Biomimicry – it's benefits and barriers

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Is this progress? Is this sustainable?

And is sustainable good enough?

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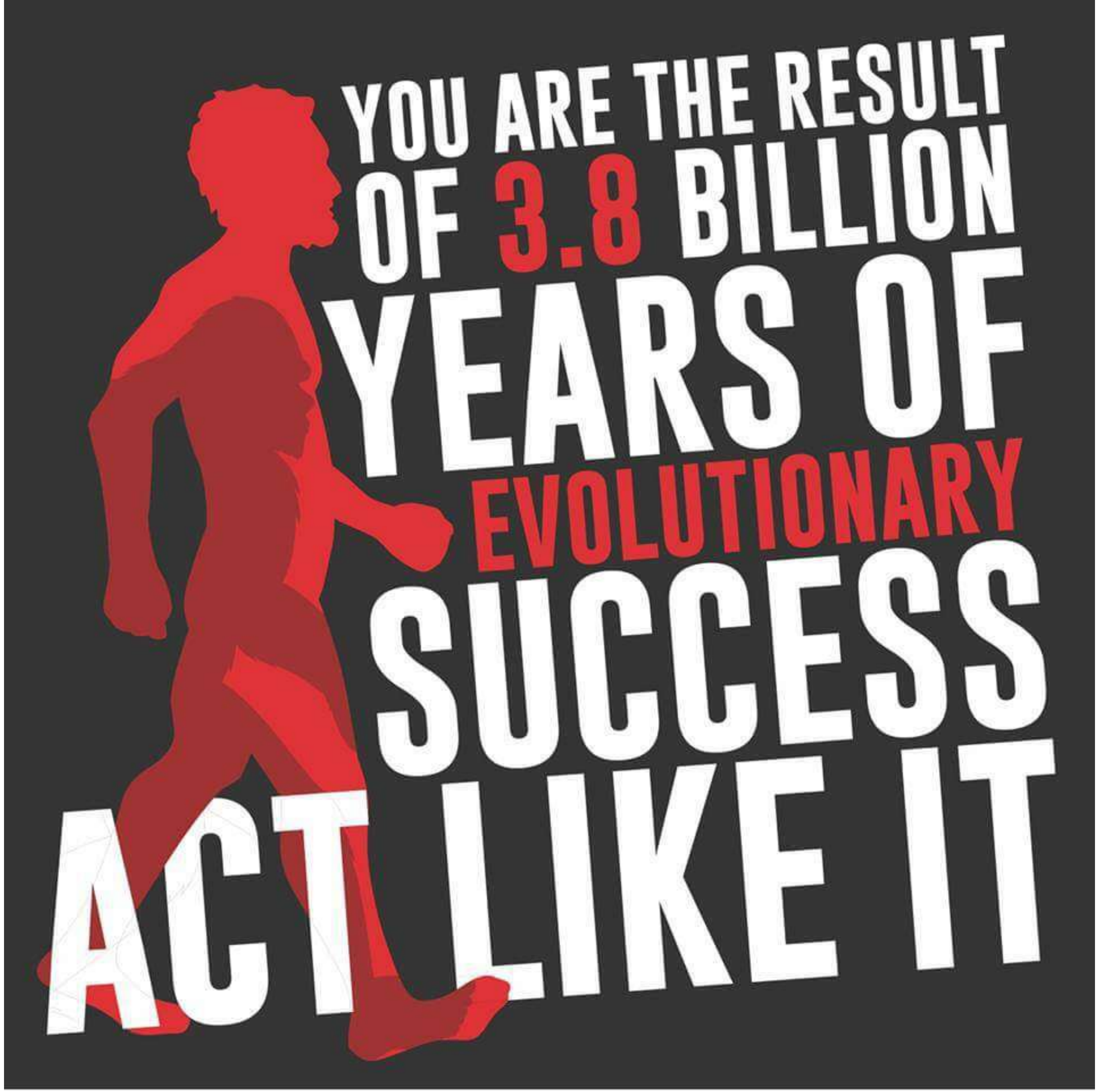
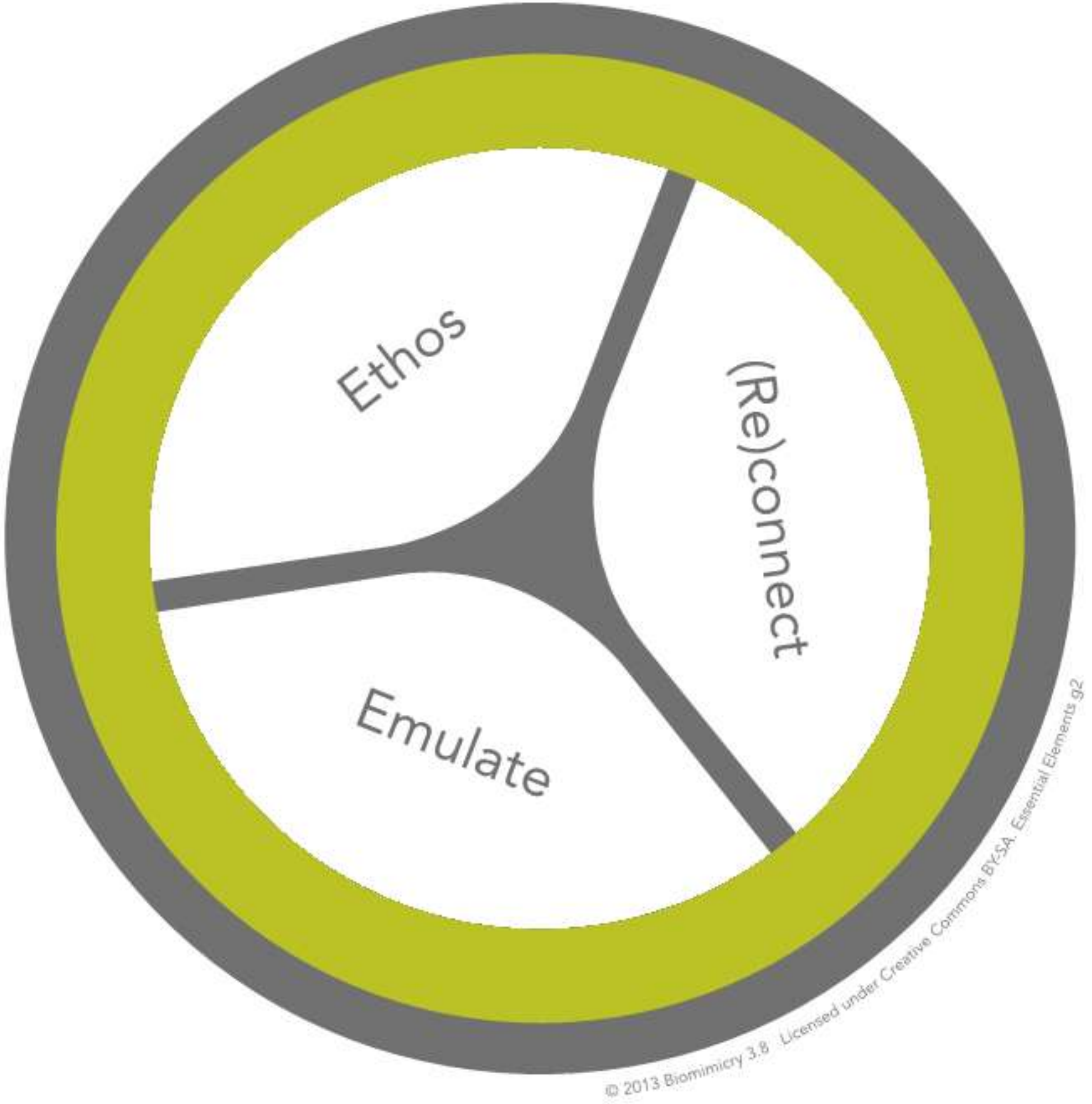

YOU ARE THE RESULT
OF 3.8 BILLION
YEARS OF
EVOLUTIONARY
SUCCESS
ACT LIKE IT

Why biomimicry?

"I believe we are as ingenious, as fragile, and as beautiful as any of these creatures that enrapture us when we practice biomimicry. It's time to shed that lonely myth; the truth is we ARE nature."



Nature…

… runs on sunlight.

… uses only the energy it needs.

… fits form to function.

… recycles everything.

… rewards cooperation.

… banks on diversity.

… demands local expertise.

… curbs excesses from within.

… taps the power of limits.

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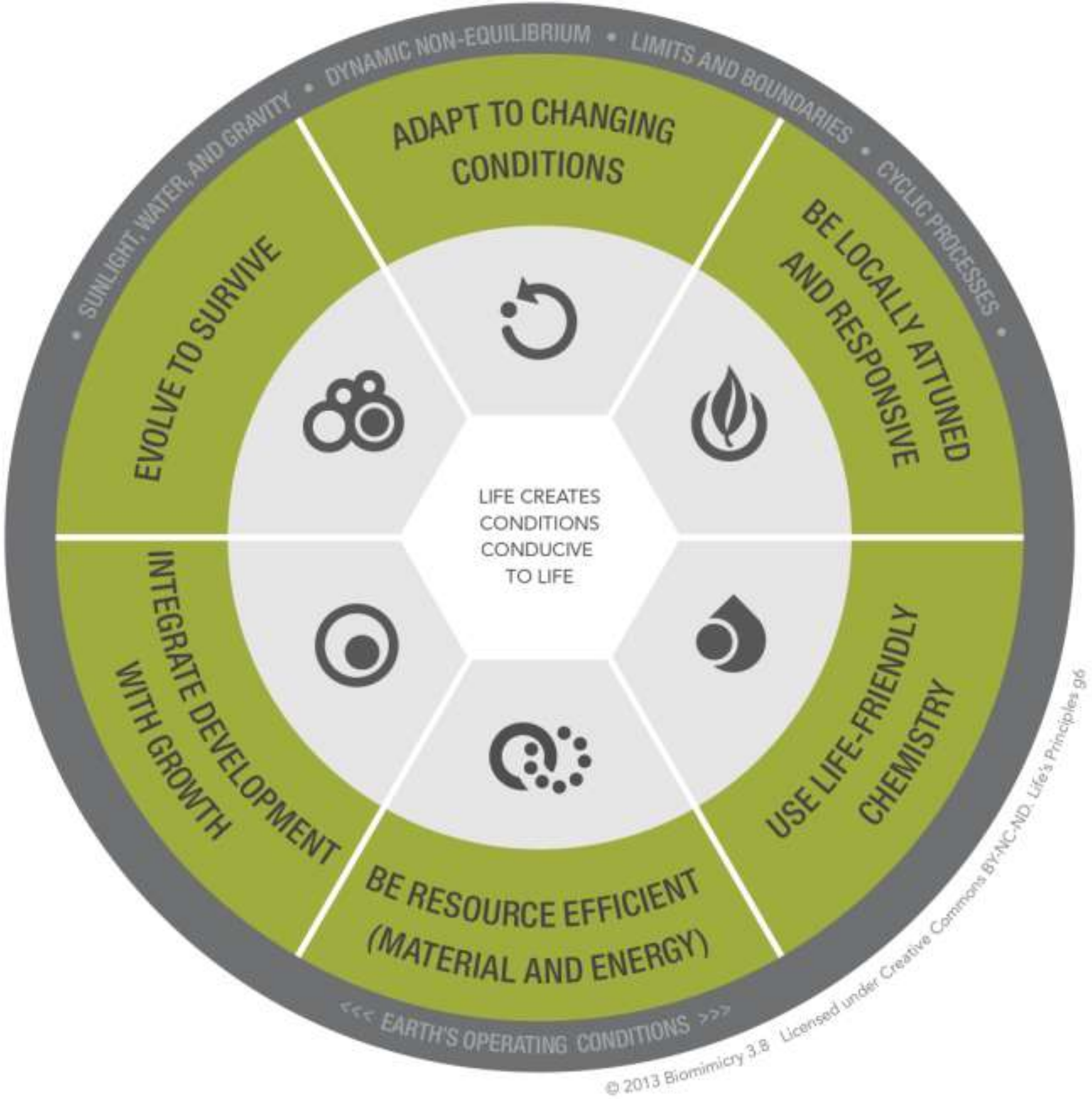
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ADAPT TO CHANGING CONDITIONS
BE LOCALLY ATTUNED AND RESPONSIVE
USE LIFE-FRIENDLY CHEMISTRY
BE RESOURCE EFFICIENT (MATERIAL AND ENERGY)
INTEGRATE DEVELOPMENT WITH GROWTH
EVOLVE TO SURVIVE
LIFE CREATES CONDITIONS CONDUCIVE TO LIFE
<<< EARTH'S OPERATING CONDITIONS >>>
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Reverse engineer biology

A working definition: *functional biomimicry* – the practice that successfully translates physical characteristics from biology to building design.

There is no reason for biomimetic design to be more environmentally sustainable than any other process.

Designers need to be careful to avoid using biomimicry purely as an aesthetic inspiration.

The task is to make the science predictable and the designs physically realisable.

Part 3: Benefits

Lens for innovation

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Image: Wikipedia

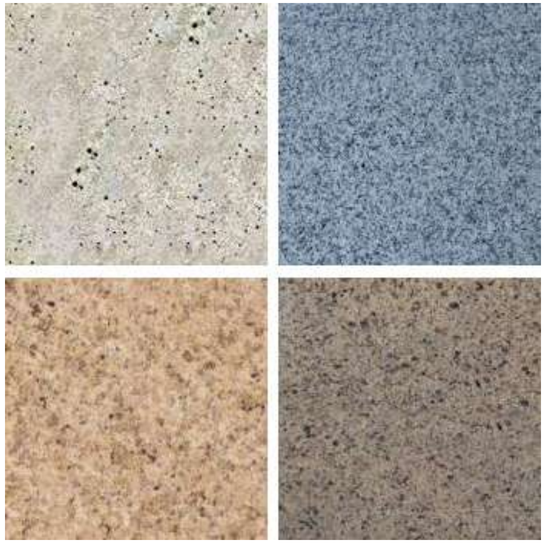
Calera – creating cement in solution

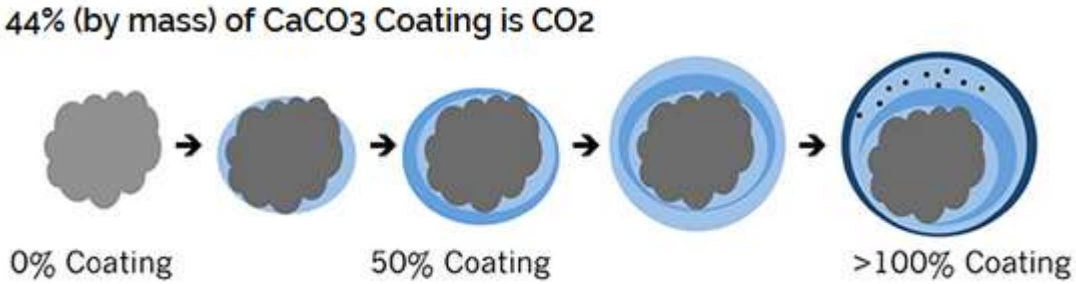
CO_2 from flue gas (industrial emitters)
Use raw flue gas – no concentration required

CO_2 captured and converted to a solid
Calcium Carbonate novel cement

Used to make a range of building
material products

Calera®





Figures: blueplanet-ltd.com

Resilience and adaptability


Image: Tim Shief (unsplash)

Connection to nature

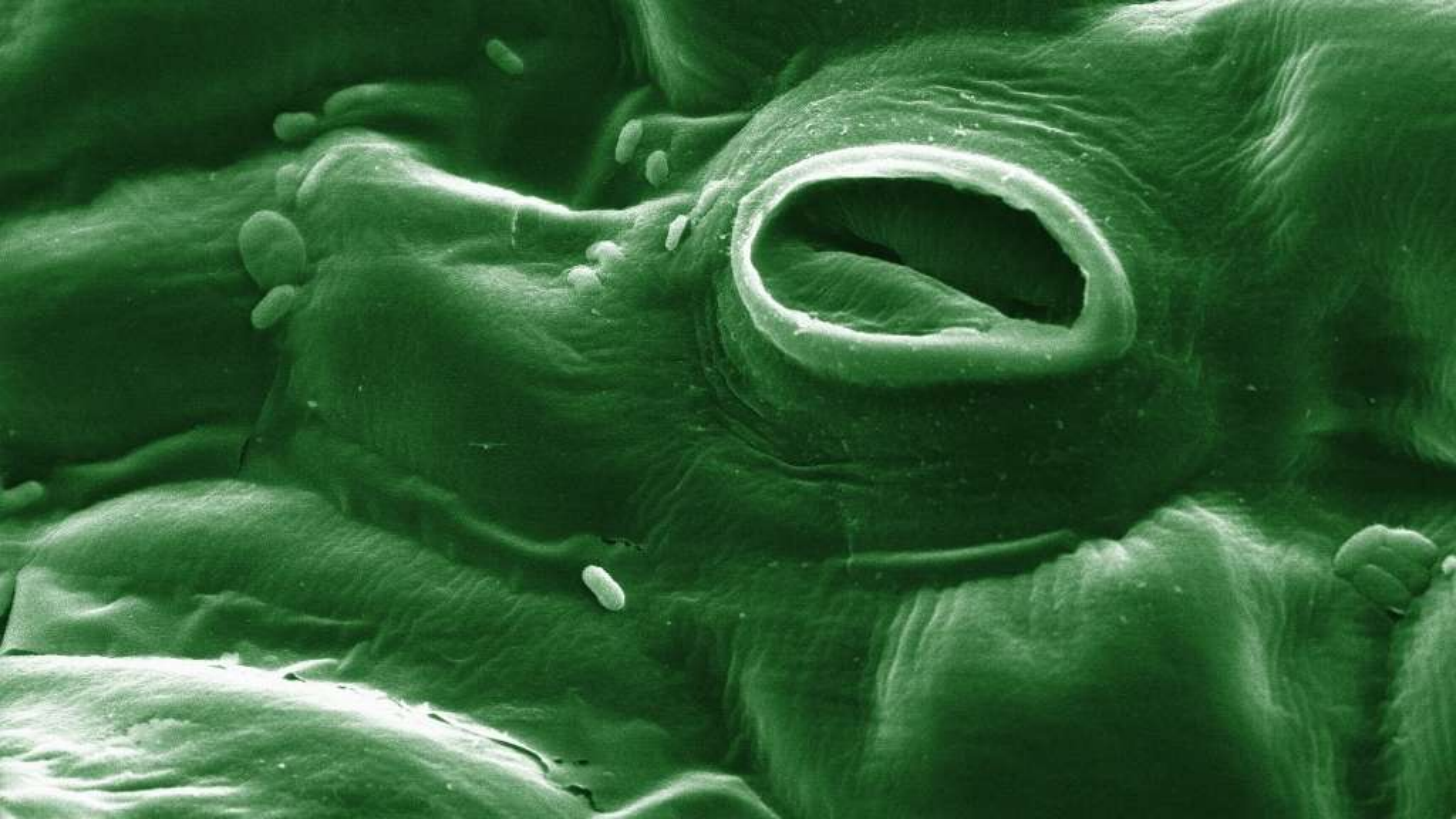



Image: Chris King (Unsplash)

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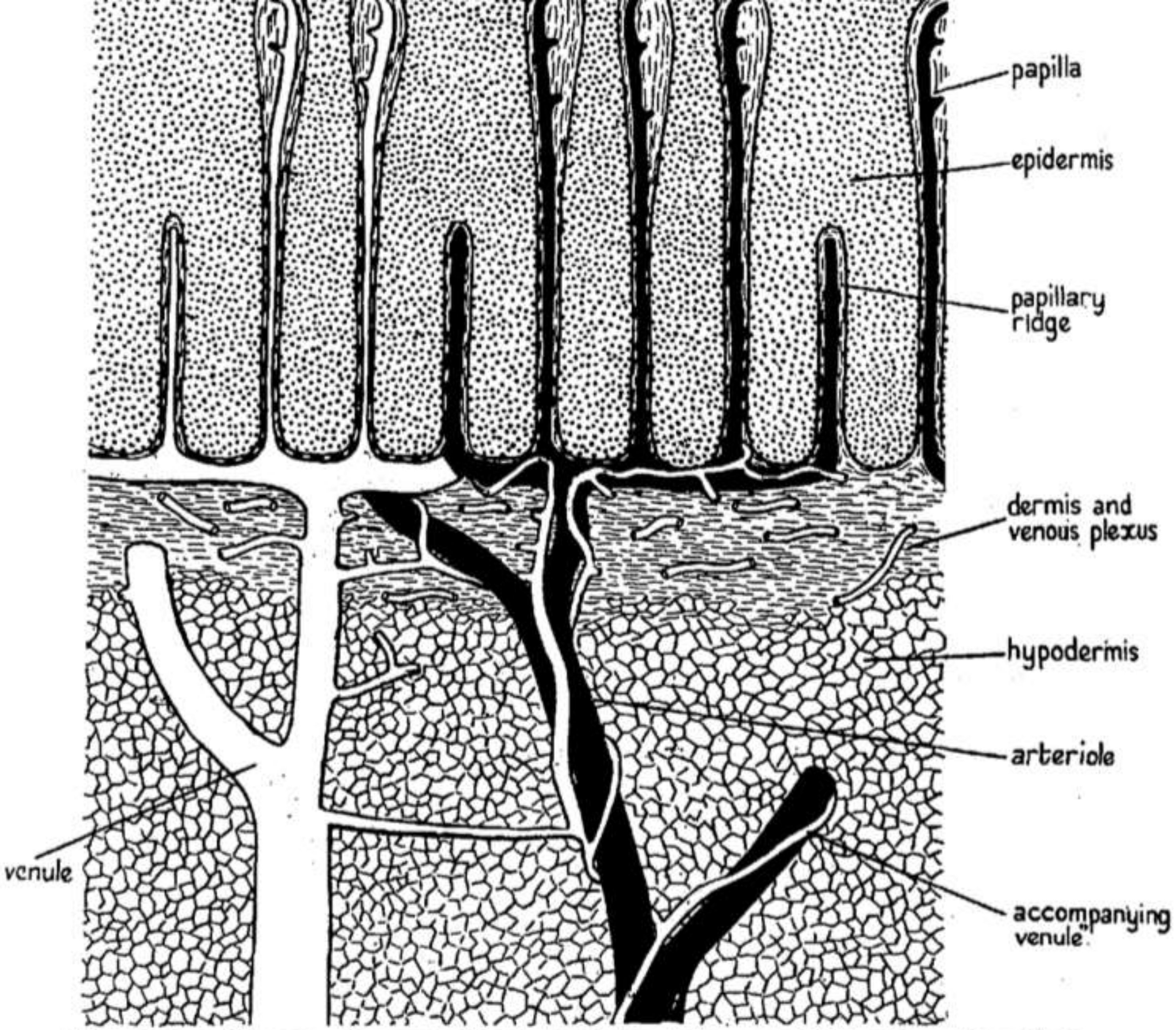

TEXT-FIG. 2. *Phocaena phocaena*. Blood circulation in the superficial regions of the blubber. To avoid confusion, arterial and venous vessels are not both shown in the same dermal ridge and papilla. Based on numerous serial drawings.

Figure: Parry (1949)

Blubber structure

Creative Innovation

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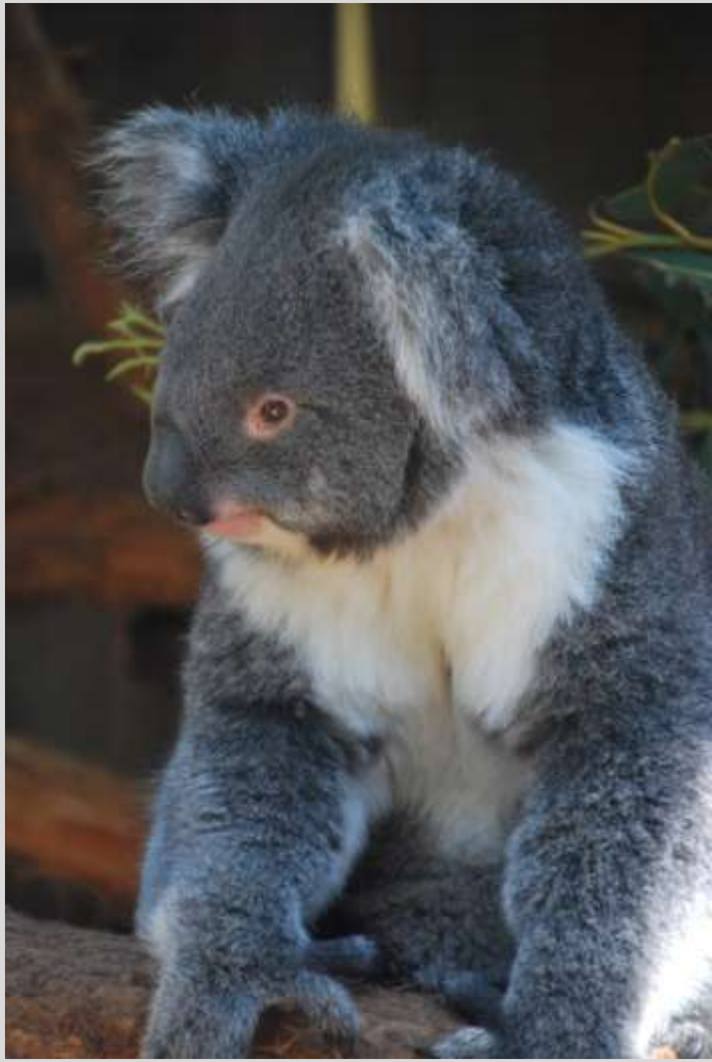
How does nature regulate heat transfer?

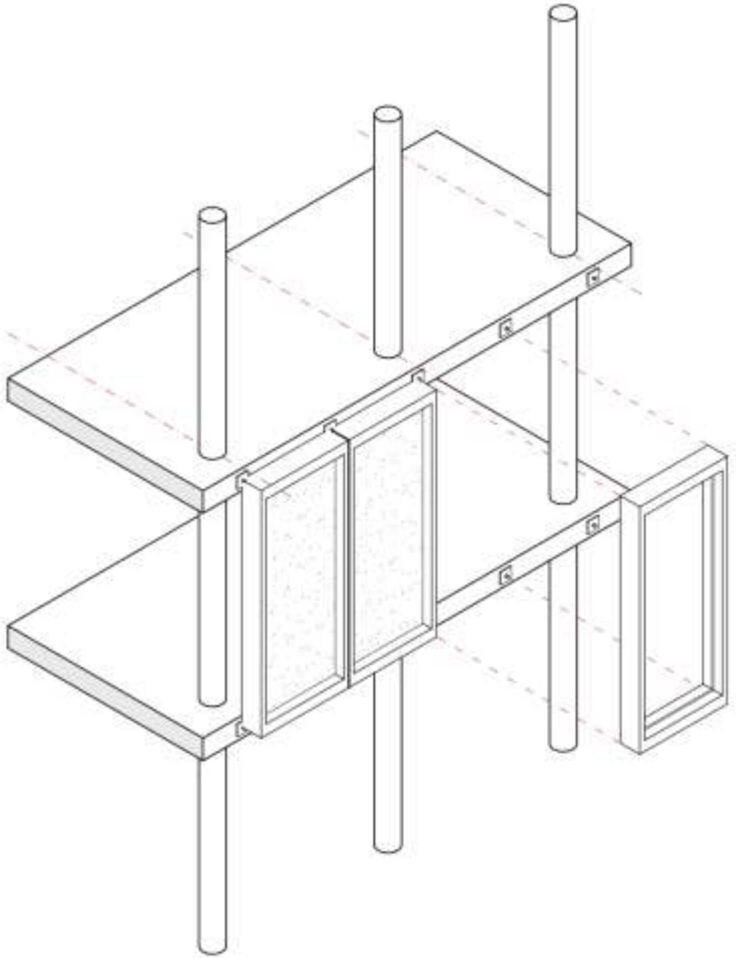
- Are there any general principles we can follow or learn from?
- Look to warm-blooded animals instinctively, because they can control their temperature very accurately regardless of the external conditions.
- This is how we like to control our buildings for better comfort – within a specific range.
- But do cold-blooded animals offer any opportunities?
- What about plants?
- What has worked and continues to work?

Natural patterns in heat transfer

- Pervasive use of fluid flow and conduction and convection
- Lightweight fibres
- Fat and blubber
- Heat exchangers (counter-current)
- The transfer of heat in human tissue – bioheat transfer



Design problem – challenge to biology



Unitised façade system

Example: Westhafen Haus, Frankfurt

Images: Knaack et al. (2007)

Design innovation

One of the fundamental building functions is to protect occupants from temperature extremes and to maintain thermal comfort.

Achieving desired thermal comfort levels is a key design concern in current practice.

However, buildings are also significant contributors to greenhouse gas emissions, and thus energy minimisation is also a key design goal.

Biomimicry offers architects and engineers alternative methods and strategies to overcome this inherent design conflict.

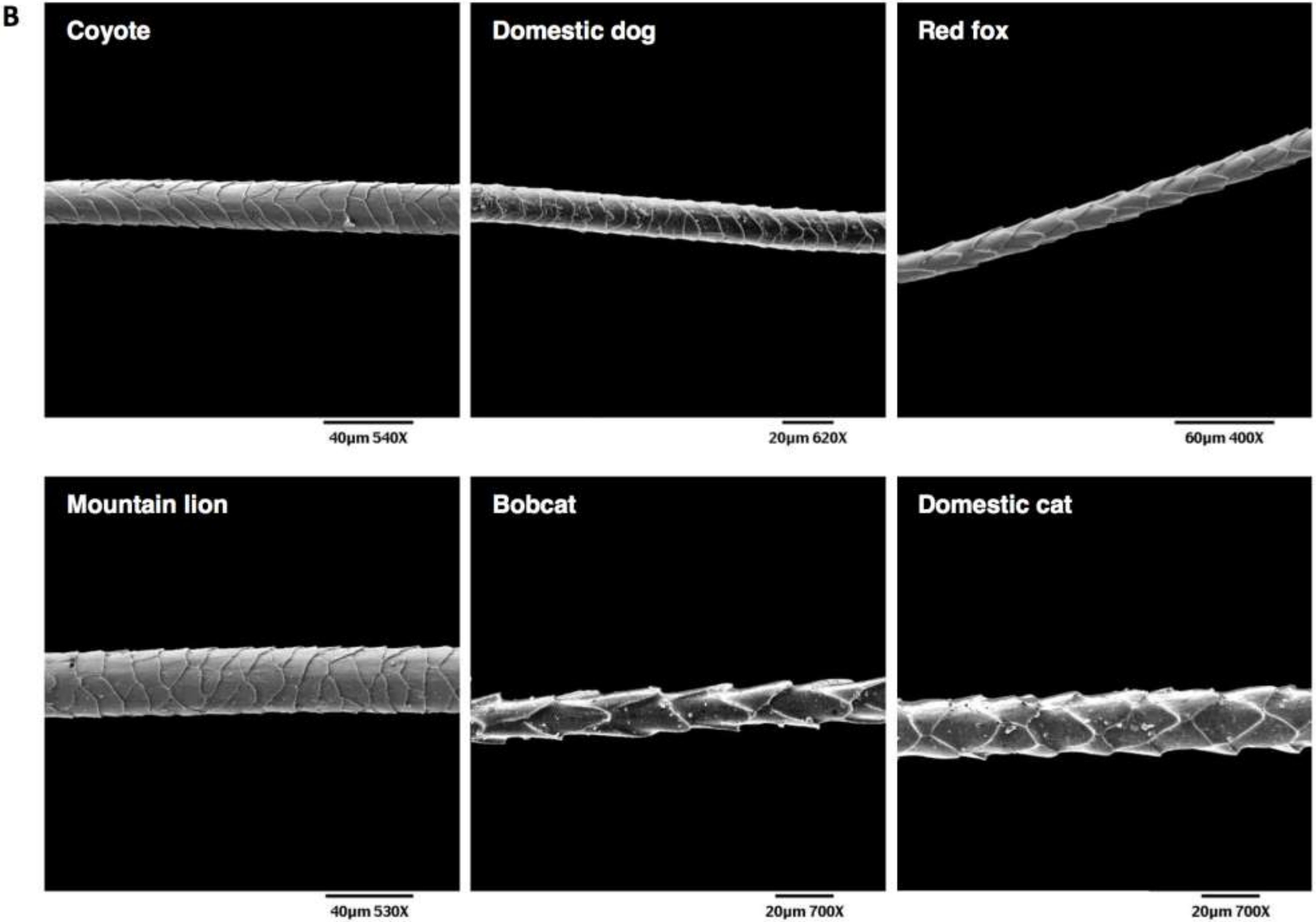


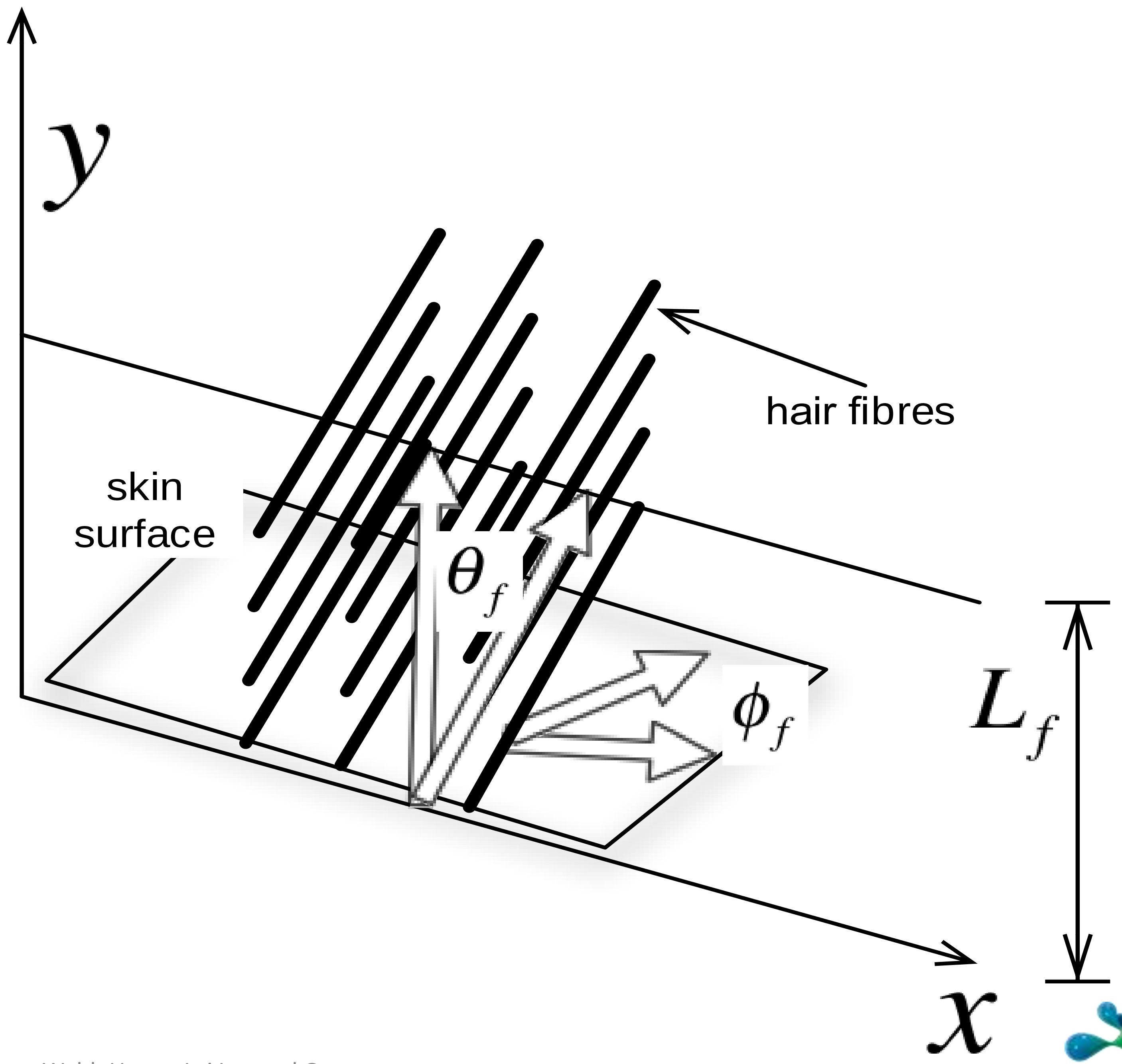
Image: Mostman Liwanag (2008)

Image:
manyang.com

What if we lined building facades with fur?

$$q_f = \frac{k_{eff}}{L_f}\left(T_{s,e} - T_{f,e}\right) + \left(1 - \left[\frac{\cos q_s}{N_{f,s}F_s}\right]\right) q_{f,t}$$

$$- \left(\frac{a_{f,s}\left(S_b + S_d\right)\cos^2 q_s}{N_{f,s}F_s}\right)$$



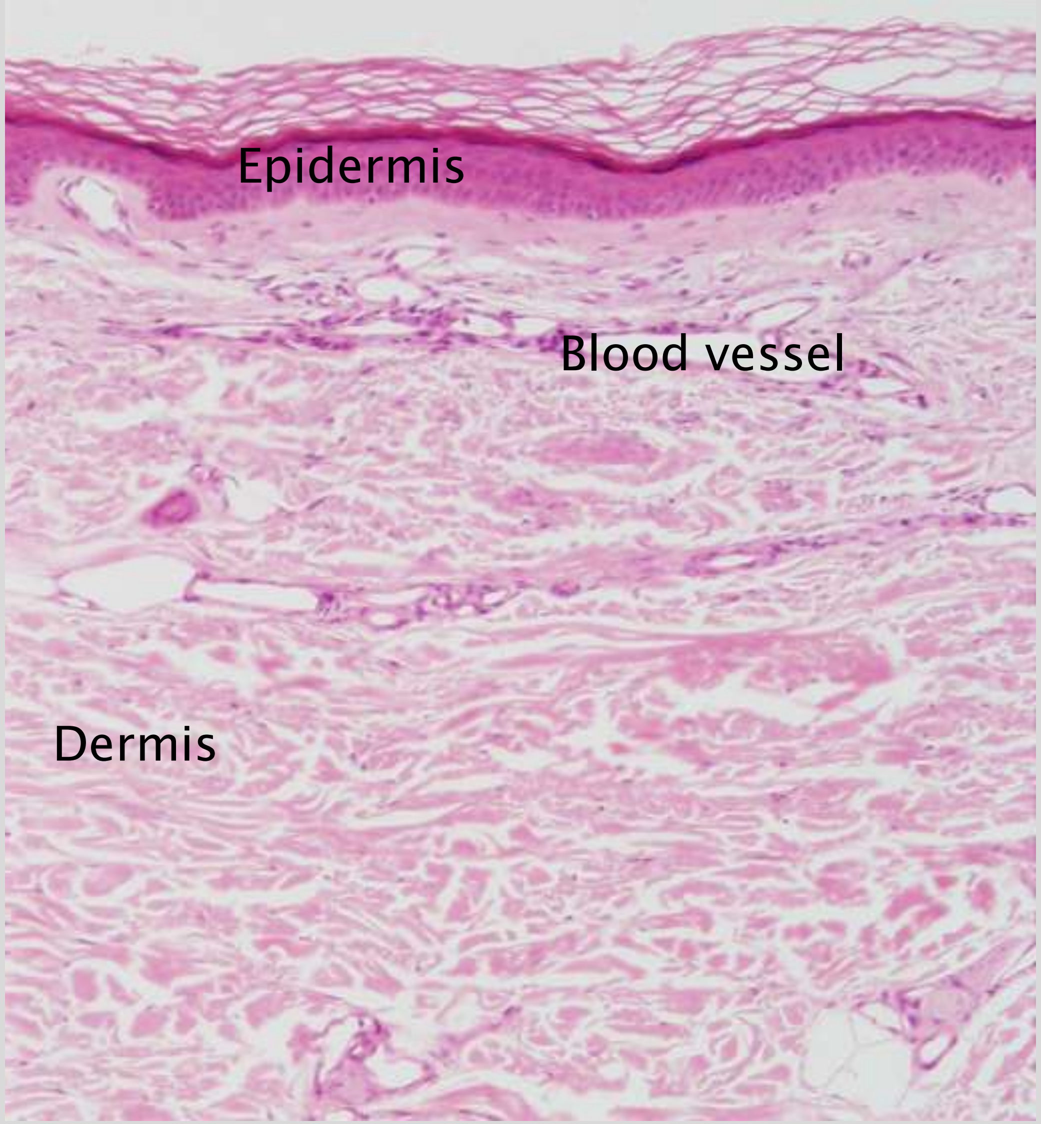
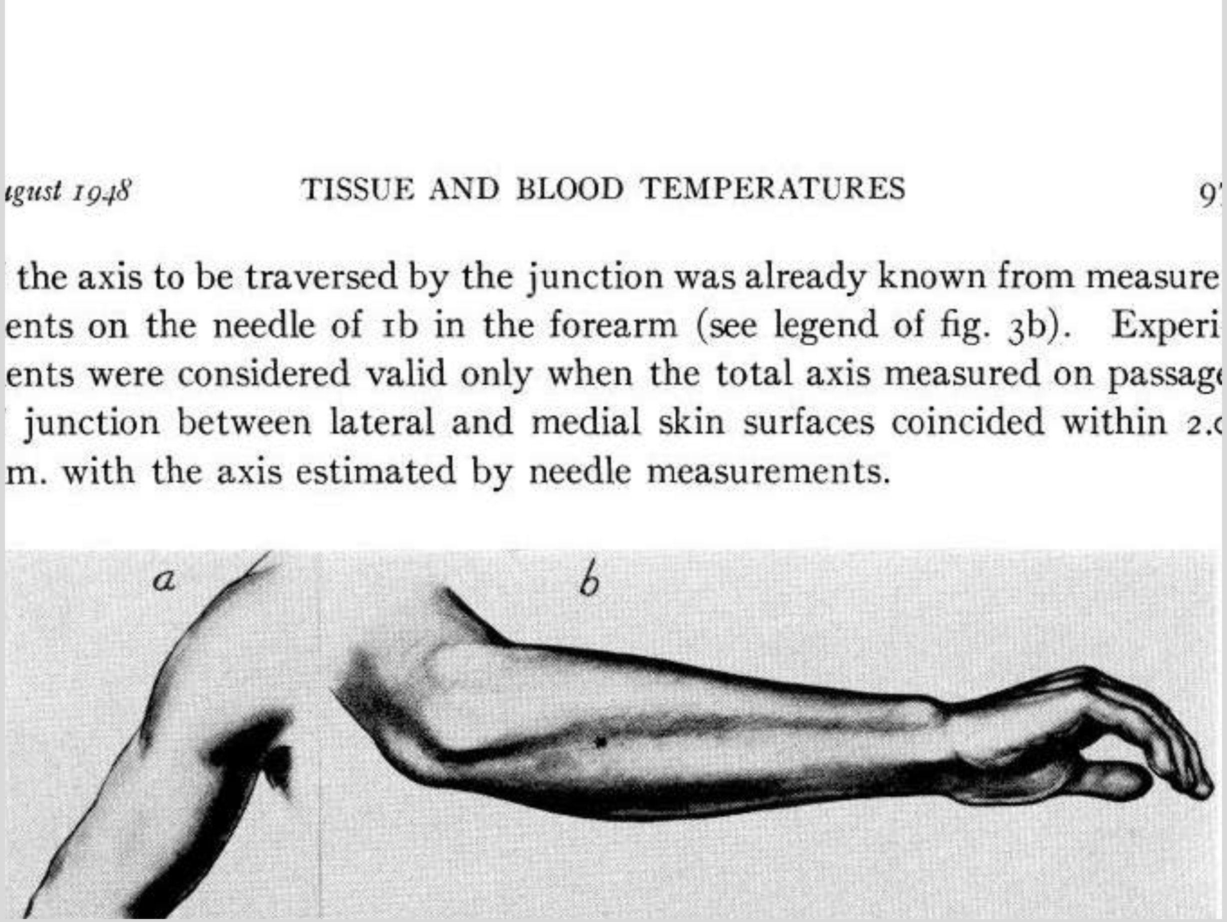


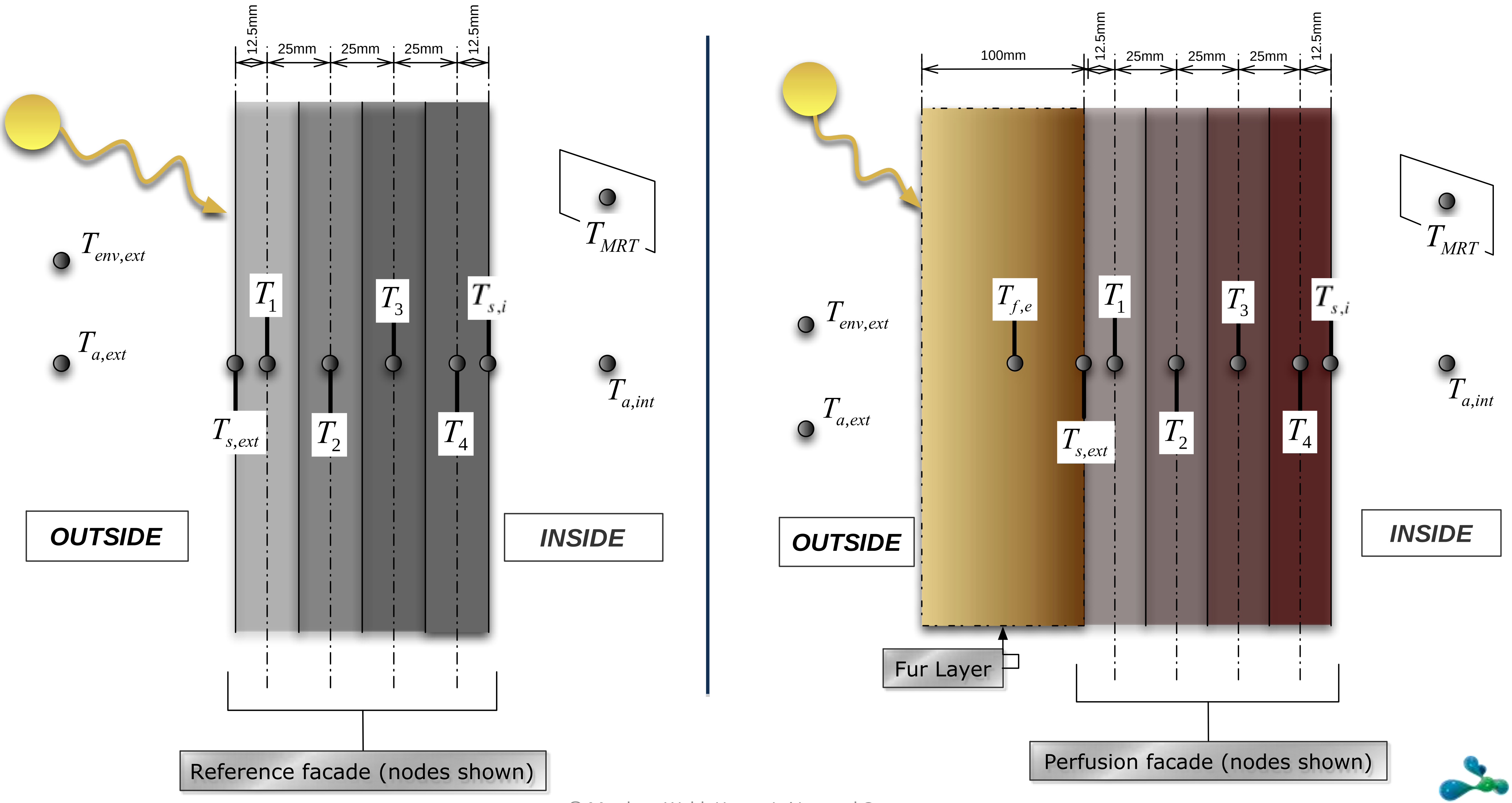
Image: Blue Histology,
University of WA



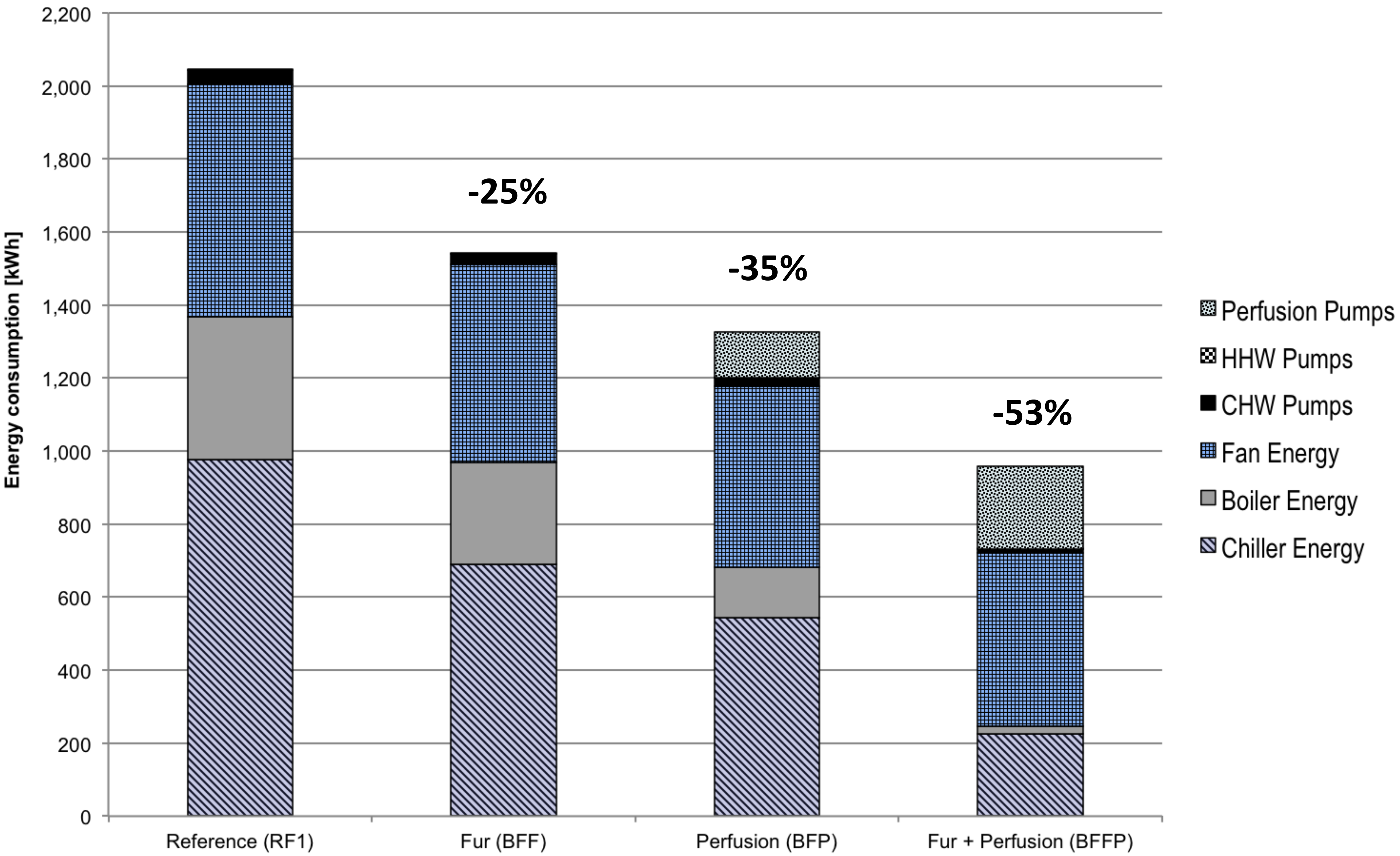
the axis to be traversed by the junction was already known from measure ents on the needle of 1b in the forearm (see legend of fig. 3b). Experi ents were considered valid only when the total axis measured on passage junction between lateral and medial skin surfaces coincided within 2. m. with the axis estimated by needle measurements.

Image: Pennes (1948)

$$\rho_t c_{p,t} \frac{\partial T}{\partial t} = k_t \nabla^2 T + \rho_b c_{p,b} \dot{w}_b \left(T_{a0} - T \right) + q_m'''$$


12.5mm
25mm
25mm
25mm
12.5mm
$T_{env,ext}$
$T_{a,ext}$
T_1
T_3
$T_{s,i}$
$T_{s,ext}$
T_2
T_4
T_{MRT}
$T_{a,int}$
OUTSIDE
INSIDE
Reference facade (nodes shown)
100mm
12.5mm
25mm
25mm
25mm
12.5mm
$T_{env,ext}$
$T_{a,ext}$
$T_{f,e}$
T_1
T_3
$T_{s,i}$
$T_{s,ext}$
T_2
T_4
T_{MRT}
$T_{a,int}$
OUTSIDE
INSIDE
Fur Layer
Perfusion facade (nodes shown)

Energy



Energy consumption [kWh]
2,200
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
-25%
-35%
-53%
Reference (RF1)
Fur (BFF)
Perfusion (BFP)
Fur + Perfusion (BFFP)
Perfusion Pumps
HHW Pumps
CHW Pumps
Fan Energy
Boiler Energy
Chiller Energy

Energy Simulation

Component	Fur	Perfusion	Fur + Perfusion
Chiller Energy	-29%	-44%	-77%
Boiler Energy	-29%	-65%	-95%
Fan Energy	-15%	-22%	-25%
CHW Pumps	-25%	-38%	-74%
HHW Pumps	-29%	-65%	-95%
Perfusion Pumps	0%	0%	0%
Total	**-25%**	**-35%**	**-53%**

…it’s everywhere

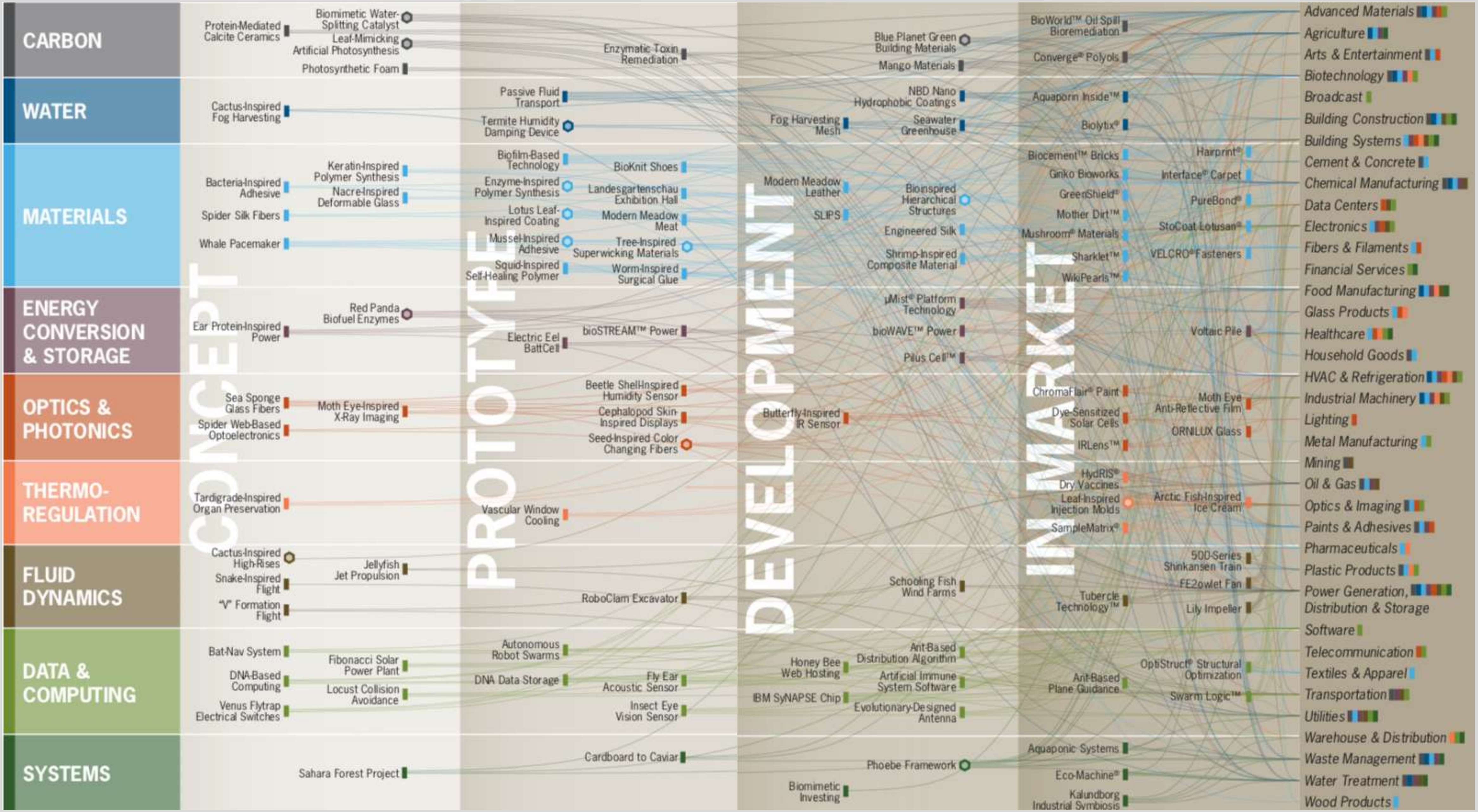
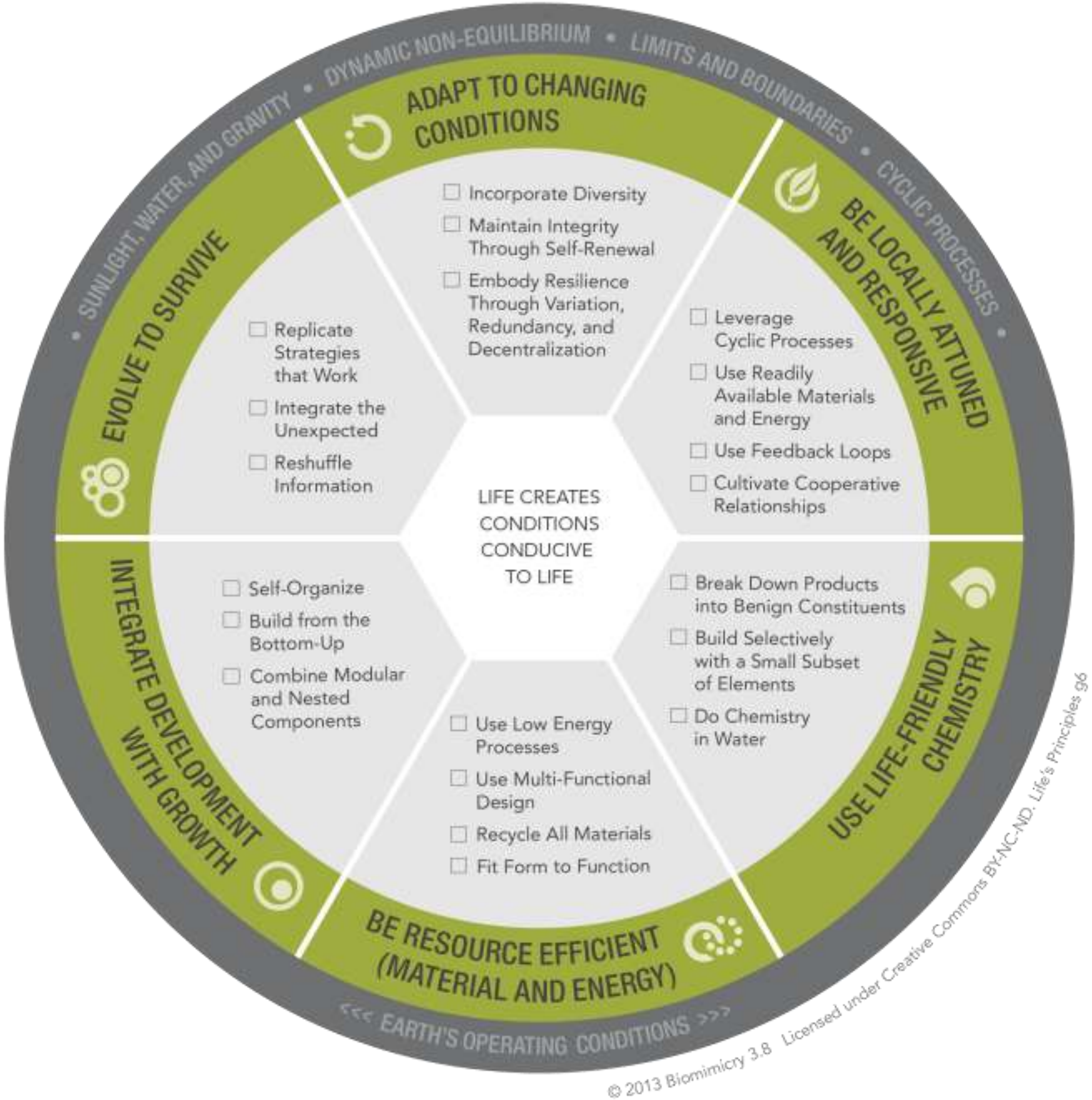


Figure: Terrappin Bright Green (2016)

Part 4: Barriers

Lack of awareness



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ADAPT TO CHANGING CONDITIONS
Incorporate Diversity
Maintain Integrity Through Self-Renewal
Embody Resilience Through Variation, Redundancy, and Decentralization
BE LOCALLY ATTUNED AND RESPONSIVE
Leverage Cyclic Processes
Use Readily Available Materials and Energy
Use Feedback Loops
Cultivate Cooperative Relationships
USE LIFE-FRIENDLY CHEMISTRY
Break Down Products into Benign Constituents
Build Selectively with a Small Subset of Elements
Do Chemistry in Water
BE RESOURCE EFFICIENT (MATERIAL AND ENERGY)
Use Low Energy Processes
Use Multi-Functional Design
Recycle All Materials
Fit Form to Function
INTEGRATE DEVELOPMENT WITH GROWTH
Self-Organize
Build from the Bottom-Up
Combine Modular and Nested Components
EVOLVE TO SURVIVE
Replicate Strategies that Work
Integrate the Unexpected
Reshuffle Information
LIFE CREATES CONDITIONS CONDUCIVE TO LIFE
<<< EARTH'S OPERATING CONDITIONS >>>
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Conservatism in design?

Lack of (local) examples

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Image: Banku (Wikipedia)

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Image: http://compositesandarchitecture.com

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Image: http://compositesandarchitecture.com

Image: Marion Schneider & Christoph Aistleitner (Wikipedia)

Image: fosterandpartners.com

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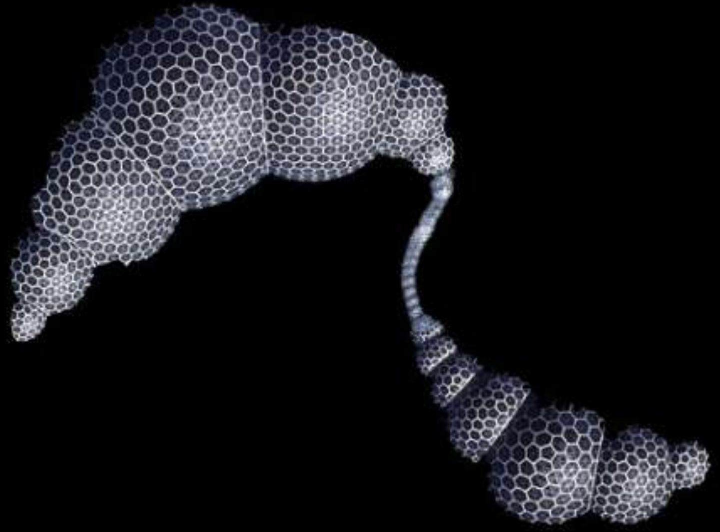
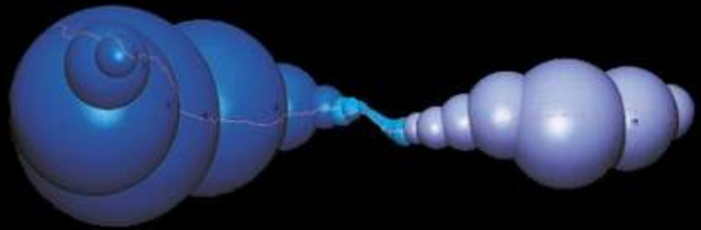
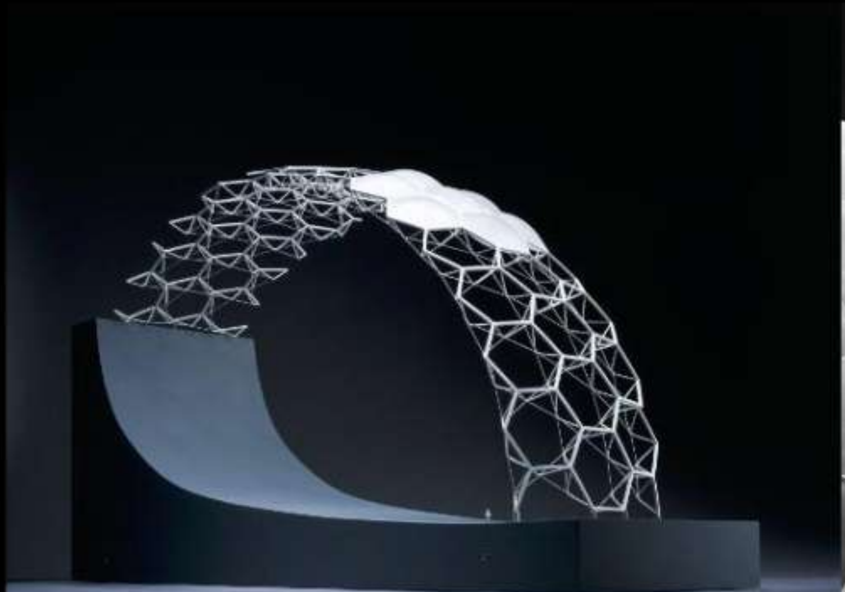




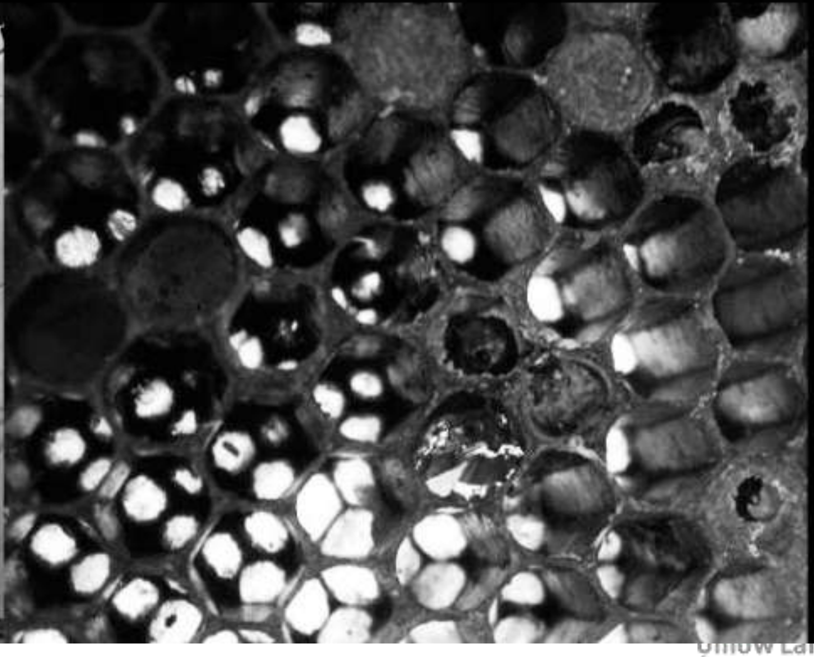


Figure: Exploration Architecture

Time!

Image: Aron Visuals (Unsplash)

Other factors

- Lack of professional knowledge
- Training and education (curriculum and professional)
- Database
- Client demand
- Uncertainty of performance
- No well-defined approach/strategy
- Perceived cost
- Perceived risk

Source: Oguntona and Ohis (2019)

Part 5: So what do we do?

Changing mindsets

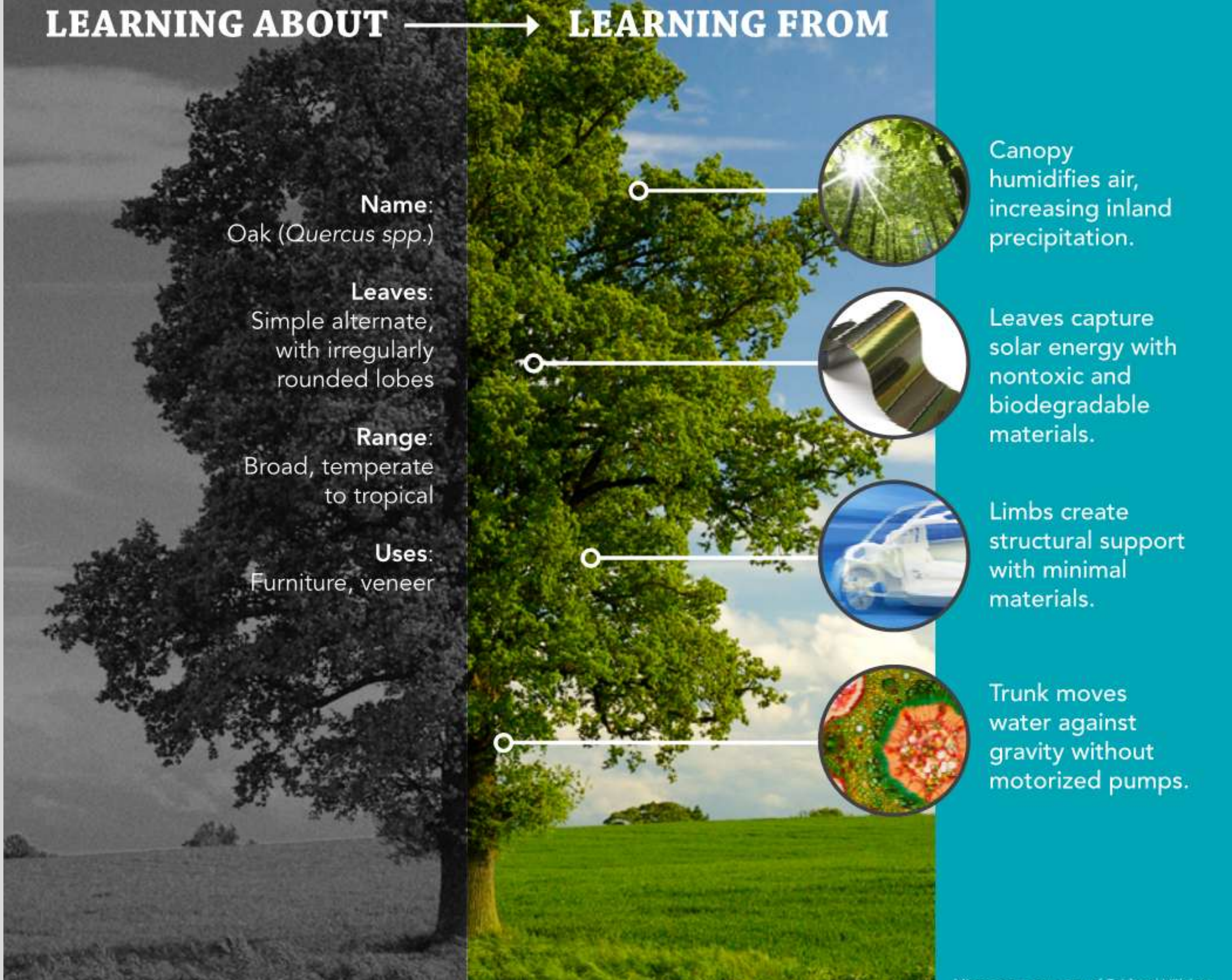


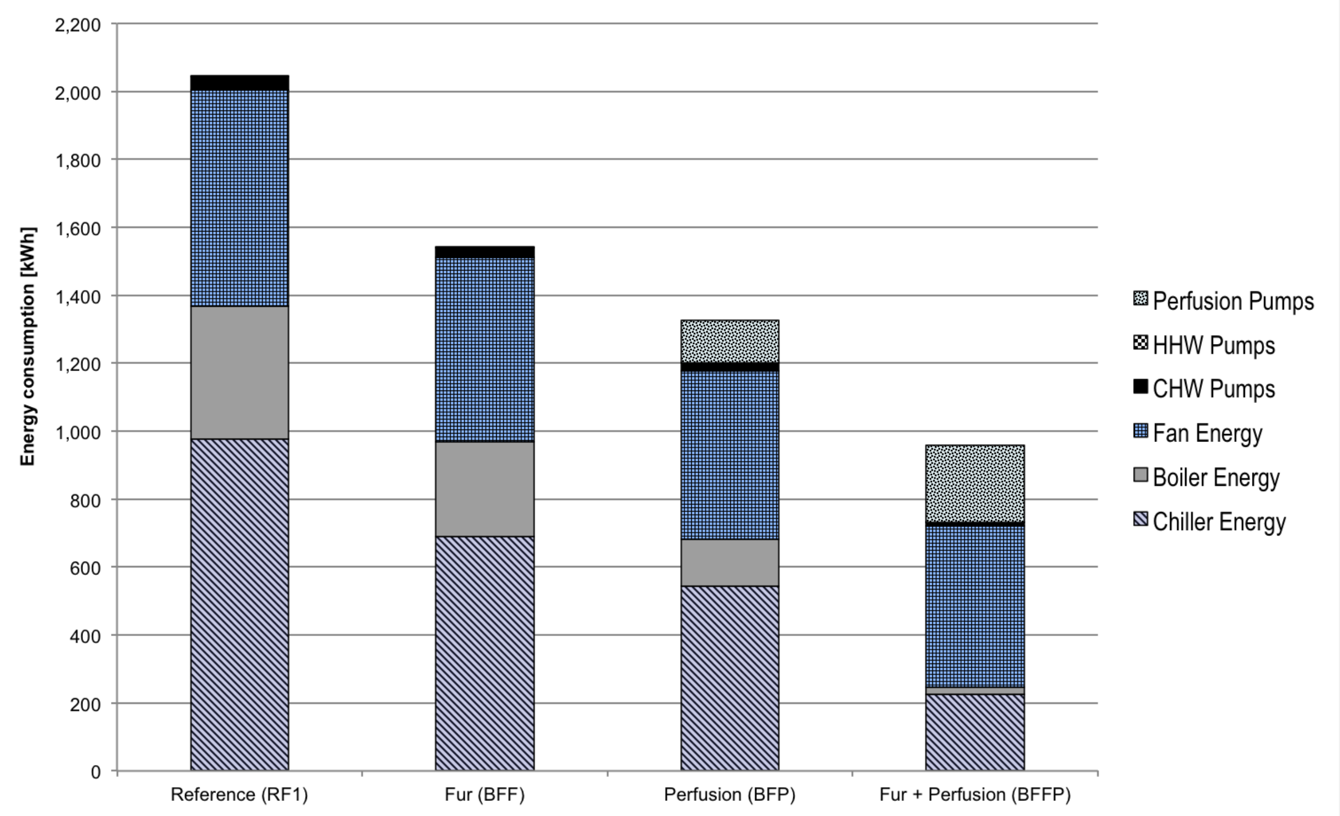
Figure: Biomimicry.net

- Changing mindset
- Function and Strategy
- Form, Process and Ecosystem
- Biomimicry vs “biogimickry”
- Patterns in nature

Patterns in nature

- Why do many aquatic animals have an ovoid shape?
- Why are plants green?
- Why do both bats and dolphins use echolocation?
- How do colonies of animals coordinate their movements?
- How does enough blood reach a giraffe's neck?

Conclusions



As an example – there are are patterns of heat transfer and temperature regulation in nature from which to learn more efficient techniques to heat and cool our buildings.

Fur is possessed by many mammals, both terrestrial and marine. It has low density, physical resilience and low thermal conductivity. Possesses attributes of flexibility.

Perfusion is the process of bioheat transfer that occurs in living tissue of warm-blooded animals. It is dynamic, responsive and requires a working fluid of water.

Substantial reductions in peak heating, cooling, surface temperatures and annual energy when compared against the reference.

Conclusions

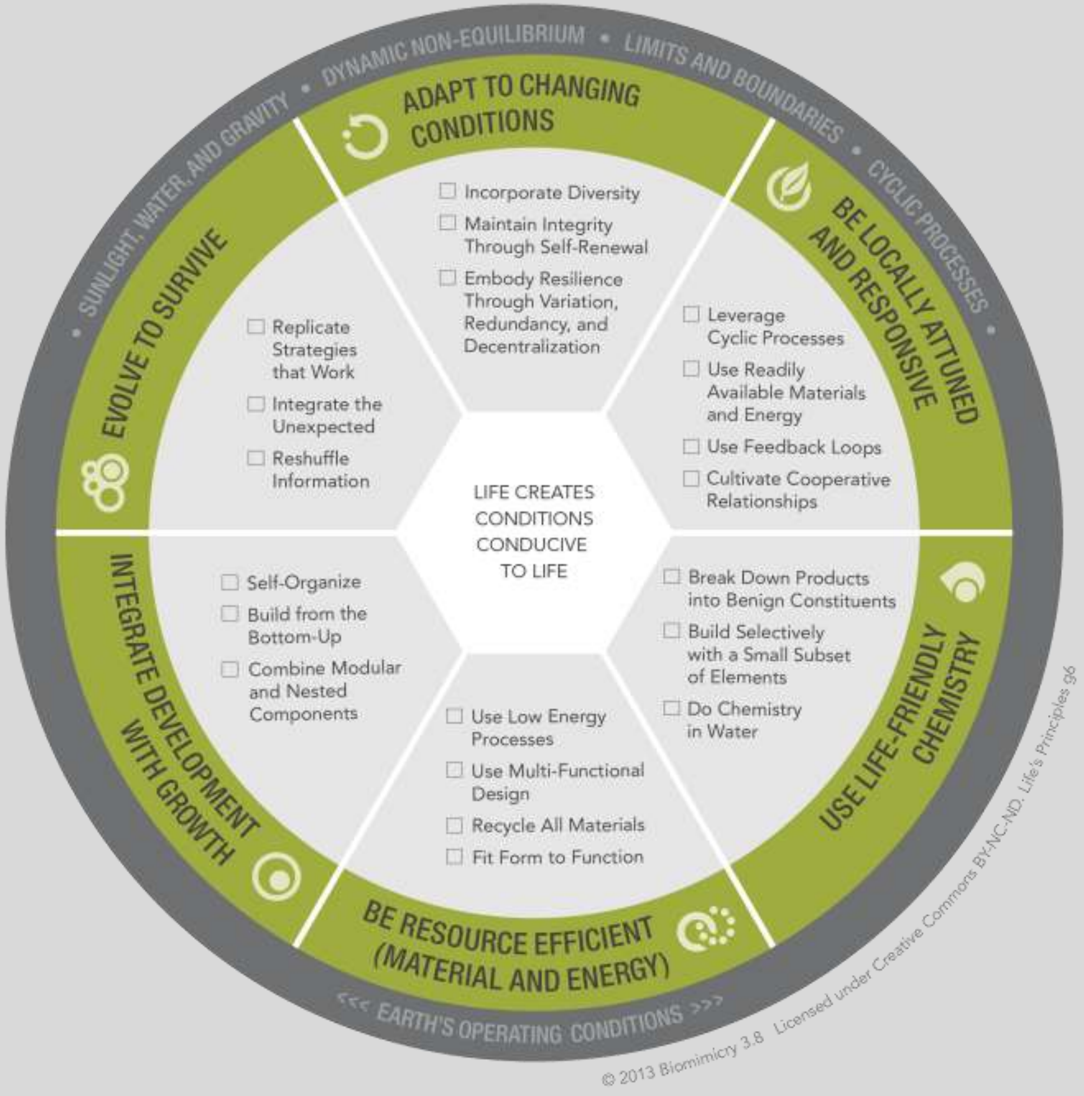
Biomimicry is a viable process for translating biological characteristics into design and technological innovation.

Observe and *Understand* nature, quiet your ‘intelligence’.

Form, process and ecosystem.

What are the functions and strategies employed?

The focus is always function, function and function.



Future possibilities?

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Be on the lookout!

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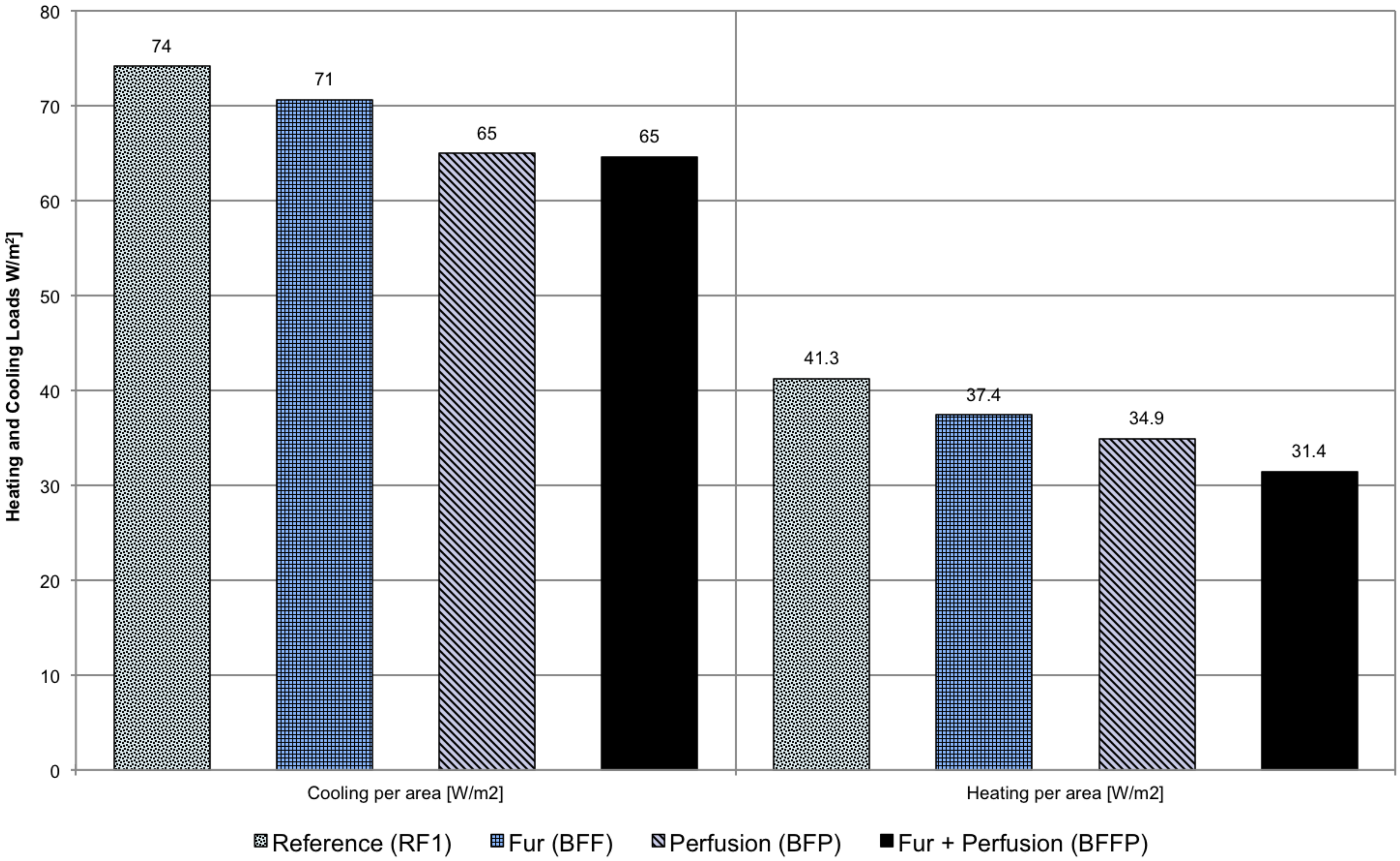
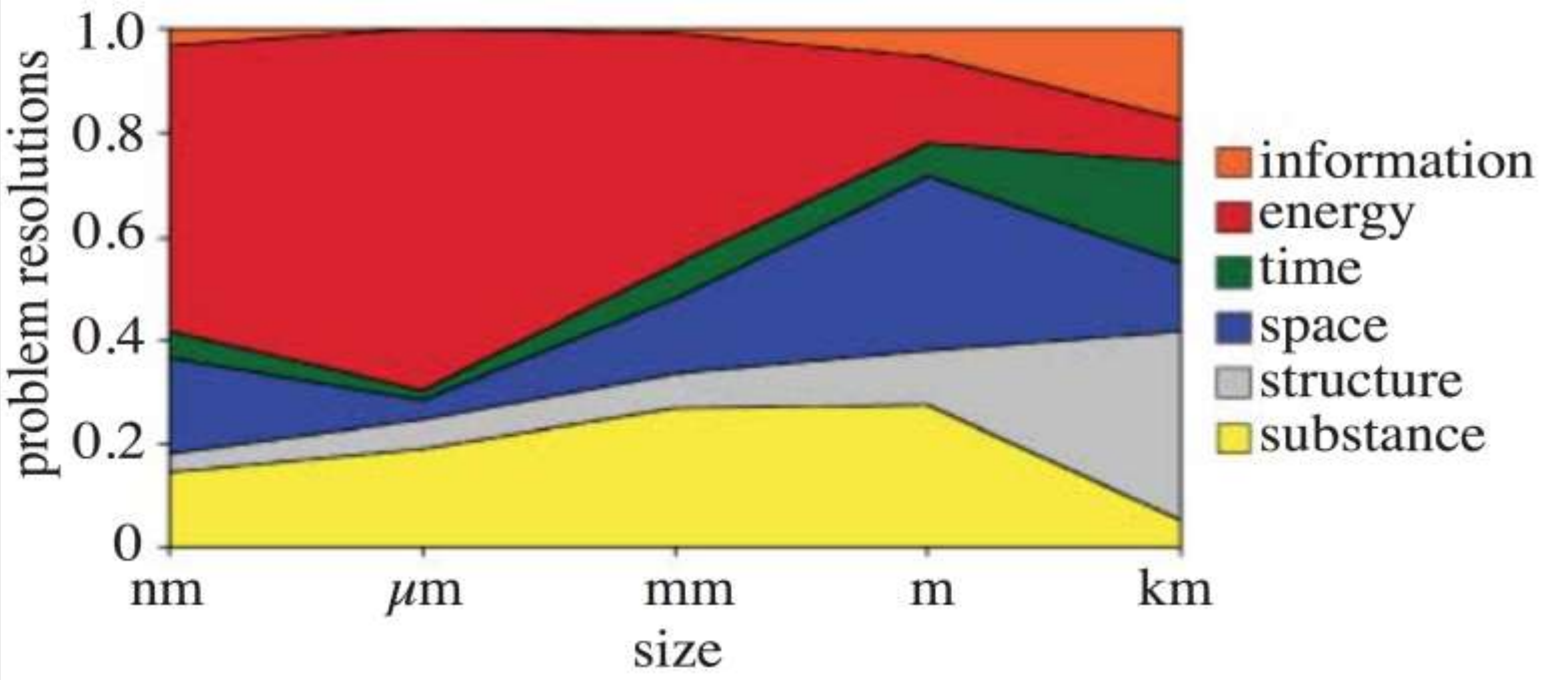
Function: the purpose / objective
Strategy: how you do it

Façade peak loads




1.0
0.8
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0.2
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problem resolutions
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μm
mm
m
km
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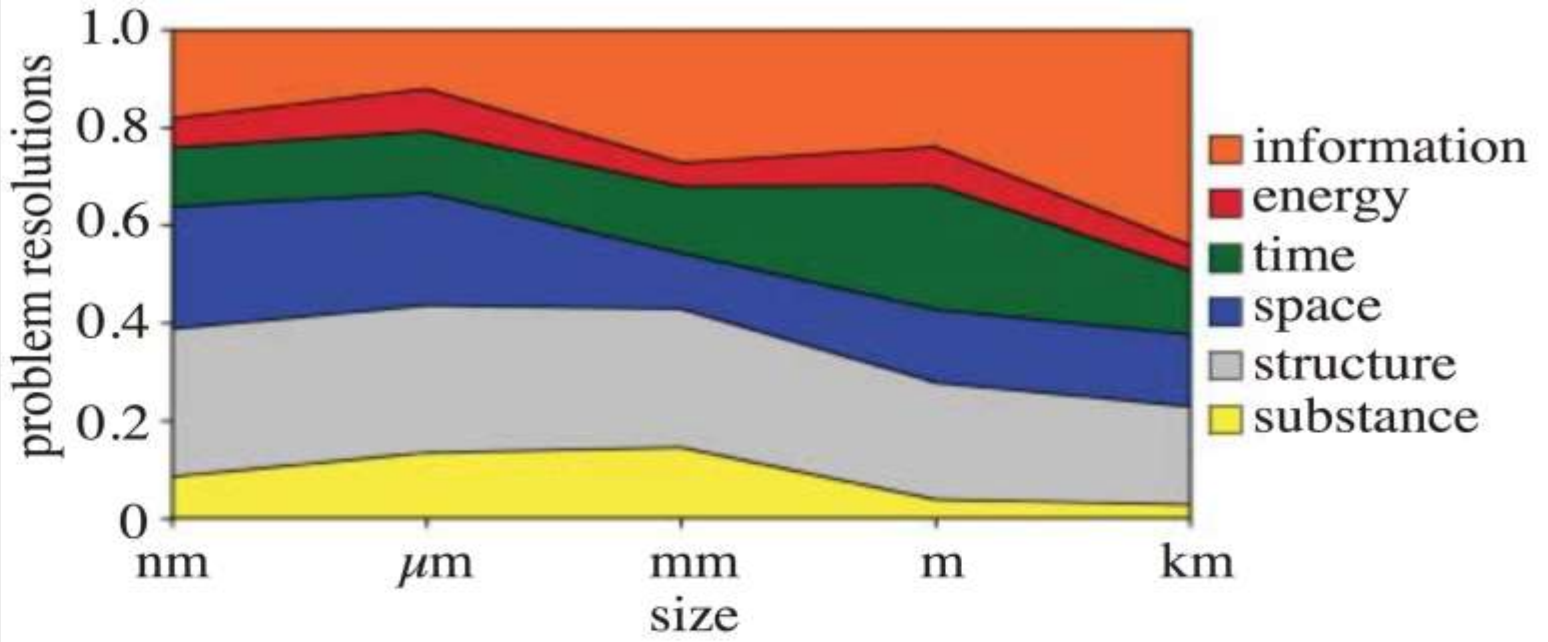
energy
time
space
structure
substance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structure
substance

$$q_f = \frac{k_{eff}}{L_f}\left(T_{s,e} - T_{f,e}\right) + \left(1 - \left[\frac{\cos\theta_s}{N_{f,s}F_s}\right]\right)q_{f,t}$$

$$- \left(\frac{\alpha_{f,s}\left(S_b + S_d\right)\cos^2\theta_s}{N_{f,s}F_s}\right)$$

$$\frac{\partial^2 T}{\partial x^2} = \frac{1}{\alpha_w}\frac{\partial T}{\partial t}$$

Great, partial differential equations, fun, fun, fun…

Start with a model