Creative Solutions to Fundamental Challenges

Kartik B. Ariyur and Justus I. Schollmeyer

CTO, SAMMS LLC and Purdue ME & Co-Founder, Second Negation

TRIZCON 2019

Is it possible for everyone

Fast operation

Smart Grid Stability

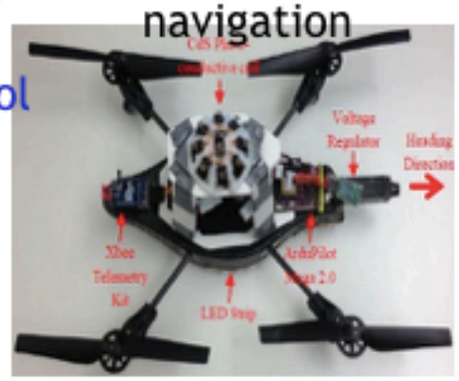
EV Traction Control

Gas Turbine Monitor

Adaptive Systems

LAAS Sigma Monitor

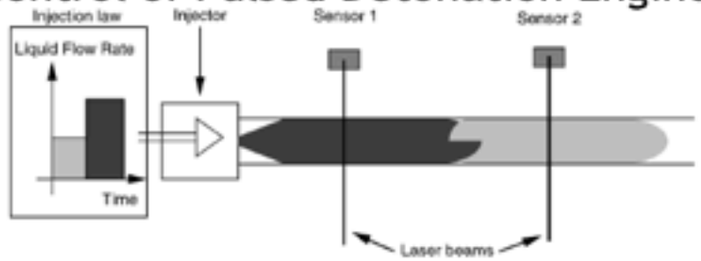
GPS denied navigation



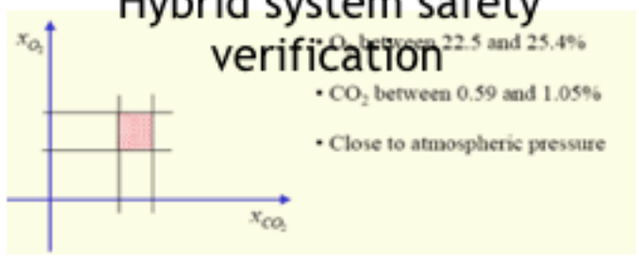
Properties of Security Systems

Multi-UAV Mission Planning

Control of Pulsed Detonation Engines



Hybrid system safety verification



Power Control in MaNets

Magnetic Mapping

Mobile geolocation

Kartik B. Ariyur

Solar Thermal Grid Integration

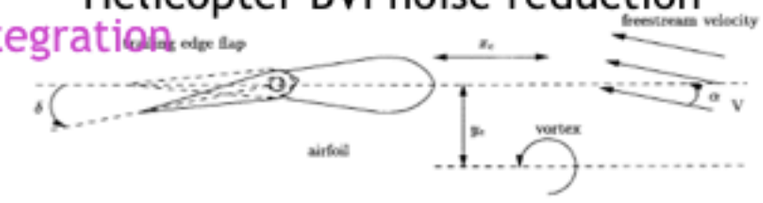
Laplacian Path Planning

Automated Celestial Navigation

Avionics GPS receivers

Acoustic Mapping

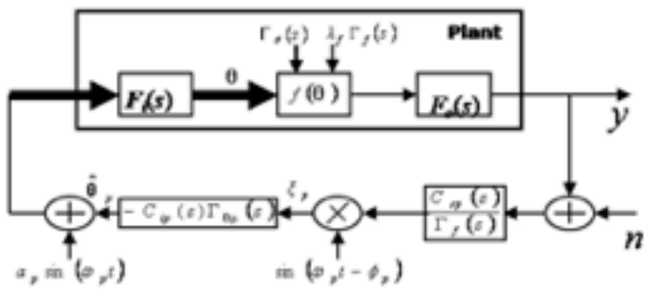
Helicopter BVI noise reduction

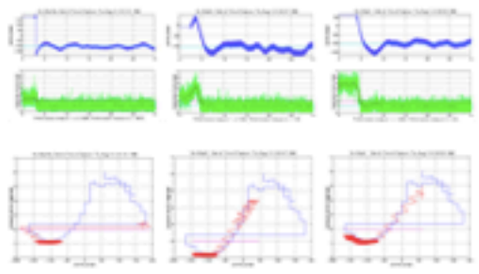


CDMA Adaptive Pilot Filter

MaNet traffic control

Hypersonic Vehicles





Extremum Seeking: Theory and Applications

...to be an innovator?

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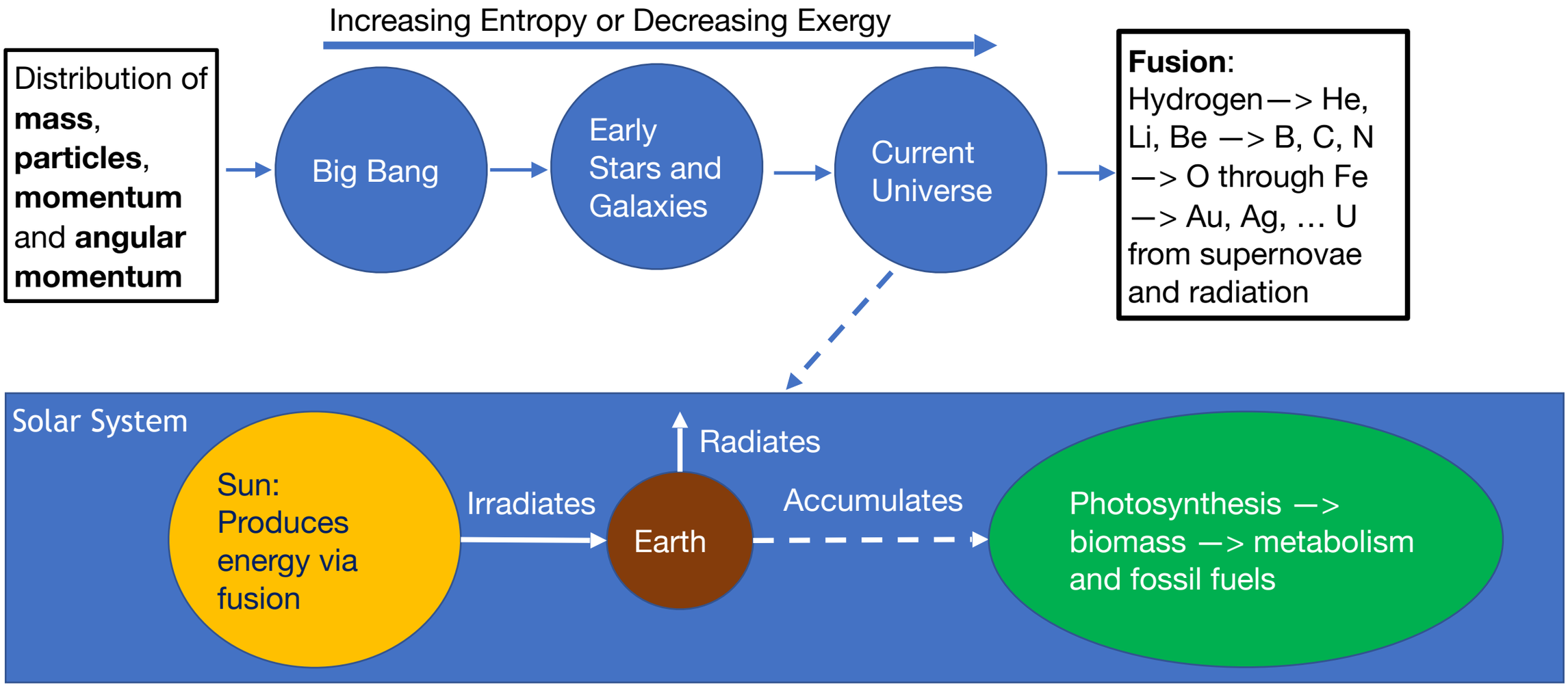
Second Negation

The evolution of our Planet



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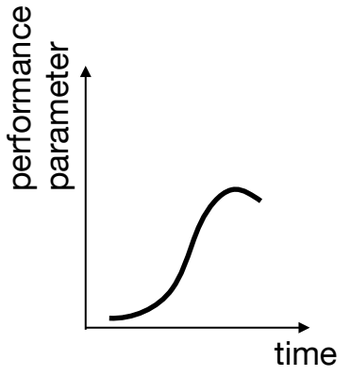
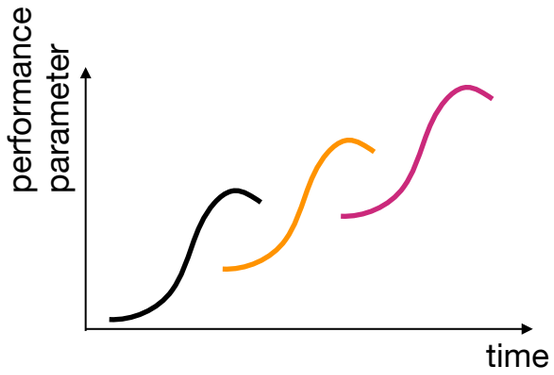
new function realized



new way of realizing existing function



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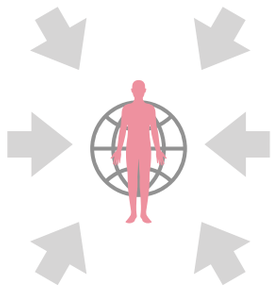
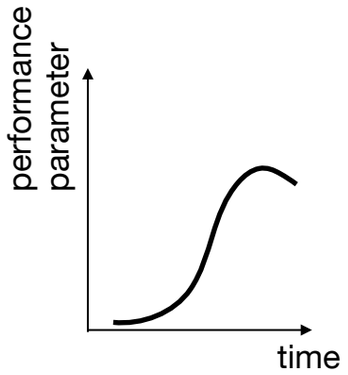
behavior of system in all kinds of contexts



system from evolutionary perspective



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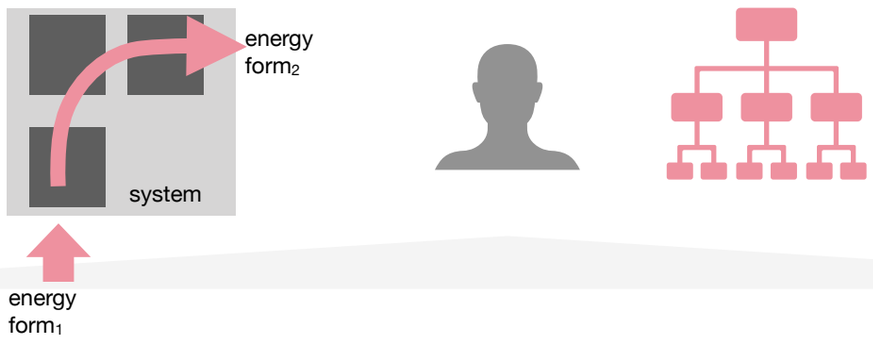

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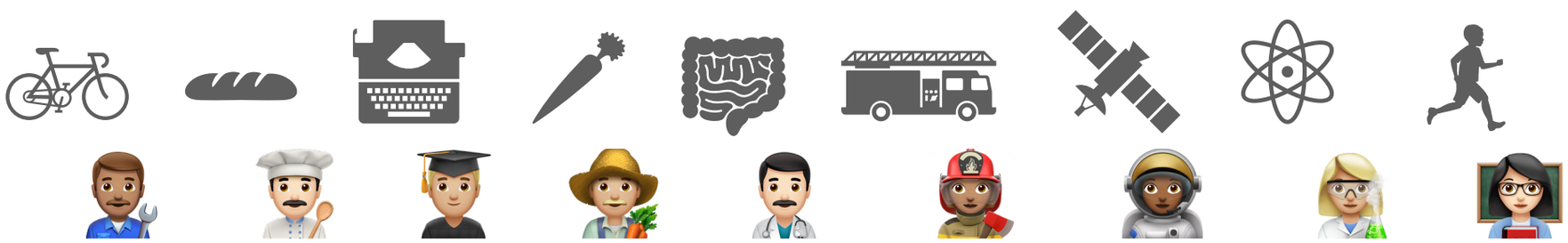

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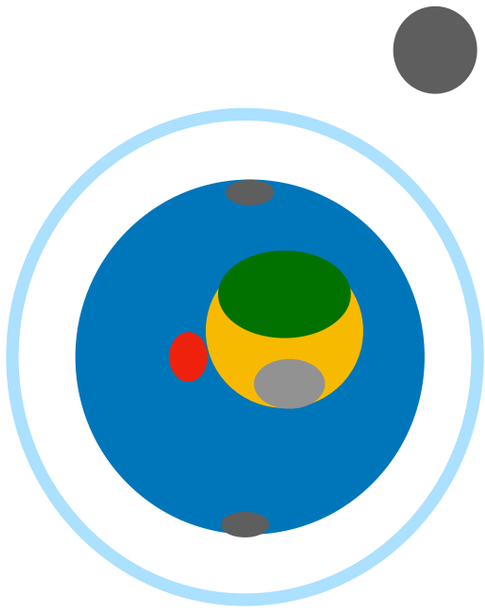
Our Planet

	S	M	E	A	O	L	P	B	C
Sun		>	>	>	>	>	>	>	
Moo				>	>	>		>	
Elem				>	>	>	>	>	>
Atmo			>		>	>	>	>	
Ocea			>	>		>	>	>	
Land			>	>	>			>	>
Pole			>	>	>			>	
Biom			>	>	>	>			
Core			>	>	>	>	>	>	

Energy in

- Sun



Moon

Elements and minerals

Atmosphere

Ocean

Landmass

Poles

Biomass

Core

Energy out

- availability of energy

…

Radiation into space

Atmospheric temperature

CO_2/O_2

CO_2 and O_2 in the atmosphere

Carbon fixation per year

Undigested waste per year

Human population

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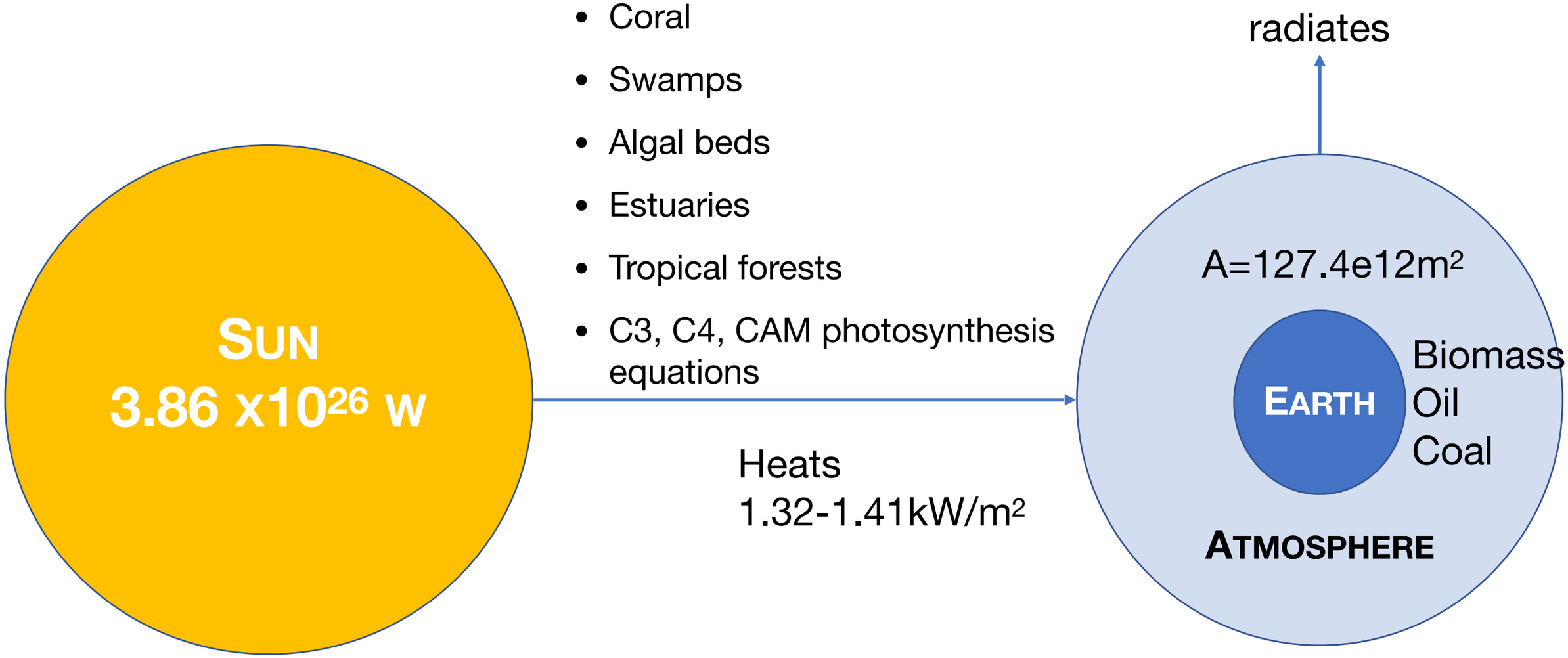
Second Negation

Some numbers

- 1% converted to biomass:
  - 10% of that is consumed by herbivores
  - 90% is detritus
    —> oil and coal eventually
- Most efficient:
  - Coral
  - Swamps
  - Algal beds
  - Estuaries
  - Tropical forests
  - C3, C4, CAM photosynthesis equations



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Question

- Can we live without fossil fuels? And if so: How?

Question

- What do you think are the most fundamental problems we are facing?

- 1) Increase energy availability

- 2) Decrease inefficiency in energy use

- 3) Improve problem solving ability

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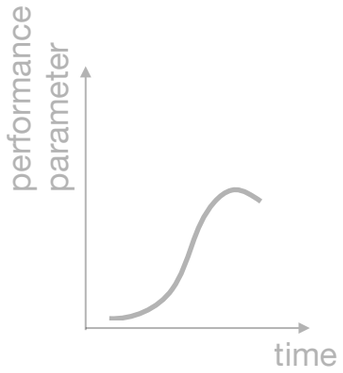
4. Self-directed experimental inquiry is key for systemic innovation

new function realized



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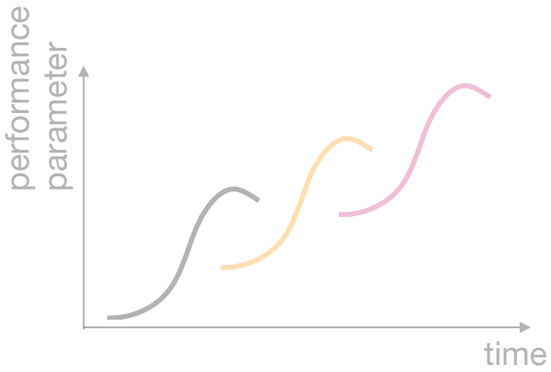

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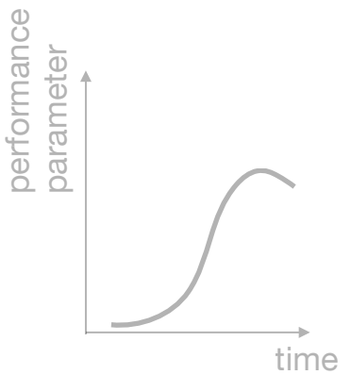

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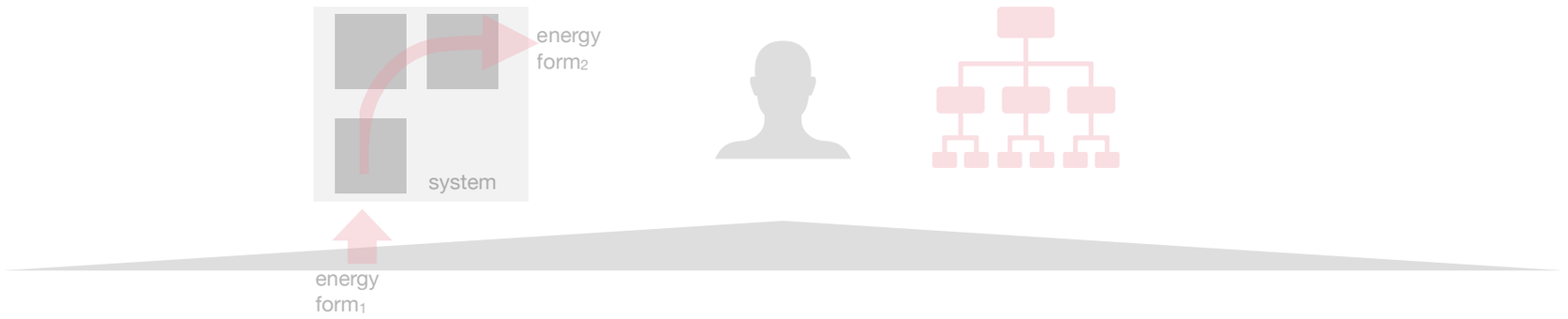

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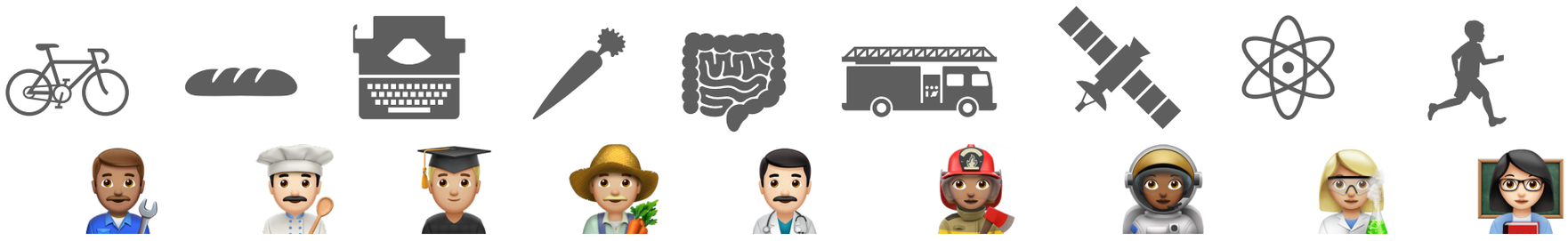

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Hierarchical Decomposition of Solution Steps: Larry Ball Generalized Heuristics at www.opensourcetriz.com

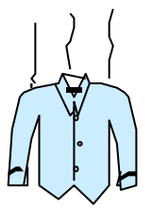
Market (Group and a Job)

University Students—
Drying Clothes

Function

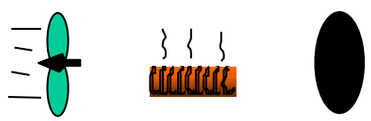
Move moisture

Physical Phenomenon



Evaporation

Objects



Fan

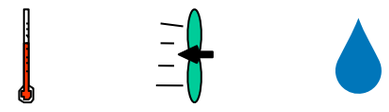
Heating coil

Drum

Improvement

Drying time

Knobs

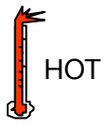


Air temp

Air speed

Moisture content

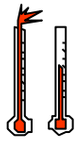
Knob Settings



HOT

...

Resolution of Contradictions



Hot and cold

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Second Negation

Who is the Market ? (Group, Job, Circumstances)
Focus on Non-Consumers

- Group—Non-Experts
- Job—”Suture” a wound
- Circumstances—
  Outdoors or at Home

Aha !!—There is a group of people that are non-consumers that want to do the job themselves—Since nobody meets this need, they will likely be forgiving.

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What Functions? What Part of the Job?

What Functions will our system steal from its job environment?

Aha!!—The Solar panel must take on the function of the roof tile

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Second Negation

What Constitutes Delight of the Market ?
(How Well are the Functions Performed?)

Market: Women who want to exercise at home, but who lack the equipment or companionship to do this consistently.
— Here is what they face.

Aha!!—What they really want is a setting where they feel comfortable (like home) and can enjoy ready companionship. No fuss of changing the equipment—No mirrors, a private place to change and NO MEN! (*Curves*)

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What Phenomena Will Deliver The Function?

I want to split diamonds along the internal fault faces. How can I do this so that I do not create more faults?

Aha!!—A way exists to split many objects such as eggs, nuts and peppers. Apply high pressure and wait until the pressurized gas fills all the small spaces. Then suddenly release the tank pressure.

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What Objects Deliver the Phenomena?

How to get the scoop to the top after putting on the bottom and then filling the container with powder?

Aha!!—Use existing objects—The vibration of the Truck

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Second Negation

How Can We Simplify the System?

Situation—Cars that bolt often end up in a high speed police chase

Aha!!—Sticky GPS Tracking system shot from an air-powered rifle allows the police to vector the car rather than starting or continuing a high-speed chase

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Second Negation

What is the Main Problem?

(People take Things for Granted)

We build bathtubs—For most people, our tubs are adequate—we take for granted how people interact with bathtubs

Aha!!—When it comes to a new market:
People who have trouble lifting their legs, (elderly, disabled) there is a discovered problem.

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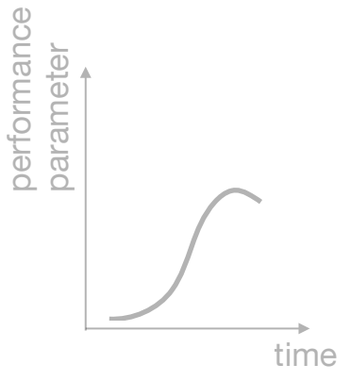
Second Negation

4. Self-directed experimental inquiry is key for systemic innovation

new function realized



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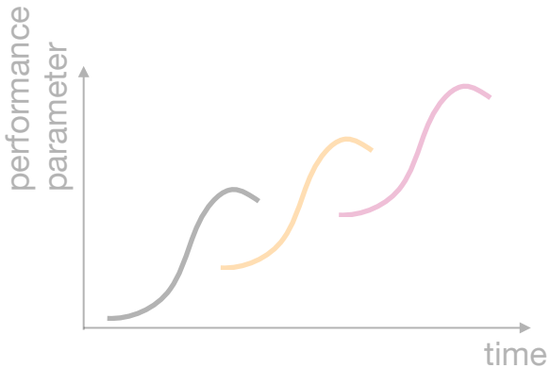

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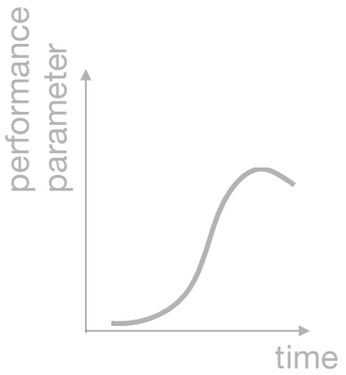

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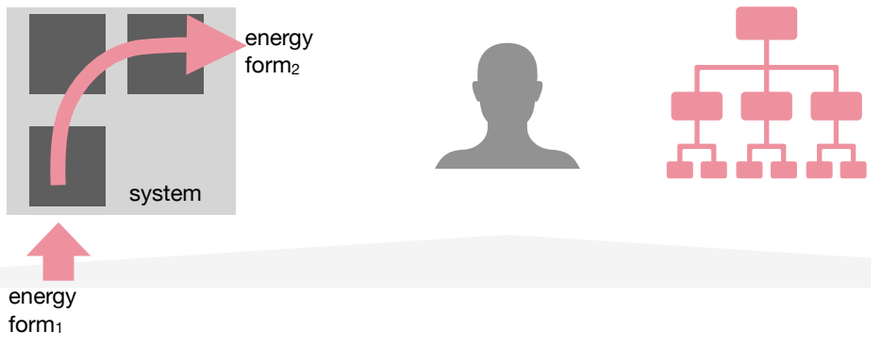

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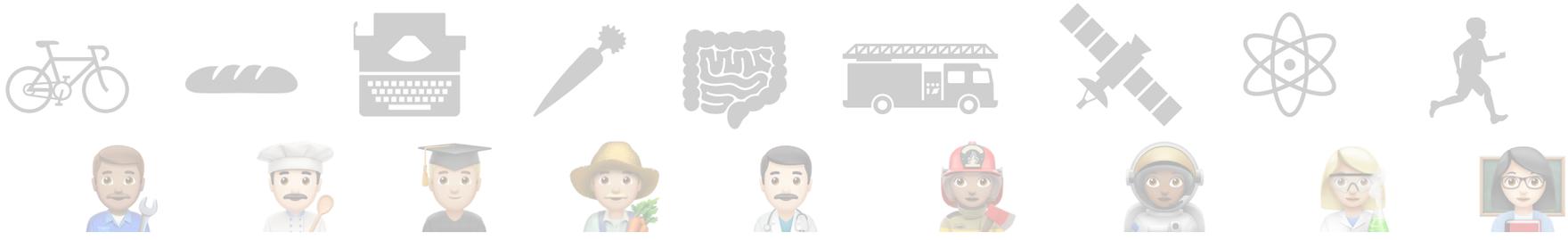

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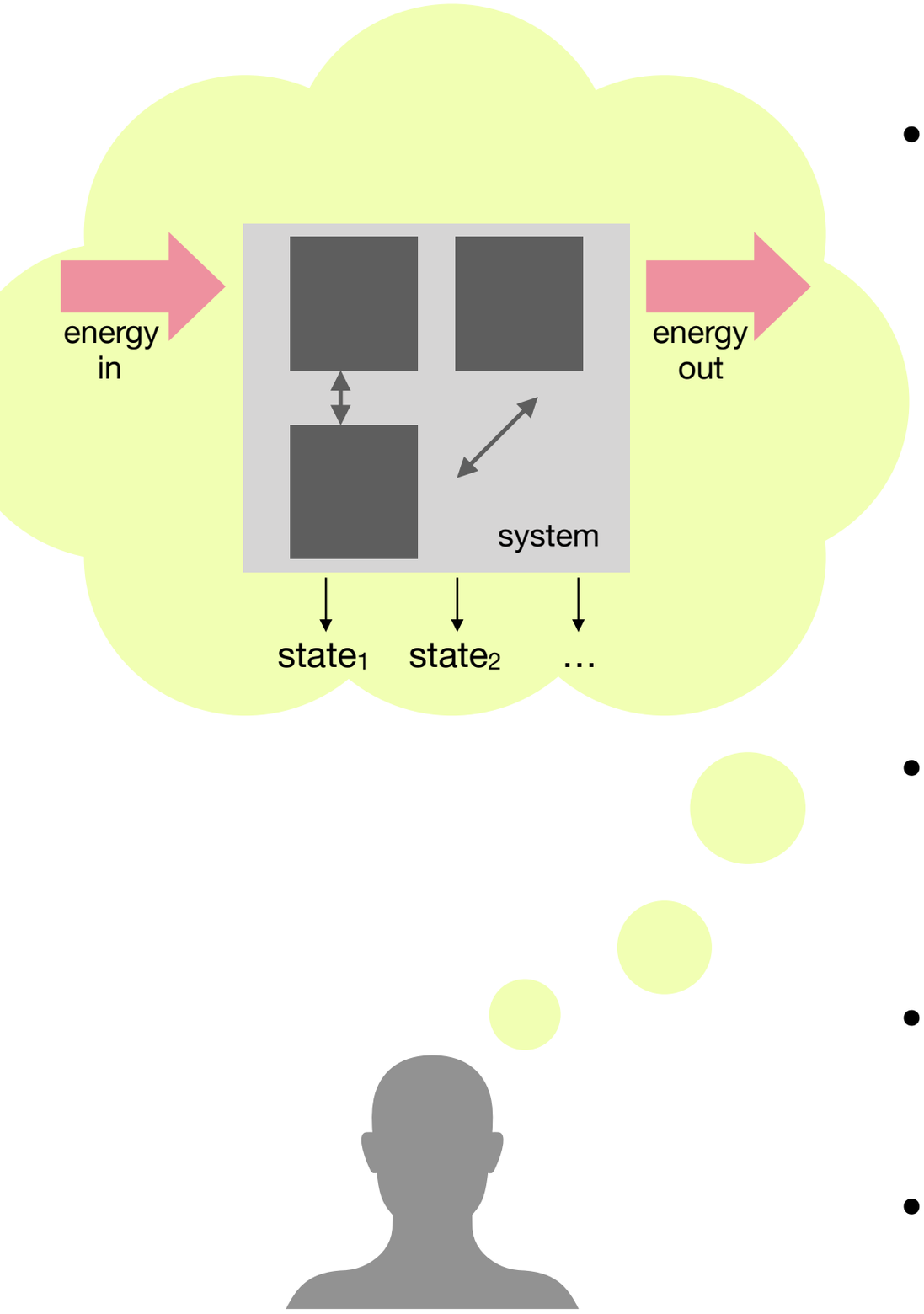
Second Negation

Problem Formulation From a Systemic Perspective



- A system is a collection of energy storage elements
  - The energy levels are characterized as states (can be classical or quantum)
  - Subsystems: Subsets of the collection of elements.
  - Supersystems: Collections of systems
- All **changes** or **functions** involve **interactions of such energy storage elements through energy exchange**.
- **Beliefs**, or **models** list the properties of systems and functions.
- **Problem solving** is action (sensing, actuation, calculation) attaining our aims.

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Acknowledgement:
Larry Ball for function exercises

www.opensourcetriz.com

Describing the System Function

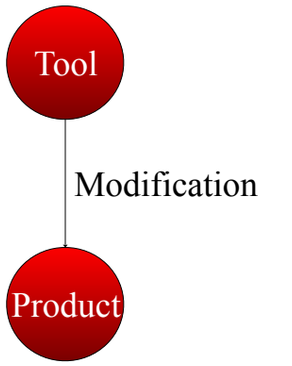
1. Are all of the functional elements present?

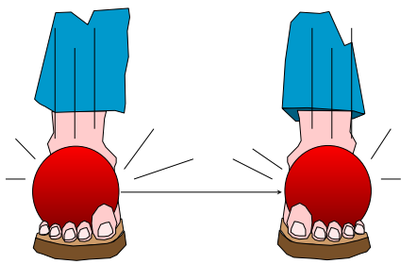
2. Are the tool and product something you could drop on your foot? (system or energy storage elements)

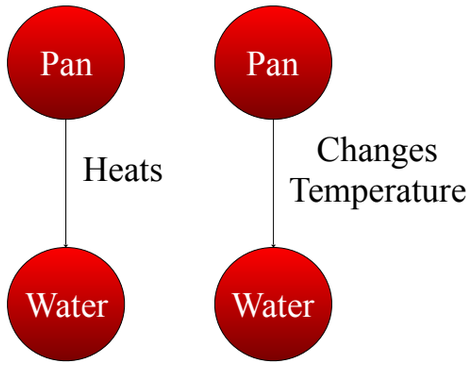
3. Does the modification describe a physical <u>change</u> or <u>control</u> of the product? (use longhand if conventional language isn't accurate)

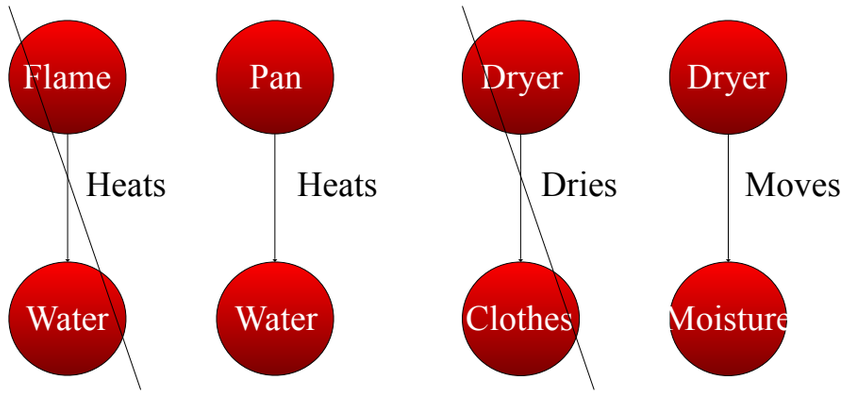
4. Does the tool <u>directly</u> modify the product?

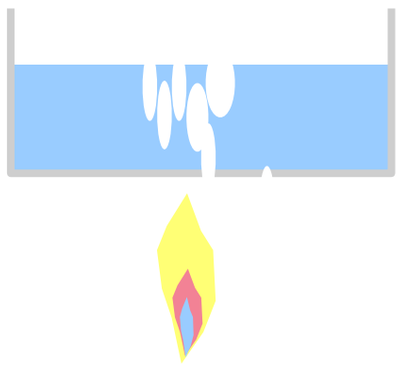
5. Does it describe what is really happening? (be careful with confusing functions)











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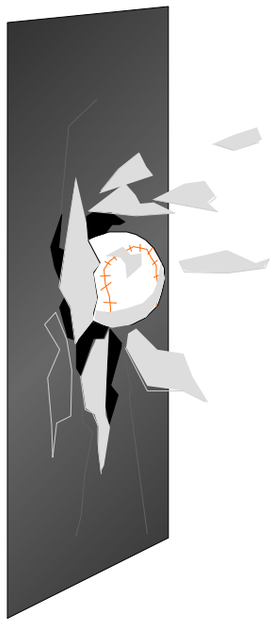
Everyday Language | Functional Language

The Ball Breaks the Glass



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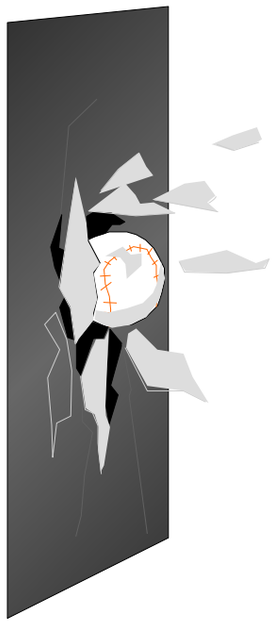
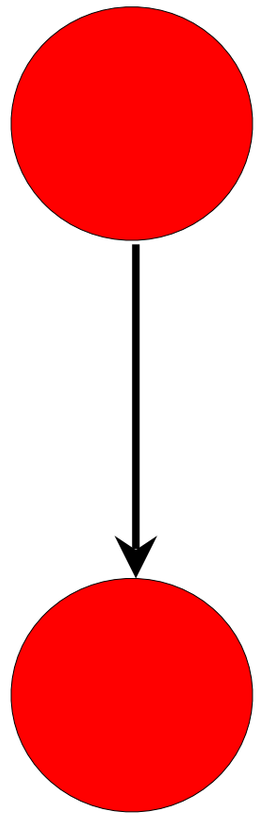
Everyday Language | Functional Language

The Ball Breaks the Glass





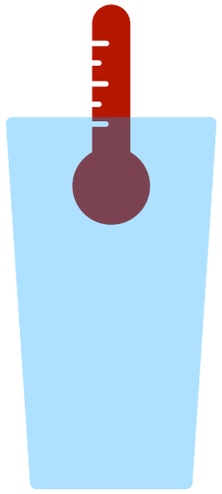
Ball

Breaks (changes # pieces)

Glass

Everyday Language | Functional Language

The Thermometer measures the temperature



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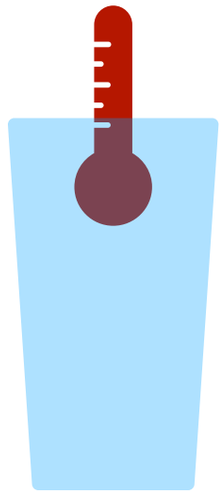

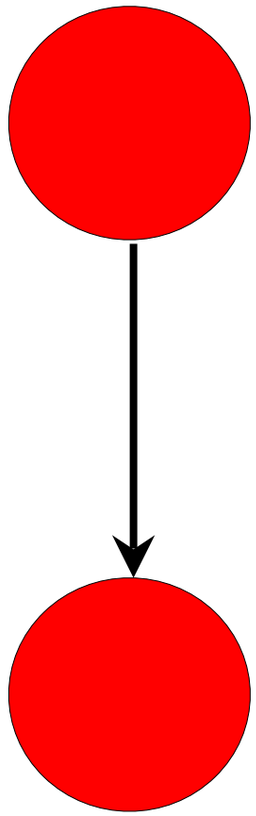

Liquid

cools (changes temperature)

Thermometer

Everyday Language | Functional Language

The wire conducts electricity

?

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Second Negation

Everyday Language | Functional Language

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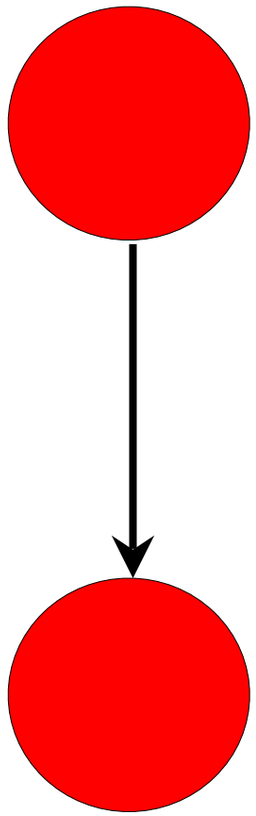


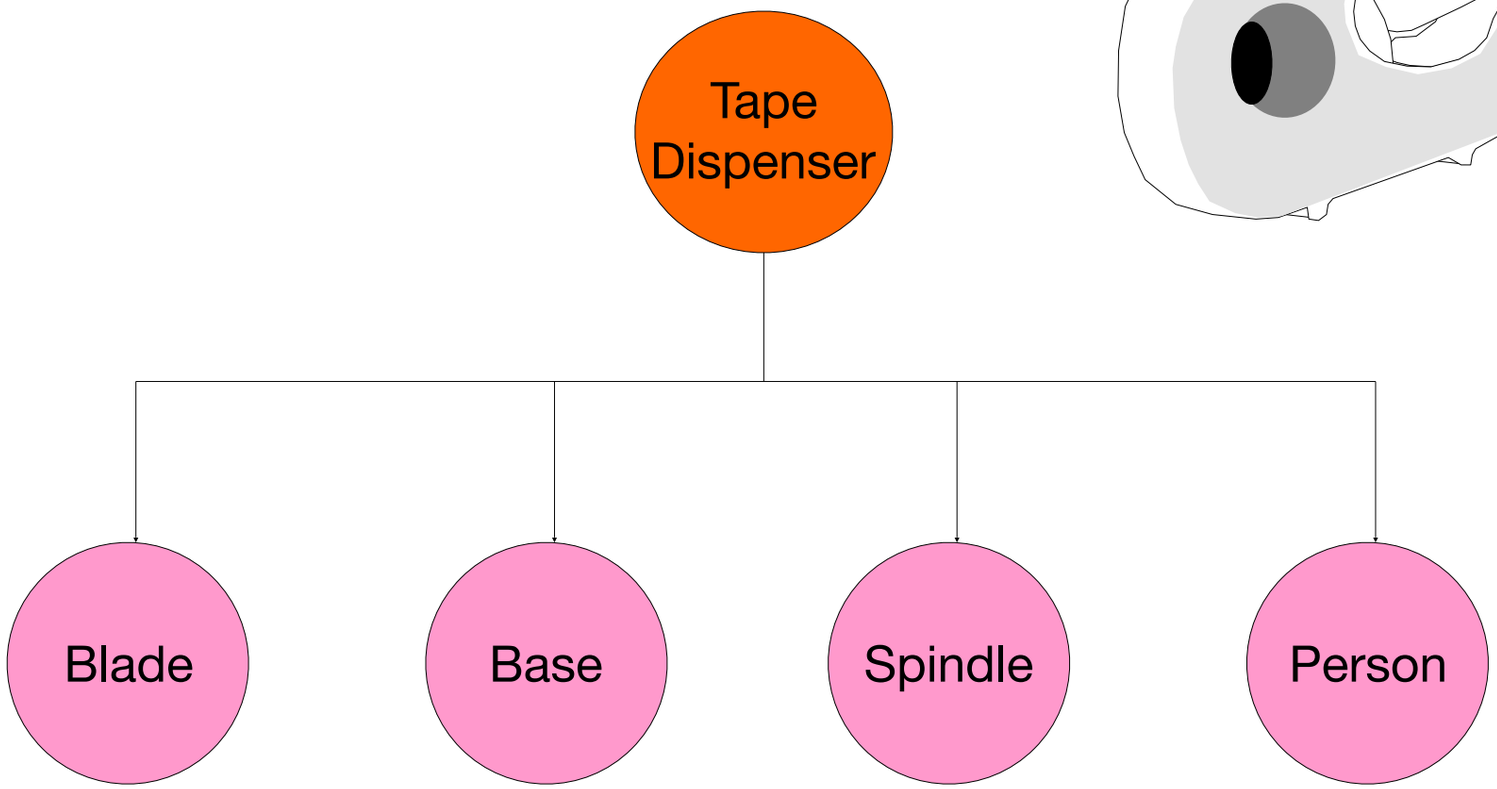
Wire

Conducts (controls path)

Charges

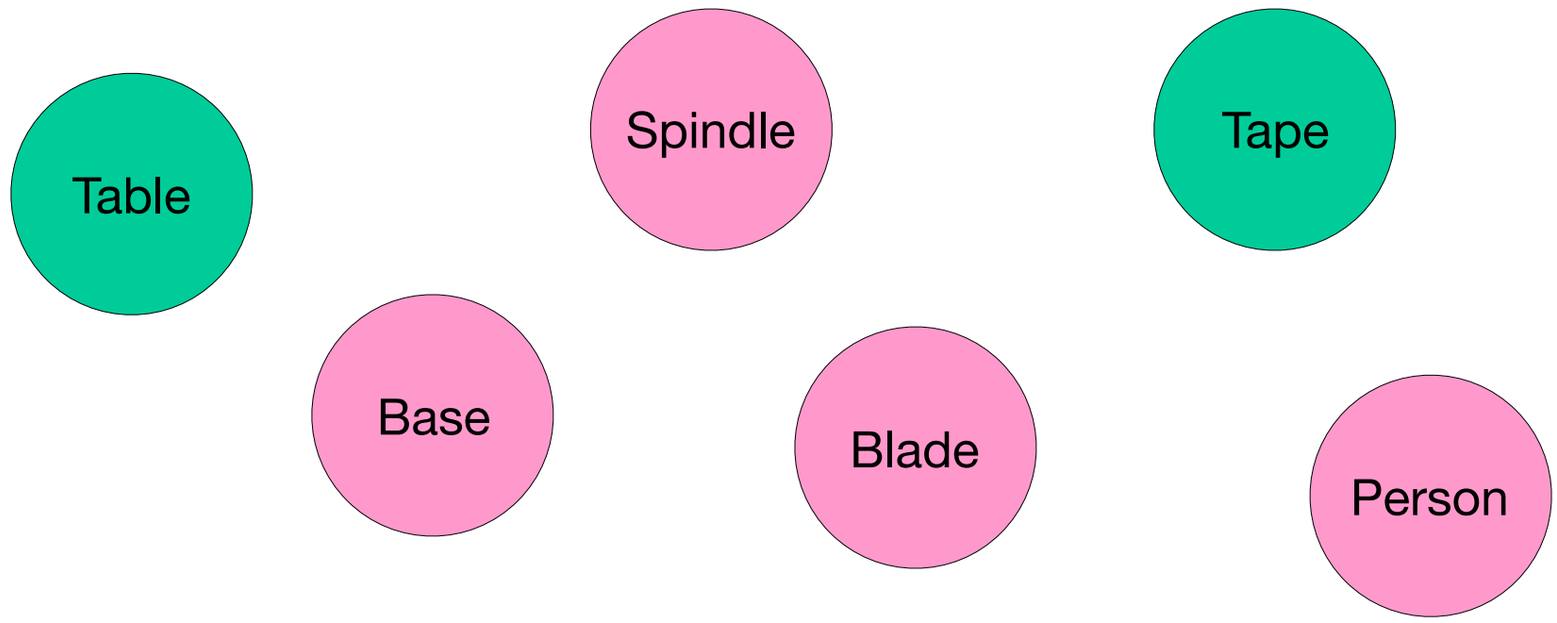
Writing Systems of Functions

1. Break System Down into Functional Parts



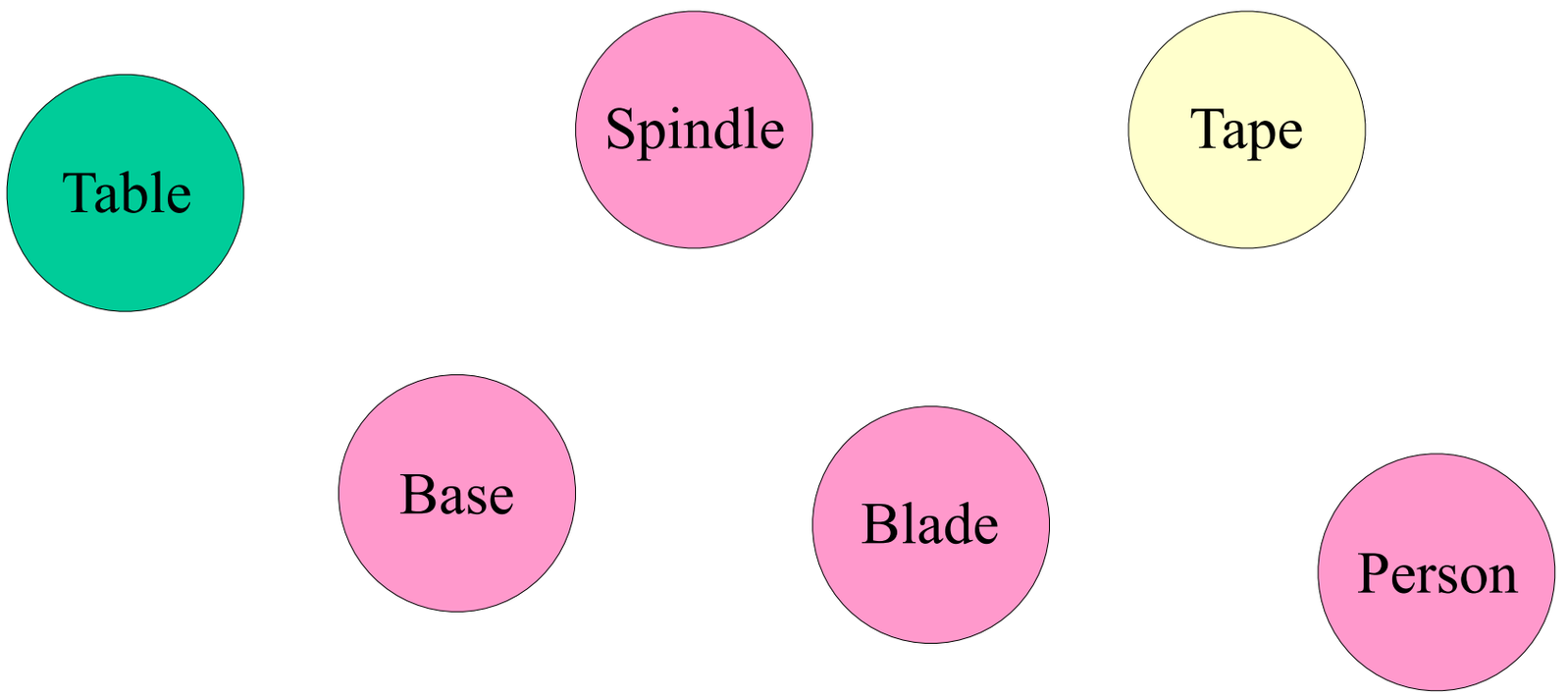
2. Identify super-system elements

(The system interacts directly with these Objects—
These Objects are involved in the Job being done)



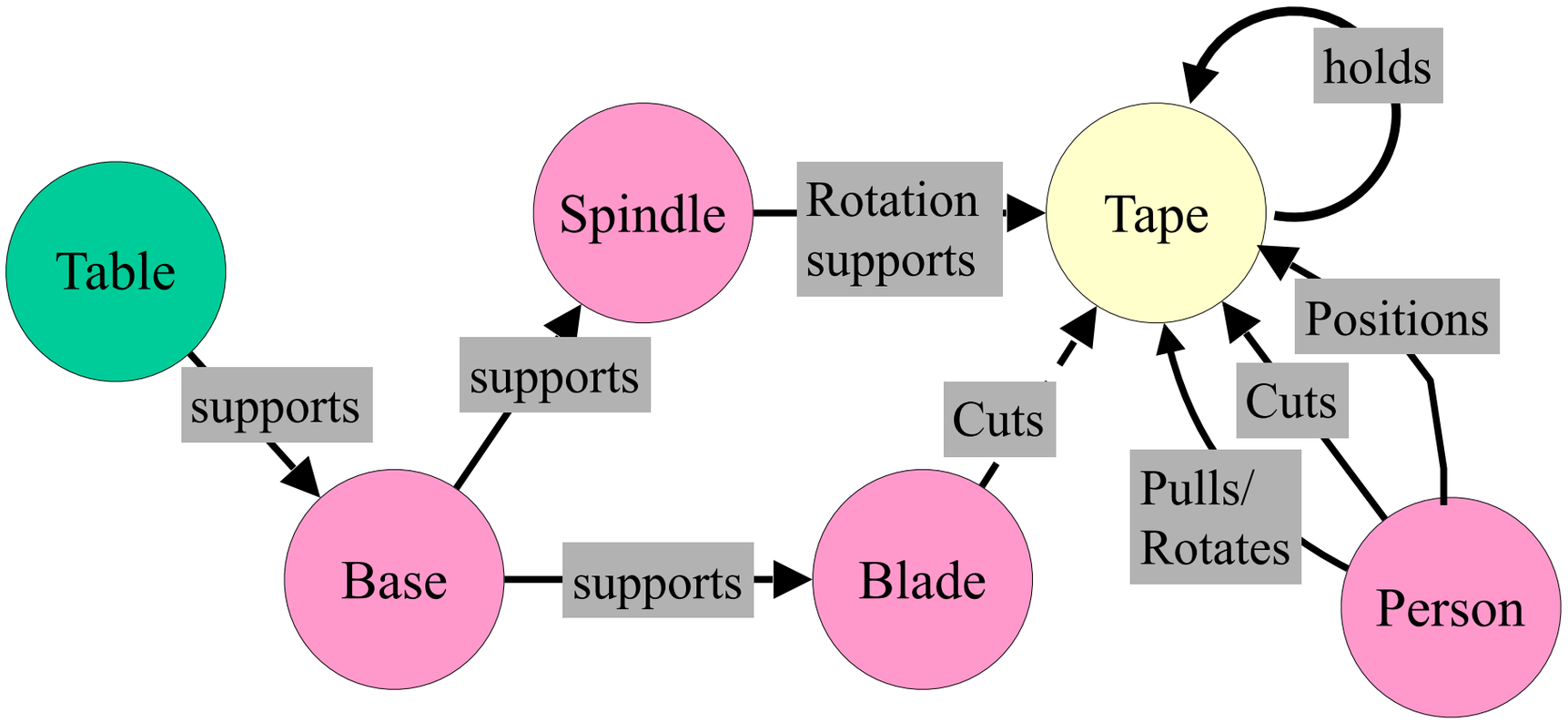
Super-System Elements are those we do not have direct control over

3. Identify the "System Products"
(The primary objects that the system seeks to modify)



4. Draw function links between the elements

(links between super-system elements is not usually necessary)



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Second Negation

Everyday Language | Functional Language

The cap seals the bottle

?

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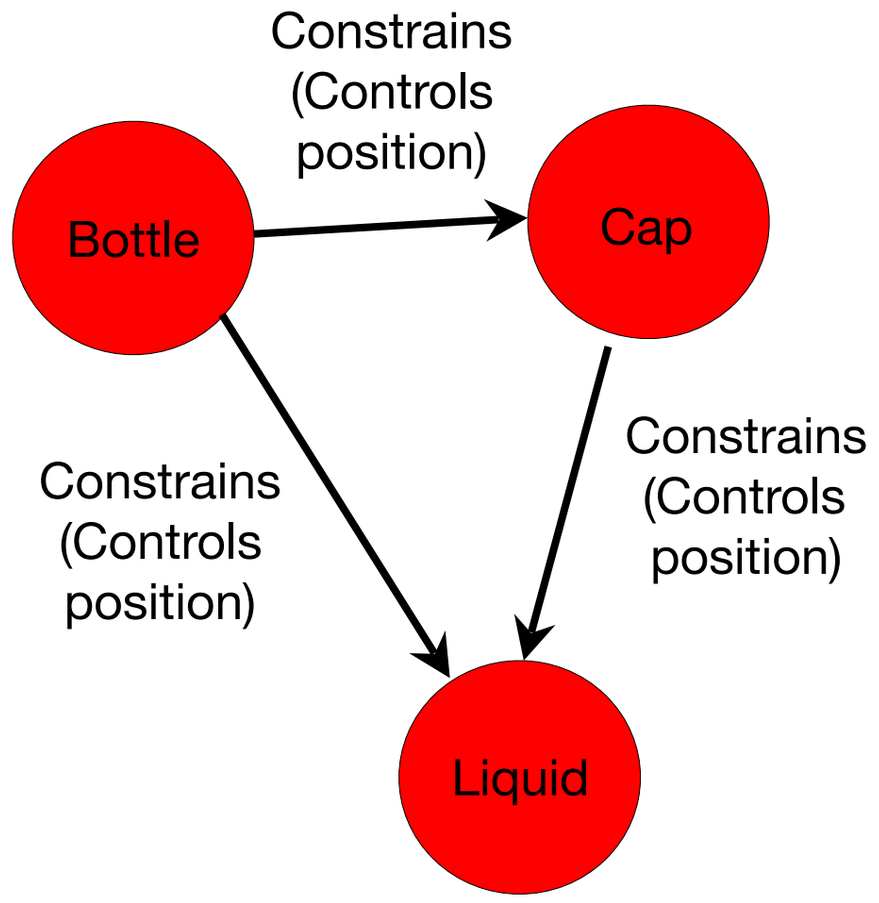
Second Negation

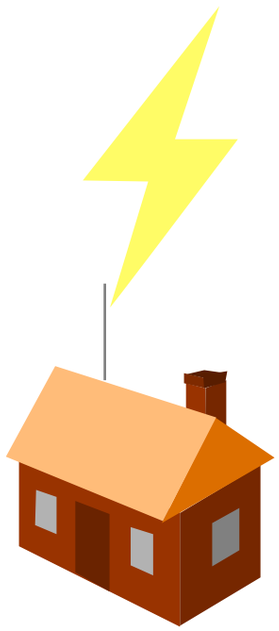
Everyday Language | Functional Language

The cap seals the bottle



Everyday Language | Functional Language

The lightening rod protects the house



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Second Negation

Everyday Language | Functional Language

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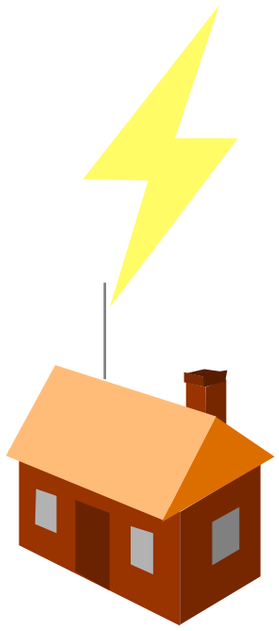
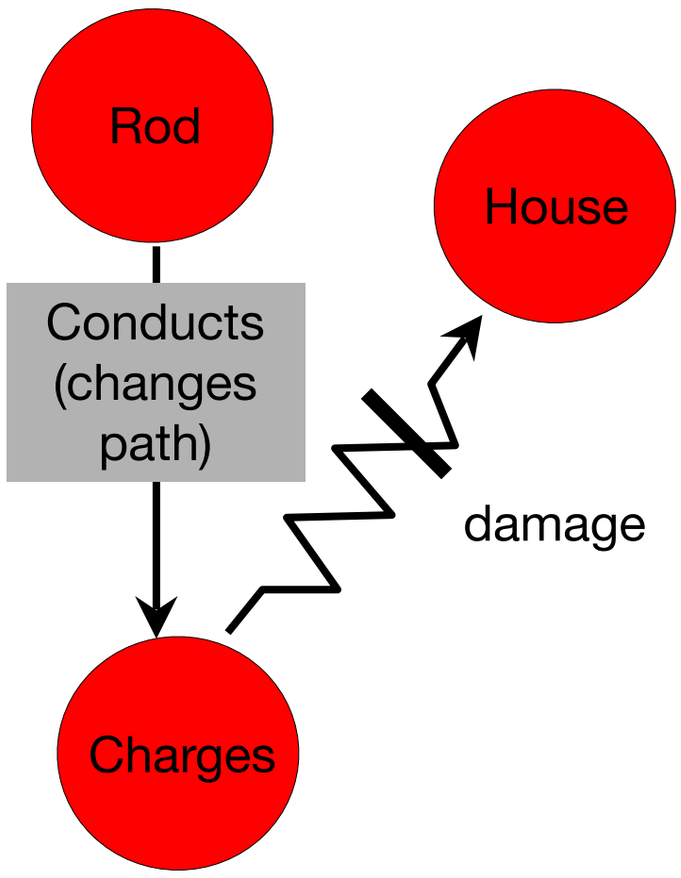
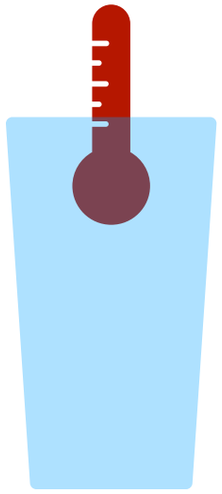




Everyday Language | Functional Language

The Thermometer measures the temperature



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Everyday Language | Functional Language

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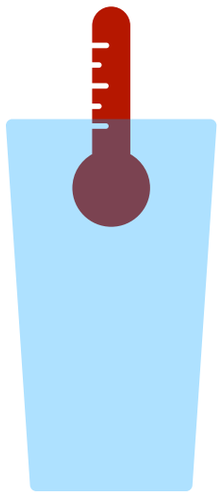
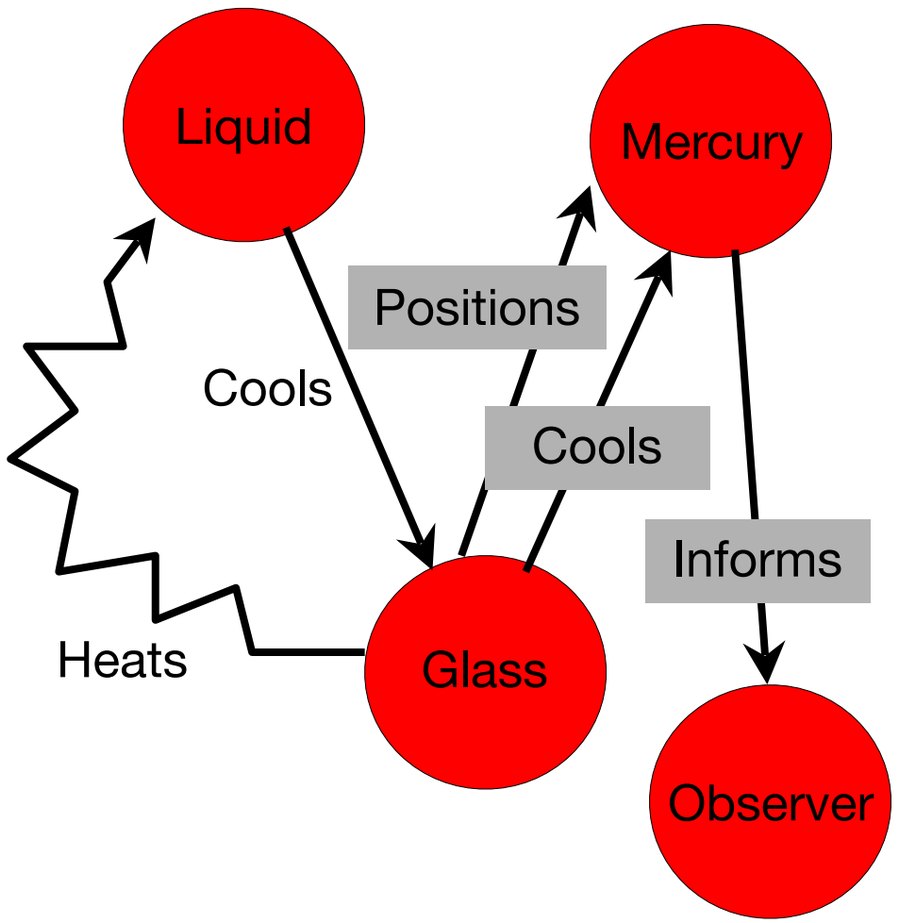
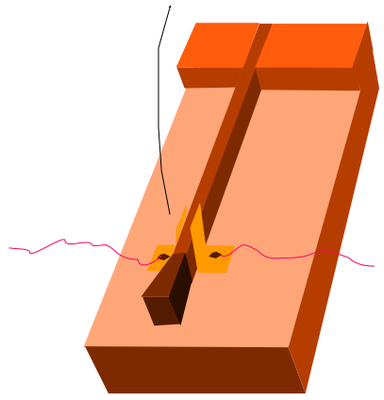




Everyday Language | Functional Language

The gold improves the reliability

Shown is a sliding contact switch. Gold coats the switch arm and the contacts that stick up.



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Everyday Language | Functional Language

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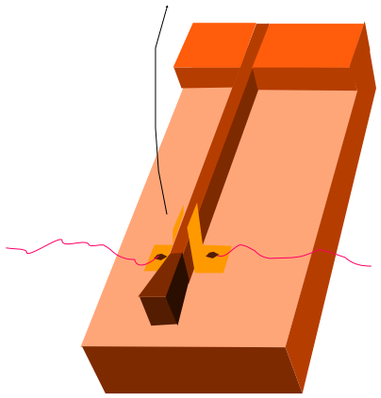

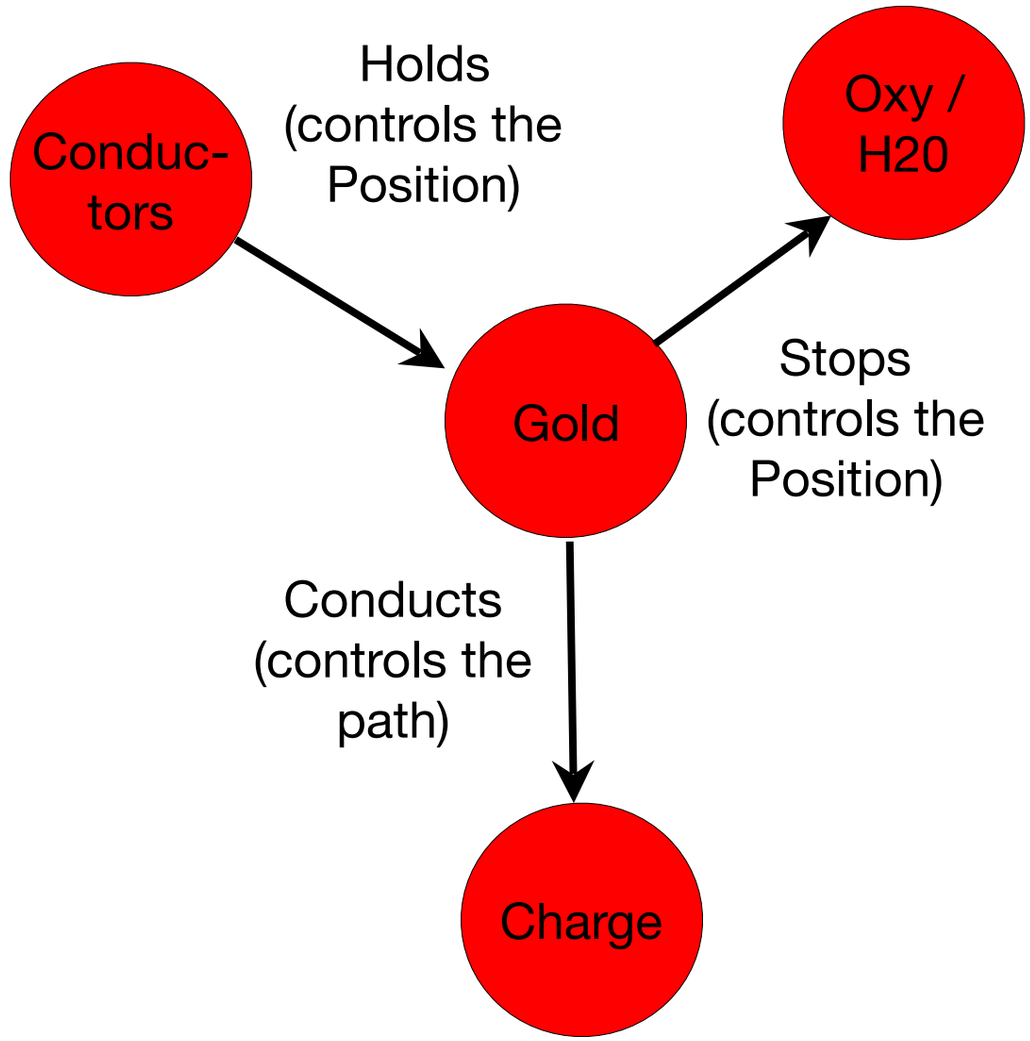

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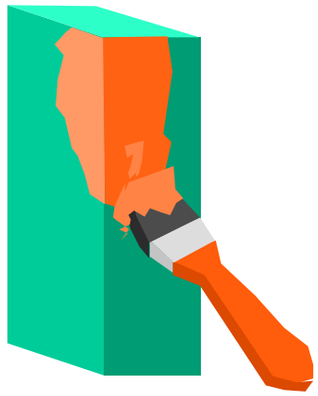
Everyday Language | Functional Language

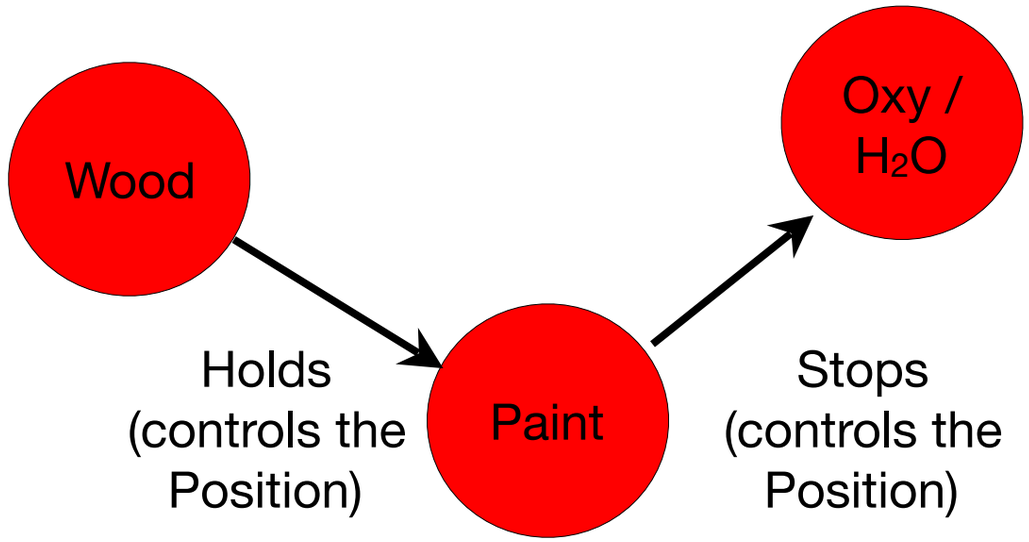
The paint stops deterioration

?

Everyday Language | Functional Language

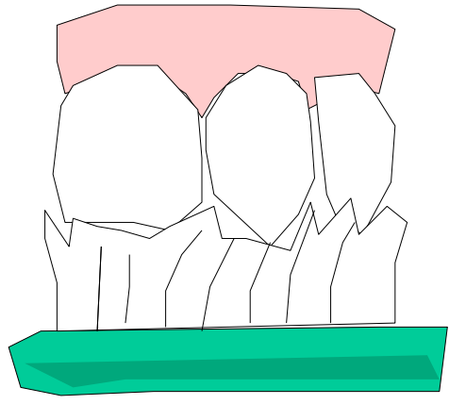
The paint stops deterioration





Everyday Language | Functional Language

The toothbrush brushes the teeth



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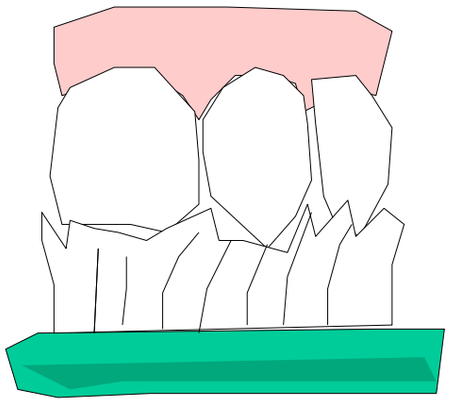
Second Negation

Everyday Language | Functional Language

The toothbrush brushes the teeth



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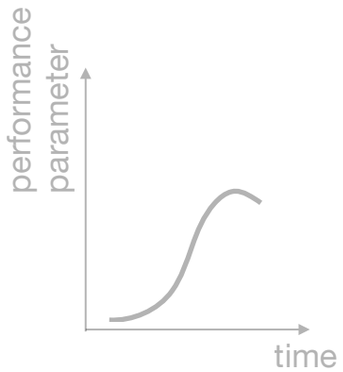
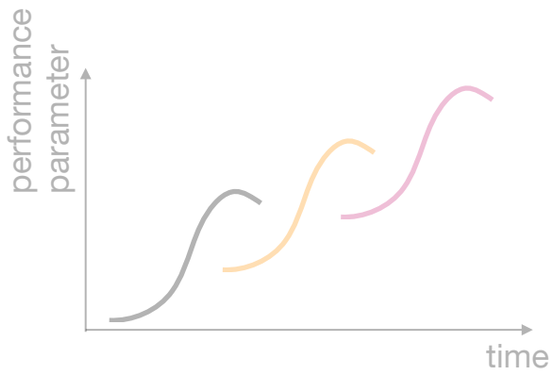
4. Self-directed experimental inquiry is key for systemic innovation

new function realized

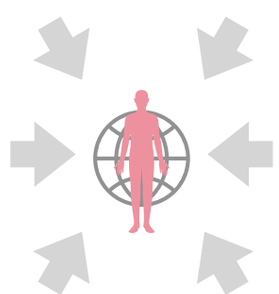


new way of realizing existing function

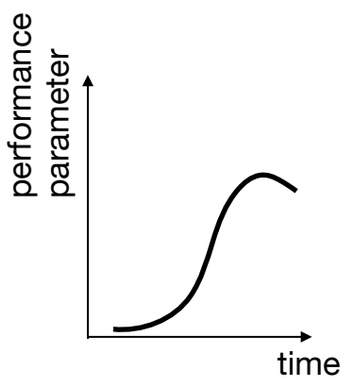


3. Systemic thinking allows to understand and control global system behavior

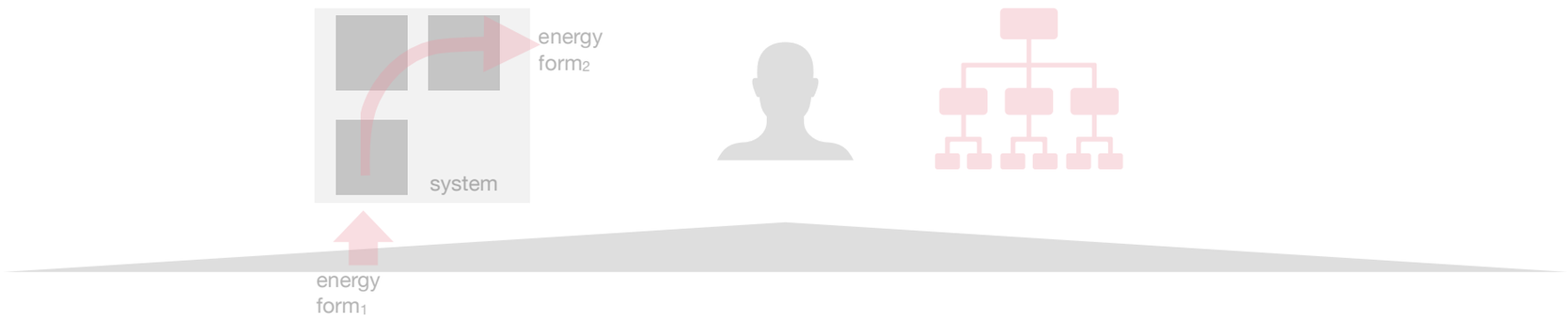
behavior of system in all kinds of contexts



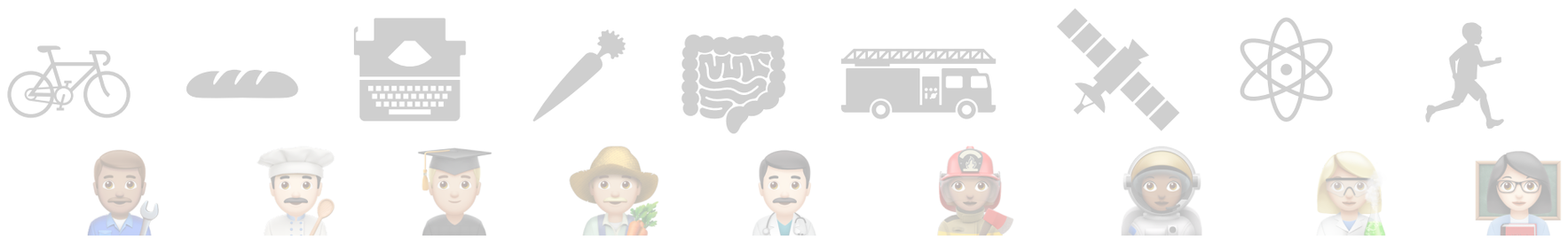
system from evolutionary perspective



2. Ability to understand systems as energy storage elements and their dynamics



1. Specialized knowledge (specialized systems/contexts)



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Second Negation

Propose / Contract
Touch

Design
Touch

Documentation
Touch

Fabrication
Touch Time
Cycle Time
Variability
Labor

Testing
Cycle Time
Touch Time
Waste
Safety

Packaging
Deterioration
Hard Opening
Tampering
Recyclable
Confusing
Disposal
Dangerous
Messy

Mass Transport
Loading
Messes
Volume
Safety
Special Equipment
Contamination

Fueling / Energizing
Weight
Cost
Availability

Customer Testing
Difficulty
Labor
Confusing

Assembly or Setup
Difficulty
Labor
Confusing

Customer Transport
Difficulty
Labor

Order Purchase or Disposition
Loading

Disposition For Sale
Loading

Mass Storage
Loading
Messes
Volume
Safety
Special Equipment
Contamination

Operational Waste
Secondary Harm
Waste of Useful Materials

Resource Consumption
Energy
Materials
Time
Other Machines Req.

Ease of Operation
Ergonomic
Convenience
Functions on Hold
Memory Required
Confusion
Complexity

Range of Operation
Human Intervention
Condition Range
Environment Range
Unusual Uses
Adjustability
Robustness

Direct Use or Operation

Lifecycle Jobs and Competitive Factors

Stowing
Difficulty
Waste
Environment
Storage Space
Damage to other Objects

Protecting Others
Harm User
Harm Bystanders
Harmful Functions during Use as Weapon

Protecting Users
When Anxious
Non-Value Worry
Tampering
Ease of Stealing

Protecting System
Ease of Stealing
Corrosion

Control / Monitoring
Frequency
Time
Human Required

Storage
Difficulty
Waste
Environment
Storage Space
Damage to other Objects

Maintenance
Cost
Waste Handling
Material Consumption
Human Intervention
Cycle Time
Touch Time
Ease of Monitoring

Fixing Messes
General Eyesore
Frequency
Human Intervention

Dealing With Failure
Operation During Failure Modes
Probability / Life
Durability
Fault Detection
Removal Time

Repair
Tracking
Ease
Cycle Time
Touch Time
Human Intervention
Waste Handling
Consumables
Ordering

Recycling
Ease of-Disassembly
Environmental Friendliness

Disposal
Ease of Disposal
Environmental-Issues

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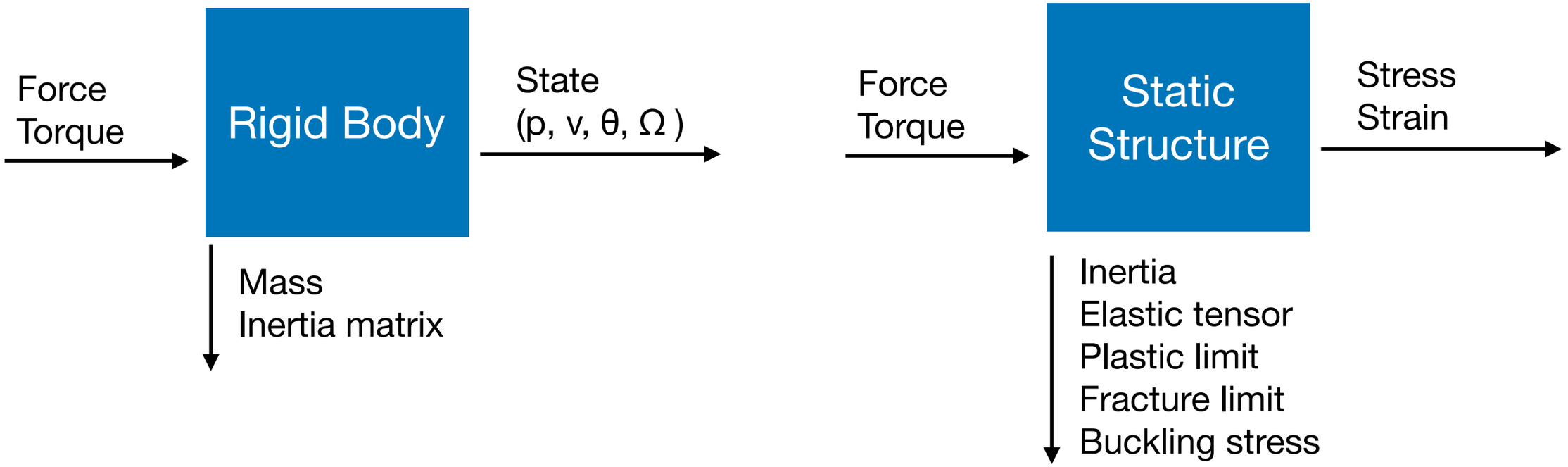
Second Negation

Benefits of The Systems Approach



This universal representation permits us to proceed promptly from **representation** to **simulation**, **experiment**, and **optimization**

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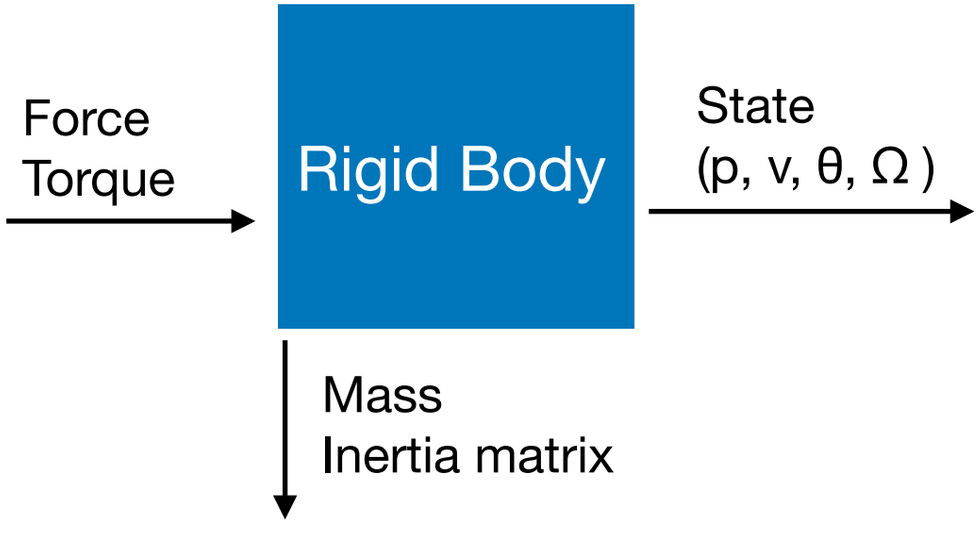
Uncertainty As Important As Dynamics



- **Noise**—Characterized probabilistically
  - Examples: Johnson noise, shot noise and flicker enter measurements additively
  - Arises from a great variety of interacting elements, and is therefore very stable in its properties such as amplitude distribution, frequency range, and temperature dependence.
  - This can arise from both components and environment. Many competitors resemble noise while just one or two are very uncertain.
- **Disturbance** from environment—properties or range of properties well known, e.g., frequency, amplitude, entry point into dynamics.
- **Interference**—measurable but irrelevant signals from environment or dynamics—can be systematically eliminated.
- **Component or environment parametric uncertainty**—characterized by parameter uncertainty intervals. This arises from uncertainty in measurements.
- **Input uncertainty**—other agents with other objectives operating the dynamics. Ex: pests, outlaws, weeds, competitors, friends, employees, neighbors

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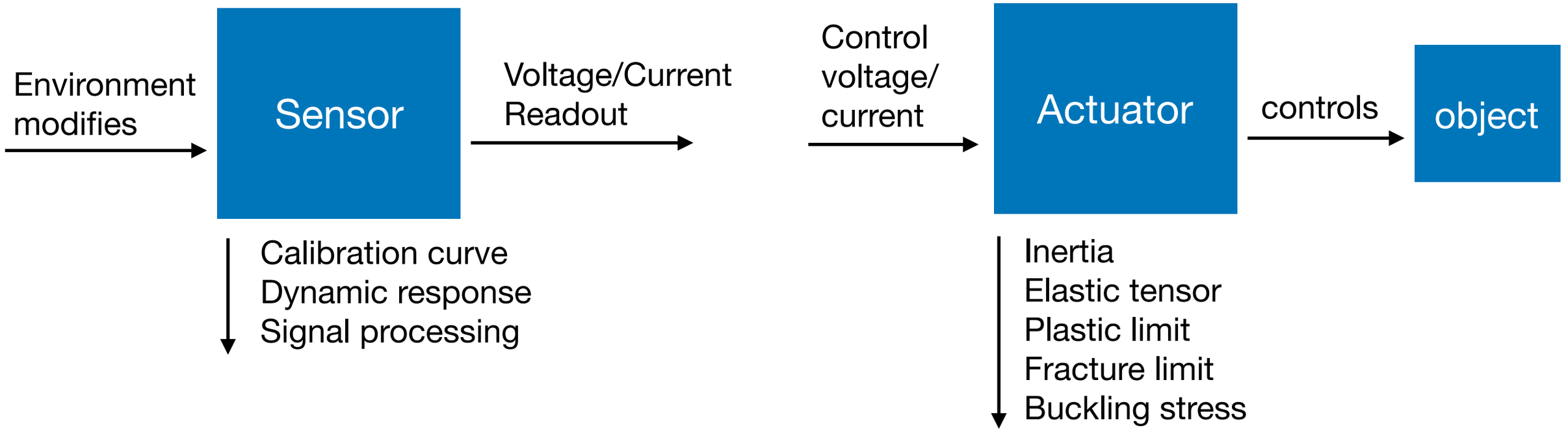
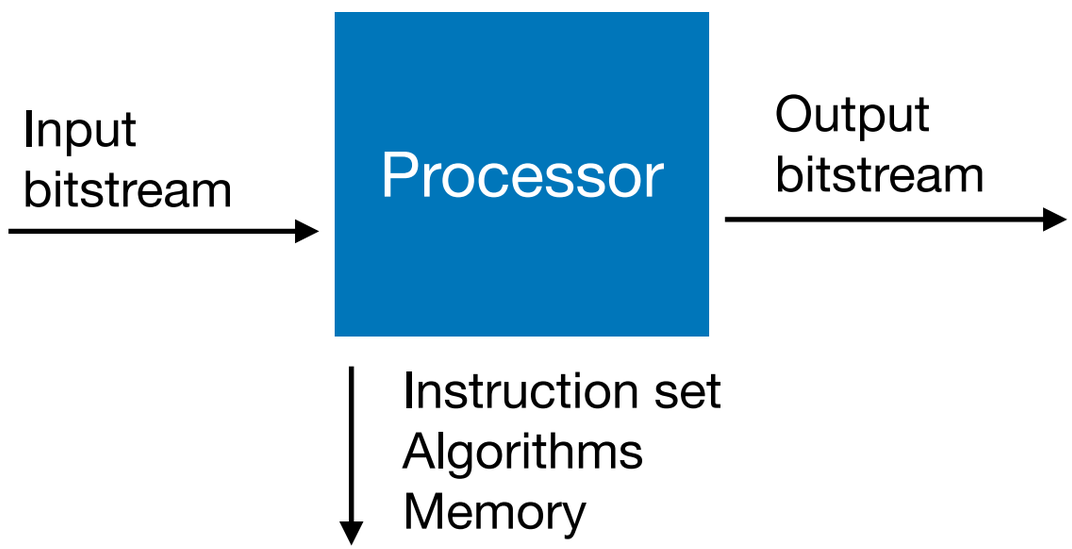
Common Sub-Systems





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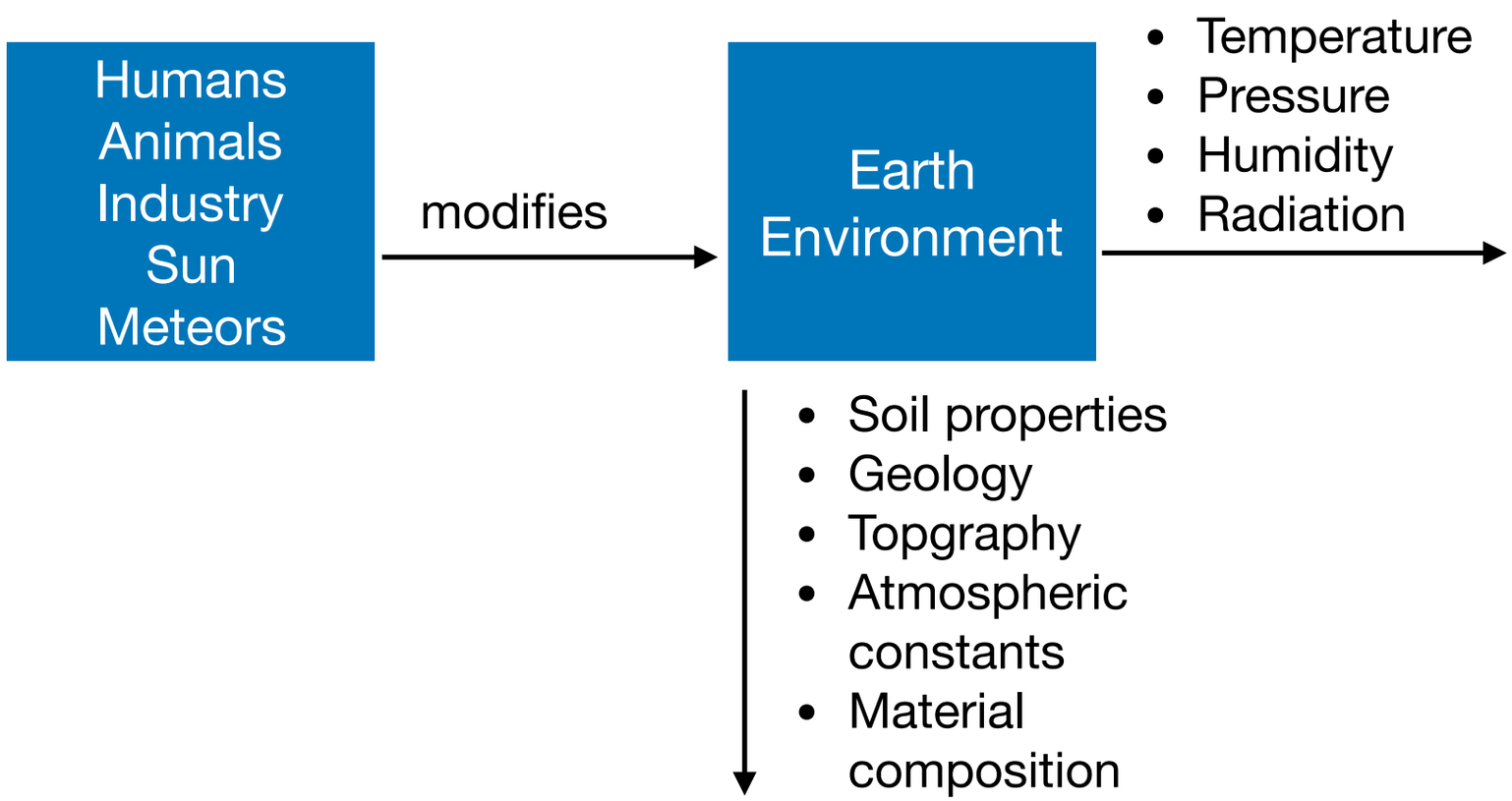
Common Super-Systems



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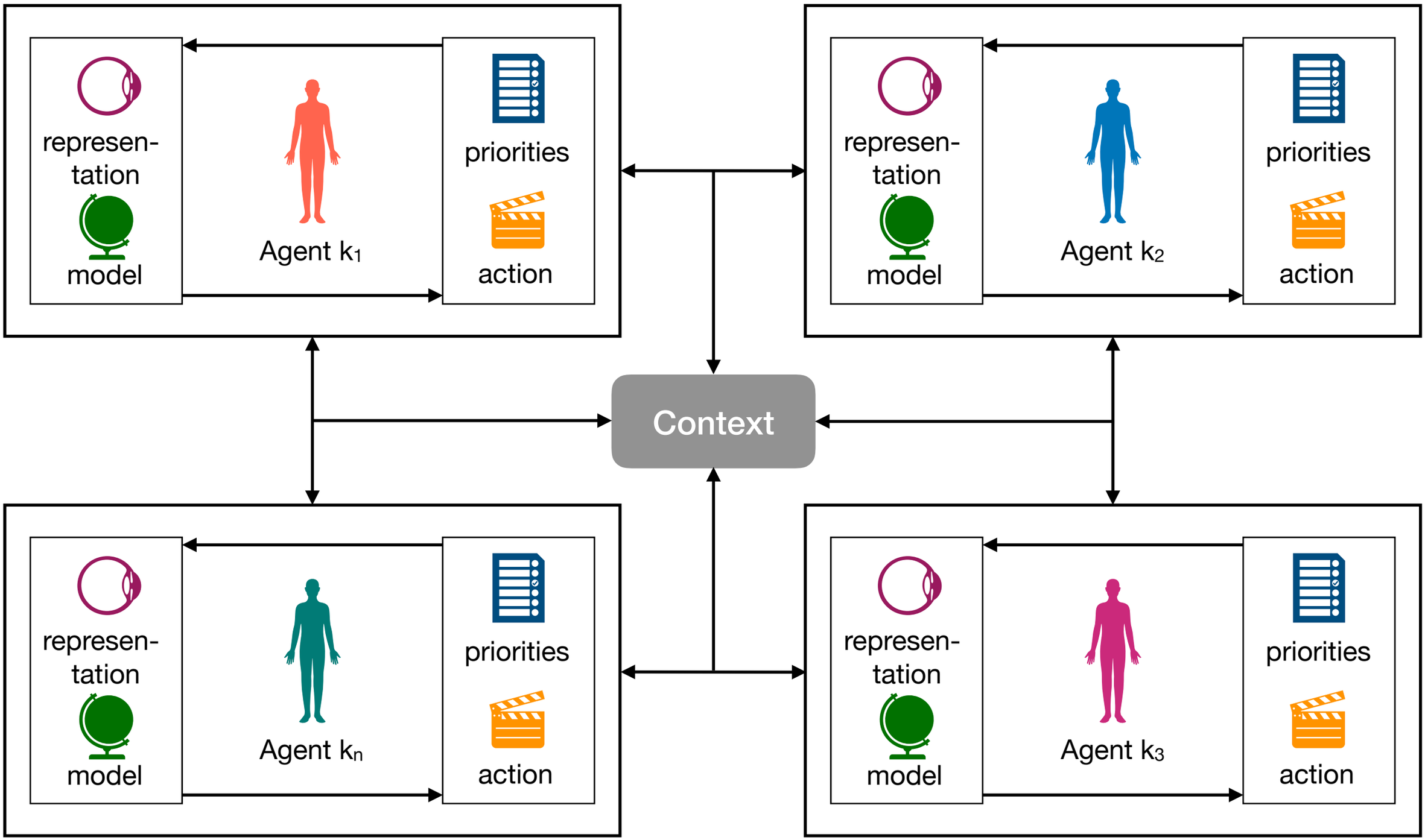
Second Negation

Context or Human Environment on Earth (1)



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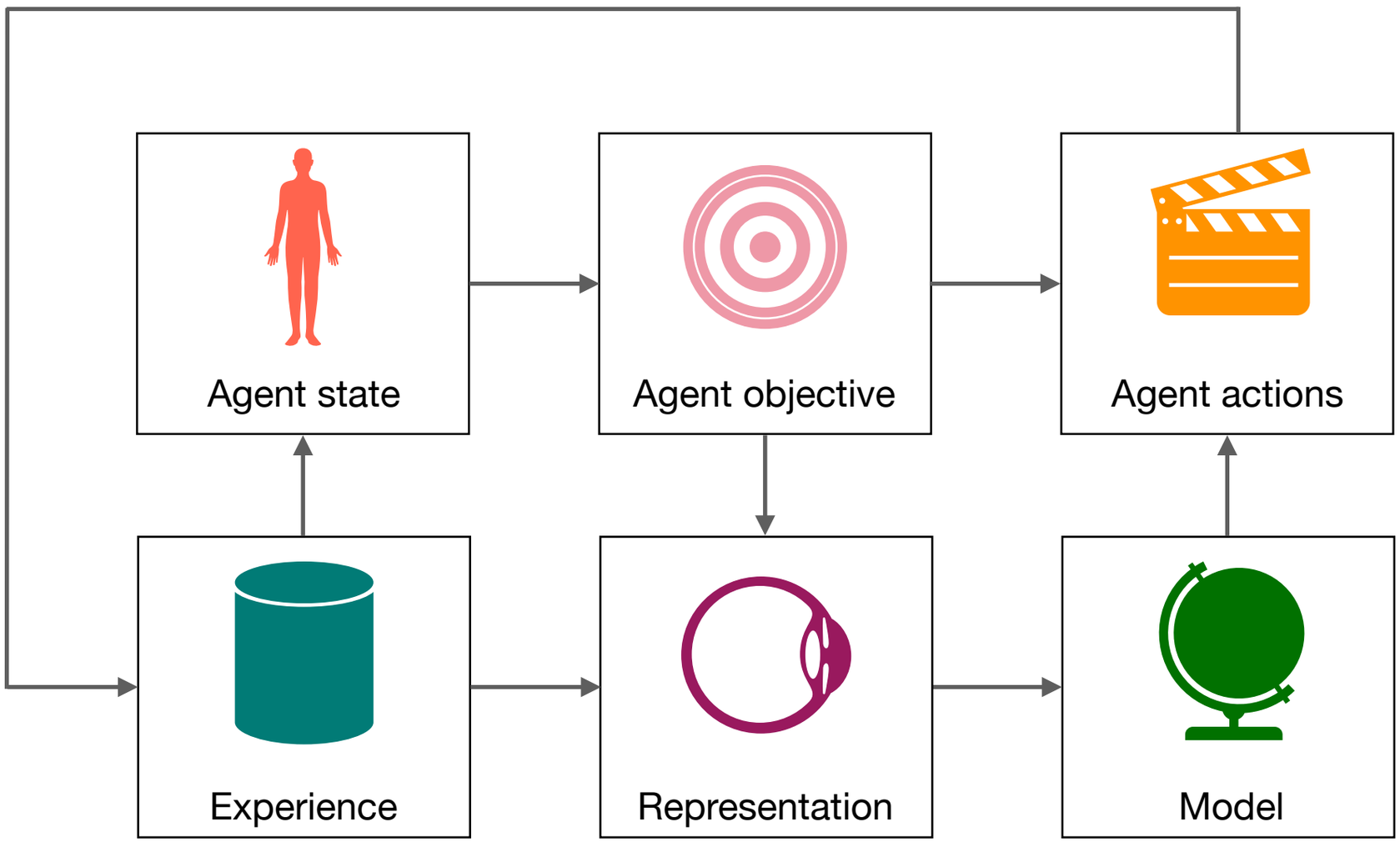
Context or Human Environment on Earth (2)



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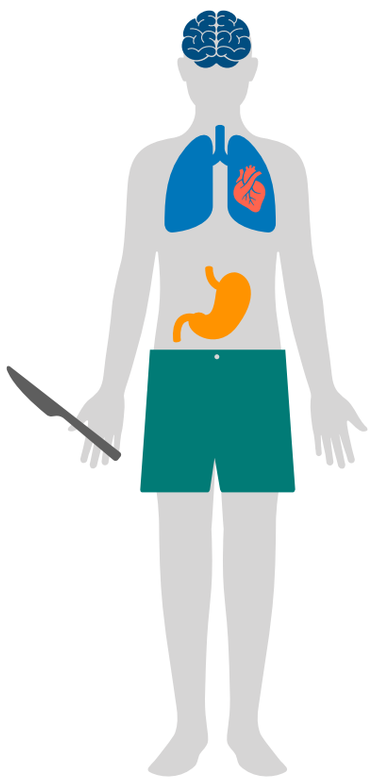
Second Negation

Human body

Energy in

- Food
- Sun
- Oxygen
- Water



brain

respiration

blood circulation

digestion

reproductive organs

immune system

Energy out

- all human action
  - sensing, actuation, calculation

...

Heat

Lung capacity usage

Oxygen use efficiency

Density of capillaries

Waste removal ratio

BMI

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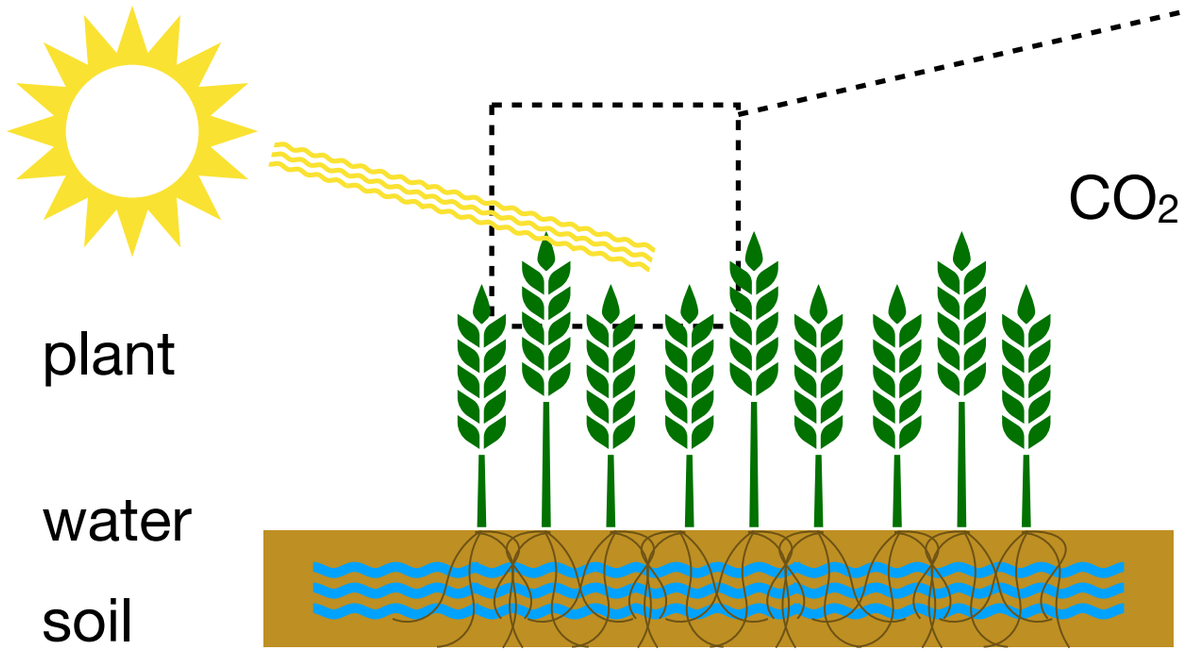
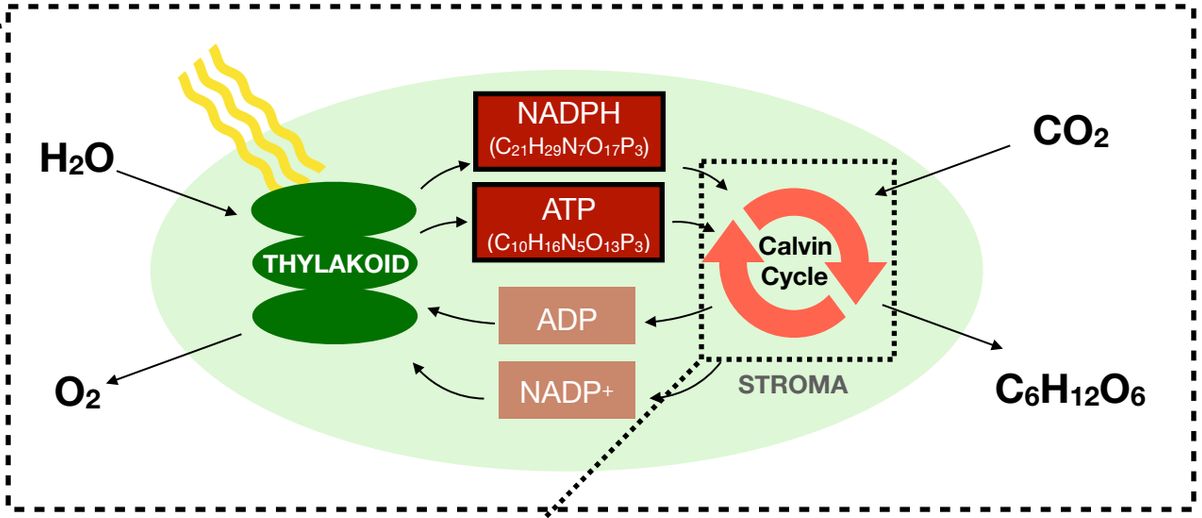
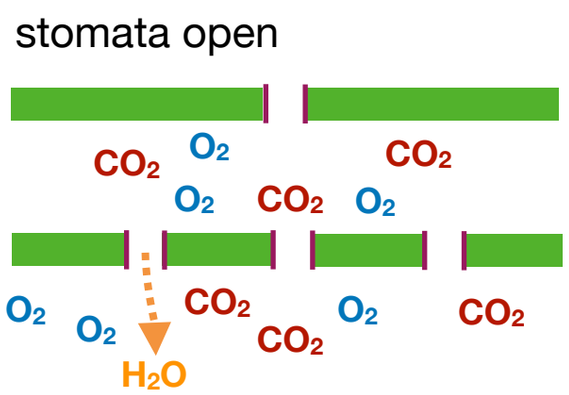
Second Negation

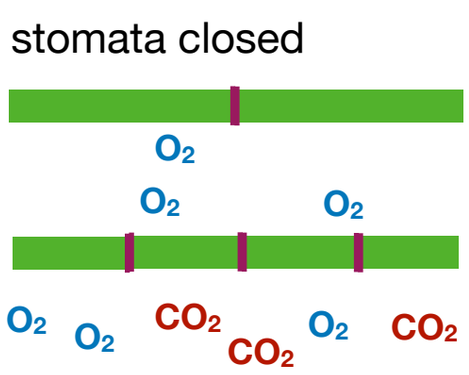
Contradictions





Problem in C3 plants





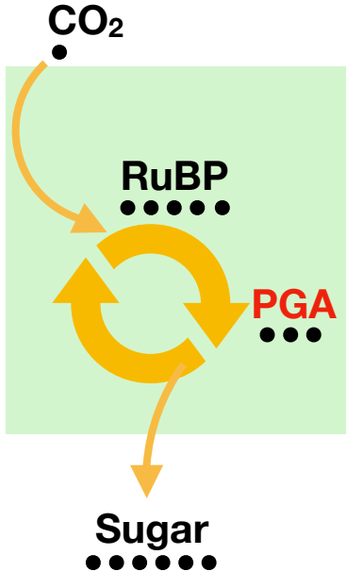
—> photorespiration

System	Sub-System
Space 1	Space 2
Time 1	Time 2

CO_2 binds to RuBP	H_2O is lost
stomata open	

O_2 binds to RuBP	H_2O not lost
stomata closed	

C3 plants



Legend

Mesophyll cell

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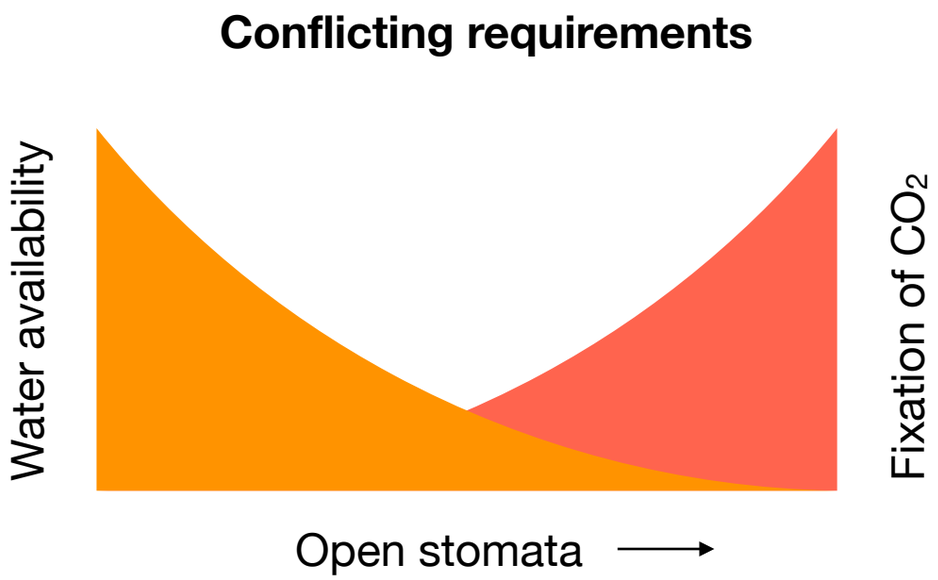
Second Negation

* reaction center with chlorophyll; plants hold them in chloroplasts, bacterias in plasma membrane

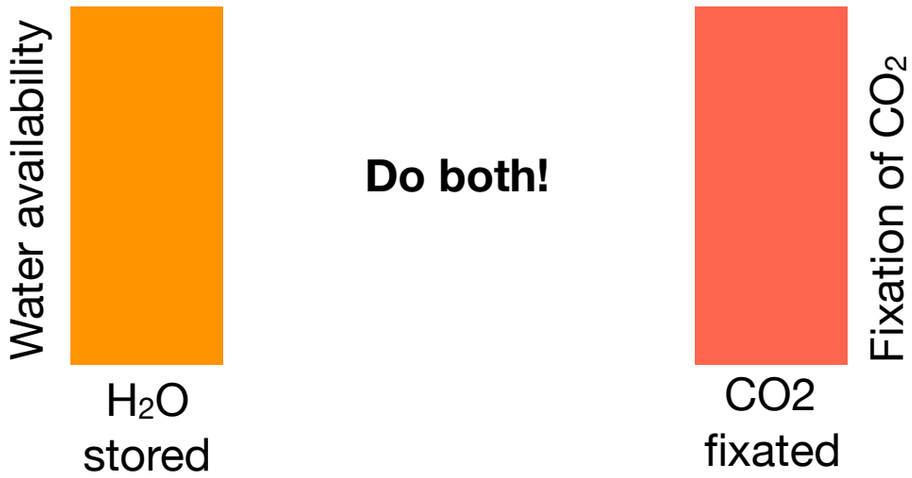
Compromise Solutions



Something improves
Something else gets worse

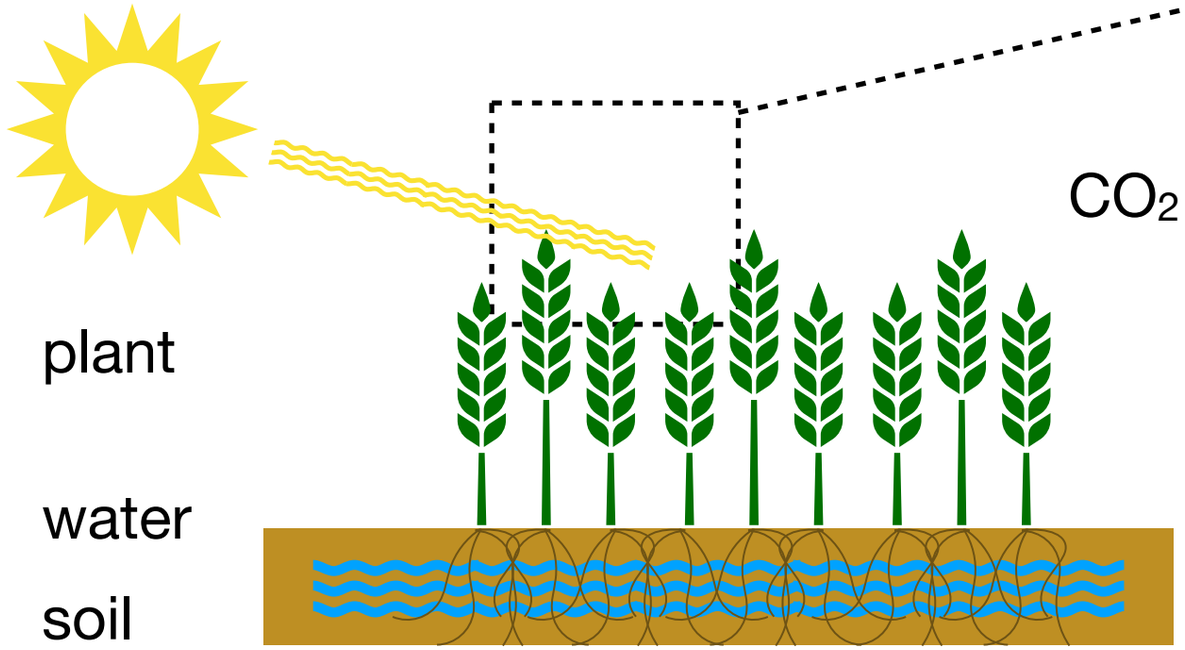
- Guarantees risk
- Consumes time
- Delays the solution

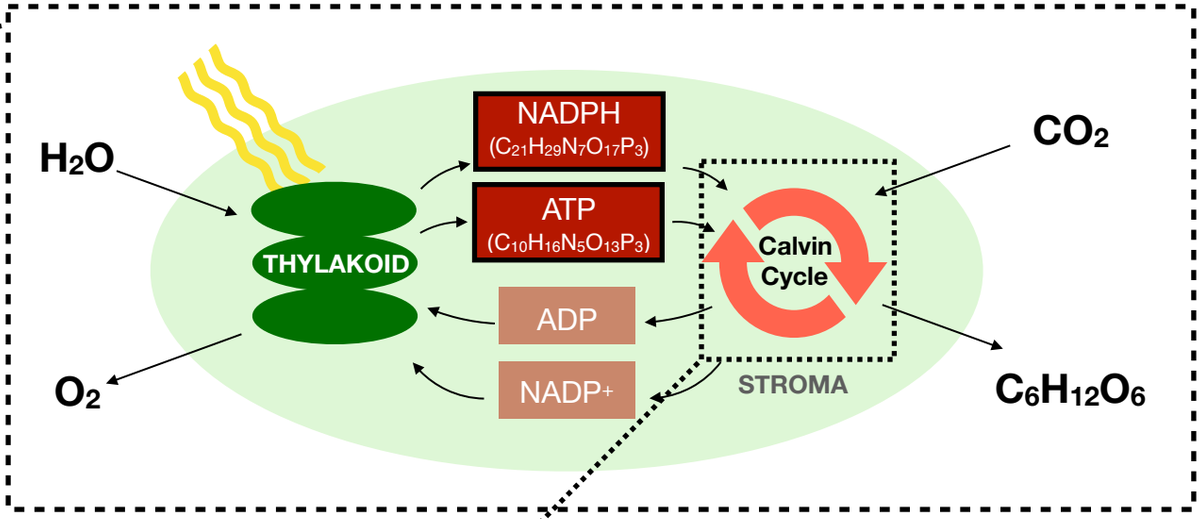
Don’t Compromise — Idealize (Do Both)!



Create the invulnerable concept

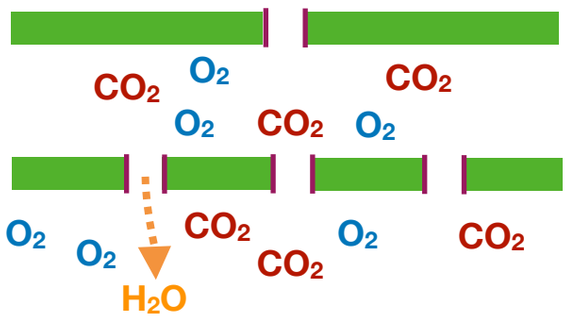
- Reduces risk
- Reduces analysis time
- Gives once-and-for-all solution



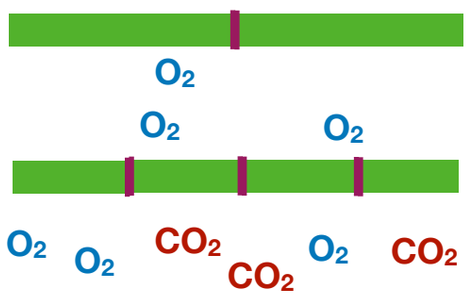


Problem in C3 plants

stomata open



stomata closed



—> photorespiration

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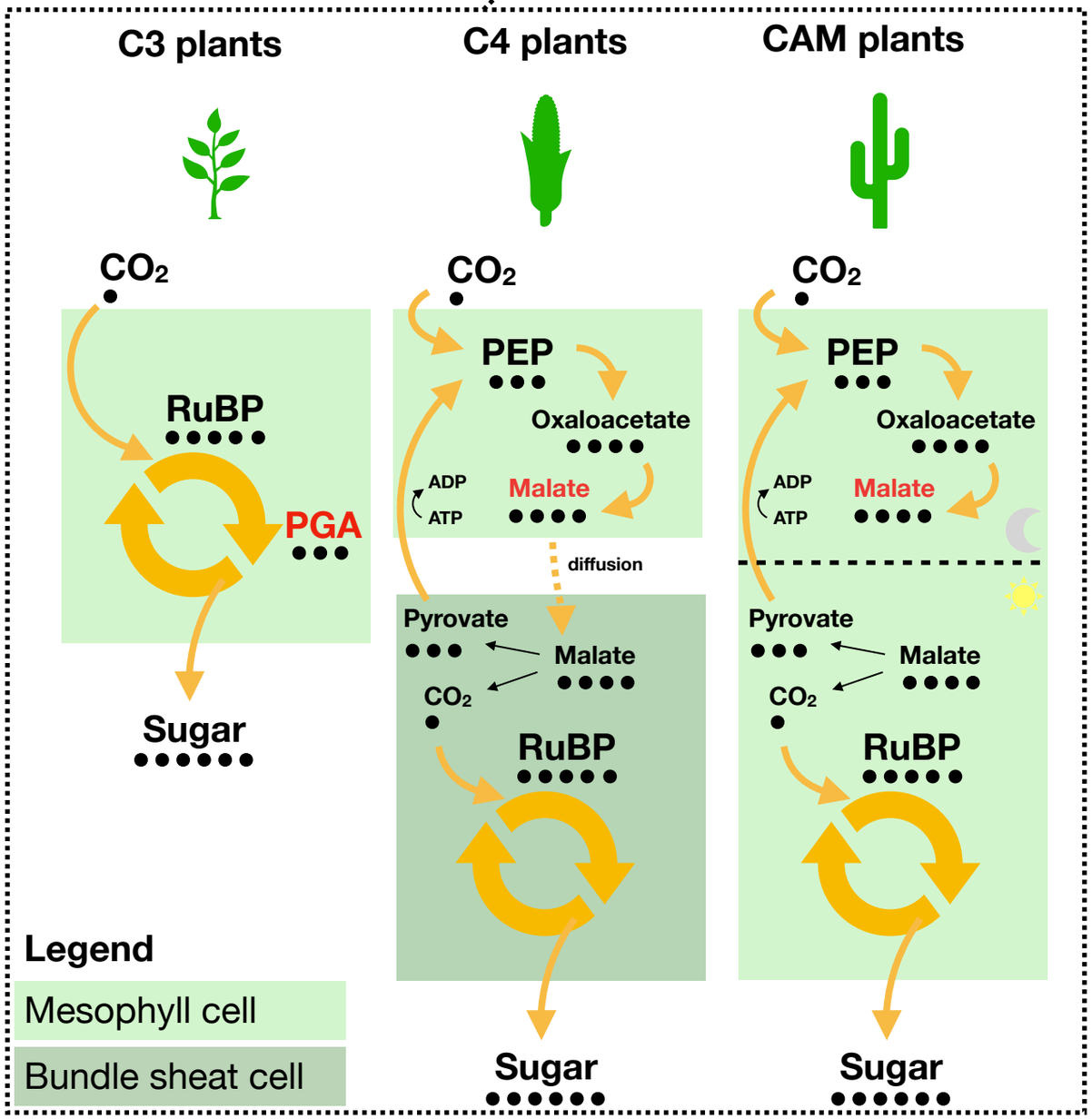


* reaction center with chlorophyll; plants hold them in chloroplasts, bacterias in plasma membrane

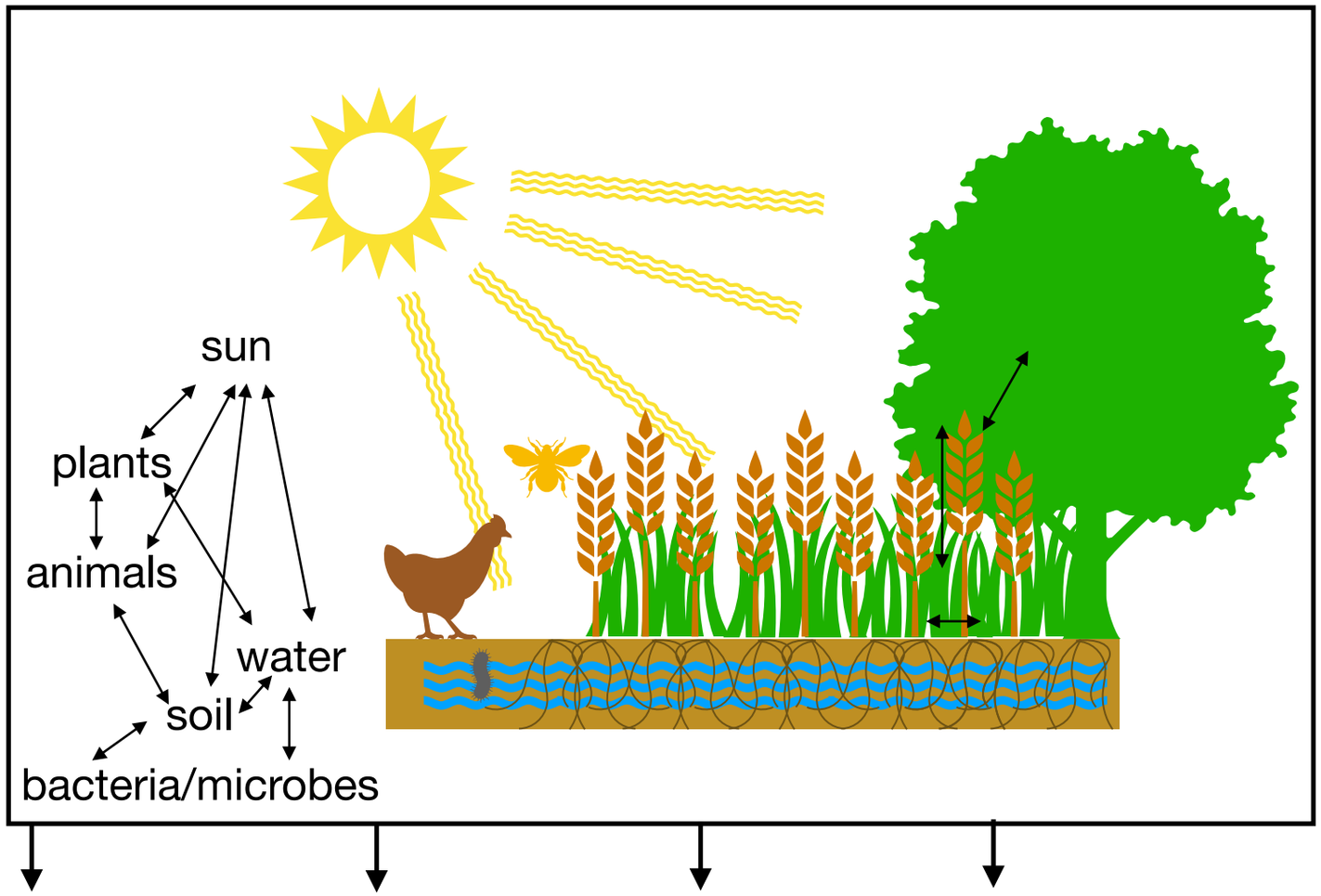
Contradiction Game

- Find objects that are **flexible & rigid**
- Points = *number of systems in all categories* X *number of categories*

Harvesting solar energy

Energy in

- W? and time
- oil/gas/coal/ solar …
- money
- food



Energy out

- biomass cal/g
- food

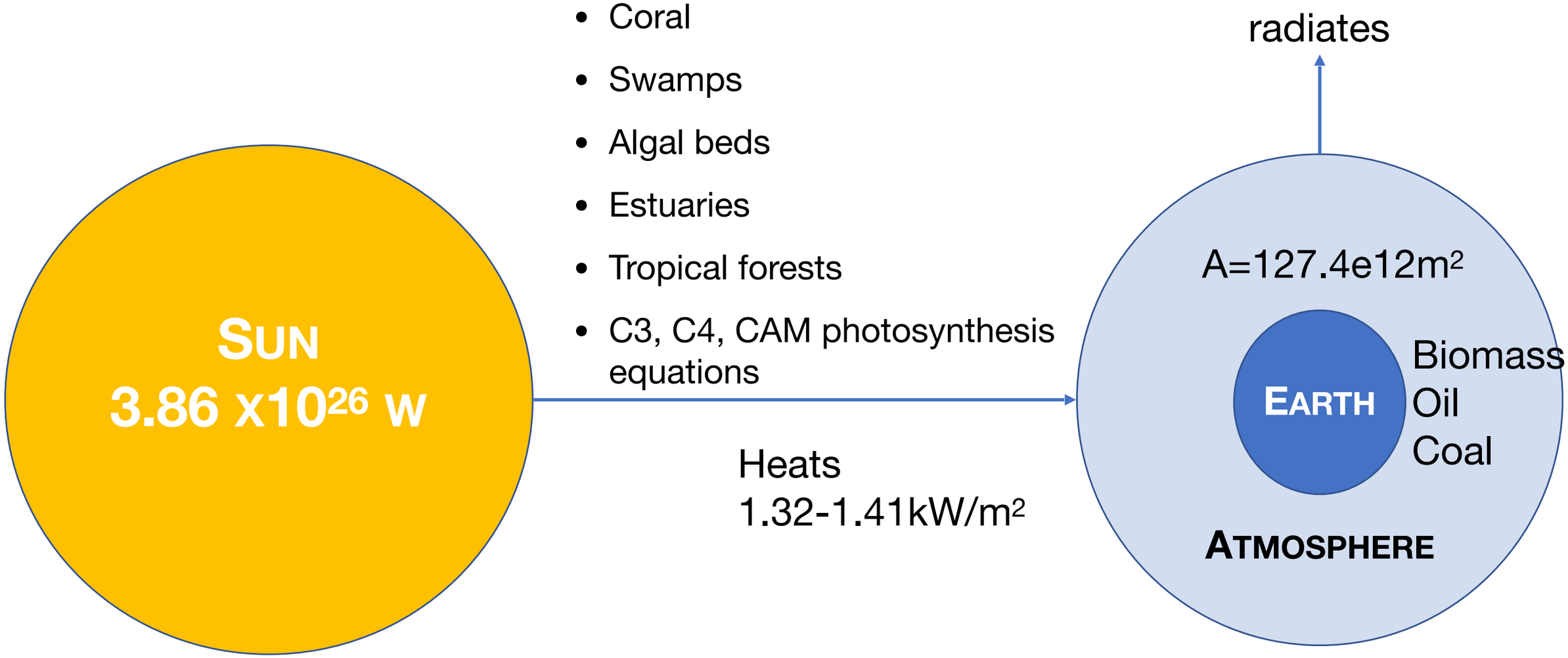
soil nutrition | water salinity | microbes per cm^3 of soil | …

Question

- How can we live without fossil fuels?

Some numbers

- 1% converted to biomass:
  - 10% of that is consumed by herbivores
  - 90% is detritus
    —> oil and coal eventually
- Most efficient:
  - Coral
  - Swamps
  - Algal beds
  - Estuaries
  - Tropical forests
  - C3, C4, CAM photosynthesis equations



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Some EROIs

(from http://www.daretothink.org/dfr-the-dual-fluid-reactor/)

Pressurized water reactor a): 80
Run-of-the-river hydroelectricity: 36
Black-coal fired power: 29
Gas-steam power: 28
Solar thermal (desert)b): 9
Wind power (German coast)c): 4
Photovoltaics (desert) b): 2,3
DFR (500 MWe powerplant): 1200
DFR (1500 MWe powerplant): 2000

- a-current fuel mixes; b and c: with pumped hydroelectric storage

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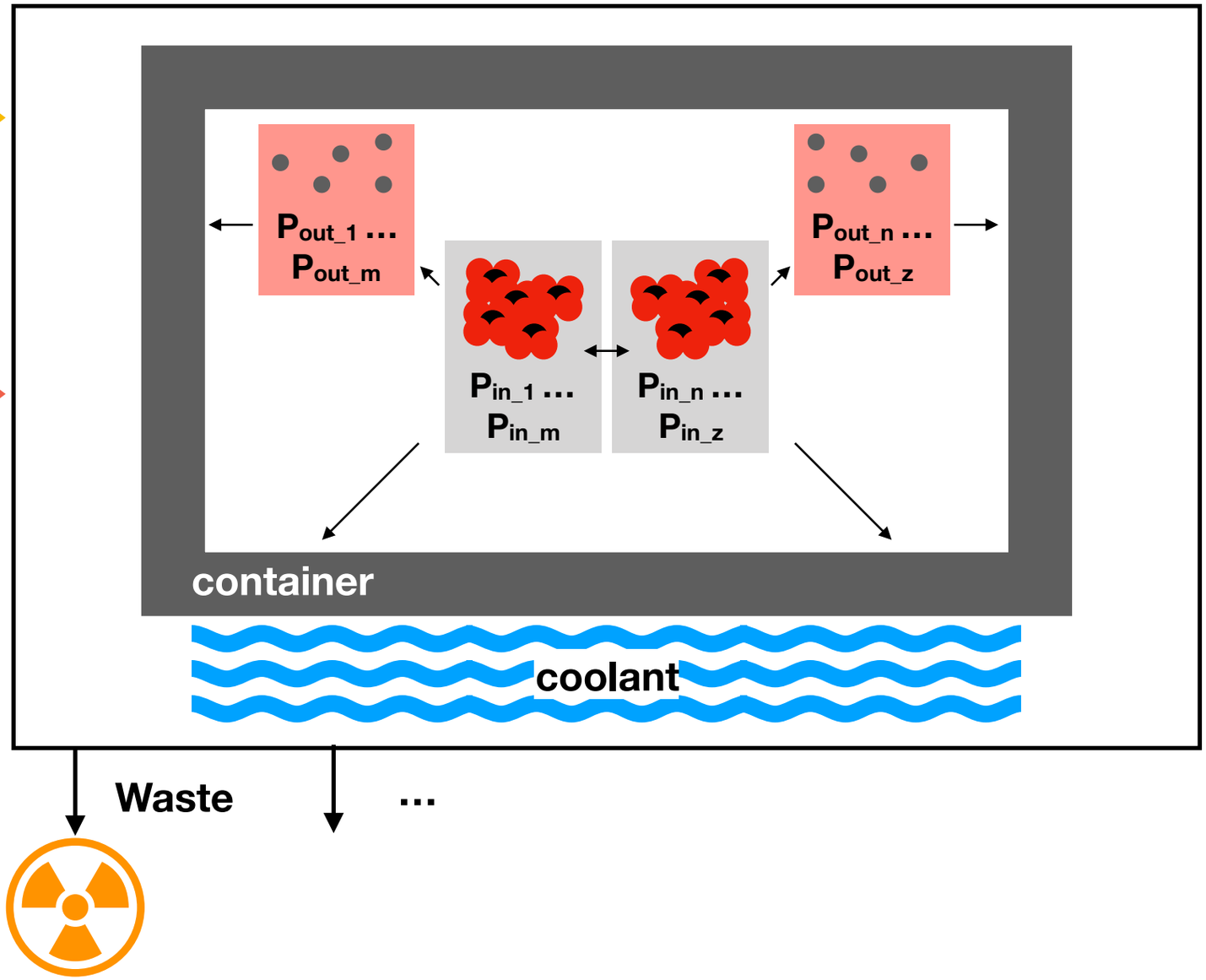
Nuclear Reactions

Energy in

- initiating
- maintaining

Maintenance

- time



Energy out

- KWh

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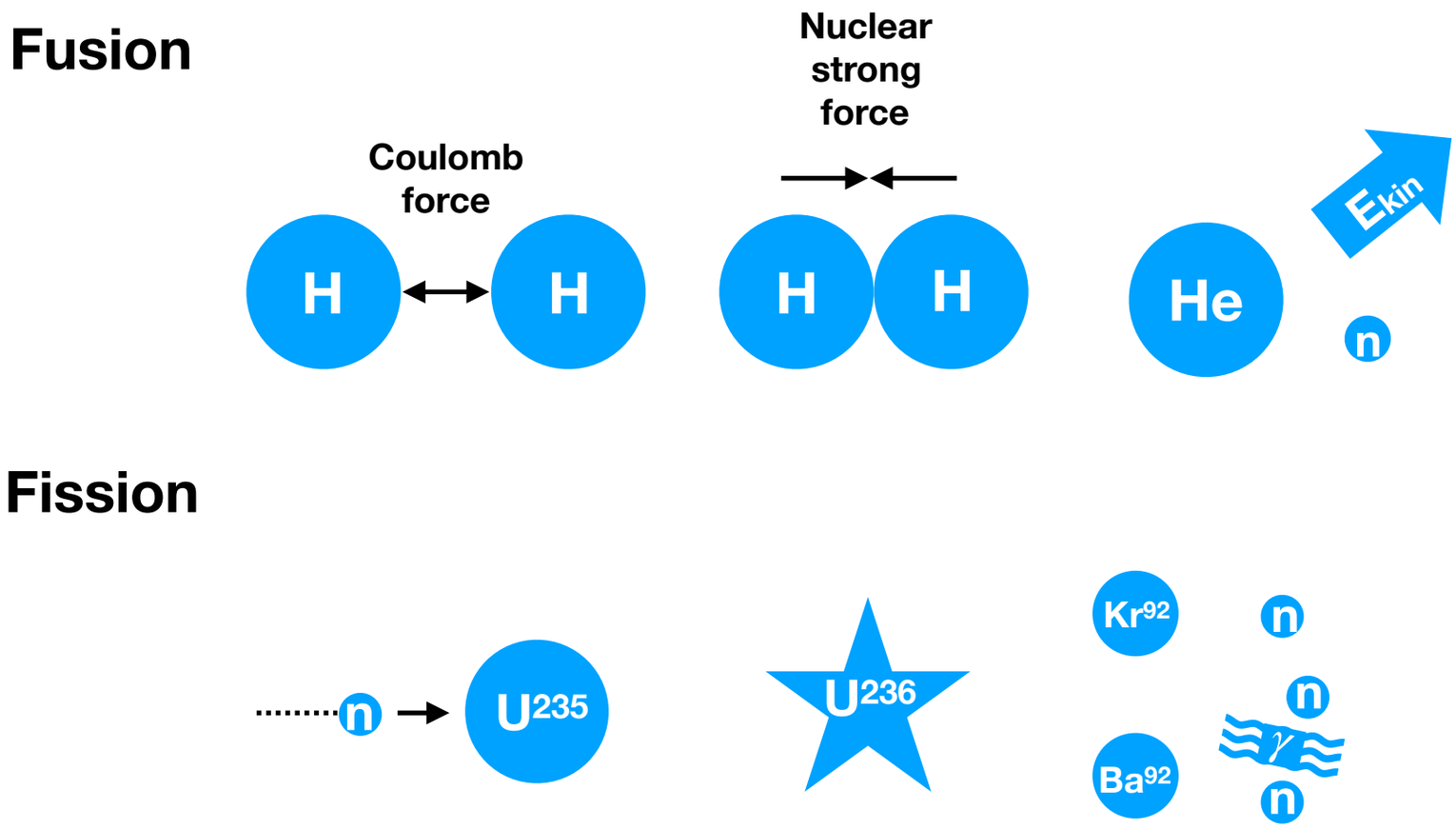
Question

- How will you harness nuclear reactions with high EROI



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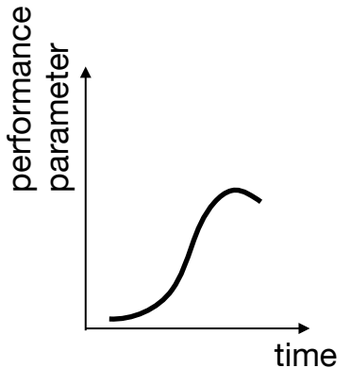
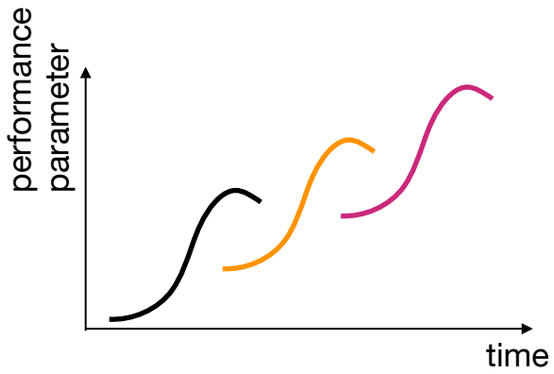
4. Self-directed experimental inquiry is key for systemic innovation

new function realized



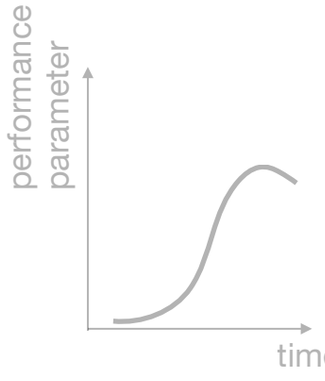
new way of realizing existing function



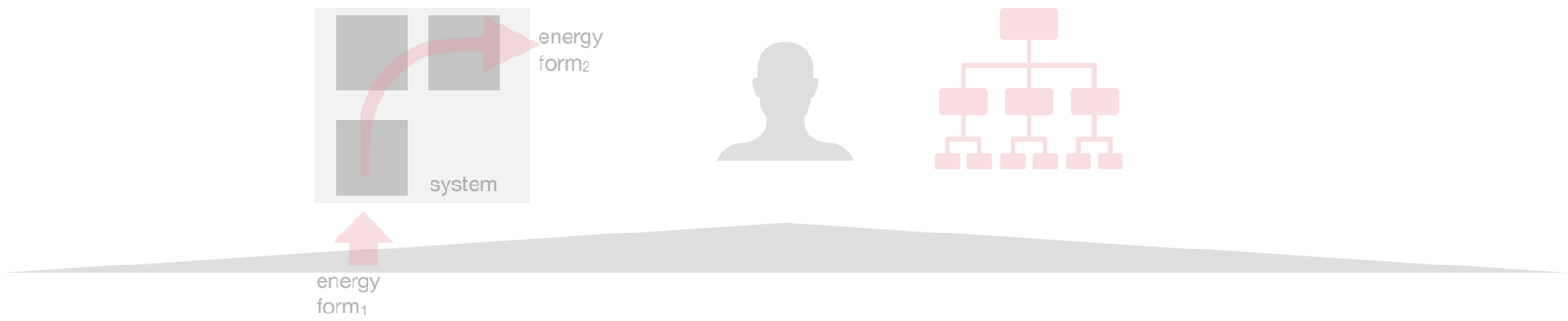
3. Systemic thinking allows to understand and control global system behavior

behavior of system in all kinds of contexts

system from evolutionary perspective



2. Ability to understand systems as energy storage elements and their dynamics



1. Specialized knowledge (specialized systems/contexts)

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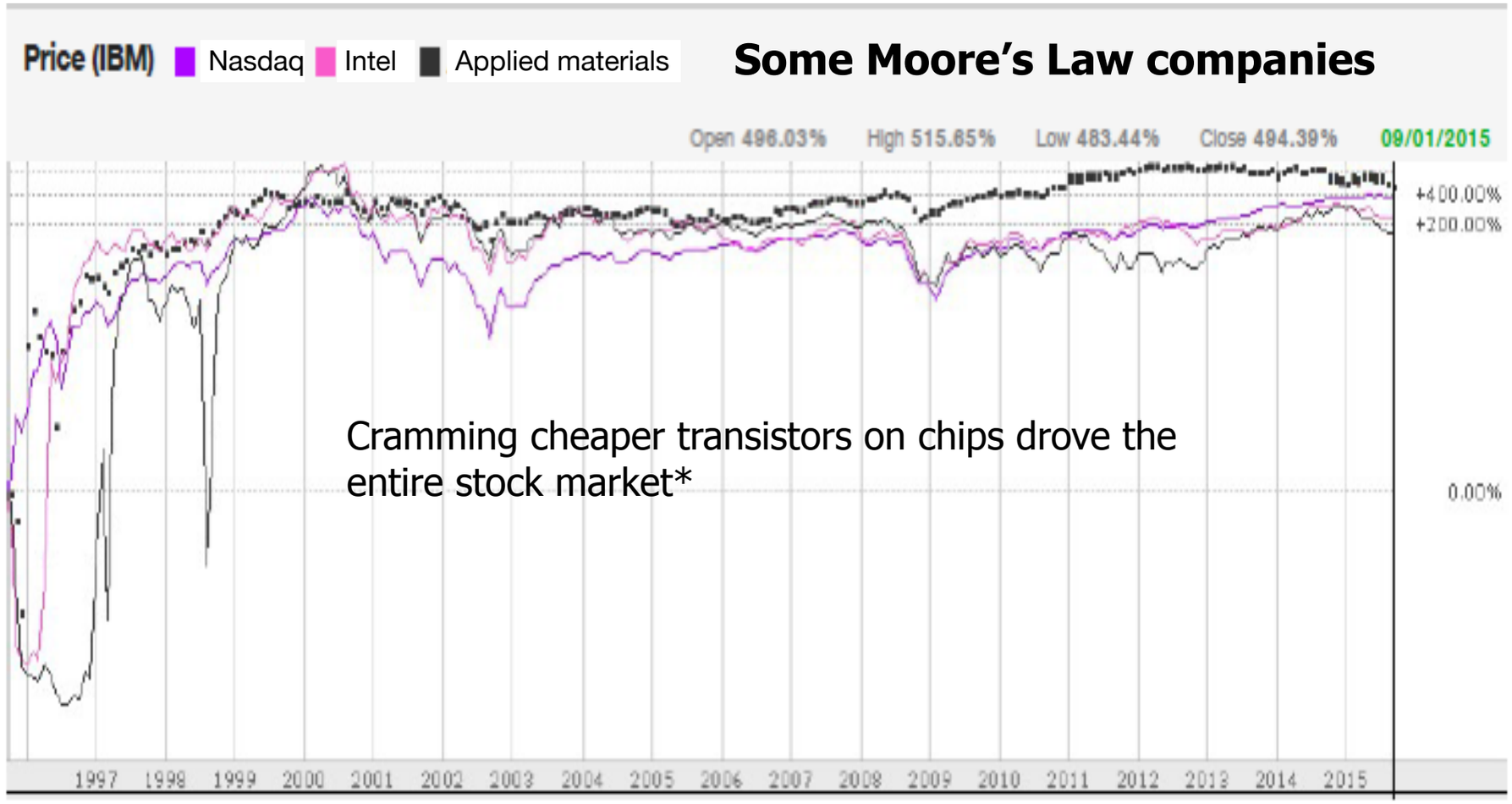
Innovation at Work: Value Driven by Productivity Increases



*Deviations predicted tipping points due to debt

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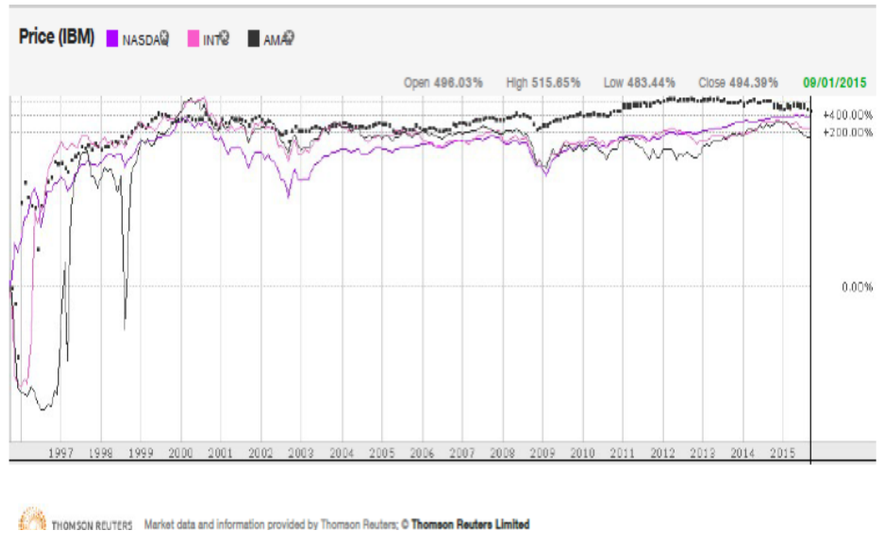
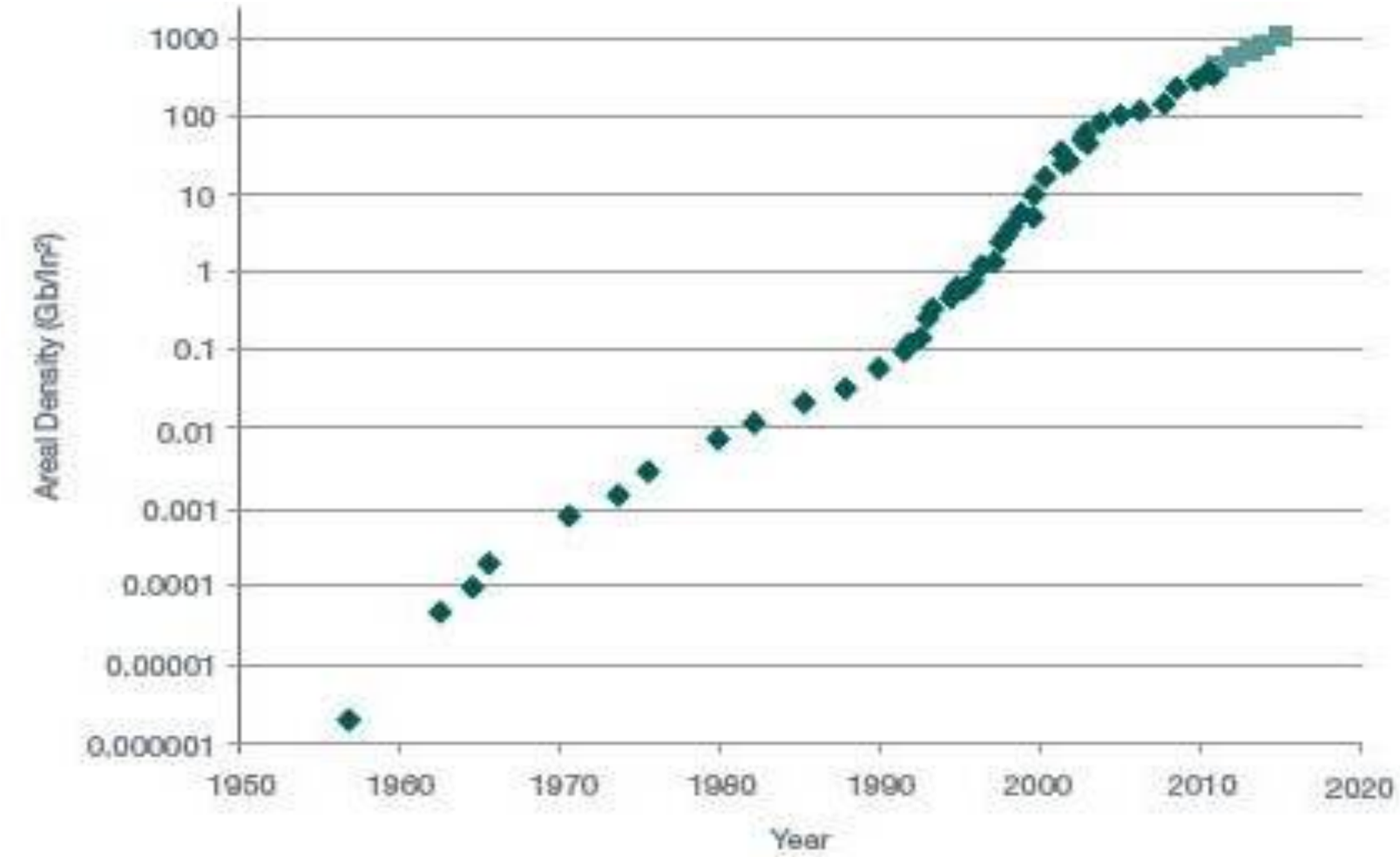
Example: Moore's Law in Memory





Source: IBM

- Exponential productivity increase should imply hyper exponential stock growth
- However, the growth becomes flat
- Why?

http://www.seagate.com/point-of-view/sshd-and-natural-evolution-master-pov/

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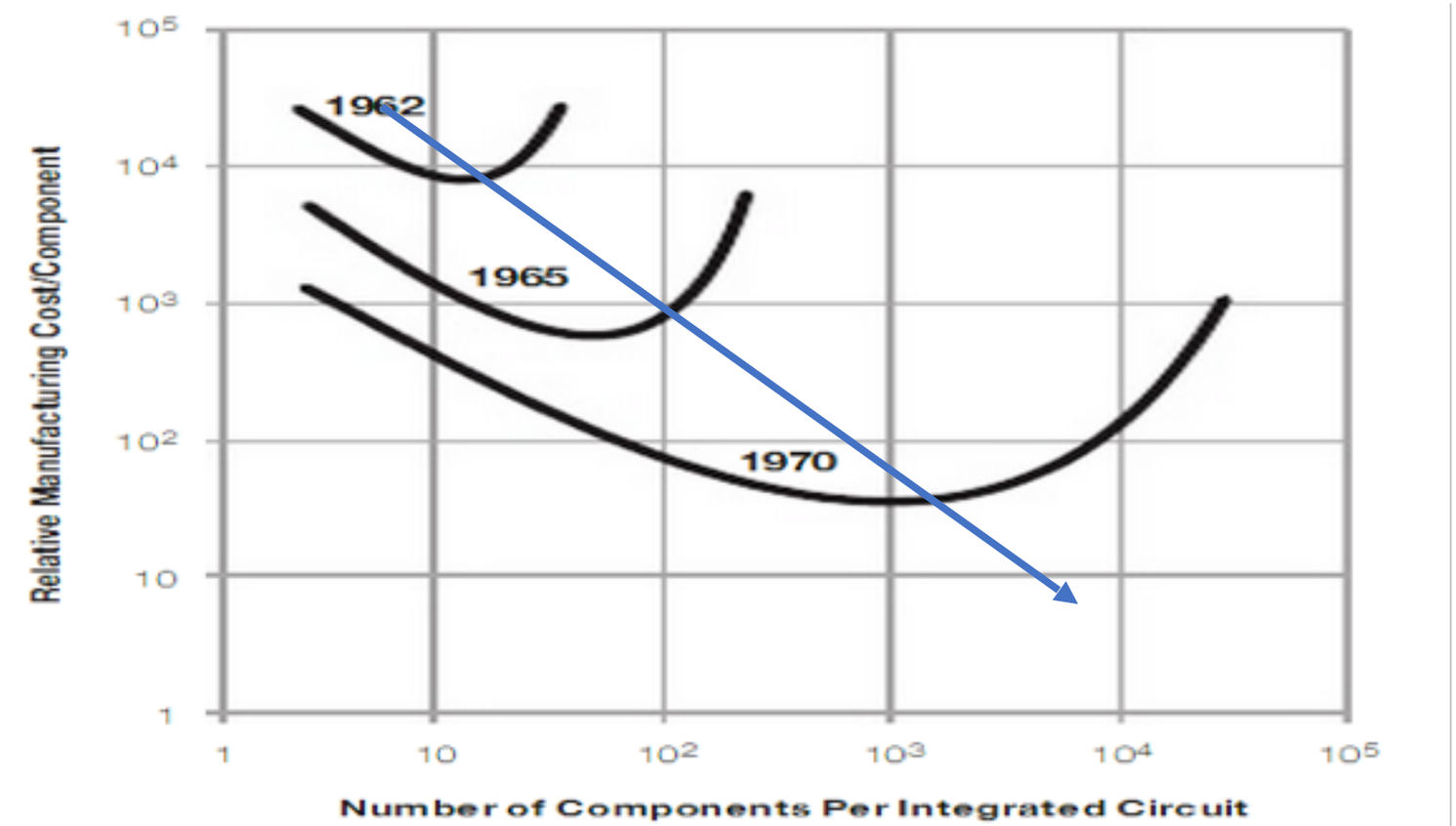
Moore's Law Arises from Design Optimization

as do all supply curves



- Over the years the minimum transistor cost has occurred in a circuit with greater density of transistors

Source: http://electroiq.com/blog/2014/03/moores-law-has-stopped-at-28nm/

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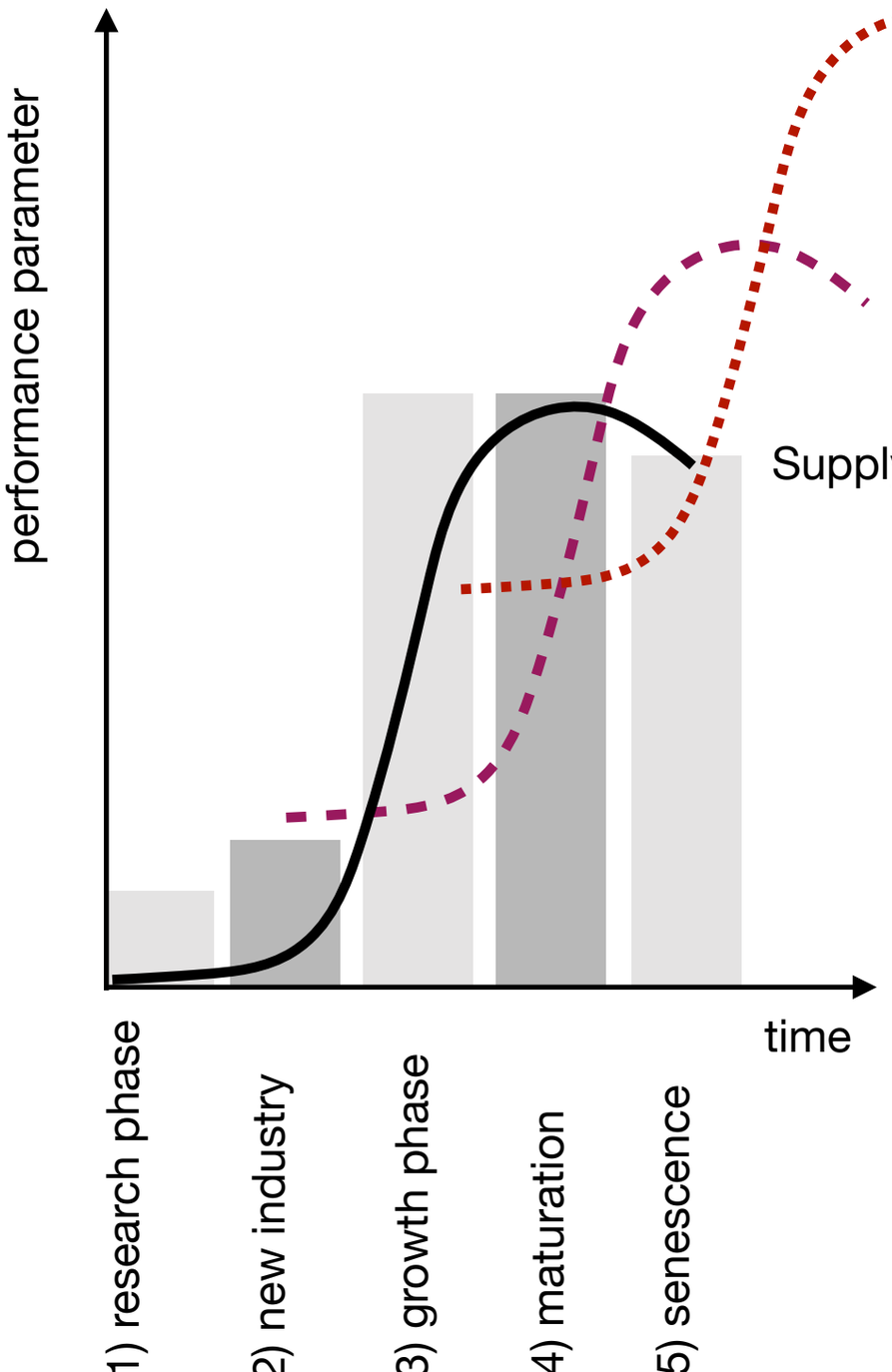
Moore's Law Arises from Design Optimization

Supply Curves: Interplay of Interdependence and Modularity



1) lots of trial & error/high quality team

2) tiny/no returns

3) large returns/competitive industry

4) diminishing returns/consolidation

5) declining returns

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Recent growth rates

industry	period	Growth rate
transistors	1965—2005	46%
corn yield	1950—2015	2%
Lighting lumens/W	1881—2014	2.6% indoors 3.1% outdoors
Steel cost	1950—2010	1.7%
steam genr. eff.	1900—2000	1.5%
travel speed	1900—1958	5.6%
auto fuel eff.	1973—2014	2.5%

http://spectrum.ieee.org/energy/renewables/moores-curse

Negative growth rates exist:
education, healthcare and government

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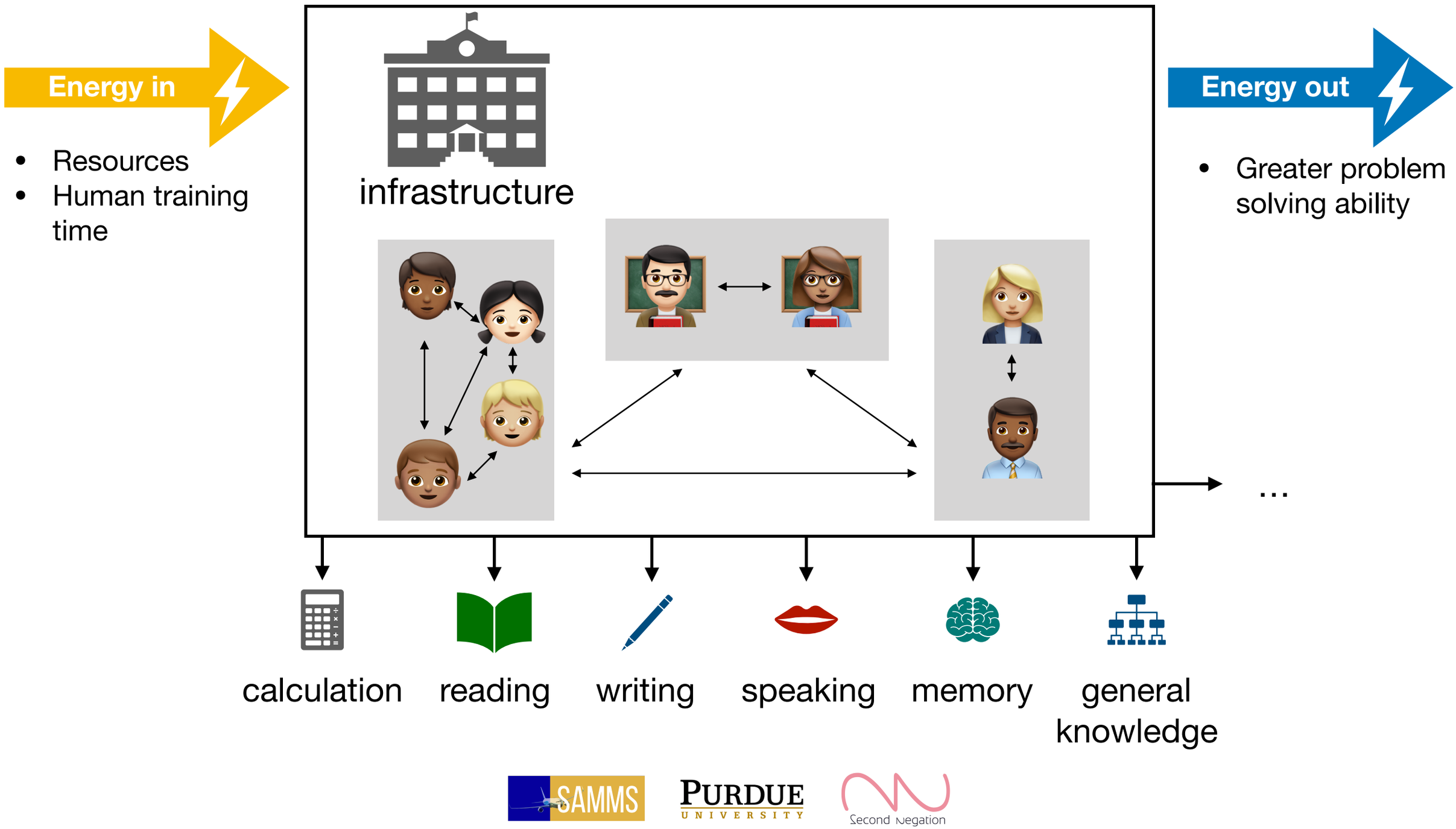
Education

- How would you increase the productivity of our education system?



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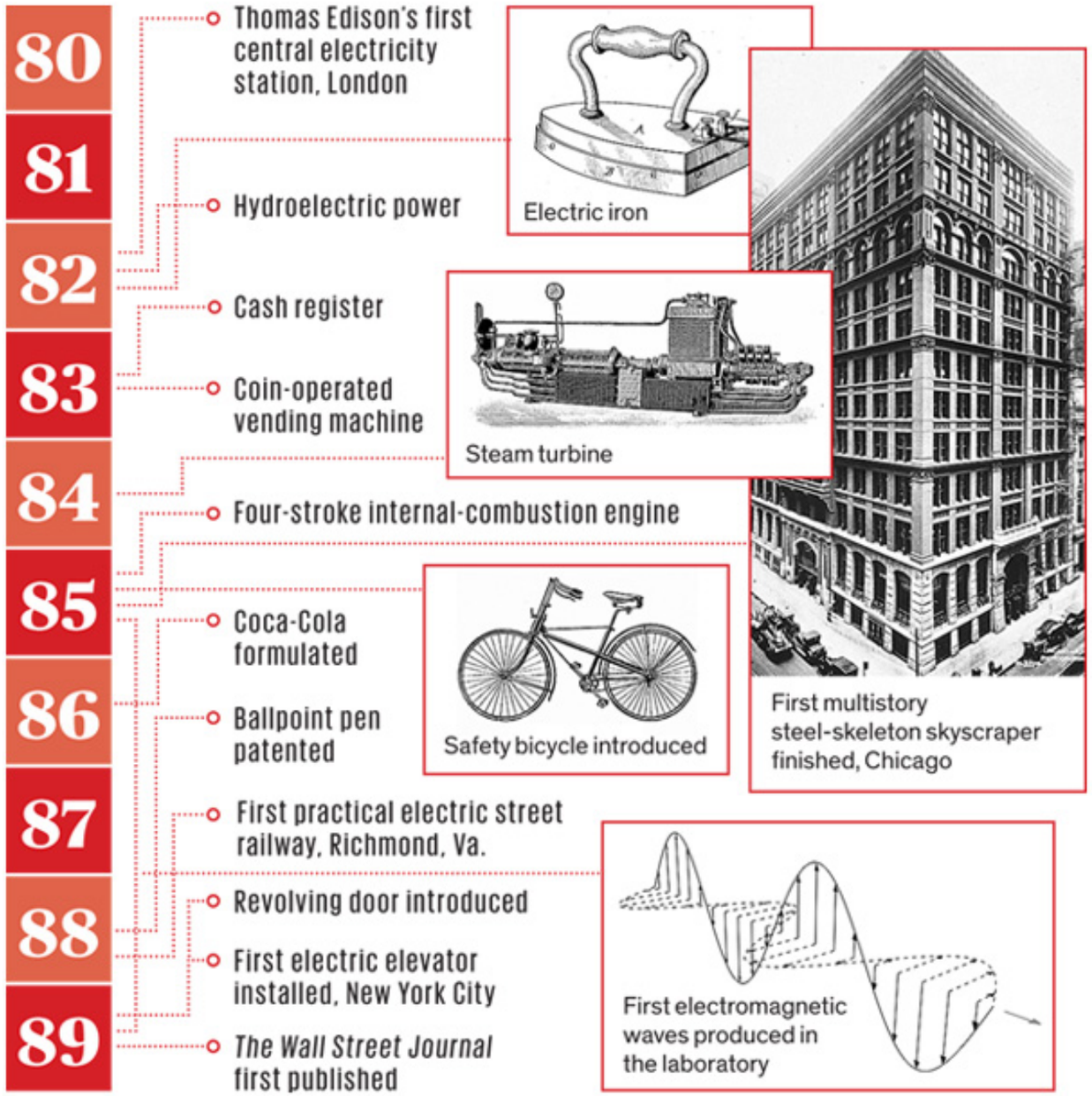
When We Were Actually Creative!

The Miraculous 1880s, Vaclav Smil, IEEE Spectrum, 06/29/2015



Deflation was good for those who were productive

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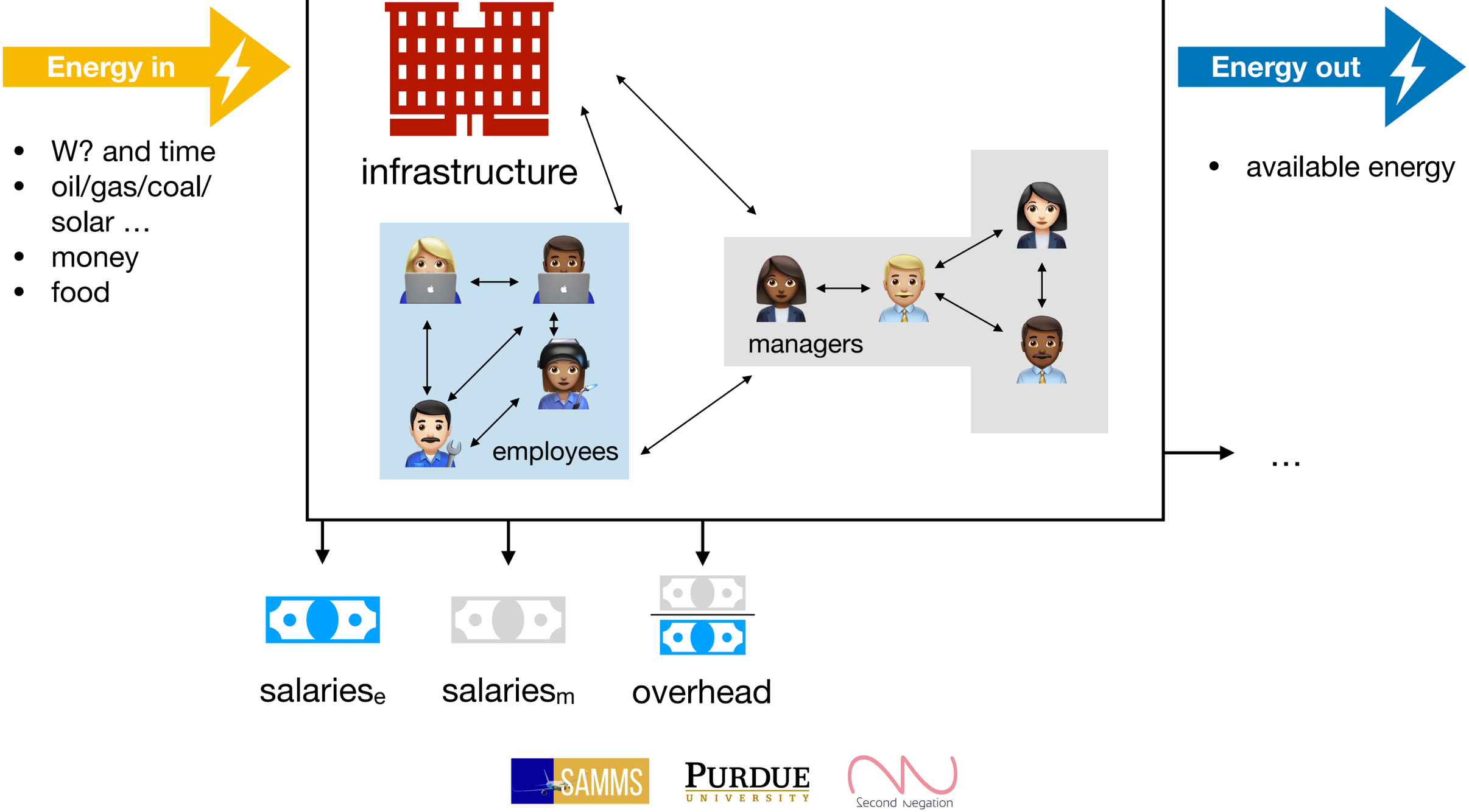
Overhead

- How do we design more productive organizations?



How to reach self directed experimental inquiry

increasing utilization

increasing cognitive overhead

humanities	Representation to communicate with minimum mutual entropy (min energy, max bandwidth).
social sciences	Calculate, organize, and act to increase joint exergy
biology	Increase individual exergy
engineering	Achieve performance objectives amid uncertainty that contribute to exergy
physics	Most compact description of human experience available
mathematics	More efficient calculation via approximation

Hierarchy of knowledge

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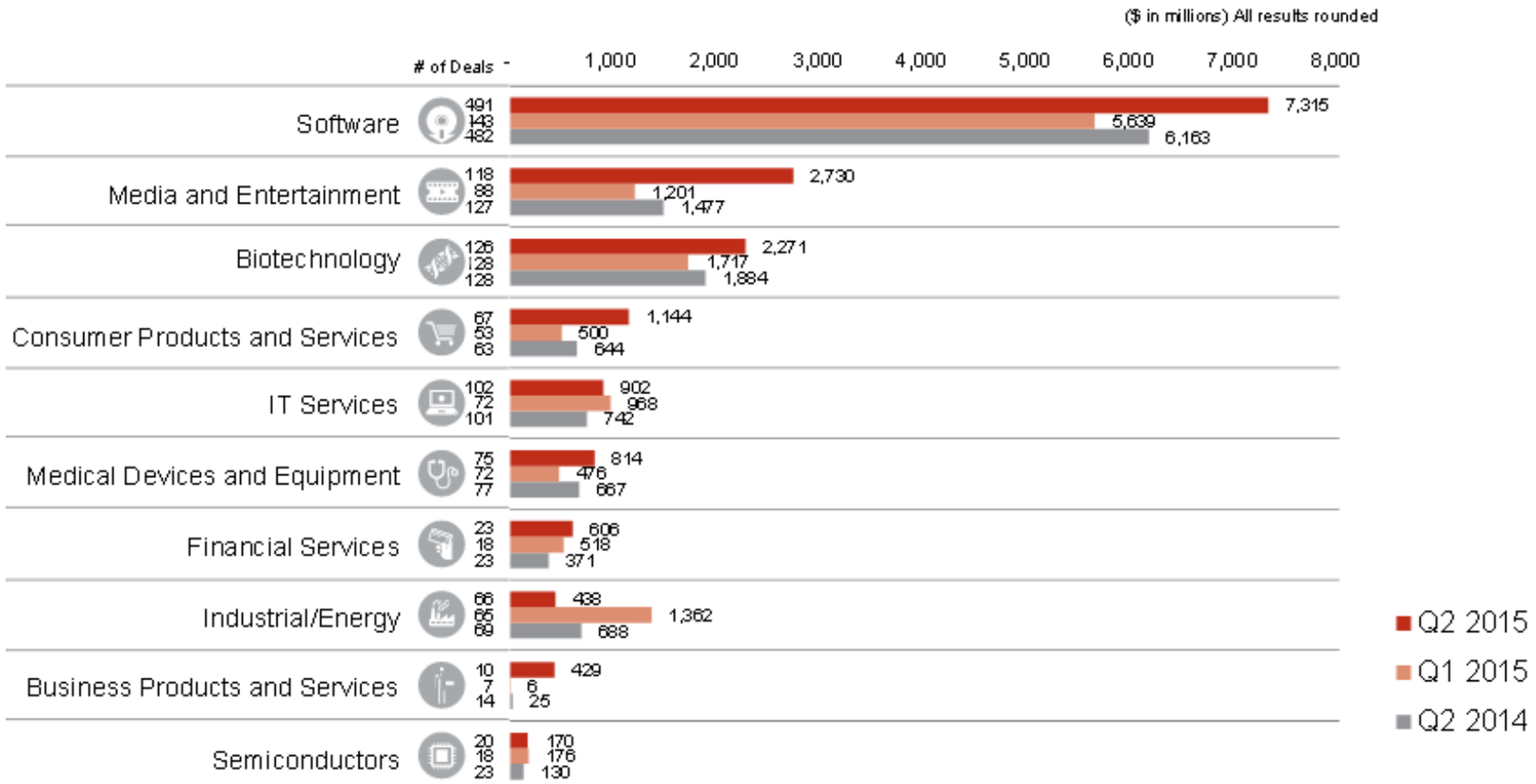
The Hardest Problems Make the most Profit



http://www.pwcmoneytree.com/Reports/FullArchive/National_2015-2.pdf

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Thank you very much!

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