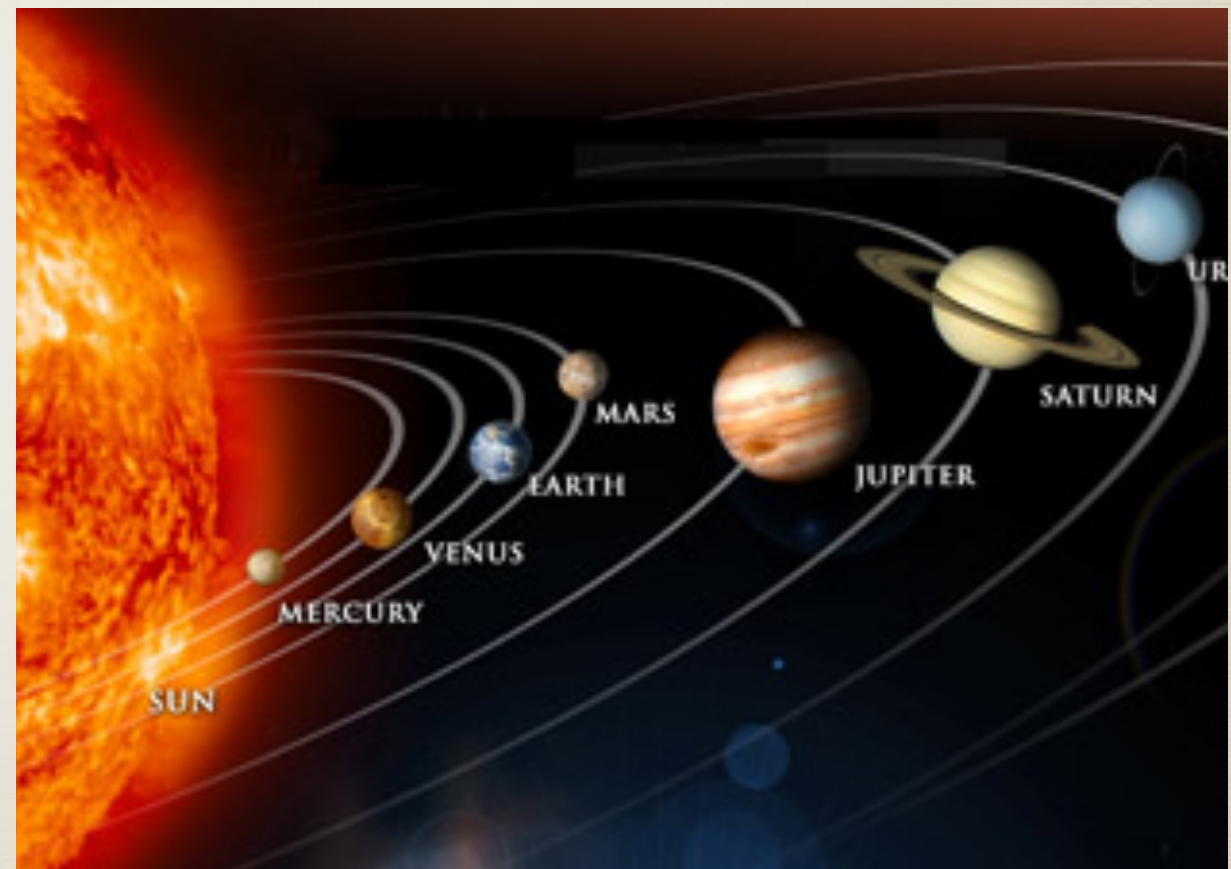
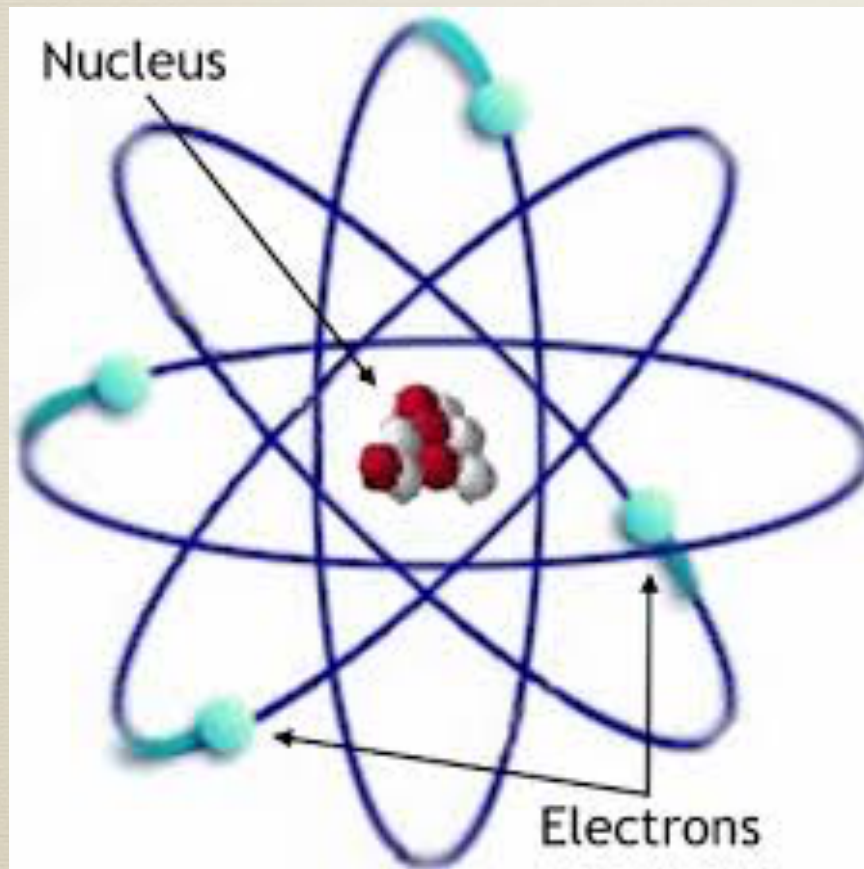


BIO-INSPIRED DESIGN

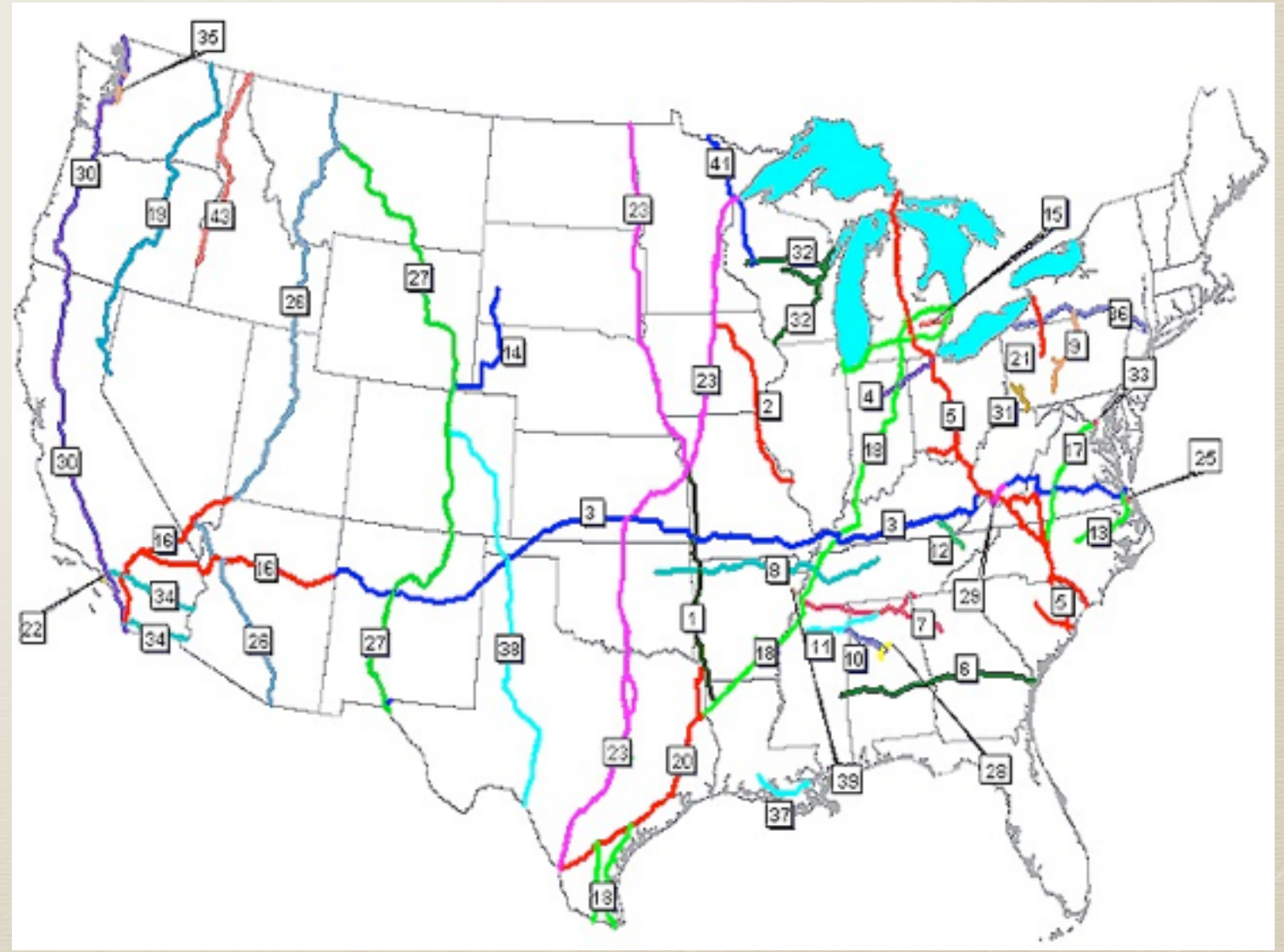
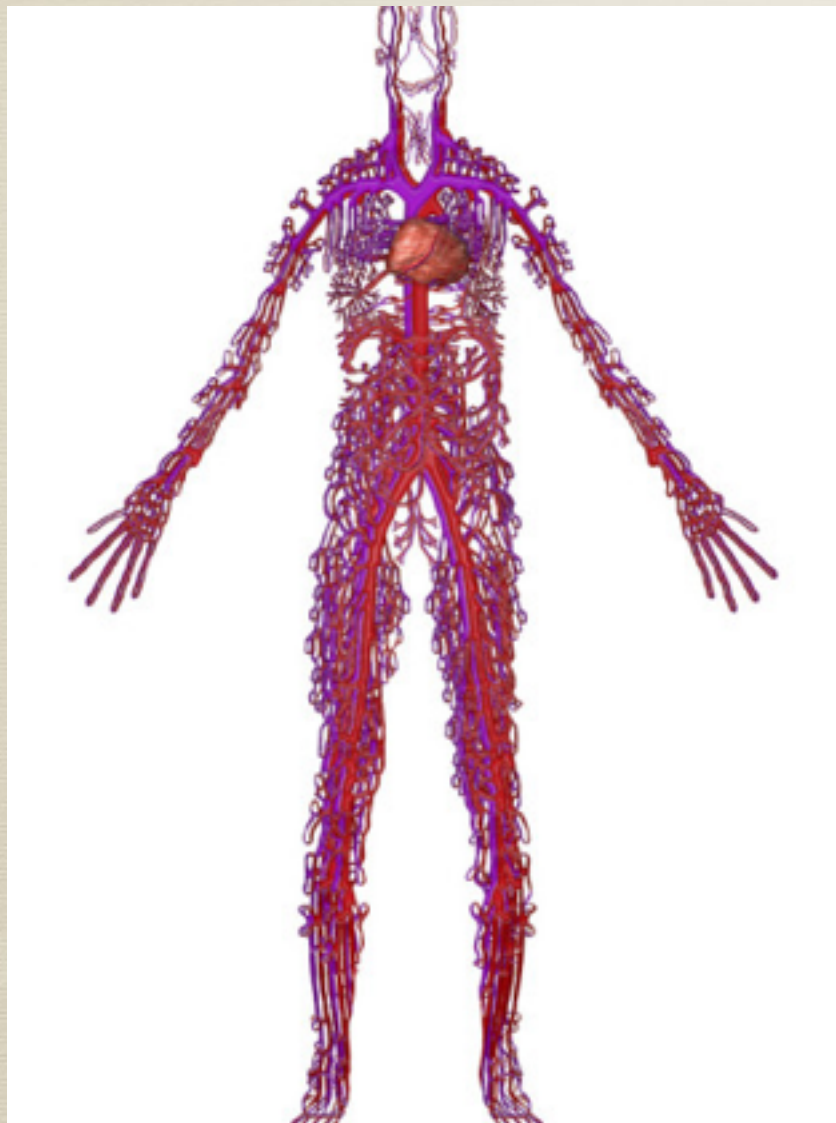
Design by Analogy

- * **Analogy:** Similarity in some respects between things that are otherwise dissimilar; a comparison between two things, typically for the purpose of explanation or clarification.
- * Analogies can be used to solve problems, by recognizing when the design task is similar to a previously solved problem.
- * A 2011 study measuring the ideation performance of senior engineering students (N =153) found that ideas stimulated by far-field analogies (out of domain) were more likely to be novel (innovative) than others.

The motion of electrons about the nucleus of an atom is analogous to the Earth's rotation about the sun.

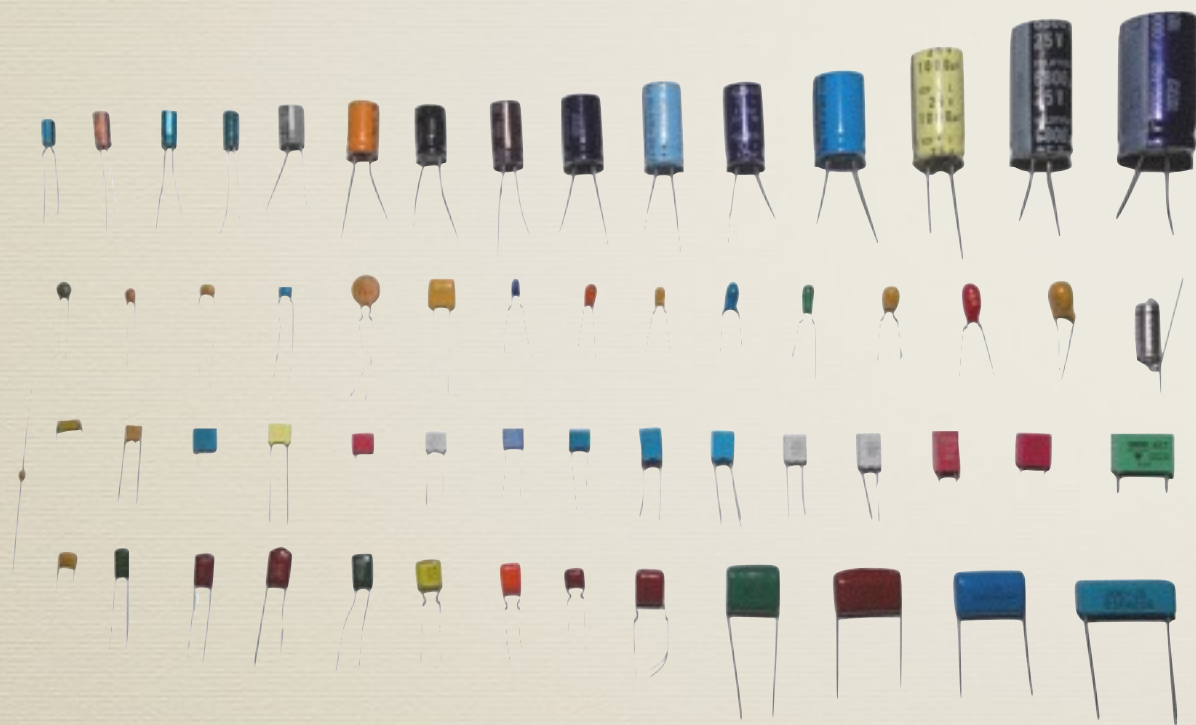


A blood clot is analogous to a traffic jam and prevents the blood cells from making their vital deliveries.



Analogies within Engineering

* What mechanical device is analogous to a capacitor?



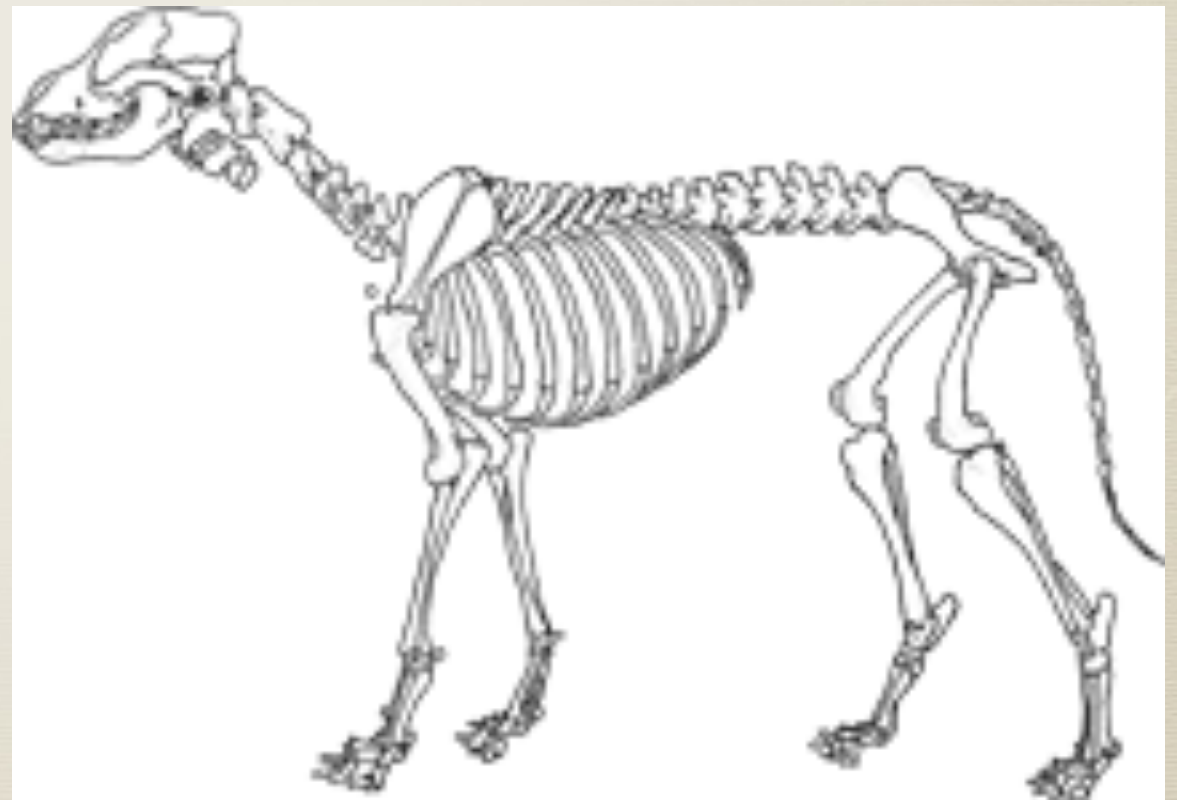
Capacitors



Springs

Analogies Outside Engineering

* What in nature is analogous to a bike frame?



Analogies Outside Engineering

- * What in nature is analogous to a barbed wire?



Analogy Example

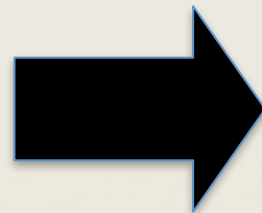
- * Exercise equipment - Develop a concept for an exercise device capable of being easily carried in a suitcase



What items have a full weight version and also a portable and lightweight version?

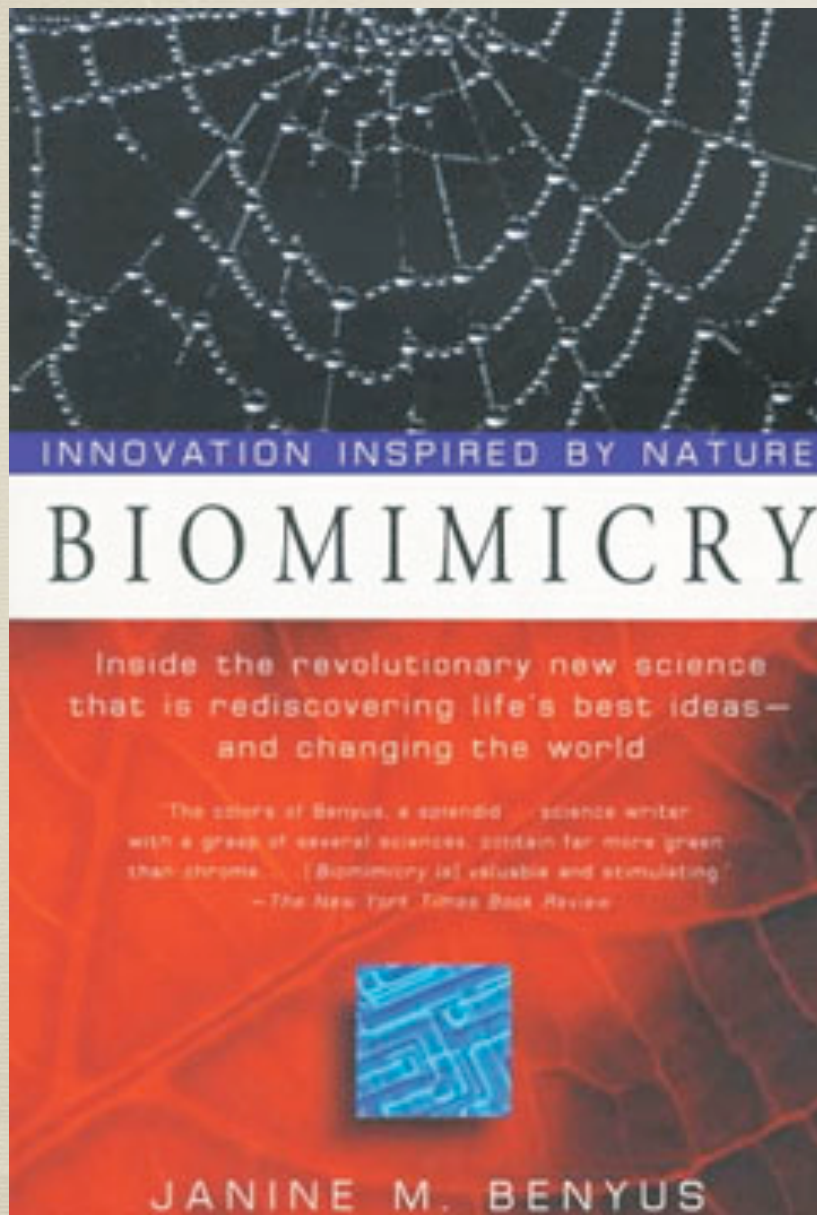
Analogy Example

- * Exercise equipment - Develop a concept for an exercise device capable of being easily carried in a suitcase



The key relationship that is used in both devices is they “use a fluid (or another substance) at the location where they are being used and export the fluid allowing for easy storage”

Bio-inspired Design



- * A particularly intriguing source of analogies is those that are inspired by biological systems.
- * Analogical reasoning requires creative thinking or lateral thinking – using the right side of the brain.
- * Not popularized until the 1990s, when Janine Benyus founded the Biomimicry Guild and wrote a book on Biomimicry.

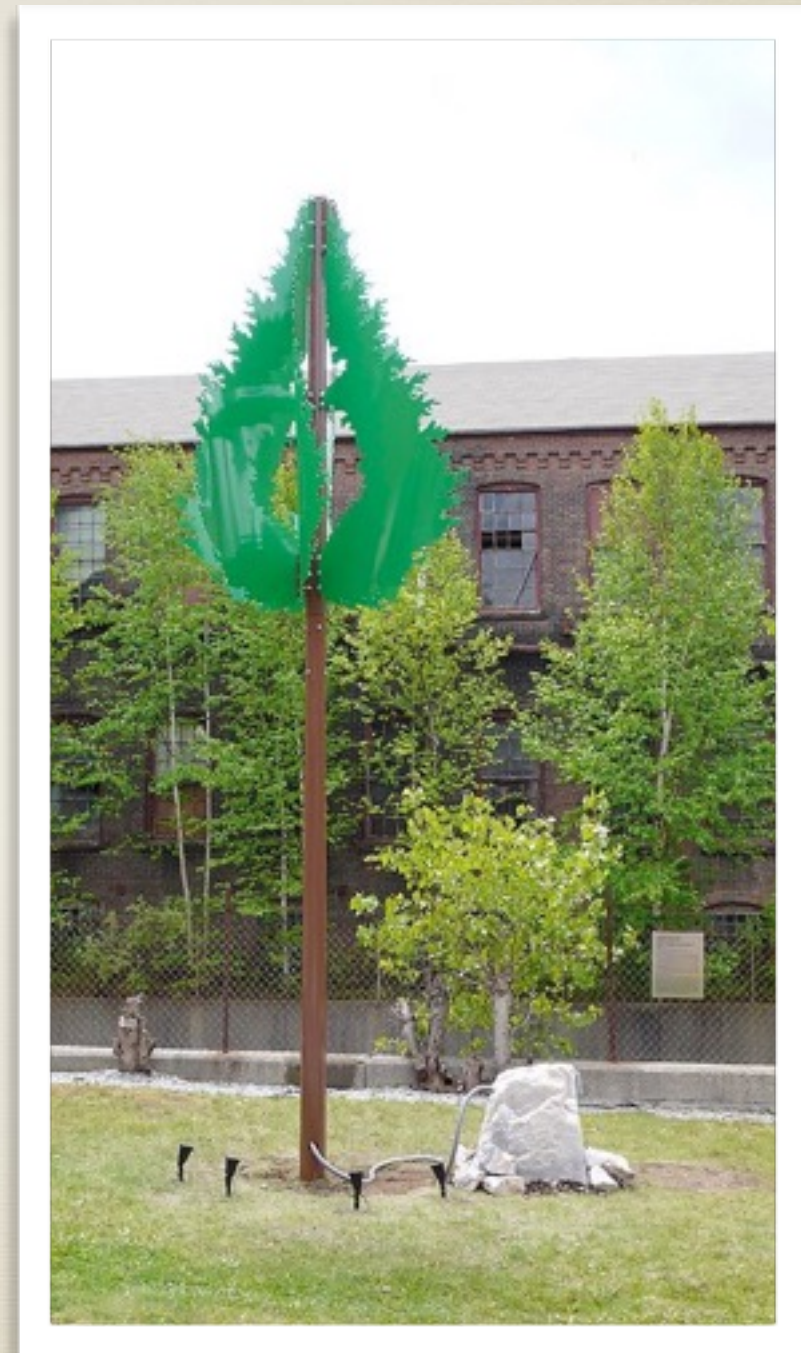
Bio-inspired Design



- * The term biomimicry comes from the Greek words:
 - * bios—meaning life
 - * mimesis—meaning to imitate
- * **Purpose of Biomimicry:** To study and imitate nature to solve human problems
- * **Bio-inspired Design:** Discovery of non-conventional solutions to problems that are often more efficient, economic and elegant

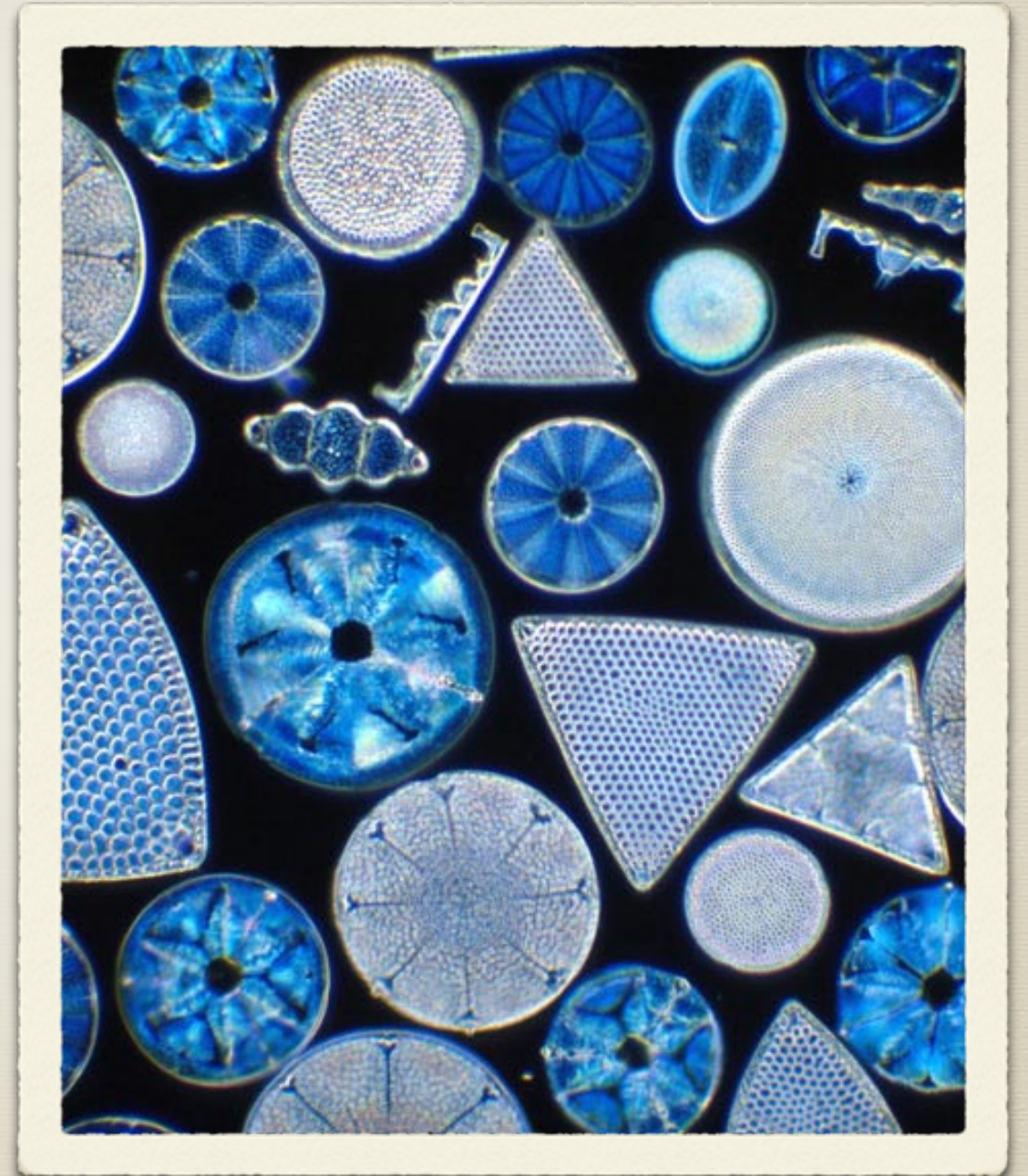
What it is not...

- * Bio-utilization
 - * Acquiring the biological product or producer
- * Bio-assisted
 - * Using the biological product or producer in the design to accomplish a function



Inspiring Innovation

- * The focus is not on what we can extract from the natural world, but what can we **LEARN** from nature
- * Challenges one to think about the problem differently, and apply engineering knowledge differently



Function

Structure



System



Form

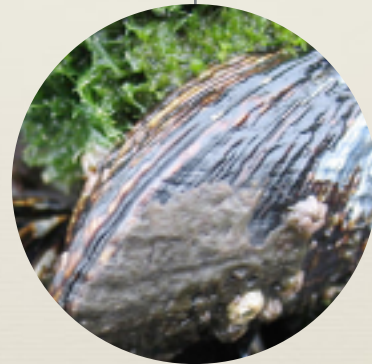


Physical and
Non-physical
Characteristics
to explore

Process



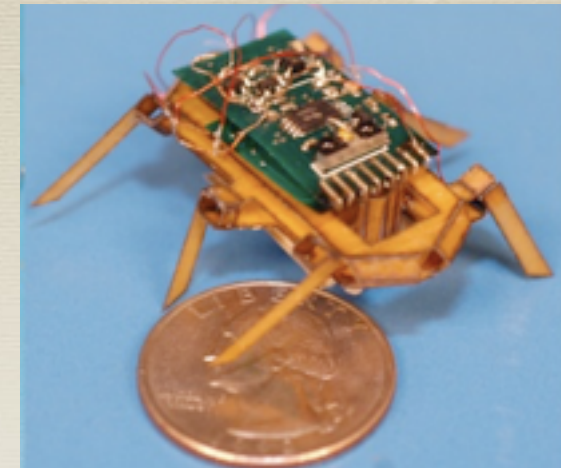
Surface



Material

Function

Structure

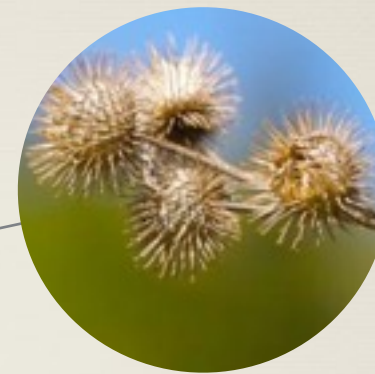


System

Form



Physical and Non-physical Characteristics to explore



Process

Surface

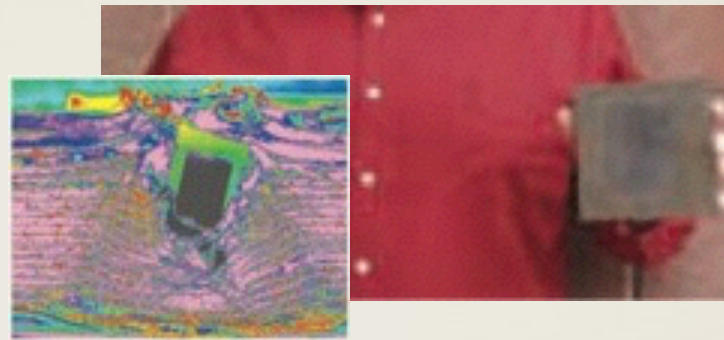


Material

Learning from Nature to Innovate



Color display
viewable in sunlight



Lightweight
armor



High efficiency fan
or turbine blades



Self-heating &
cooling building

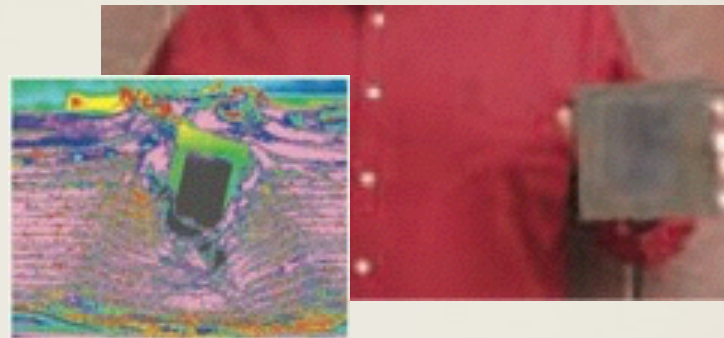
Learning from Nature to Innovate

How to utilize available light



Color display viewable in sunlight

How to efficiently use materials



Lightweight armor

How to capture wind energy at low speeds



High efficiency fan or turbine blades

How to build strategic, sustainable architecture

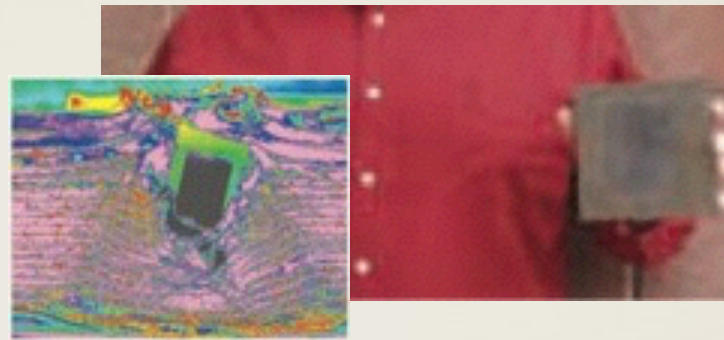


Self-heating & cooling building

What Inspired These Innovations?



Color display
viewable in sunlight



Lightweight
armor



High efficiency fan
or turbine blades

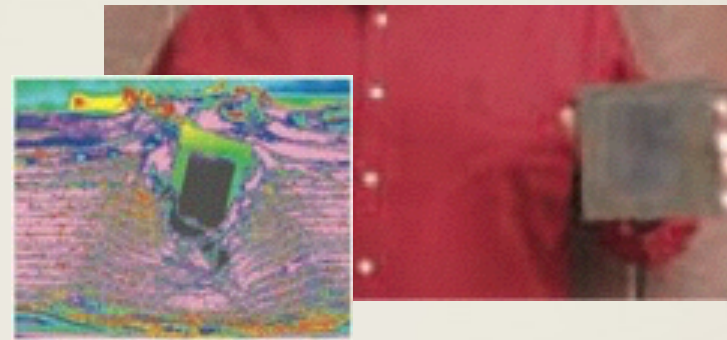
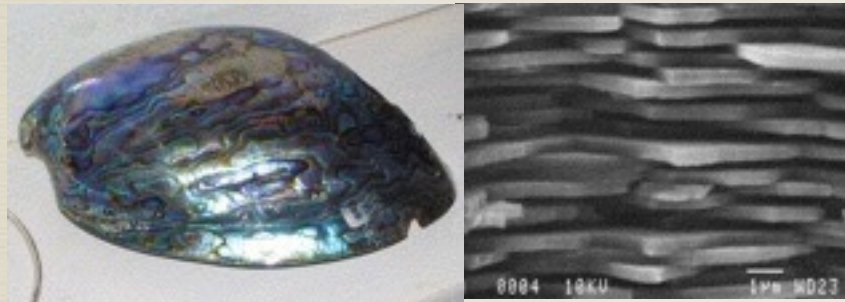


Self-heating &
cooling building

What Inspired These Innovations?



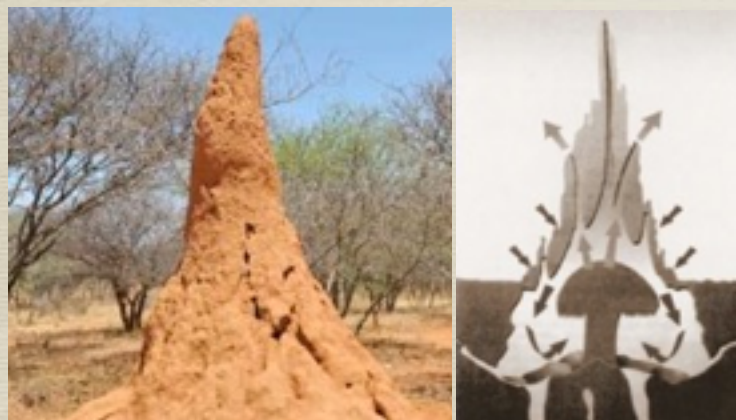
Color display
viewable in sunlight



Lightweight
armor

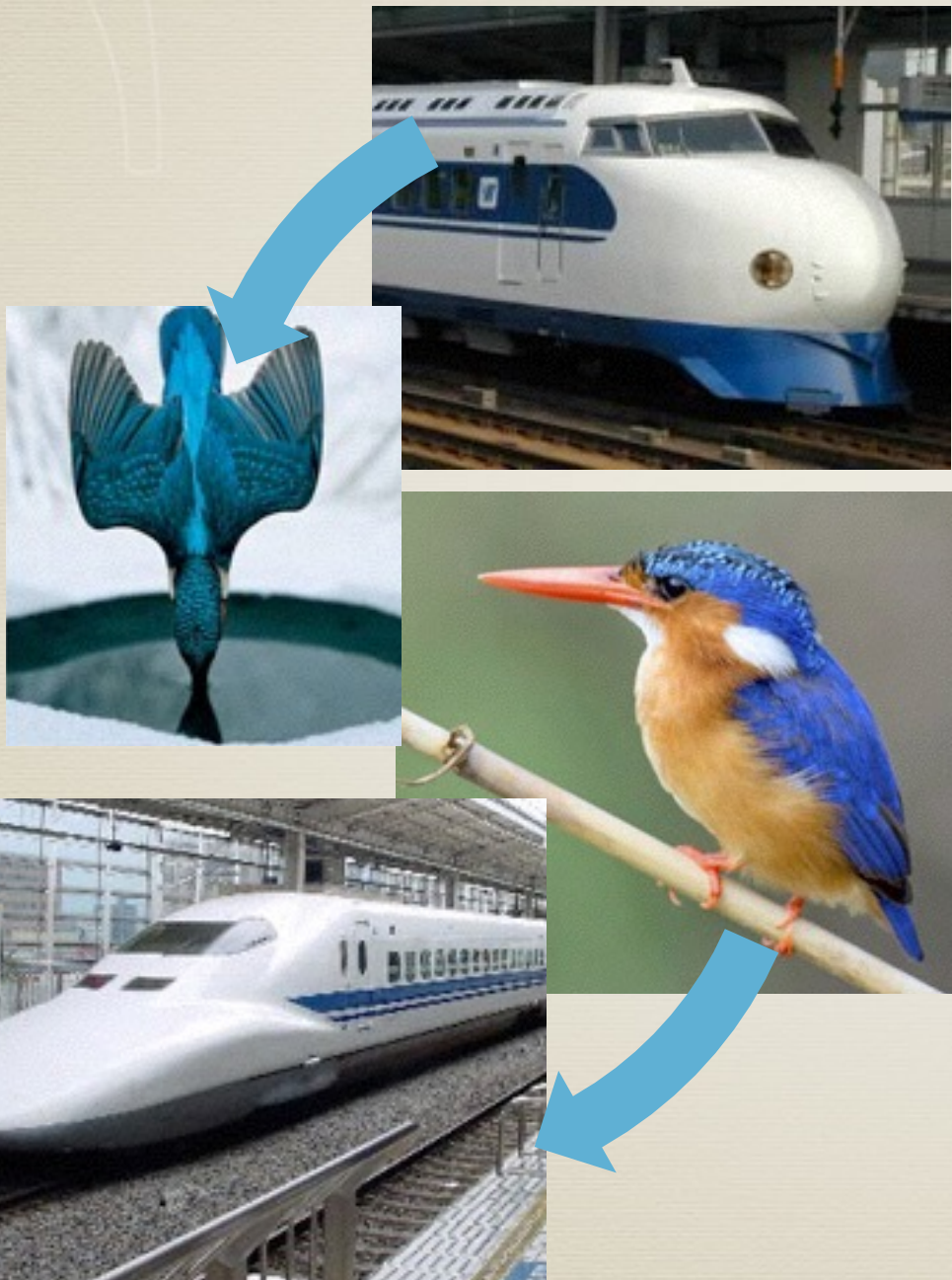


High efficiency fan
or turbine blades

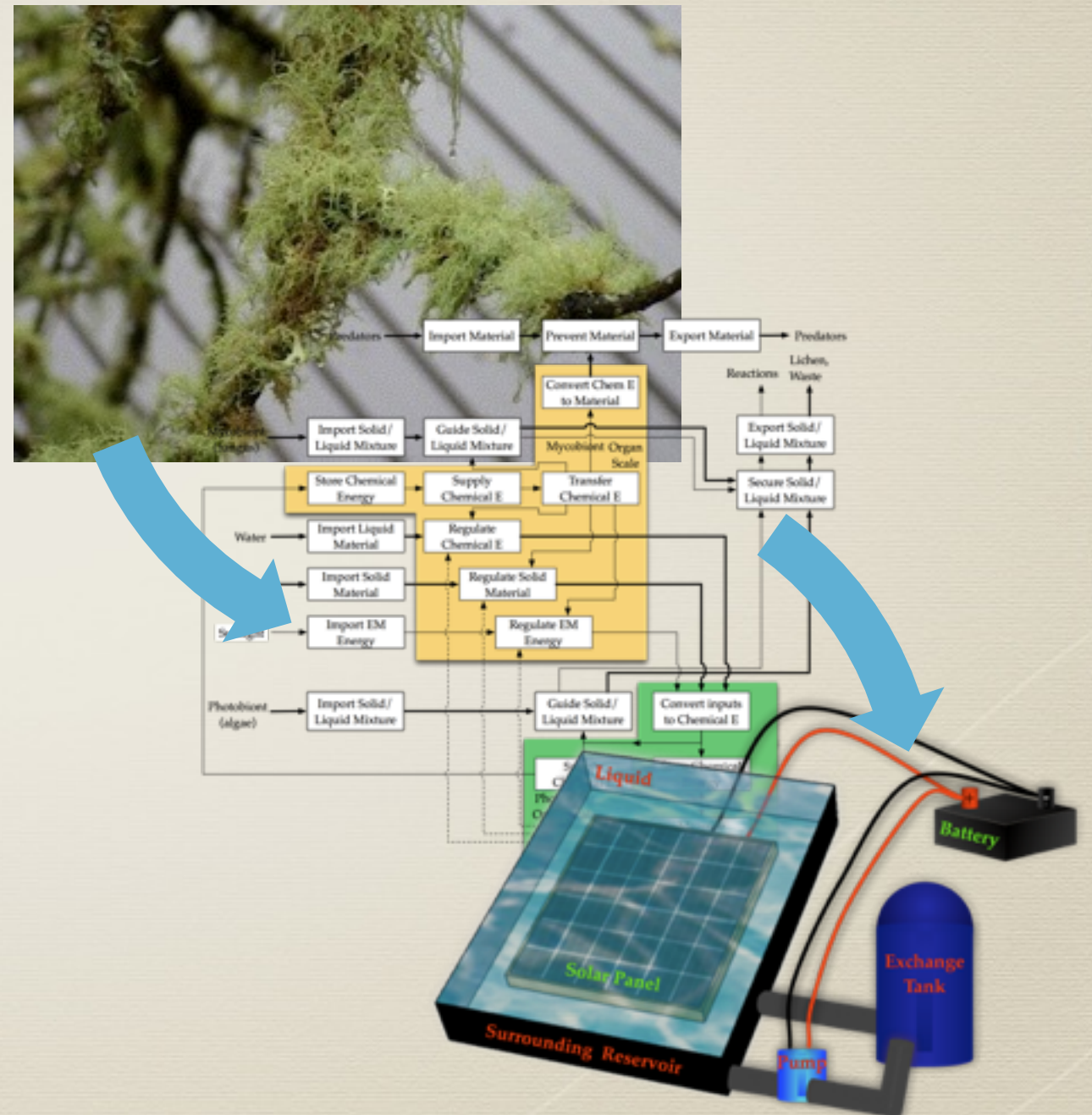


Self-heating &
cooling building

Follows Two Major Paths



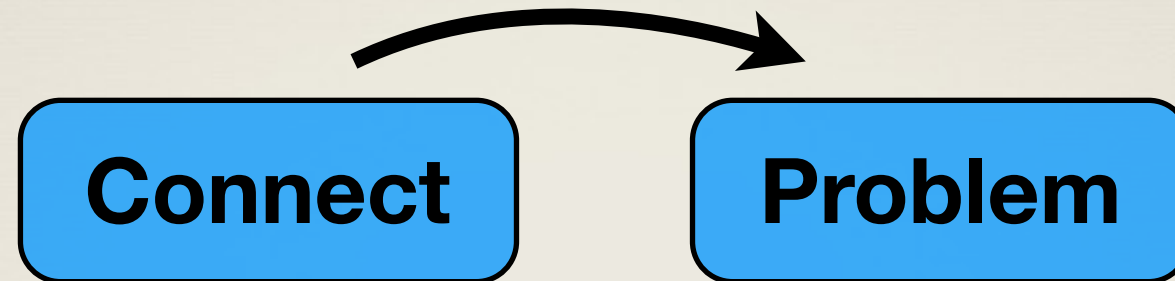
Problem-Driven



Biology-Driven

At a high level...

Apply biological
inspiration to
solve the problem



Abstract the
problem to
be solved

Identify
analogies to
engineering,
governing
principles

Search for
biological
inspiration

Abstract the biological information

The Process of Discovery starting from a problem

- * Shading buildings with irregular geometries is very difficult since most sun protection systems were developed for planar façades.
- * The pollination mechanism of the Bird-of-Paradise flower offered inspiration based on the elastic kinematics of plant movements.



The Process of Discovery

Concept Space

C0: Design an adaptable and energy efficient facade shading system

Knowledge Space

Traditional Knowledge

Biology Knowledge

→ Design Path

The Process of Discovery

Concept Space

C0: Design an adaptable and energy efficient facade shading system

Knowledge Space

Existing Solution

Hinges and rollers used in building shading systems (blinds) wear and require maintenance. Only work well for square buildings.

Traditional Knowledge

Biological system: Bird of Paradise

Unexpected Property

Absence of local hinges

Biology Knowledge

→ Design Path

The Process of Discovery

Concept Space

C0: Design an adaptable and energy efficient facade shading system

C1: With hinges

C1: Without hinges

Knowledge Space

Existing Solution

Hinges and rollers used in building shading systems (blinds) wear and require maintenance. Only work well for square buildings.

Traditional Knowledge

Biological system: Bird of Paradise

Unexpected Property

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→ Design Path

The Process of Discovery

Concept Space

C0: Design an adaptable and energy efficient facade shading system

C1: With hinges

C1: Without hinges

Knowledge Space

Existing Solution

Hinges and rollers used in building shading systems (blinds) wear and require maintenance. Only work well for square buildings.

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Unexpected Property

Absence of local hinges



Reversible deformation, bending the perch unfolds the petals exposing the pollen

Biology Knowledge

→ Design Path

The Process of Discovery

Concept Space

C0: Design an adaptable and energy efficient facade shading system

C1: With hinges

C1: Without hinges

Knowledge Space

Existing Solution

Hinges and rollers used in building shading systems (blinds) wear and require maintenance. Only work well for square buildings.

Traditional Knowledge

Biological system: Bird of Paradise

Unexpected Property

Absence of local hinges



Reversible deformation, bending the perch unfolds the petals exposing the pollen

Biology Knowledge

→ Design Path

The Process of Discovery

Concept Space

C0: Design an adaptable and energy efficient facade shading system

C1: With hinges

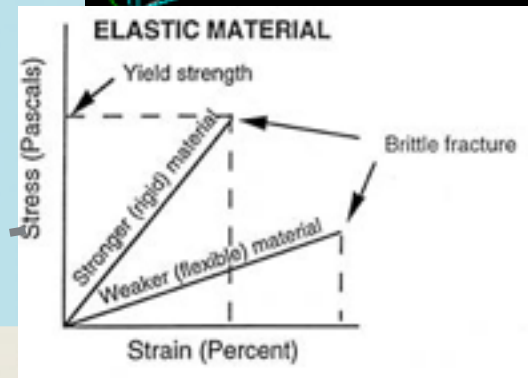
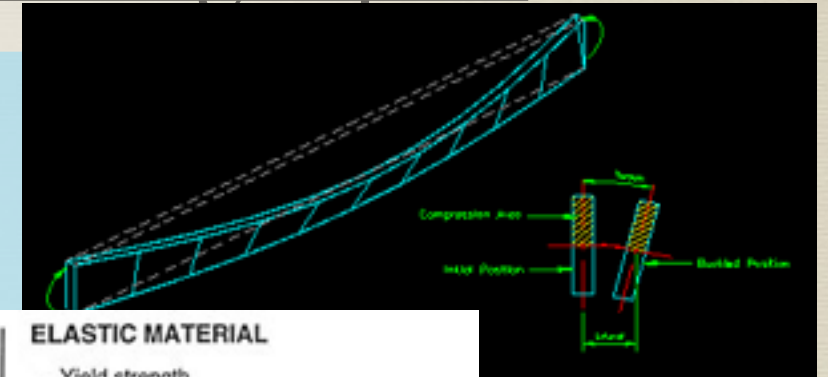
C1: Without hinges

→ Design Path

Knowledge Space

Existing Solution

Hinges and rollers used in building shading systems (blinds) wear and require maintenance. Only work well for square buildings.



Local Knowledge

Biological system: Bird of Paradise

Unexpected Property

Absence of local hinges

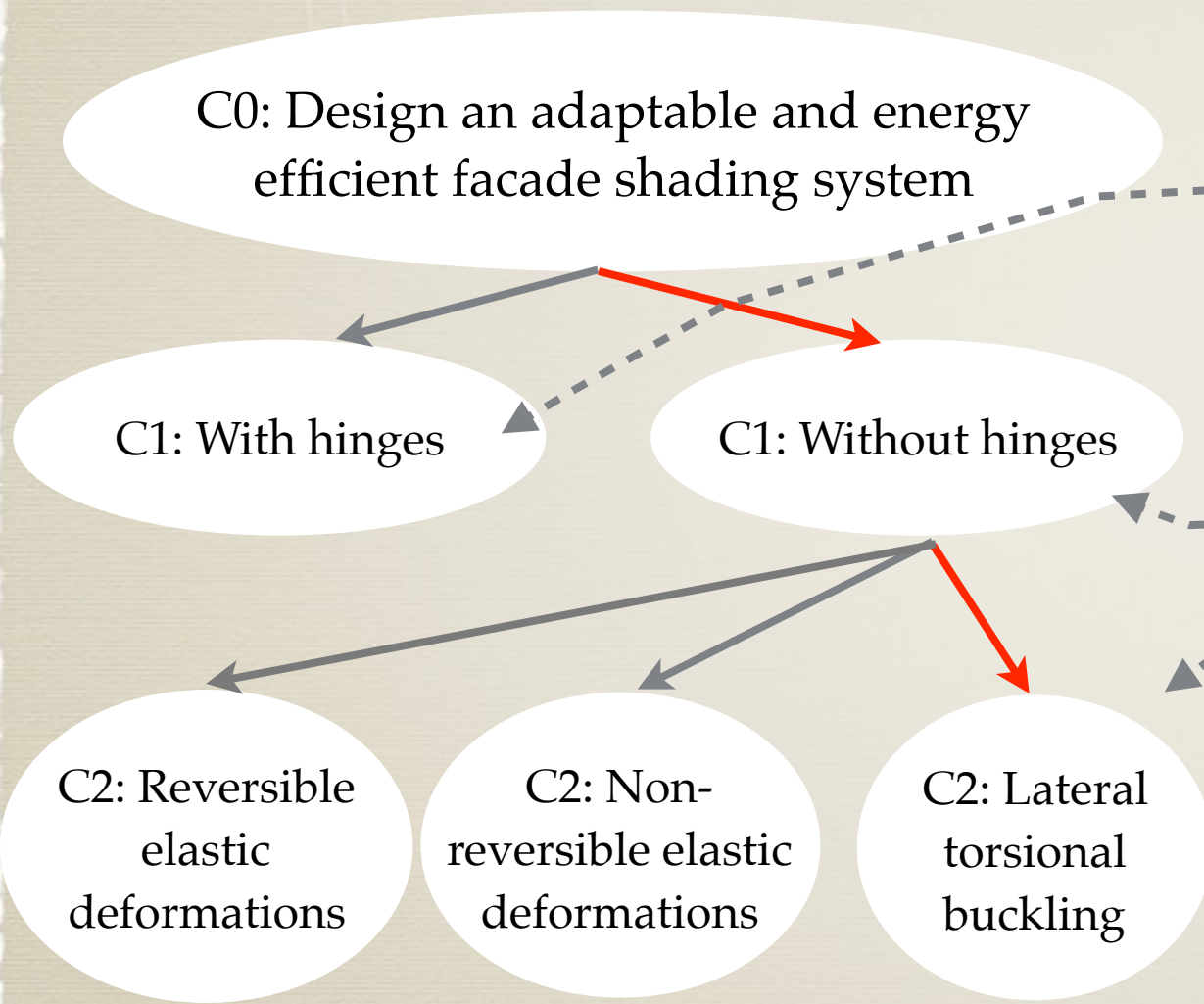


Reversible deformation, bending the perch unfolds the petals exposing the pollen

Biology Knowledge

The Process of Discovery

Concept Space

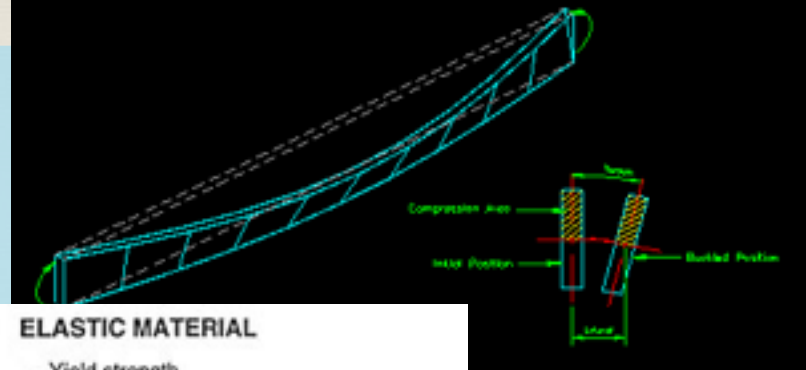
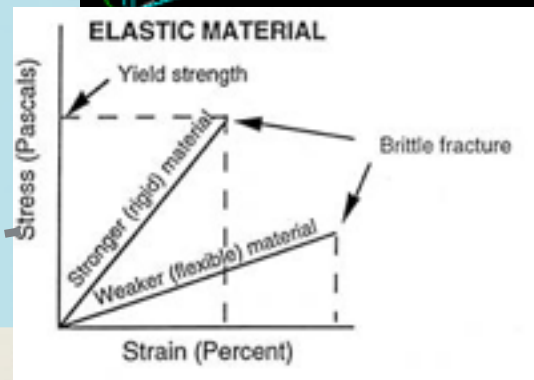


→ Design Path

Knowledge Space

Existing Solution


Hinges and rollers used in building shading systems (blinds) wear and require maintenance. Only work well for square buildings.

Biological system: Bird of Paradise

Unexpected Property

Absence of local hinges



Reversible deformation, bending the perch unfolds the petals exposing the pollen

Biology Knowledge

The Process of Discovery

Concept Space

Knowledge Space

C0: Design an adaptable and energy efficient facade shading system

C1: With hinges

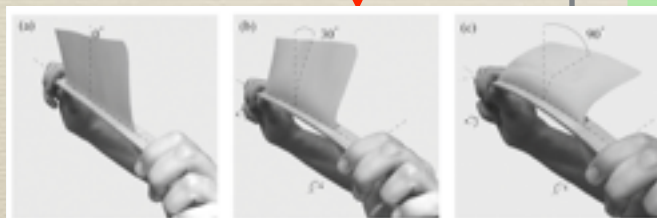
C1: Without hinges

C2: Reversible elastic deformations

C2: Non-reversible elastic deformations

C2: Lateral torsional buckling

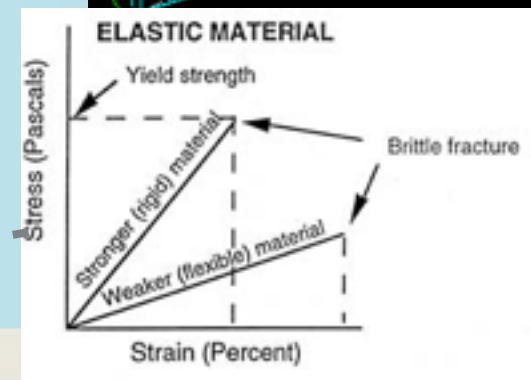
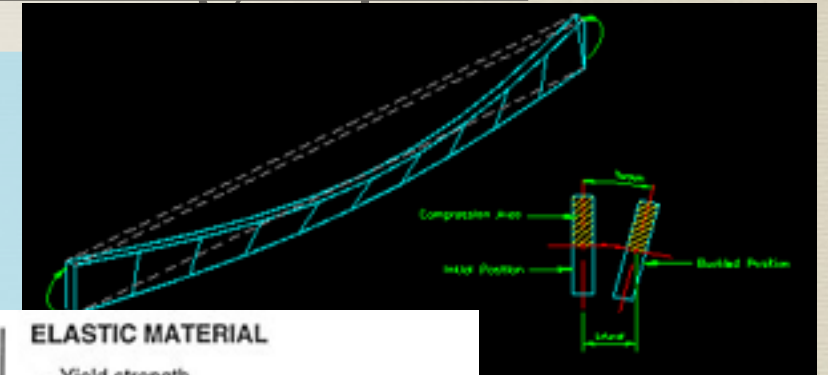
C3:



→ Design Path

Existing Solution

Hinges and rollers used in building shading systems (blinds) wear and require maintenance. Only work well for square buildings.



Local Knowledge

Biological system: Bird of Paradise

Unexpected Property

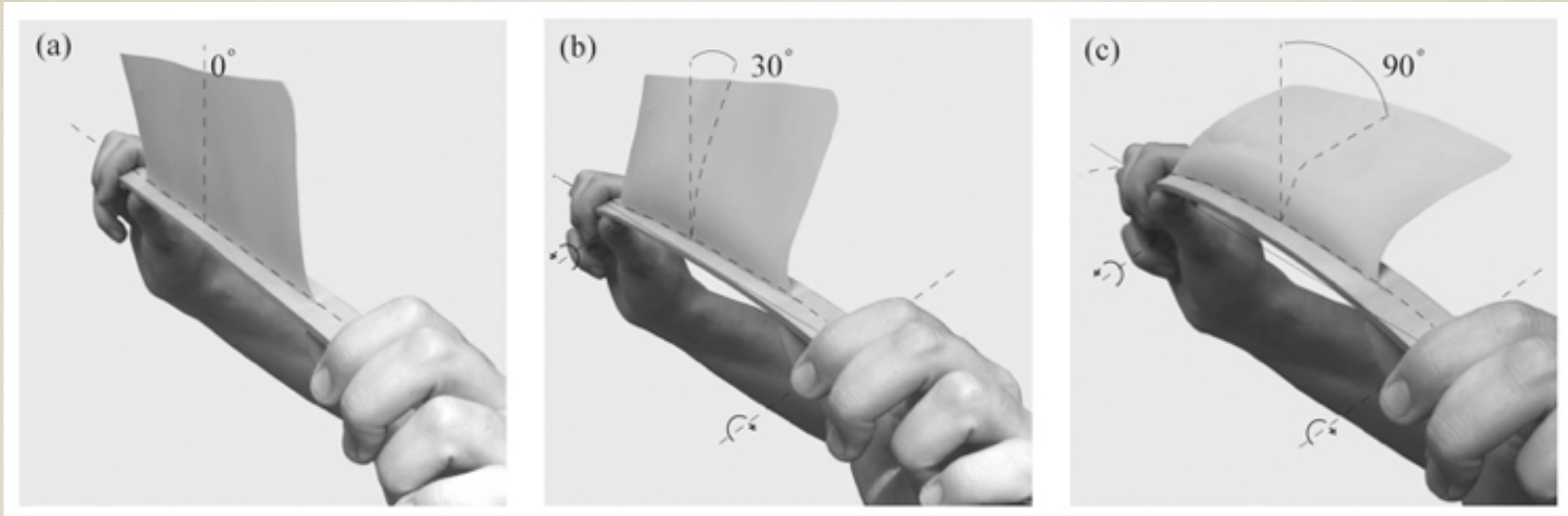
Absence of local hinges



Reversible deformation, bending the perch unfolds the petals exposing the pollen

Biology Knowledge

The Process of Discovery Resulted in Technical Innovation



Bio-inspired Design applied to the Human Powered Vehicle

- * Taking inspiration for the *entire* HPV is not productive (just like taking inspiration for the facade system and not the entire building)
- * Our goal is to arrive at sub-system solutions that can be added to the morphological matrix and used in the second round of concept generation
- * Lets focus on propulsion....

HPV Example

Concept Space

C0: Design a human powered vehicle propulsion system

Knowledge Space

Existing Solution

Gears with a chain will produce propulsion when turned with a pedal.

Traditional Knowledge

Biological system: Snakes

Unexpected Property

Snakes use lateral undulation to move quickly across the ground and push off of bumps to get going.

Biology Knowledge

→ Design Path

HPV Example

Concept Space

C0: Design a human powered vehicle propulsion system

C1: Using pedaling motion

C1: Without using pedaling motion

→ Design Path

Knowledge Space

Existing Solution

Gears with a chain will produce propulsion when turned with a pedal.

Traditional Knowledge

Biological system: Snakes

Unexpected Property

Snakes use lateral undulation to move quickly across the ground and push off of bumps to get going.

Biology Knowledge

HPV Example

Concept Space

C0: Design a human powered vehicle propulsion system

C1: Using pedaling motion

C1: Without using pedaling motion

Knowledge Space

Existing Solution

Gears with a chain will produce propulsion when turned with a pedal.

Traditional Knowledge

Biological system: Snakes

Unexpected Property

Snakes use lateral undulation to move quickly across the ground and push off of bumps to get going.

- Snakes use their muscles and scales to move in four different ways: serpentine motion, concertina motion, sidewinding, and rectilinear motion.
- Propulsion is by lateral thrust in all segments of the body in contact with the ground

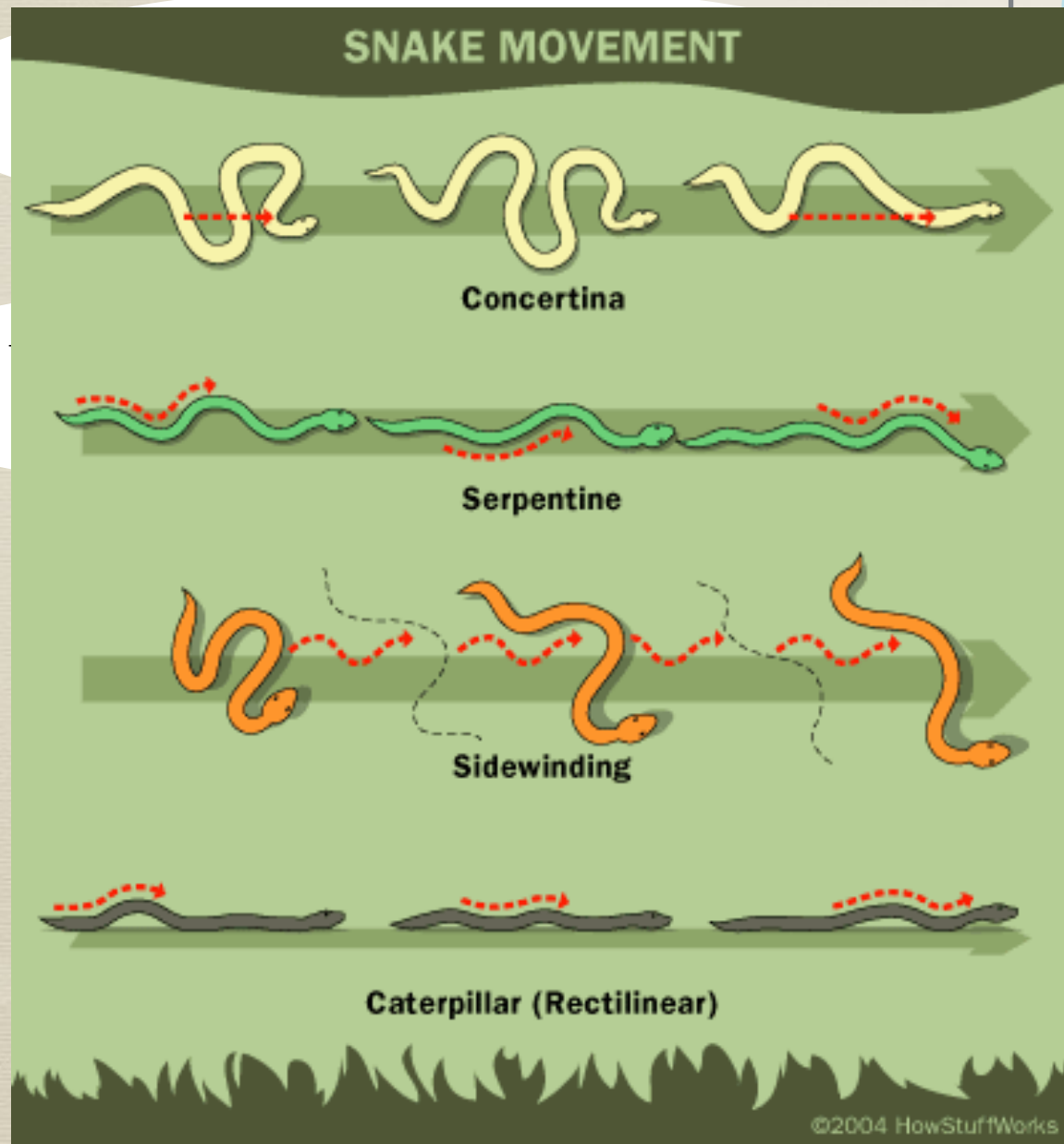
Biology Knowledge

→ Design Path

HPV Example

Concept Space

Knowledge Space



C1:

Existing Solution

Gears with a chain will produce propulsion when turned with a pedal.

Traditional Knowledge

Unexpected Property

Snakes use lateral undulation to move quickly across the ground and push off of bumps to get going.

Biological system: Snakes

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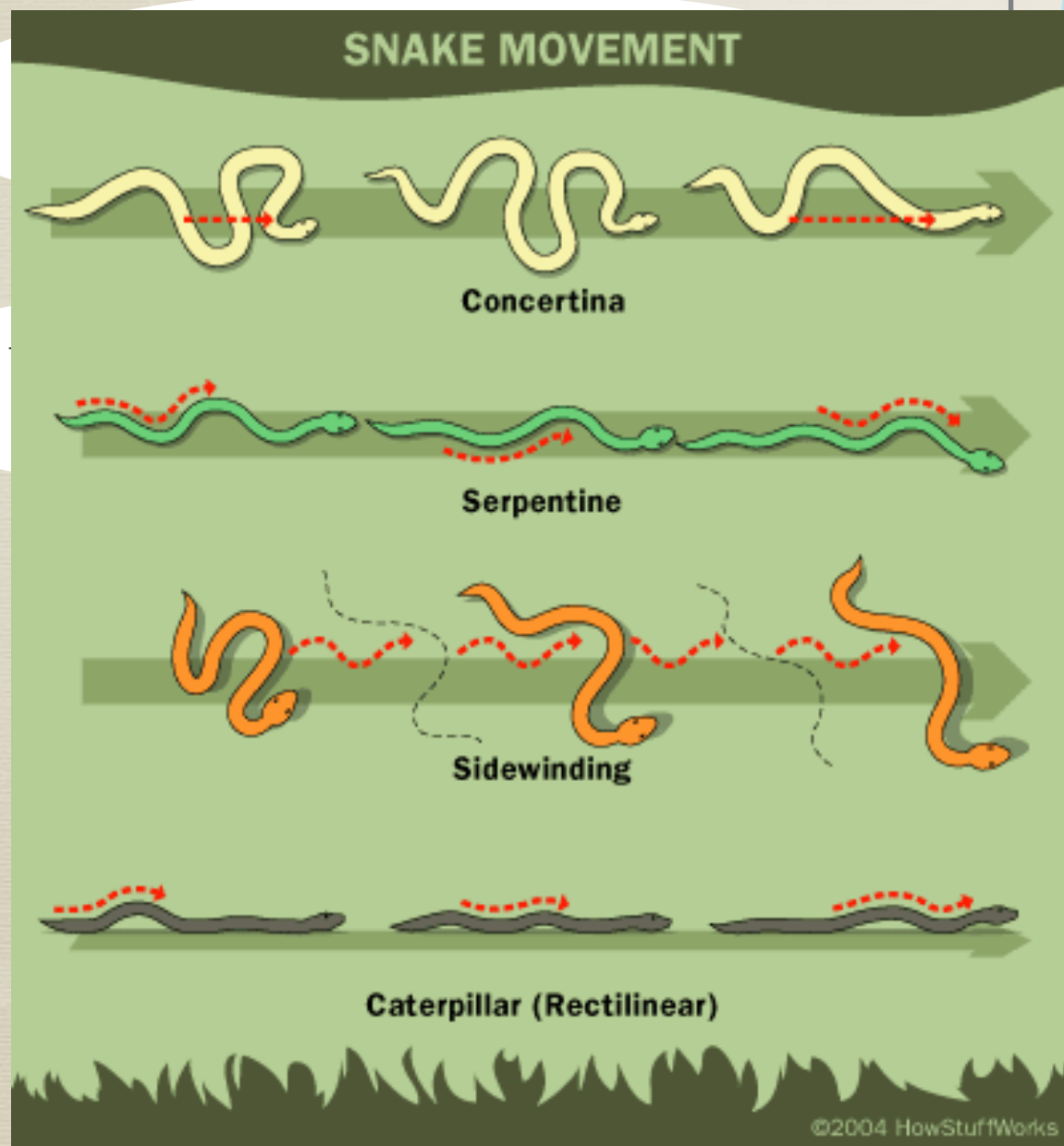
Biology Knowledge

Design Path

HPV Example

Concept Space

Knowledge Space



C1:

Existing Solution

Gears with a chain will produce propulsion when turned with a pedal.

How does this biological information connect to what I know, or what is known?

Traditional Knowledge

Biological system: Snakes

Unexpected Property

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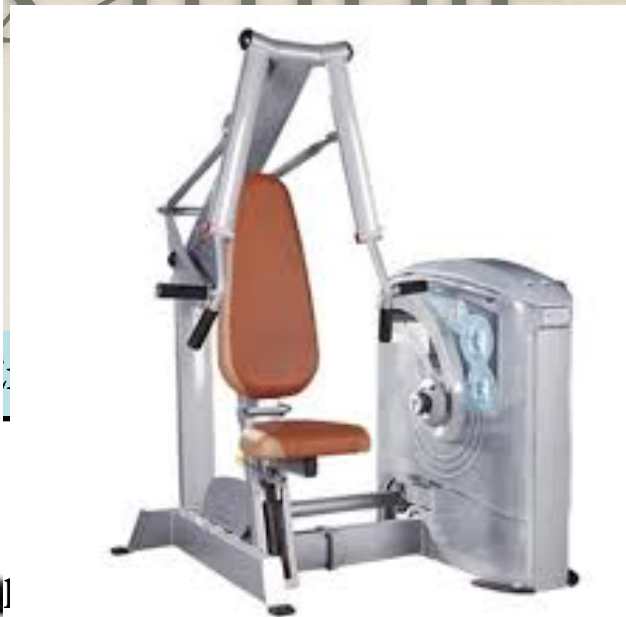
Biology Knowledge

HPV Example

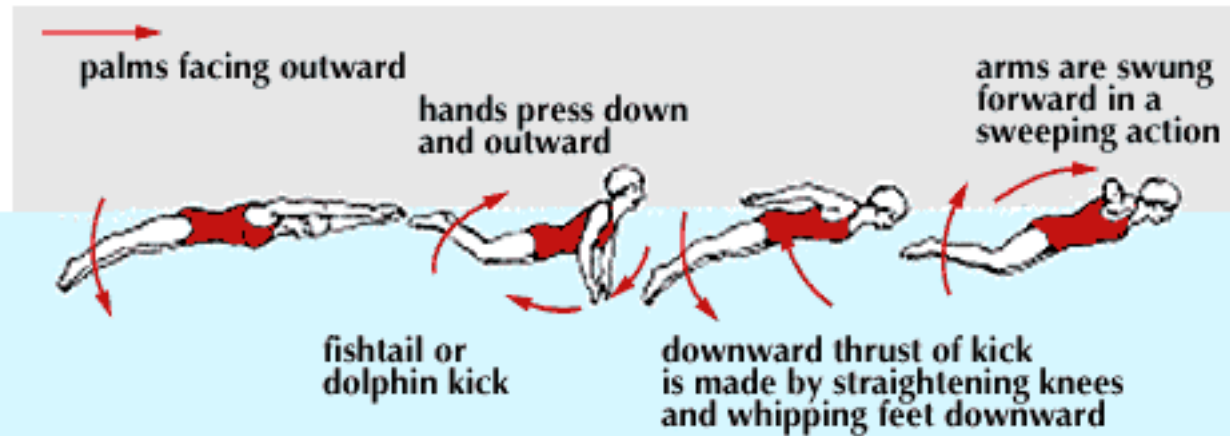
Concept Space

C0: Design a human powered propulsion system

C1: Using pedaling motion



THE BUTTERFLY STROKE



System: Snakes

their muscles and scales to move in different ways: serpentine

Snakes use lateral undulation to move quickly across the ground and push off of bumps to get going.

motion, concertina motion, sidewinding, and rectilinear motion.

- Propulsion is by lateral thrust in all segments of the body in contact with the ground

Biology Knowledge

→ Design Path

HPV Example

Concept Space

C0: Design a human powered vehicle propulsion system

C1: Using pedaling motion

C1: Without using pedaling motion

→ Design Path

Knowledge Space

Existing Solution

Gears with a chain will produce propulsion when turned with a pedal.

- Activities/machines that cause movement in a serpentine or sidwinding motion? - Skiing, swimming, roller racer.
- Activities/machines that cause movement in a concertina motion? - leg and chest press

Traditional Knowledge

Biological system: Snakes

Unexpected Property

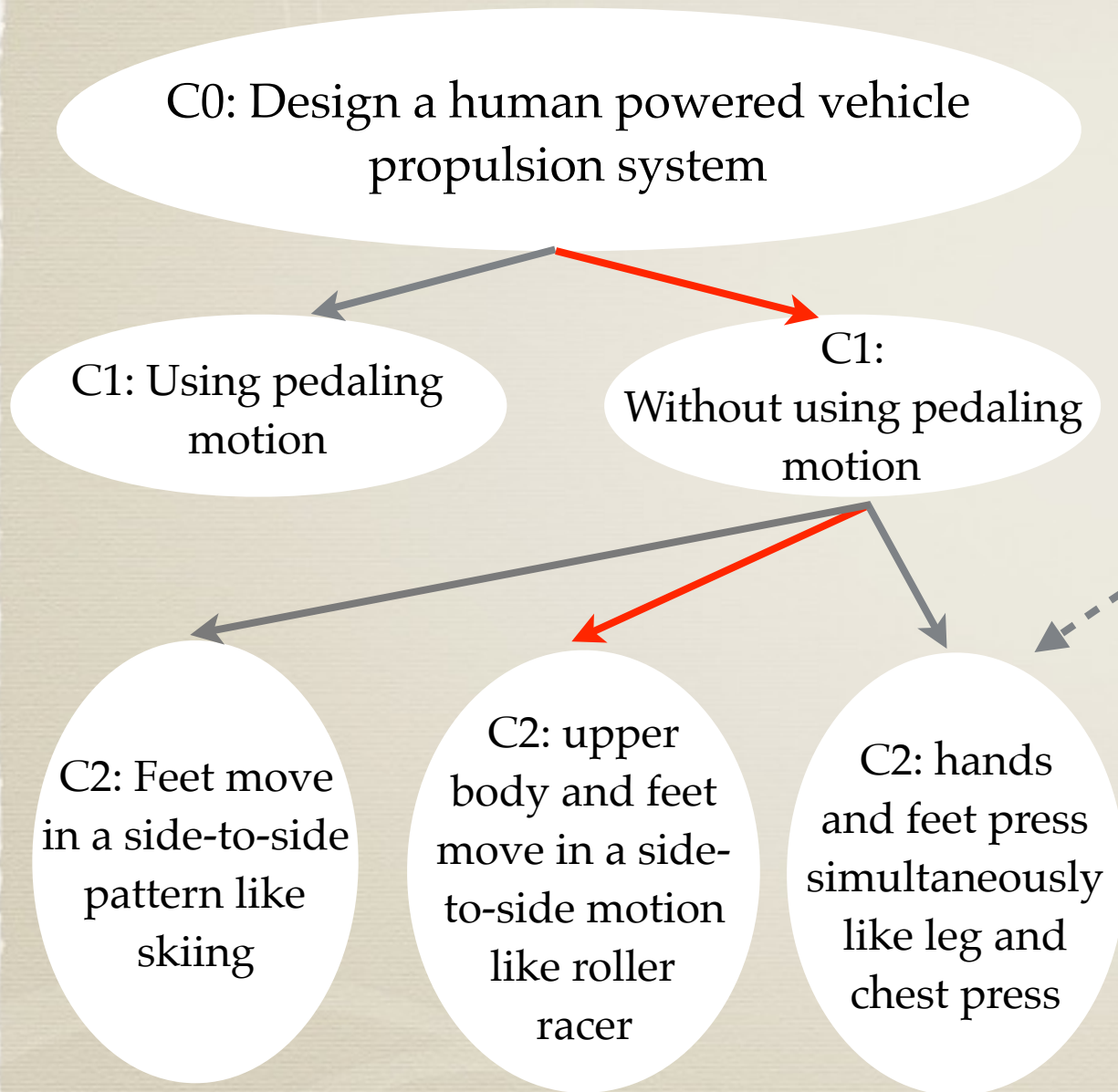
Snakes use lateral undulation to move quickly across the ground and push off of bumps to get going.

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Biology Knowledge

HPV Example

Concept Space



→ Design Path

Knowledge Space

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- Propulsion is by lateral thrust in all segments of the body in contact with the ground

Biology Knowledge

Closing Remarks

- * Biomimicry is a problem solving lens, which has resulted in technical innovation
 - * Requires clear understanding of the problem
 - * Asks “How would nature ?”
- * The focus is not on what we can extract from the natural world, but what can we LEARN from nature
- * Bio-inspired design facilitates discovery of innovative solutions without requiring expert-level knowledge, but rather a broad knowledge of many fields