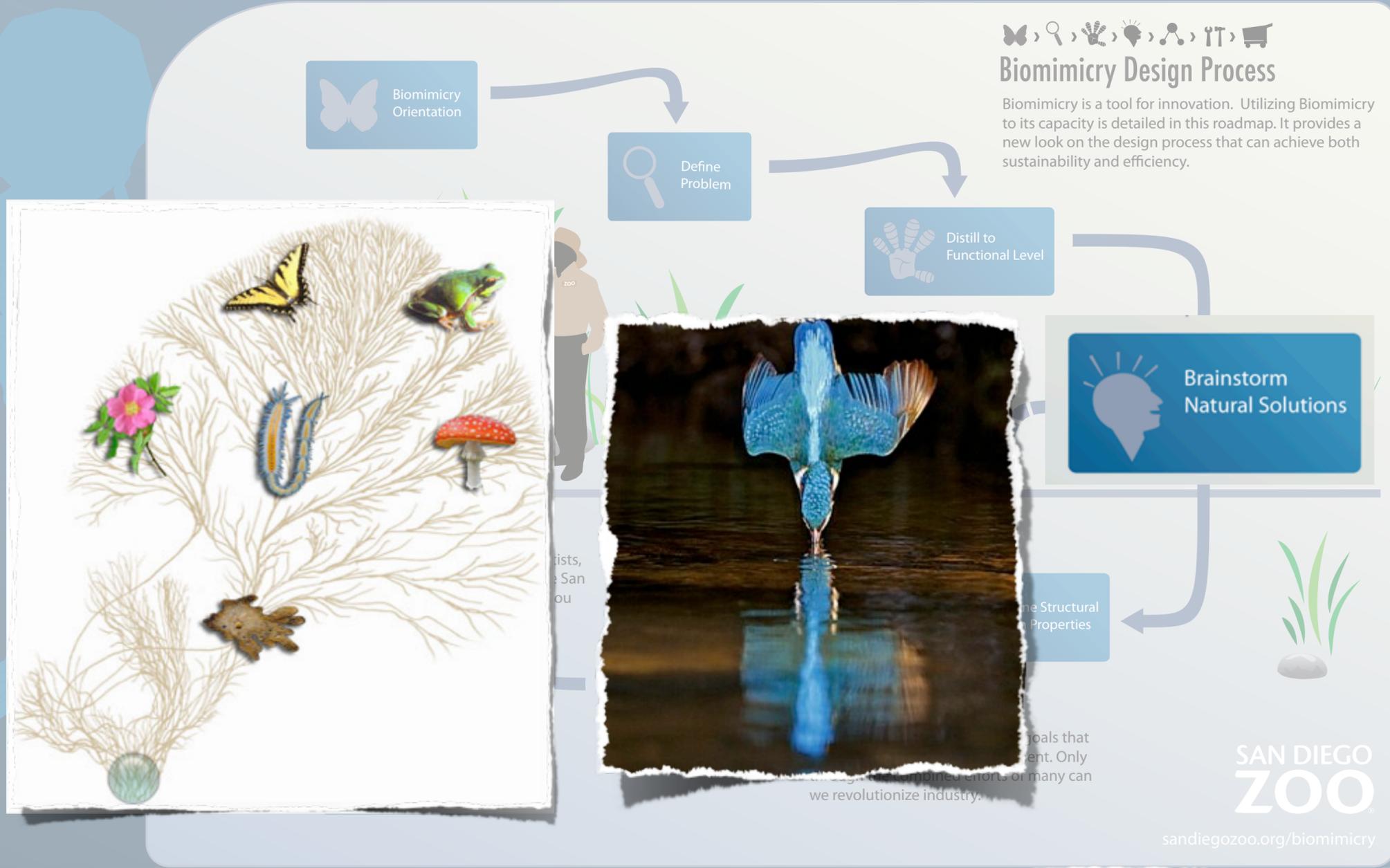
SAN DIEGO
ZOO

sandiegozoo.org/biomimicry

Distill to the functional level: what is the problem? Initially one would think: it's making a loud noise. It is important to get to the real root of the problem. What is causing the loud noise? Something is wrong with the shape of the train.

BIOMIMICRY

NATURE'S SOLUTIONS TO DESIGN CHALLENGES



Brainstorm natural solutions: It may seem initially like a large task to align a natural solution to the design problem due to the vast diversity of life on earth. Can apply plants, animals, fungi, microscopic organisms, and even move into natural systems. This is the time to bring in one or more biologists. They have the expertise to find nature's solution. In this case: engineer happened to be a bird watcher. Noted the kingfisher's ability to dive into water without making a single splash, which is important so as not to scare away the fish. Kingfisher has solved an aerodynamics problem.

BIOMIMICRY

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Distill to Function

Brainstorm Natural Solutions

IDEATION

DEVELOPMENT

Who can be involved?

Everyone. Companies, scientists, engineers, and students. The San Diego Zoo is here to guide you through the process.

Determine Structural & Design Properties

Create Prototype

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Take to Market

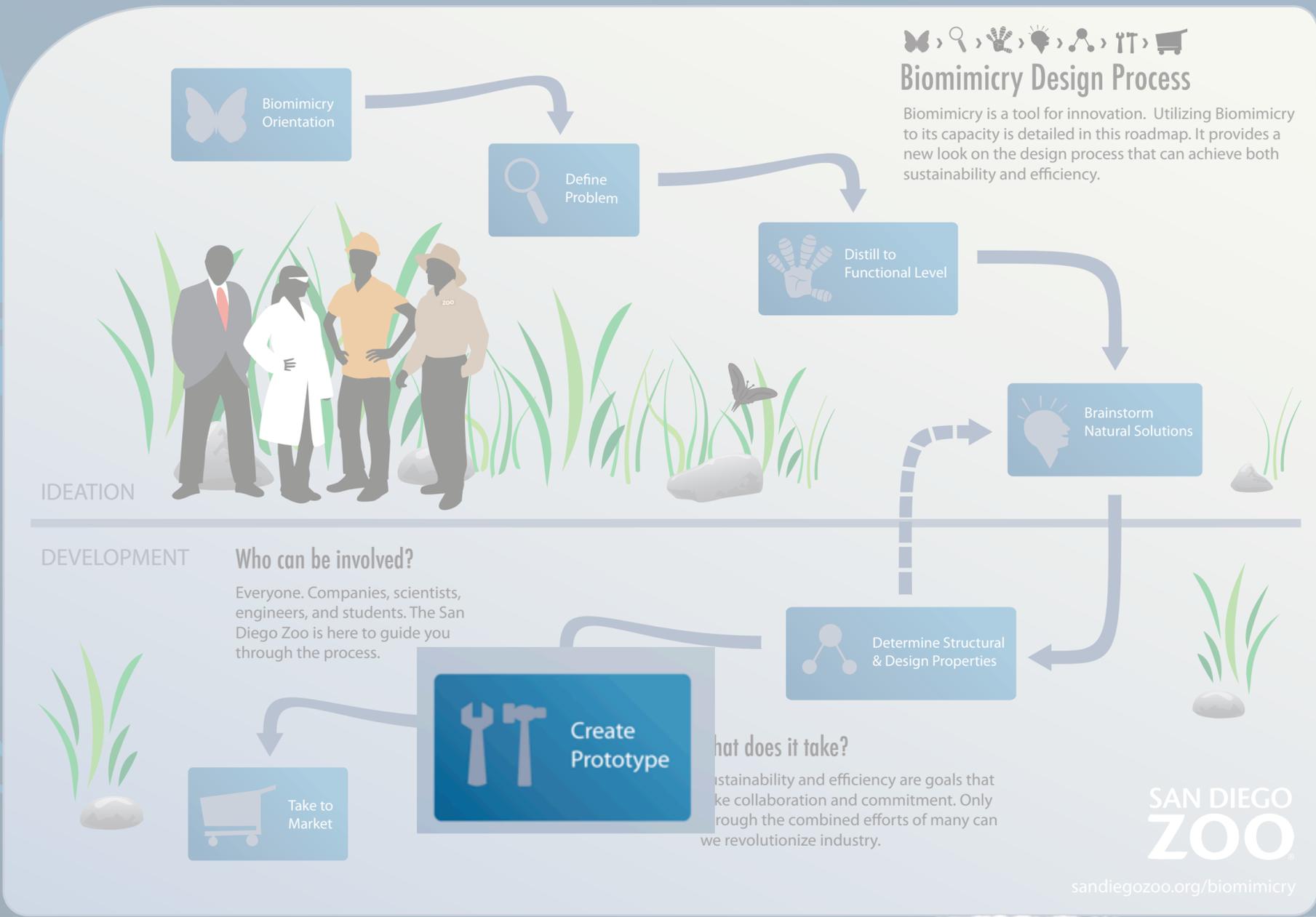
SAN DIEGO ZOO

sandiegozoo.org/biomimicry

Determine structural and design properties: how do you implement nature's design into your own? This is an important place to consider sustainability. How do you implement nature's design in a sustainable way?

BIOMIMICRY

NATURE'S SOLUTIONS TO DESIGN CHALLENGES



Create prototype: always an important step in developing a product. Ask: What would nature do here? No harsh chemicals, no high temperatures, no high pressures, no depleting natural resources. We should design with: green chemistry, renewable energy, green packaging, green branding, etc.

BIOMIMICRY

NATURE'S SOLUTIONS TO DESIGN CHALLENGES



Define Problem



DEVELOPMENT

Who can be involved?

Everyone. Companies, scientists, engineers, and students. The San Diego Zoo is here to guide you through the process.



Take to Market

Create Prototype

Determine Structural & Design Properties

What does it take?

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SAN DIEGO ZOO

sandiegozoo.org/biomimicry

Take to market: once nature's design has been implemented, take the product to market. Bullet train now designed to look like the beak of a kingfisher. Not only solved the sound issue but also reduced drag so the train goes faster and uses 10% less energy.



Nature's Principles

How nature designs a product. Nature has had almost 4 billion years of research and development. Forms efficient and elegant designs. Anything that isn't efficient is eliminated (natural selection.)

Life Creates Conditions Conducive to Life

o Optimizing Rather than Maximizing

- Using multi-functional design
- Fitting form to function

o Leveraging Interdependence

- Recycling all materials
- Fostering cooperative relationships
- Self-organizing

o Using Benign Manufacturing

- Using life-friendly materials
- Using water-based chemistry
- Using self-assembly

Life adapts and evolves

o Locally Attuned and Responsive

o Resourceful and opportunistic

- Shape rather than material

o Cellular and nested

- Simple, common building blocks

- Free energy

o Feedback Loops

- Antenna, signal, and response
- Learns and imitates

o Integrates Cyclic Processes

- Feedback loops

- Cross-pollination and mutation

o Resilient

- Diverse

- Decentralized and distributed

- Redundant

www.biomimicryinstitute.org



Optimize Rather than Maximize



Instead of creating many different building block molecules to be applied in different systems, nature optimizes the use of just a few molecules. By organizing these molecules in different ways it can form a variety of very different structures. Example here is keratin: makes fingernails, horse hooves, rhino horns, and baleen.

Heat



Beat



Use Benign Manufacturing

Treat



Deplete



All of nature's designs are fully biodegradable and don't harm the environment during production. Life creates conditions conducive to life. When we design a product we heat to high temperatures, beat with high pressures, treat with harsh chemicals, and deplete our natural resources.



Integrate Cyclic Processes



All that is created in nature eventually returns to the earth. Examples: carbon and nitrogen cycles. A more macroscopic example is composting, which is a good example as well because it highlights a unity between humans and nature. We grow our and harvest our vegetables and compost the remains. Worms and bacteria decompose the vegetation and create compost dirt, which is then returned to a garden to grow more vegetables.



Resilience

vs

Resilience in nature means something different than resilience in current human manufacturing. Resilience in nature is a long lasting organism that can fully biodegrade once its time has come. Resilience should not mean designing a plastic that is going to last in a landfill for hundreds of years. Nature has the ability to survive a wide range of stressful conditions while still following all of these principles. Our products should be able to do the same.

What is Biomimicry?

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Biomimicry Design
Process

Why Biomimicry?

A photograph of a landfill. In the center, a yellow bulldozer is working on a large pile of trash. The ground is covered in various pieces of plastic, paper, and other debris. In the background, there are some trees and a cloudy sky. Numerous birds, likely seagulls, are flying in the sky, some near the bulldozer and others scattered across the frame. The overall scene depicts a large-scale waste management operation in a natural environment.

SUSTAINABILITY

PRESERVE
BIODIVERSITY

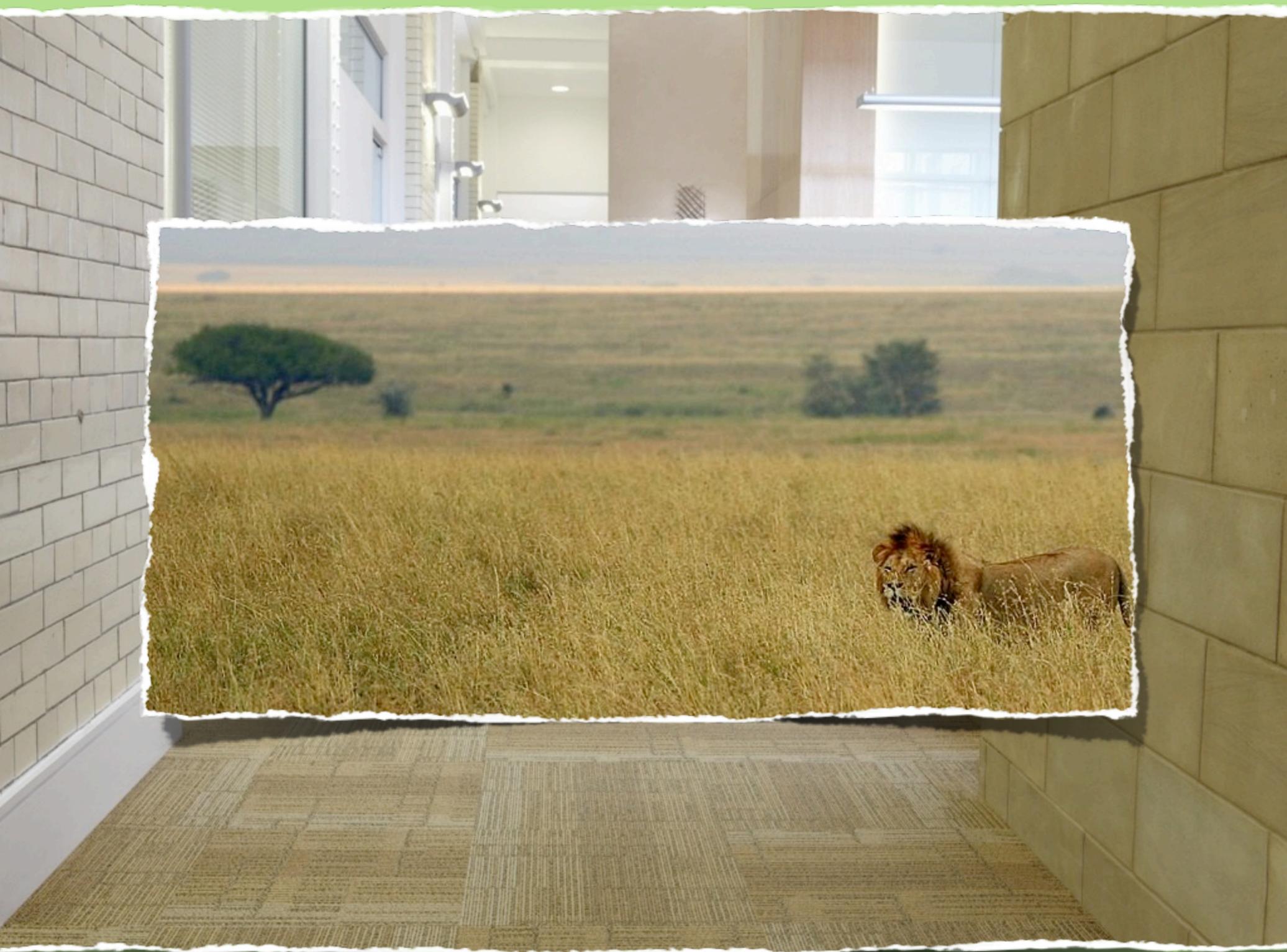
BUSINESS
BENEFITS

This picture of a landfill exemplifies the need for biomimicry. We need to be more sustainable. We cannot continue on in this linear path of depleting our natural resources and ruining the one planet we have to live on.

Preserving biodiversity: biomimicry would not be possible without an inspirational source to turn towards. By respecting nature and conserving it for generations to come, we are securing a future for biomimicry and for wildlife. Conserving biodiversity preserves systems, processes or elements that may have not had their biomimetic potential discovered yet.

Business benefits: in the examples we have seen in this presentation there were many ways to reduce costs and increase efficiencies. Biomimicry leads to increased profits and environmental benefits that businesses can boast.

*Optional to add: In his book *Natural Capitalism*, Paul Hawken calls for the next industrial revolution. In the past, resources were abundant and people scarce. Now, the opposite is the case: resources are scarce and people are abundant. Instead of increasing human productivity as the first Industrial Revolution did, we need to increase resource productivity and incorporate biomimicry into our design process.



Example: Business Benefits

Entropy by InterfaceFLOR: inspired by “nature’s carpet” Designers went into the forest and observed the pattern of leaf litter on the ground. Discovered that even though the pattern was random, it was still cohesive and aesthetically appealing.

Ray Anderson, CEO of InterfaceFLOR, had a life changing moment where he realized he didn’t want to be a part of the same old, environmentally hazardous carpet business anymore. He completely revolutionized his company. Instead of producing one piece carpets that had to be entirely torn up and replaced when they were worn or dirty, his company started producing carpets in small tiles of nonuniform color. This saves on production costs because dyes do not have to be exactly matched to each other. The tiles can be laid down in any arrangement, which saves on installation costs. There are savings on maintenance costs as well because if carpet is damaged in one section, those tiles can be replaced while keeping the non-damaged tiles in place.

Other environmental efforts: plants trees to offset plane travel emissions, company offers environmental courses taught by InterfaceFLOR specialists, “Cool Carpet” certification that all greenhouse gas emissions in the production process are zeroed out, work with local landfill to turn methane gas into energy source.



The San Diego Zoo: A living library and a living museum

San Diego Zoo Mission Statement

The San Diego Zoo is a conservation, education, and recreation organization dedicated to the reproduction, protection, and exhibition of animals, plants, and their habitats.

Why is the San Diego Zoo involved with biomimicry? We believe that we have an outstanding potential to contribute to this movement. Our facilities: the San Diego Zoo and Safari Park, offer up a living library and a living museum: a concentration of potential inspiration. Biomimicry also aligns with our mission of conserving, educating and providing recreation. With so many sustainability messages at the root of biomimicry, it aligns very well with our conservation goals. Education: the Zoo has already hosted biomimicry workshops for professors, companies and staff.

San Diego: The Biomimicry Hub of the World



San Diego Zoo can bring together universities, companies, government and offer the use of their facilities to inspire biomimetic thinking and development. Zoo is a living library and living museum full of biomimicry potential. Nature has perfected designs and processes over millions of years of evolution: the SD Zoo contains thousands of examples of this perfection.

BIOMIMICRY REFERENCES

LITERATURE

- Ausubel, Ken, and J. P. Harpignies. *Nature's Operating Instructions: the True Biotechnologies*. San Francisco: Sierra Club, 2004.
- Benyus, Janine M. *Biomimicry: Innovation Inspired by Nature*. New York: Morrow, 1997.
- Berkebile, Bob and Jason McLennan. *The Living Building: Biomimicry in Architecture, Integrating Technology with Nature*. 2003
- Forbes, Peter. *The Gecko's Foot: Bio-Inspiration: Engineering New Materials from Nature*. New York: W.W. Norton &, 2006.
- Hawken, Paul, Amory B. Lovins, and L. Hunter Lovins. *Natural Capitalism: Creating the Next Industrial Revolution*. Boston: Little, Brown and, 1999.
- McDonough, William, and Michael Braungart. *Cradle to Cradle: Remaking the Way We Make Things*. New York: North Point, 2002.

And many more! Amazon.com search: "Biomimicry"

VIDEOS

- Janine Benyus: 12 sustainable design ideas from nature. - TEDtalksDirector
⇒ <http://www.youtube.com/watch?v=n77BfxnVlyc>
- Janine Benyus: Biomimicry in action - TEDtalksdirector
⇒ http://www.youtube.com/watch?v=k_Gfq12w5WU
- The Nature of Things: Biomimicry - FireworksChannel
⇒ Part 1: <http://www.youtube.com/watch?v=aGPzYagkg-M>
⇒ Part 2: <http://www.youtube.com/watch?v=fVmnbzT1G6U>
- Natural Capitalism: The Next Industrial Revolution - UCtelevision
⇒ <http://www.youtube.com/watch?v=1zf03#W6xCw>

And many more! YouTube/Google Video search: "Biomimicry"

WEBSITES

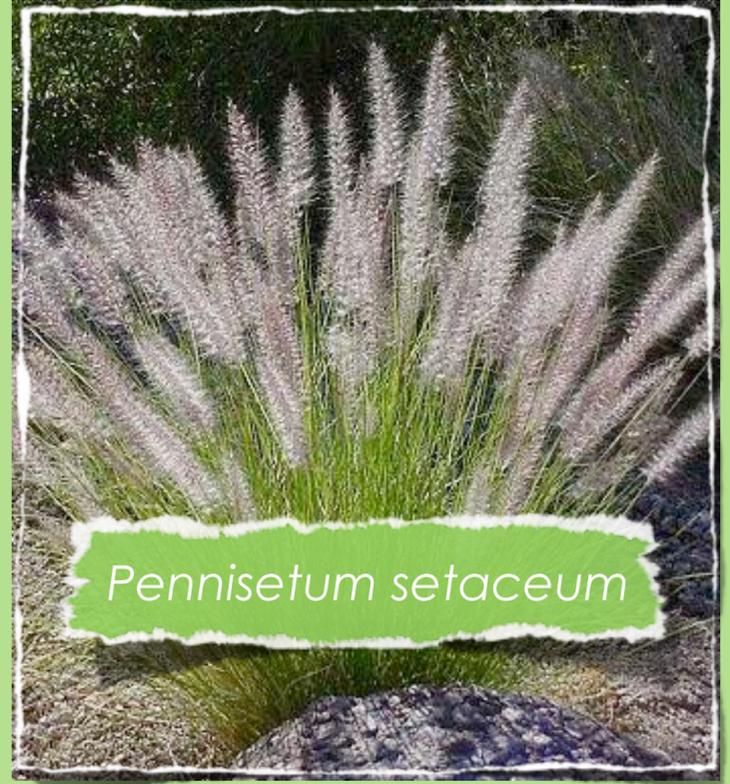
- San Diego Zoo Biomimicry
⇒ www.sandiegozoo.org/biomimicry
- The 15 Coolest Cases of Biomimicry
⇒ <http://brainz.org/15-coolest-cases-biomimicry/>
- Biomimicry Guild, Biomimicry Institute
⇒ www.biomimicry.net
- Ask Nature - The Biomimicry Design Portal
⇒ www.asknature.org
- Biomimicry News
⇒ www.biomimicrynews.com

And many more! Google search: "Biomimicry"

www.sandiegozoo.org/biomimicry



Quercus berberidifolia



Pennisetum setaceum



Artemisia californica