Accenture / Fjord   Dublin (via teleconference)   23 June 2020

Systems Theory in Design

Course Overview

Hugh Dubberly
Dubberly Design Office

Ground rules

I owe you

- clarity
- logical reasons
- examples
- applications to practice
- sources + context

I need from you

- questions: Please interrupt!
- skepticism: Don’t assume I’m right
- examples + counter-examples
- connections between ideas
- conclusions (if this, then what?)

Our agenda for today

Why systems matter in designing
Some definitions of systems
What systems literacy might be

A review of the course schedule

Fundamentals
Advanced perspectives
Applications

Why *do* systems matter in designing?

For much of the twentieth century and beyond, much of design was about giving form to objects.

—

Gerrit Rietveld
Red and Blue Chair, 1917

Raymond Lowey
Pencil Sharpener, 1933

Frank Lloyd Wright
Guggenheim Museum New York, 1959

Dieter Rams
Braun TP1 Radio, 1959

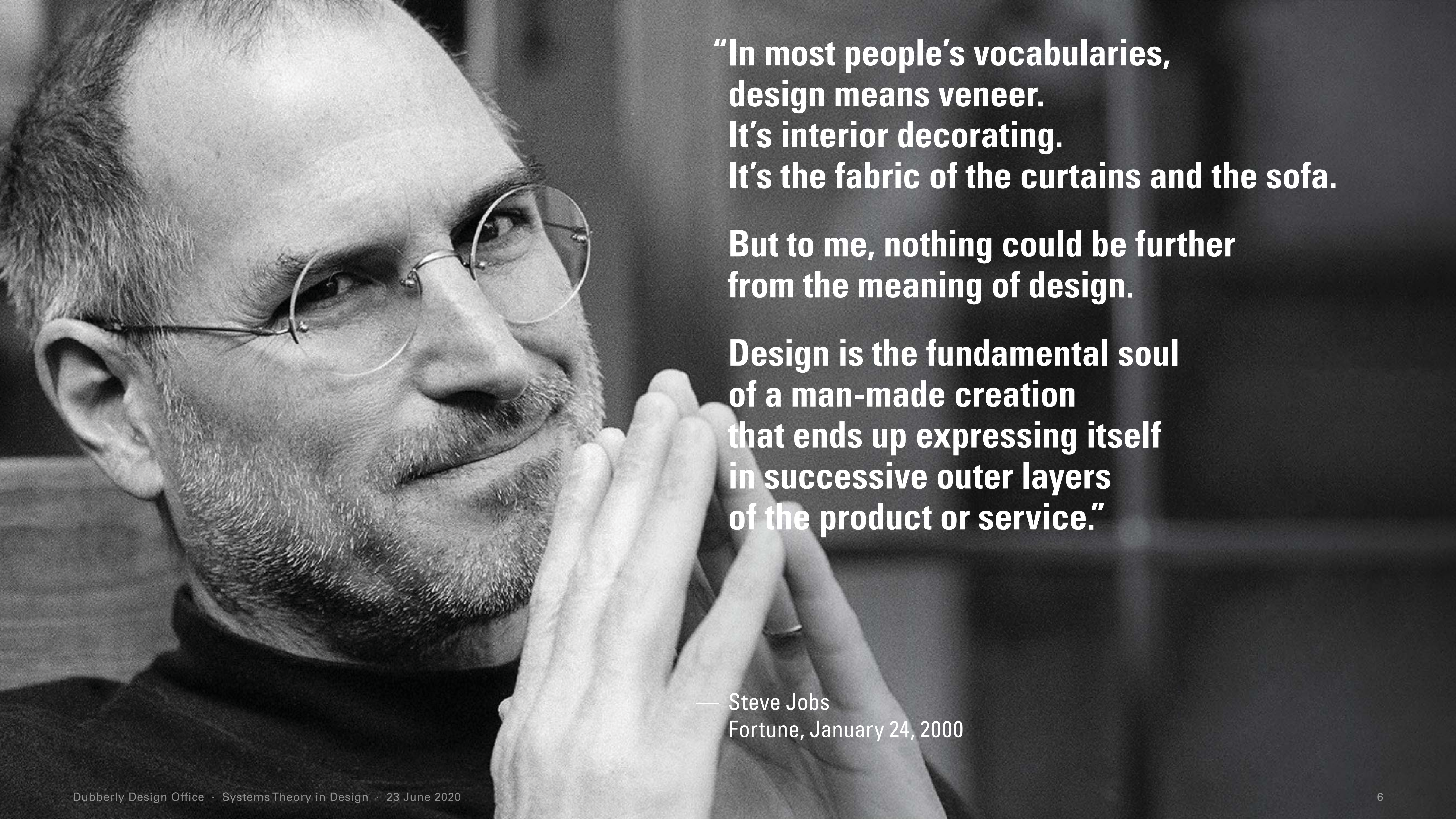
—

Memphis Bookshelf
Ettore Sottsass Jr., 1981

Raymond Lowey
PRR S1 Steam Engine, 1939

Frank Gehry
Guggenheim Museum Bilbao, 1997

Jony Ive
Apple iPod, 2001



"In most people's vocabularies,
design means veneer.
It's interior decorating.
It's the fabric of the curtains and the sofa.

But to me, nothing could be further
from the meaning of design.

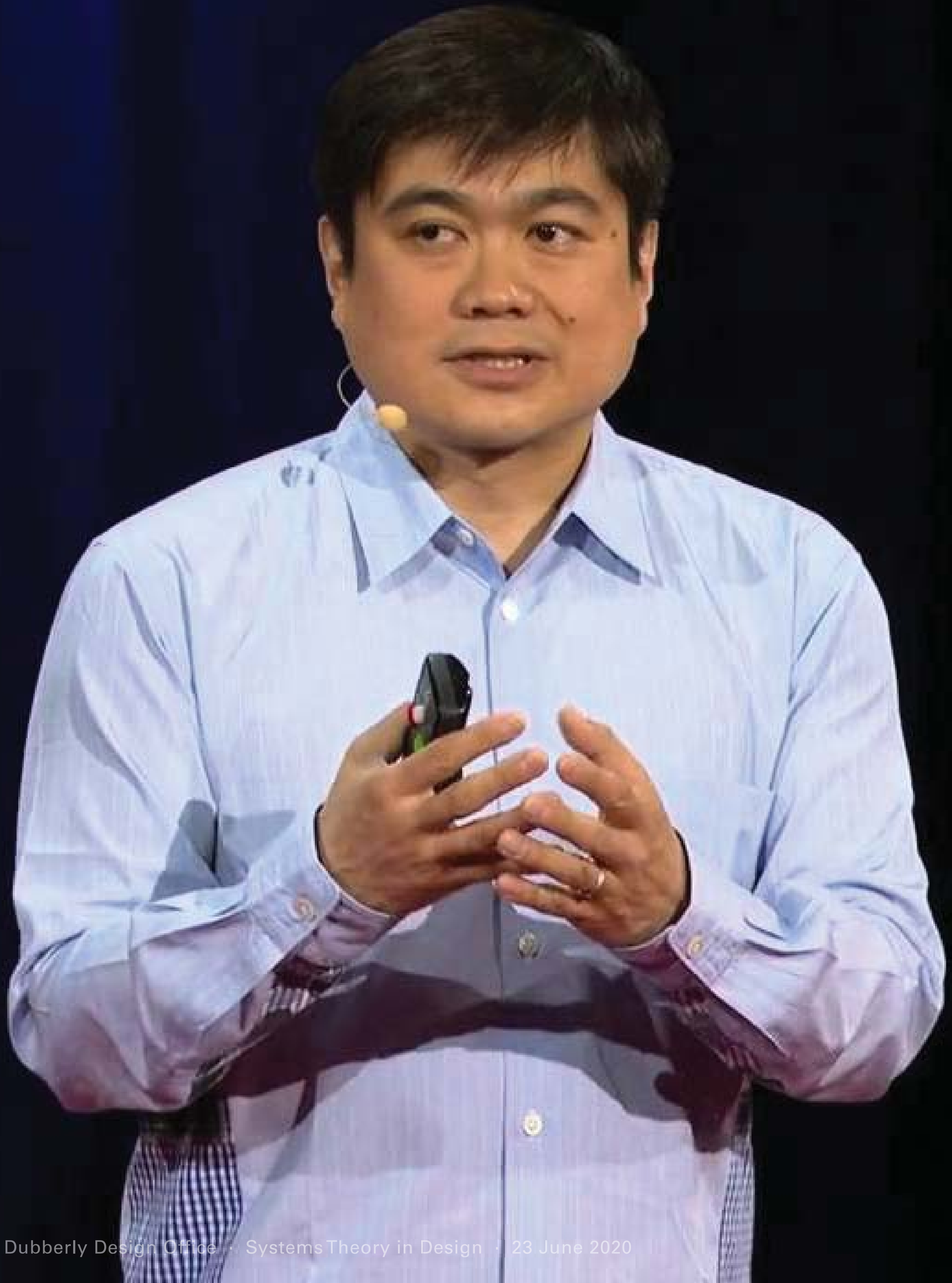
Design is the fundamental soul
of a man-made creation
that ends up expressing itself
in successive outer layers
of the product or service."

— Steve Jobs
Fortune, January 24, 2000

"…a building cannot be viewed simply in isolation…

In other words structures make sense
as parts of larger systems
that include human components
and the architect is primarily concerned
with these larger systems;
they (not just the bricks and mortar part)
are what the architect designs."

— Gordon Pask,
"The Architectural Relevance of Cybernetics,"
Architectural Design, 1969



"Design has also evolved
from the design of objects
both physical and immaterial,
to the design of systems,
to the design of complex adaptive systems.

This evolution is shifting the role of designers;
they are no longer the central planner,
but rather participants
within the systems they exist in.

This is a fundamental shift—
one that requires a new set of values."

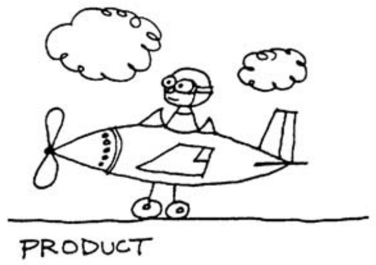
— Joi Ito
Director, MIT Media Lab
"Design and Science," January 11, 2016

A matrix of design: the six types
Jay Doblin, 1987

Tangible objects and messages

Appearance Products
Christmas ornaments
Medals
Trophies

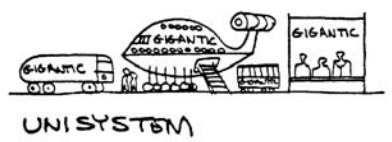
Performance Products
Crowbars
Paper clips



Sets of coordinated products and the people who operate them

Appearance Unisystems
Restaurant environment
South Street Seaport
Disneyland

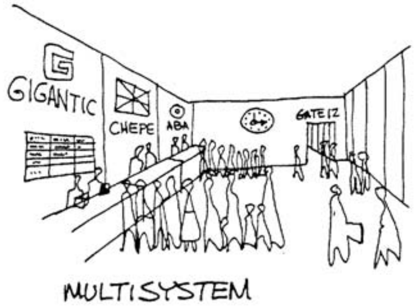
Performance Unisystems
Compact kitchen
NASA space mission
United Airlines



Competing unisystems

Appearance Multisystems
The fashion industry

Performance Multisystems
The airline industry
The computer industry



From “A Short, Grandiose Theory of Design,” STA Design Journal

John Maeda has offered a sort of era analysis.

1 **Classical Design**

There is a right way to make what is perfect, crafted, and complete.

2 **Design Thinking**

Because execution has outpaced innovation, and experience matters.

3 **Computational Design**

Design for billions of individual people and in real time, is at scale and TBD.

—Design in Tech Report, 2018

Stephen Anderson says, "The future of design is complexity + computation."

Design 1.0
Product

Design 2.0
Experience

Design 3.0
Outcomes

—https://medium.com/@stephenanderson/the-future-of-design-computation-complexity-a434d2da3cd5

Richard Buchanan proposed “four orders of design.“

1 **Communications —**
a focus on meaning and symbols

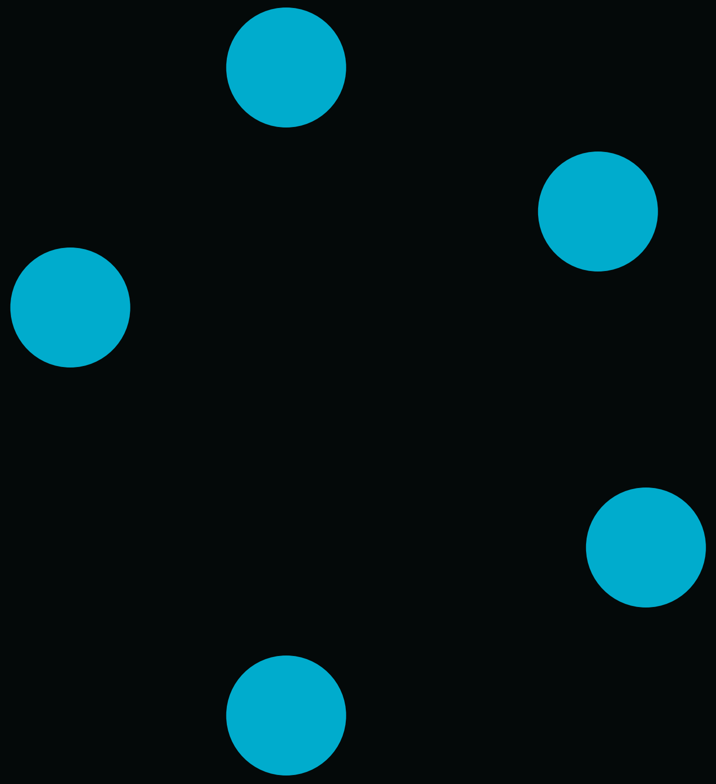
2 **Artifacts —**
a focus on form and things

3 **Interactions —**
a focus on behavior and action

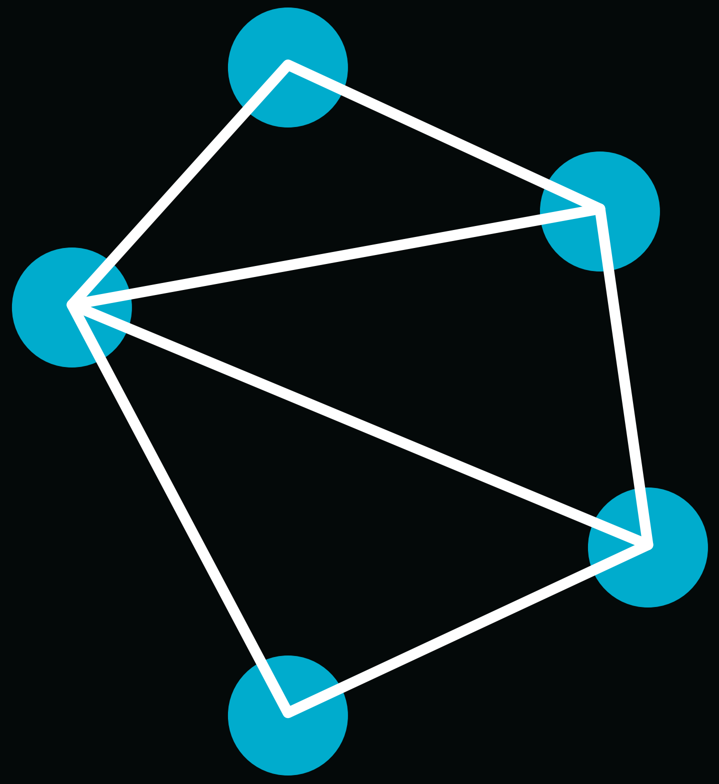
4 **Fourth order —**
a focus on “environments and systems in which all other orders exist“

We are in the midst
of a fundamental shift
in how we view the world—
how we explain it—
and how we operate in it.

from
Nodes, Nouns Objects, Products



to
Links, Verbs Relations, Systems

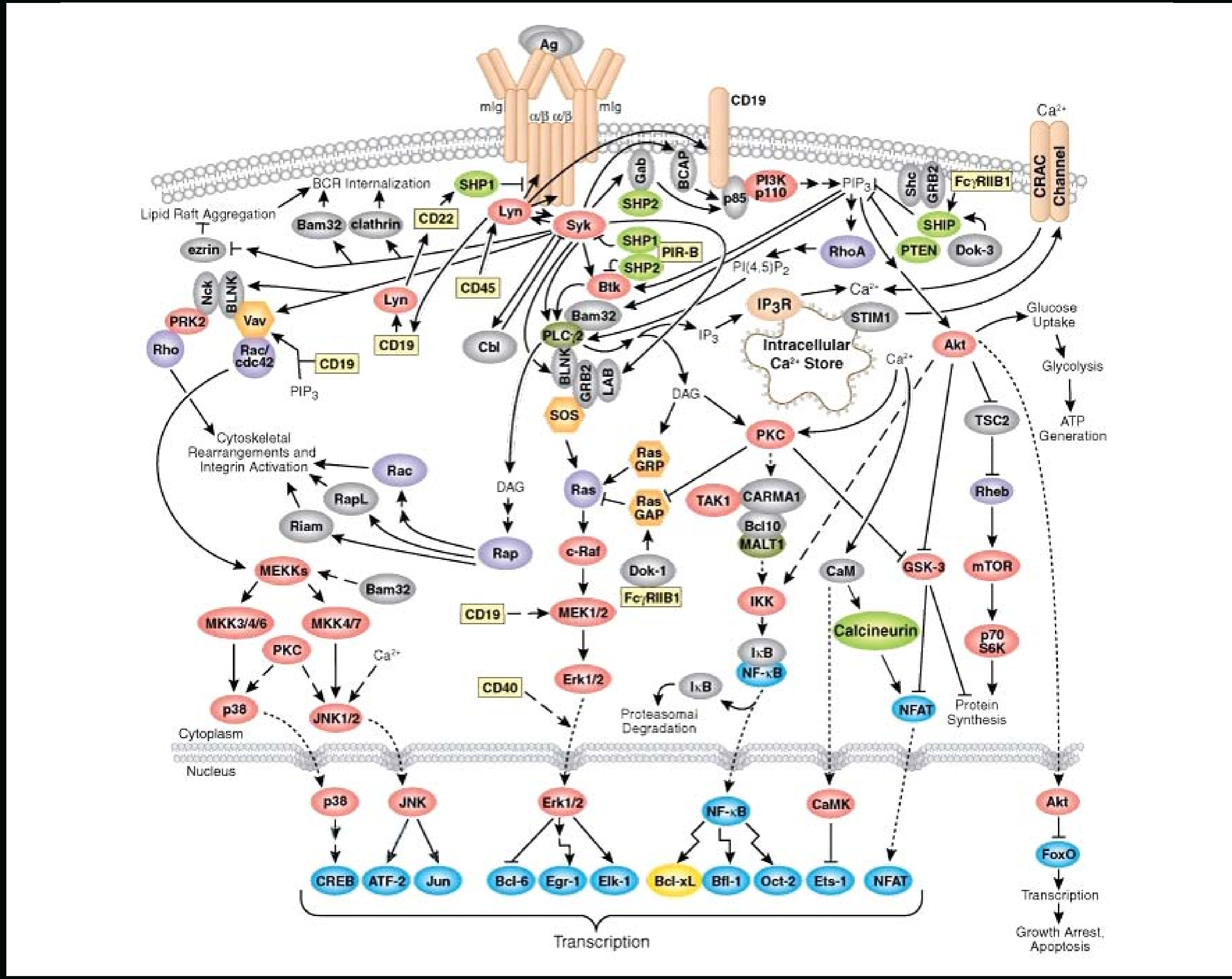


from
Linear causality

e.g., a hand crank generator

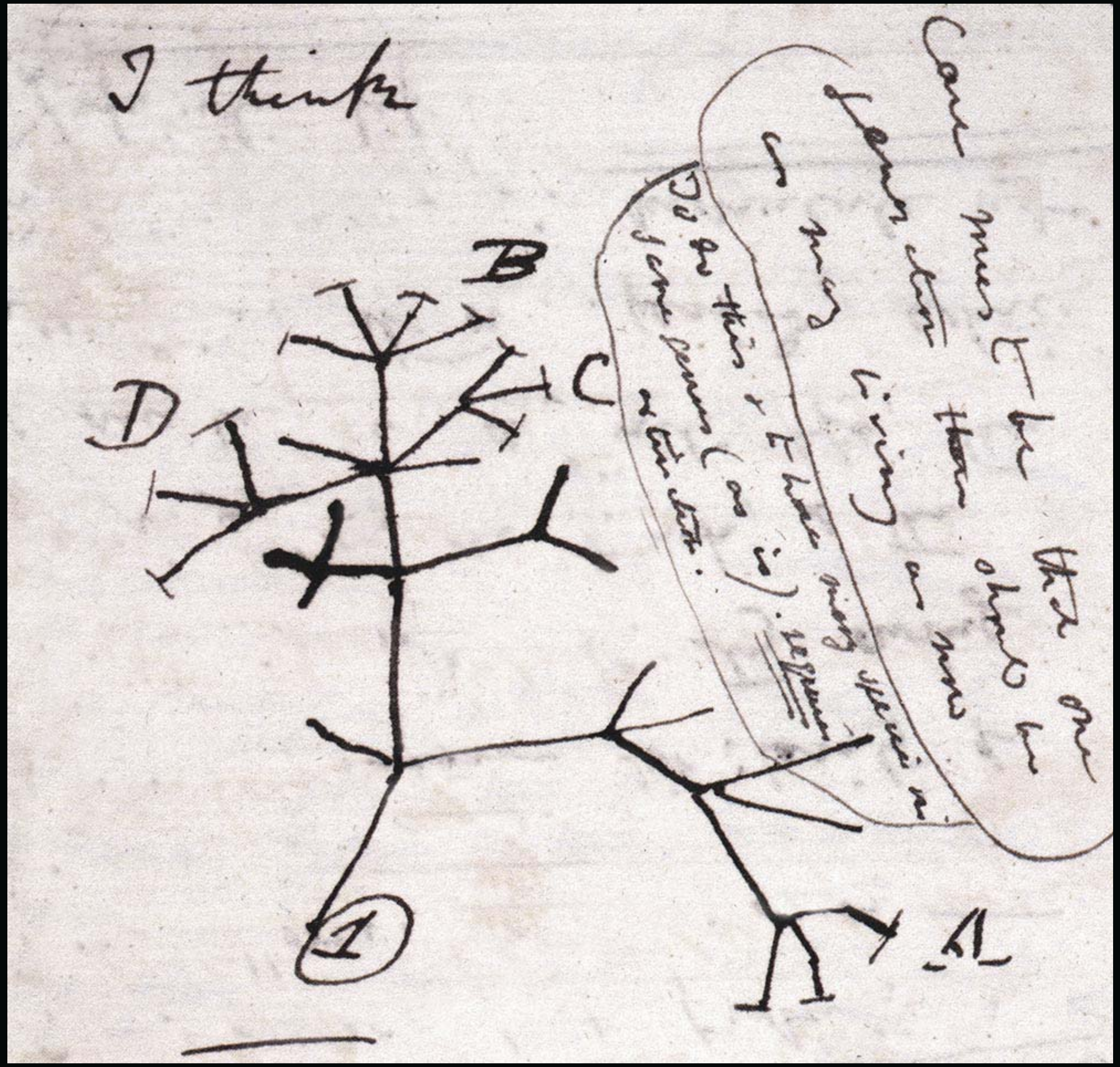
to
Cascades, feedback

e.g., cell signaling pathway



from

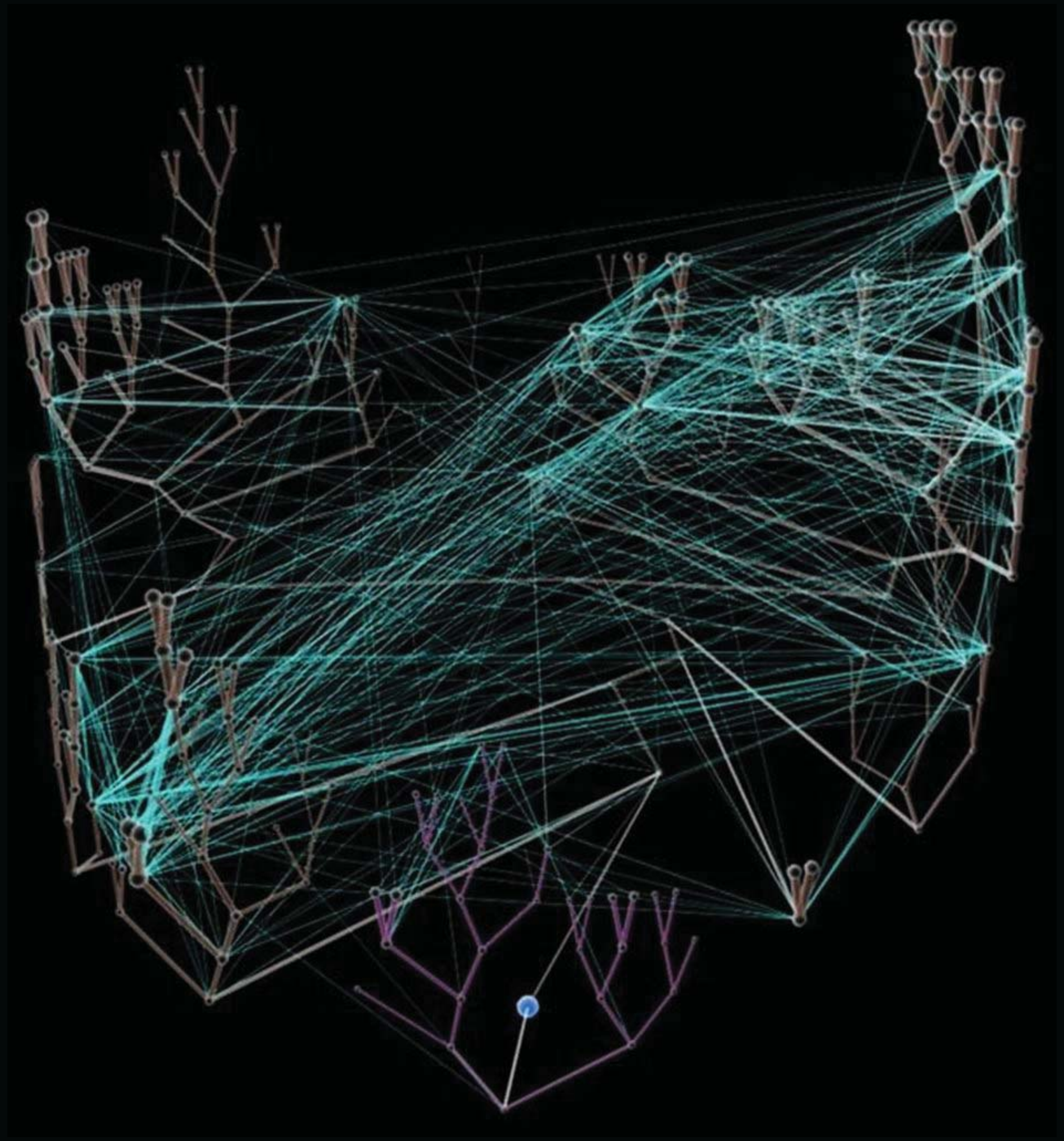
Tree of life



— Charles Darwin, 1859

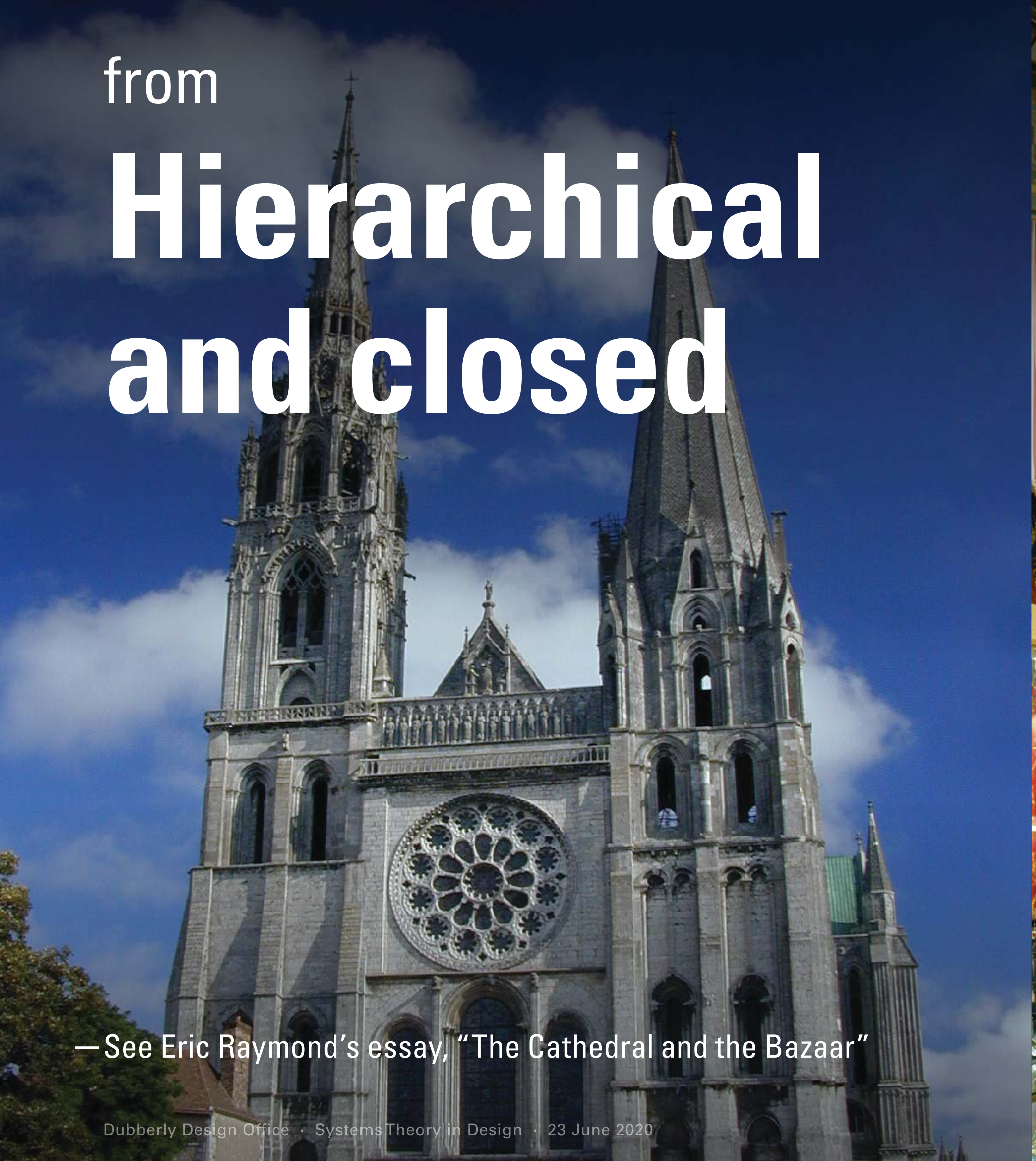
to

Web of life



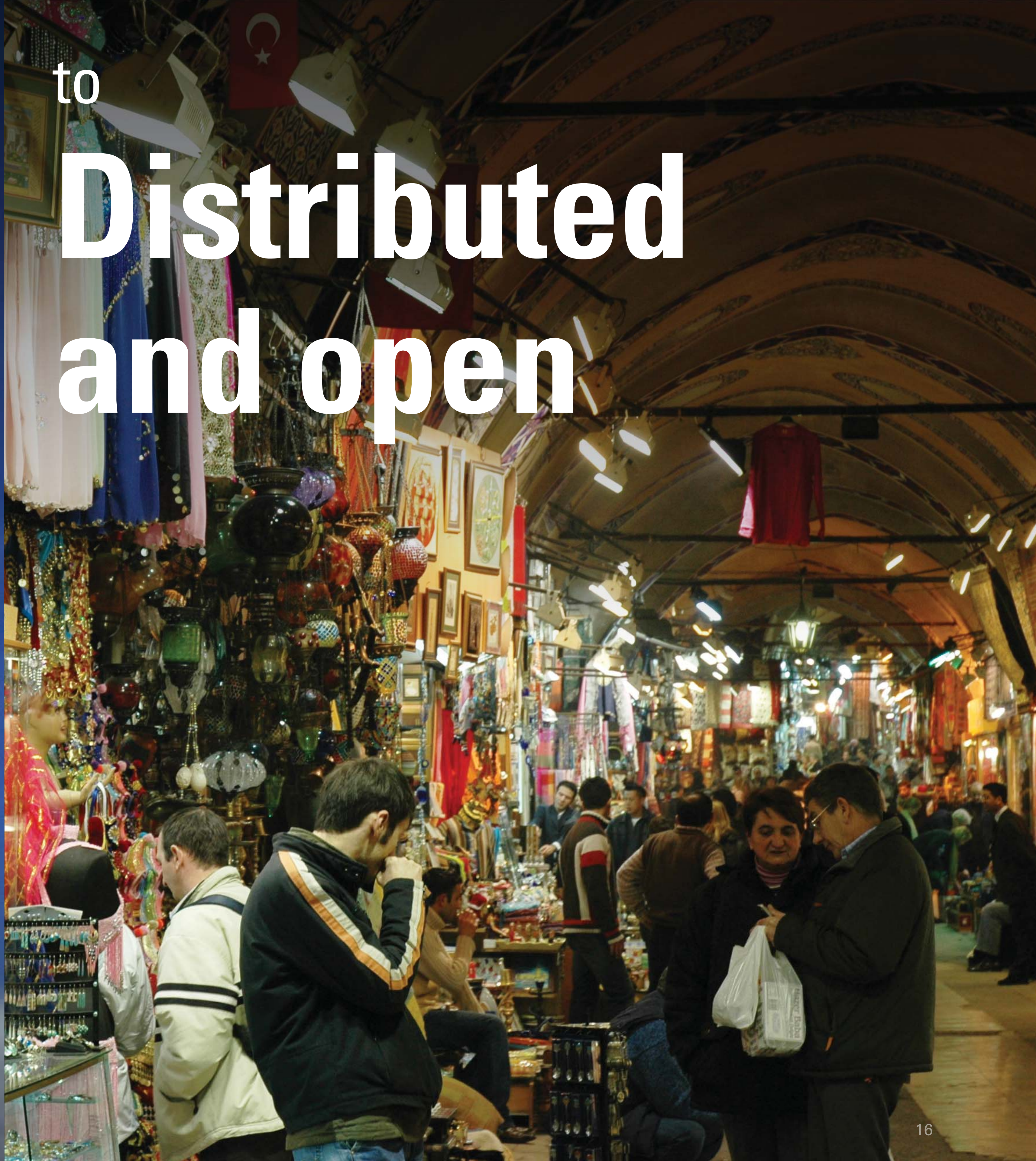
— V. Kunin, L. Goldovsky, N. Darzentas, and C. A. Ouzounis, 2005

— Manuel Lima, TED Talk, March 2015
http://www.ted.com/talks/manuel_lima_a_visual_history_of_human_knowledge#t-164372



from

Hierarchical and closed



to

Distributed and open

—See Eric Raymond’s essay, “The Cathedral and the Bazaar”

from

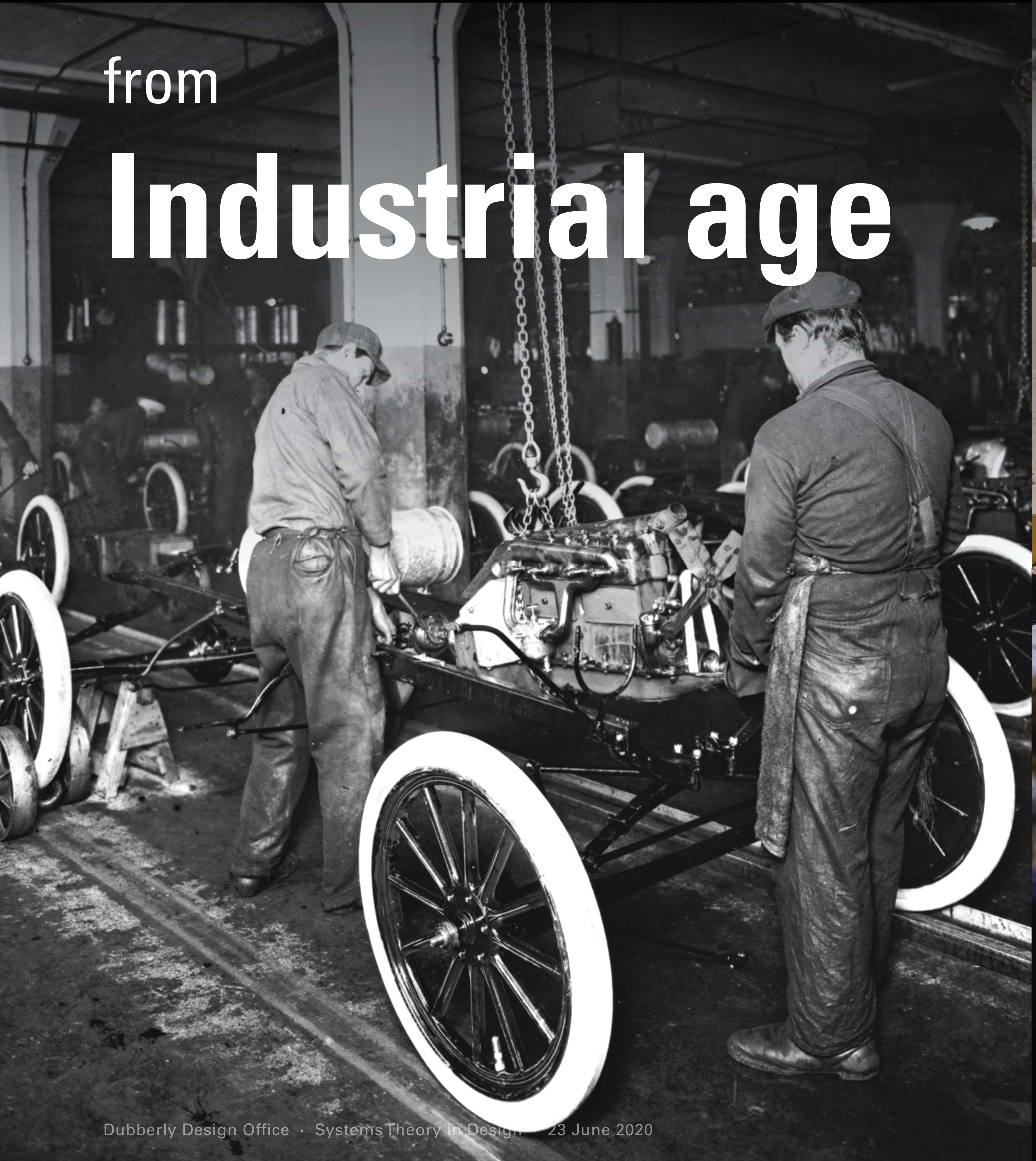
Mechanical

to

Biological

from

Industrial age



to

Information age

From
Physical artifacts — objects

To
Adaptive systems — ecologies

Product Design

Focus Groups

Human Factors

Usability Studies

Interaction Design

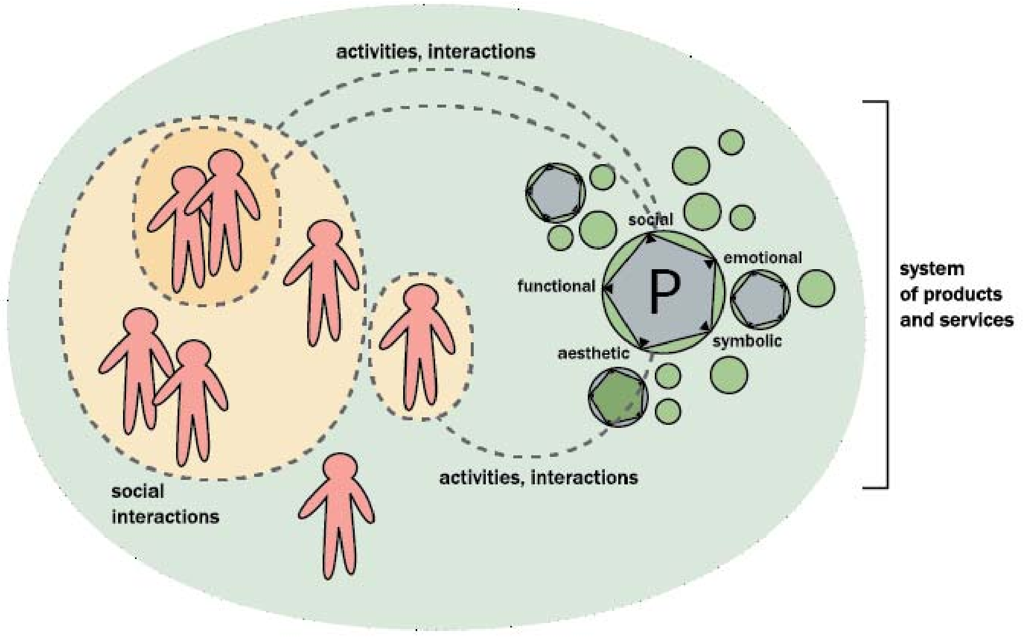
Data-driven Design

Service Design

Model-driven Design

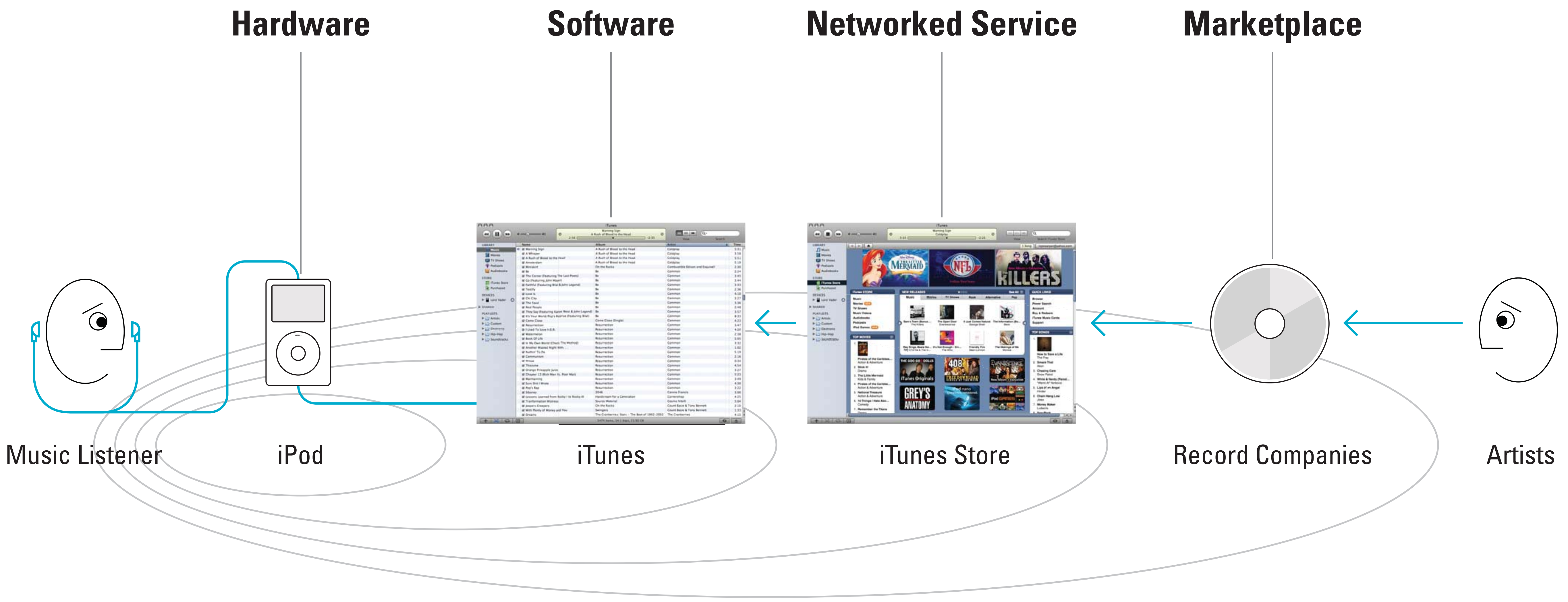
We might call them “product-service ecologies”.

“…networks of products, services, technology, people, and collective and collaborative interaction are generating value for the populations they serve.”

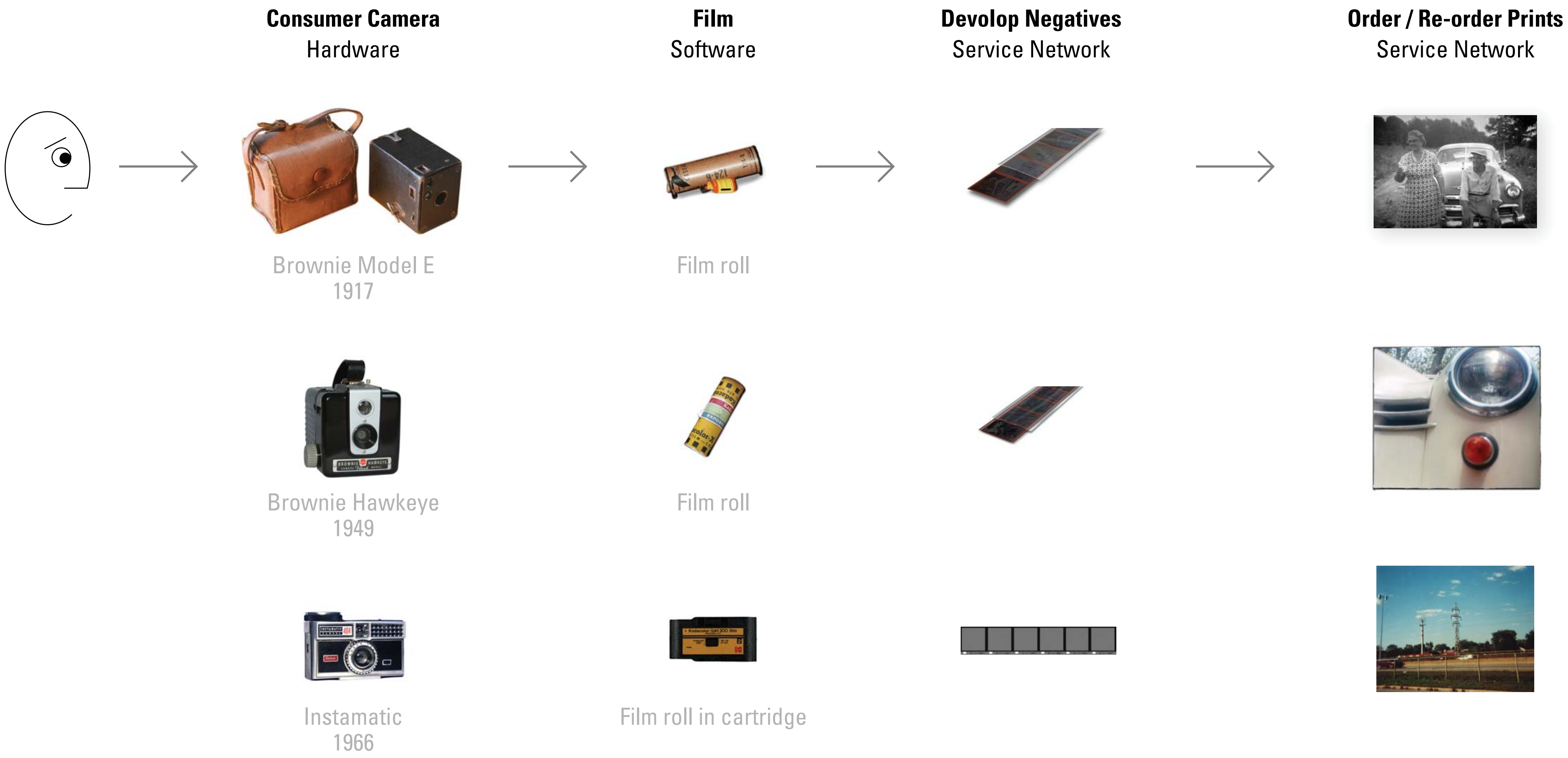


— **Jodi Forlizzi**, HCII, CMU, 2008

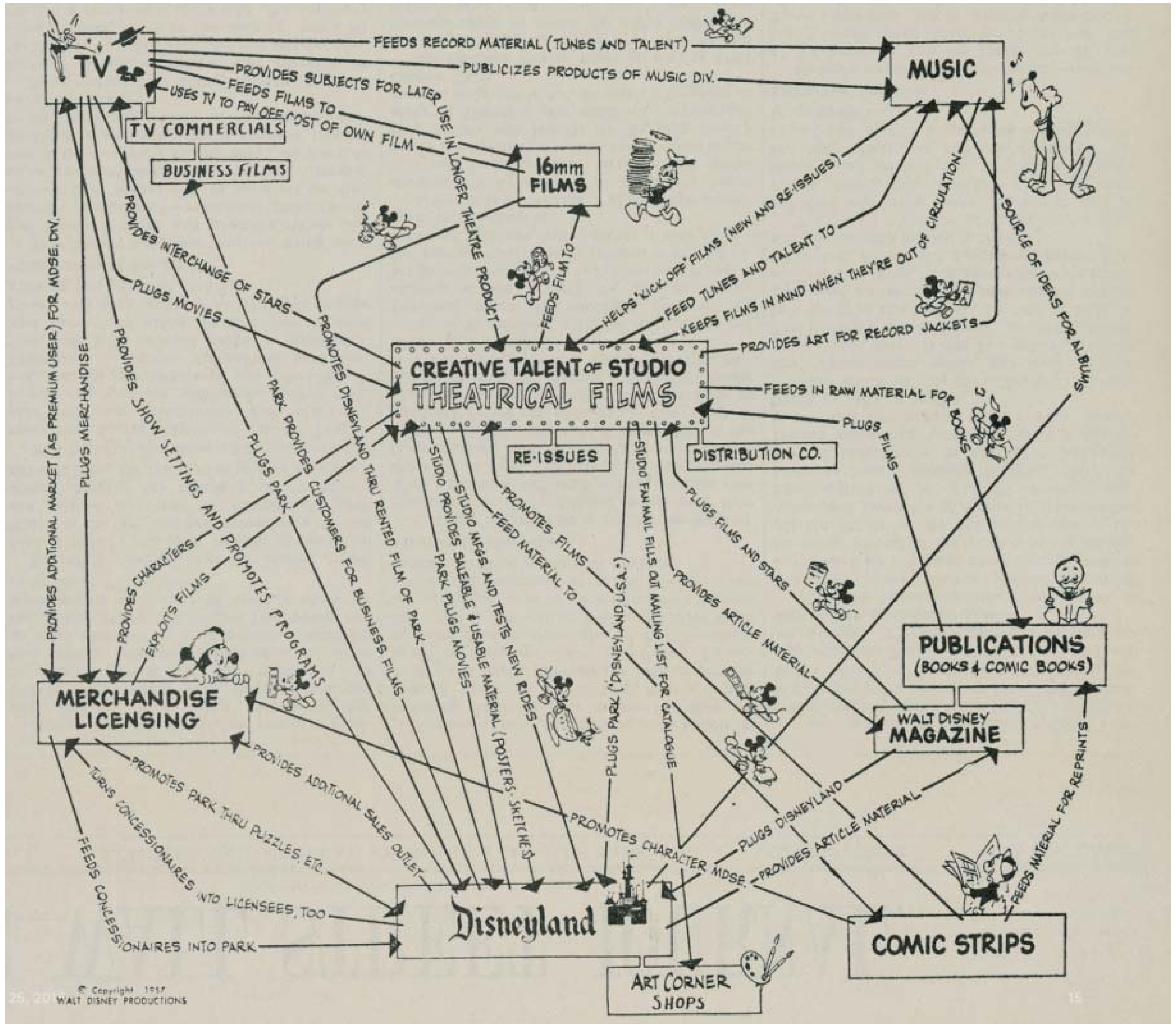
iPod was at the heart of an early product-service ecology.



Kodak may have been one of the first product-service ecologies.



Disney thought in terms of ecologies 50+ years ago.



"Managers are not confronted with problems that are independent of each other, but with dynamic situations that consist of complex systems of changing problems that interact with each other. I call such situations messes."

Horst Rittel called them "wicked problems."

—Russell Ackoff, 1979

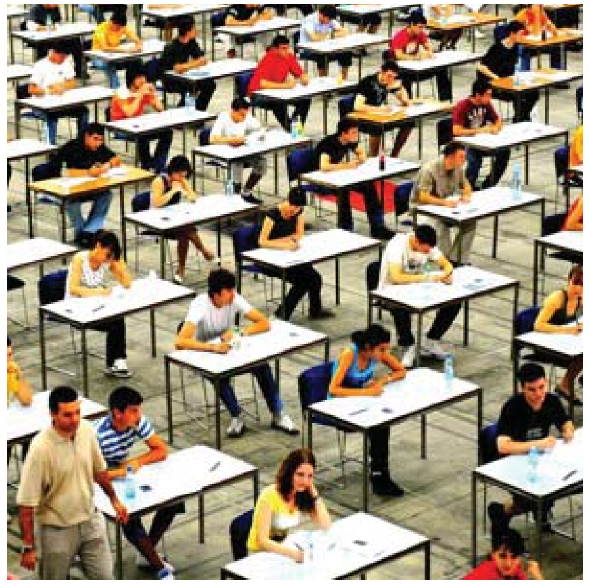
Almost all the challenges that really matter involve systems, e.g.,

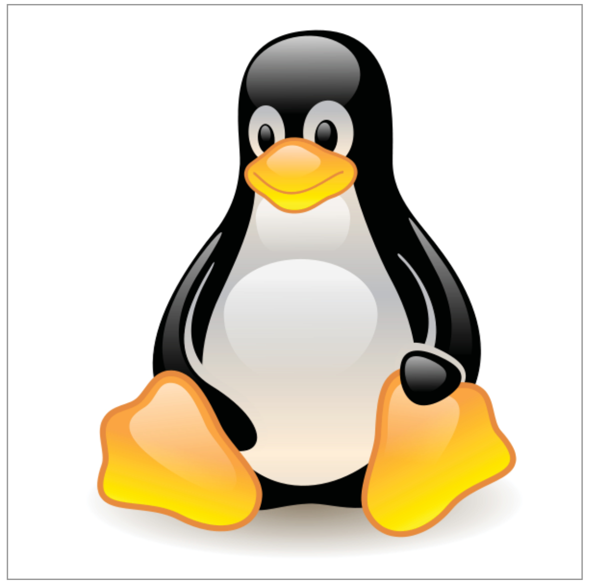
- The environment, energy, and global warming
- Water, food, and population
- Health, justice, and security

Some definitions of systems

Systems are all around us; consider these examples.
What makes them “systems”? or gives them “system-ness”?





Anti-lock Brake System (ABS)

Columbia Broadcasting System (CBS)

Criminal Justice System

Domain Name System (DNS)

Federal Reserve System

Honor System

Interstate Highway System

Linux Operating System (OS)

A definition

A system a whole or unity, also network or structure
is a set of elements parts or components, also nodes or nouns

that someone sees an observer, with a POV, by definition subjective
as related — linked or interacting, through rules or principles for action or behavior — also edges or verbs
organized in some way — The relationships unite the elements, thus separating them from their environment
often with a purpose, function or goal or goals
perhaps with unpredictable results. emergent properties

*"A system is a set of things—
people, cells, molecules, or whatever—
interconnected in such a way
that they produce their own pattern of
behavior over time."*

— Donella H. Meadows

"A system isn't just any old collection of things.

*A system is an interconnected set of elements
that is coherently organized
in a way that achieves something."*

— Donella H. Meadows.

How to know whether you are looking at a system or just a bunch of stuff :

A) Can you identify parts? **[elements]**. . . and
B) Do the parts affect each other? **[connections]** . . . and
C) Do the parts together produce an effect **[purpose]** that is different from the effect of each part on its own? . . . and perhaps
D) Does the effect, the behavior over time, persist in a variety of circumstances?

— Donella H. Meadows.

“A system is more than the sum of its parts. It may exhibit adaptive, dynamic, goal-seeking, self-preserving, and sometimes evolutionary behavior.”

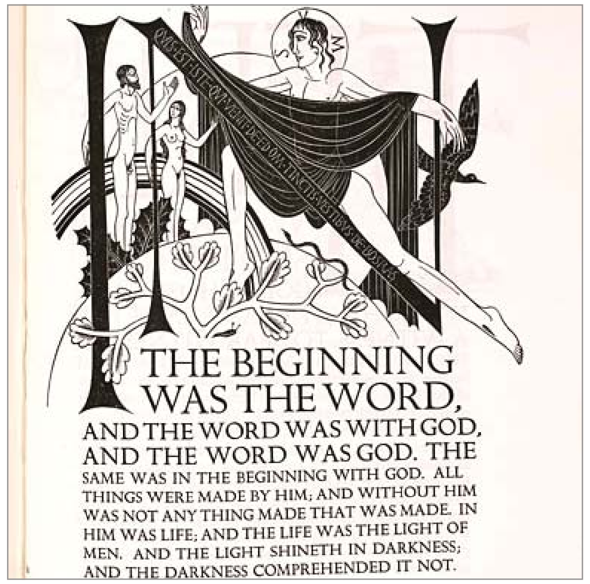
— Donella H. Meadows

West Churchman describes a system in terms of 5 “considerations”:

1. objectives
2. environment
3. resources
4. components
5. management

What systems literacy might be

Systems may be categorized in many ways—
By domain or “content type.”



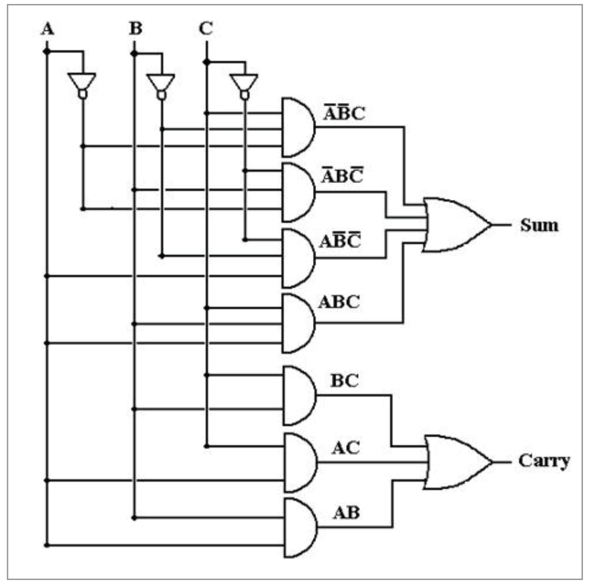
—

Energy systems

Economic systems

Explanatory systems

Information systems



—

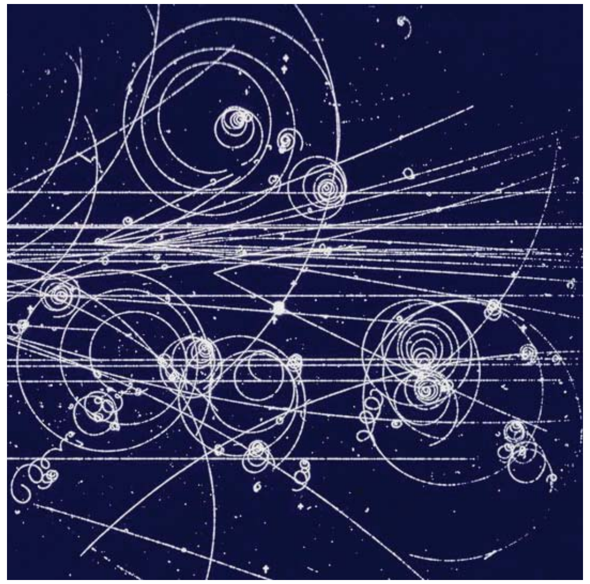
Language systems

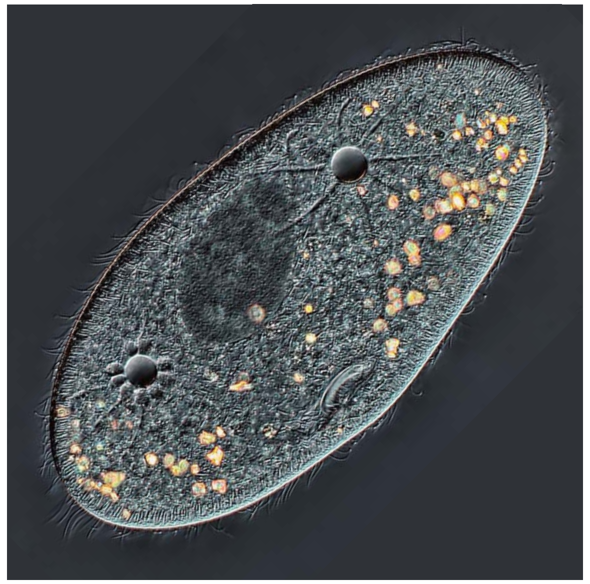
Logical systems

Physical systems

Social systems

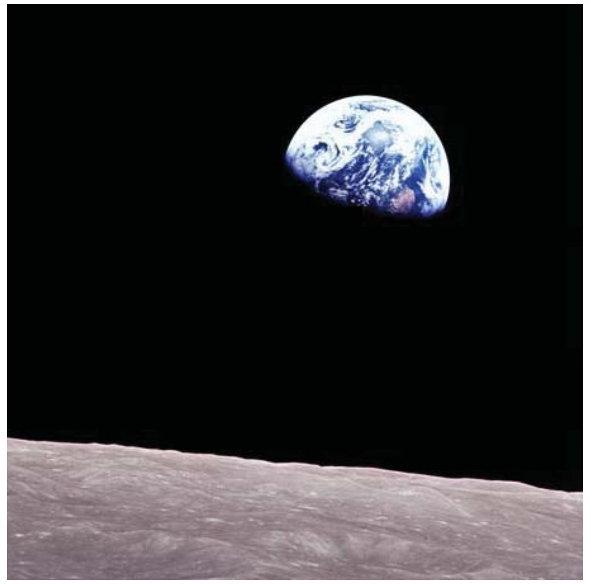
Systems may be categorized in many ways—
By scale—small or large.






- Particles
- Atoms + molecules
- Cells
- Multi-celled organisms






- Social systems
- Ecosystems
- Biosphere
- Galaxies

Systems may also be categorized by **structure** —
how they behave.

Looking past domain and scale to structure
gives the “systems approach” great power,

It creates a “lingua franca” — a universal language —
that we may apply in many situations.

Systems may also be categorized by structure — for example...

Systems can be

Static or **Dynamic**

which can be **Linear** or **Closed-loop**

which can be **Recirculating** or **Self-regulating**

which can be **First-order** or **Second-order**

which can be **Self-adjusting** or **Learning**

—After Kenneth Boulding

Levels of Systems

the level of **Frameworks**	Only the geography and anatomy of the subject is described and analyzed; a kind of system of static relations. [Most architecture and graphic design systems are of this type.]
the level of **Clockworks**	Machines that are determined.
the level of **Thermostats**	The level of control in mechanical and cybernetical [sic] systems.
the level of the **Cell**	As an open and self-maintaining system, having a throughput that transforms unpredicted inputs into outputs [what Maturana, Varela, and Uribe later called an "autopoetic" system].
the **Genetic** and **Societal** level	Of plants and accumulated cells.
the level of the **Animal**	Specialized receptors, a nervous system, and an "image".
the **Human** level	All of the previous six—plus self-consciousness. The system knows that it knows, and knows that it dies.
the level of the **Social Organism**	The unit at this level is a role, rather than a state; messages with content and meaning exist, and value systems are developed.
the level of **Transcendental** systems	The "ultimates" and "absolutes" and the "inescapables" with systematic structure.

— Kenneth Boulding, 1956

Classification of systems, Stafford Beer, 1959
from *Cybernetics and Management*

SYSTEMS	*Simple*	*Complex*	*Exceedingly complex*
Deterministic	Window catch	Electronic digital computer	EMPTY
	Billiards	Planetary system	
	Machine-shop lay-out	Automation	
Probabilistic	Penny tossing	Stockholding	The economy
	Jellyfish movements	Conditioned reflexes	The brain
	Statistical quality control	Industrial profitability	THE COMPANY

Figure 6.3. Beer's classification of systems. Source: S. Beer, *Cybernetics and Management* (London: English Universities Press, 1959), 18.

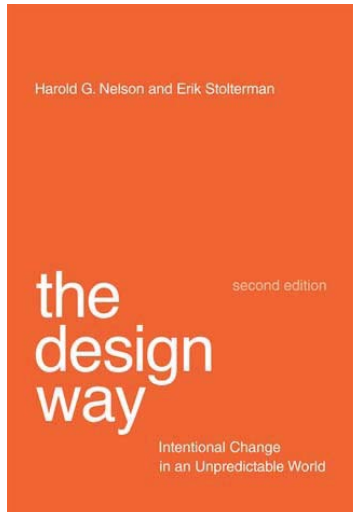
Hierarchy of change, Harold Nelson + Erik Stolterman, 2012
from *The Design Way: Intentional Change in an Unpredictable World*

change is **difference**

change of *difference* is **process**

change of *process* is **evolution**

change of *evolution* is **design**



Churchman outlines four approaches to systems:

efficiency expert:
reducing time and cost

scientist:
building (mathematical) models

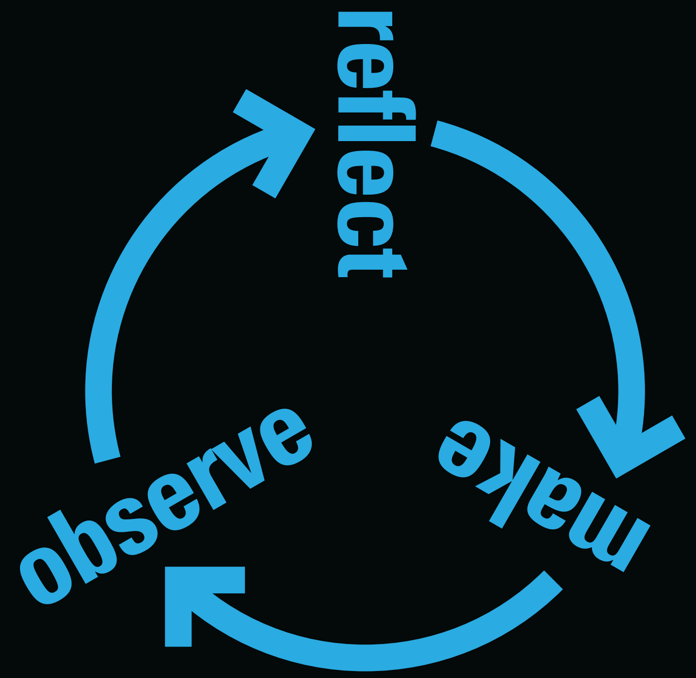
humanist:
looking to our values

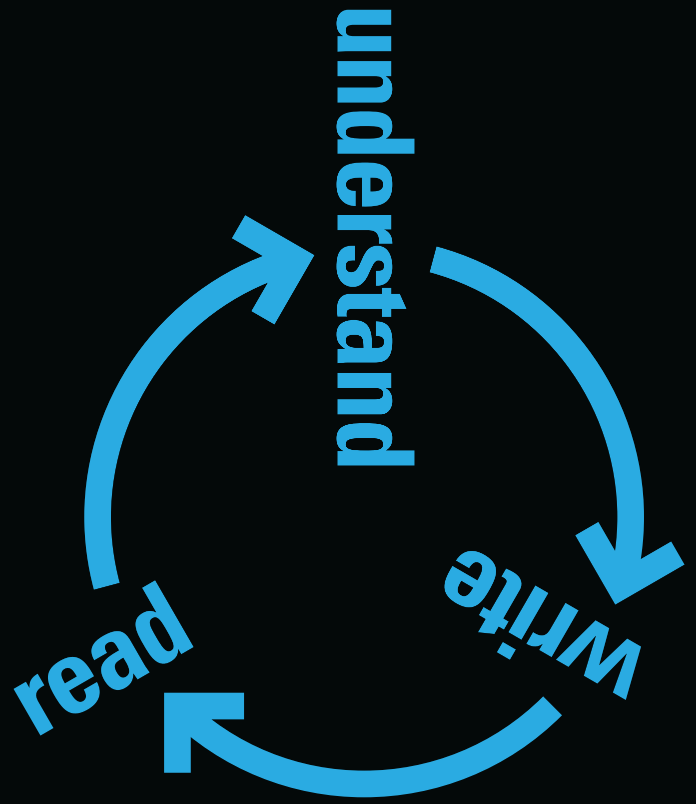
anti-planners:
living *in* systems, not imposing plans

We might consider a fifth approach:

designer:

prototyping and iterating systems
or representations of systems





Basic systems literacy includes:

- **“reading”** (skills of analysis):
  recognizing common patterns in specific situations
  e.g., identifying—finding and naming—a control loop
- **understanding** (vocabulary and frameworks):
  a set of distinctions and entailments (relationships)
- **“writing”** (skills of synthesis):
  describing the function of systems to others,
  mapping and diagramming

Reading systems means recognizing common patterns in specific situations.

e.g.,

- resource flows and cycles
- transform functions (processes)
- feedback loops
- feed-forward
- requisite variety
- second-order feedback
- goal-action trees

Understanding systems requires a vocabulary of about 150 terms:

system, environment, boundary
stocks, flows, delay (lag)
source, sink
process, transform function, cycle
information (signal, message),
goal (threshold, set-point), feedback

circular processes, circularity
closed-loop, open-loop
viscous cycle, virtuous cycle
explosion, collapse, dissipation
negative feedback, positive feedback
reinforcing, dampening, balancing
stability, invariant organization,
dynamic equilibrium, homeostasis
tragedy of the commons

behavior, action (task), measurement
range, resolution, frequency
sensor, comparator, actuator (effector)
current state, desired state
error, detection, correction
disturbances, responses

controlled variable, command signal

servo-mechanism, governor
hunting, oscillation, prediction

control, communication
teleology, purpose
goal-directed, self-regulating
co-ordination, regulation

emergence
feedforward

static, dynamic
first order, second order

essential variables
variety, “requisite variety”
transformation (table)

autopoiesis, allopoetic systems
constructivism
recursion

observer, observed
controller, controlled

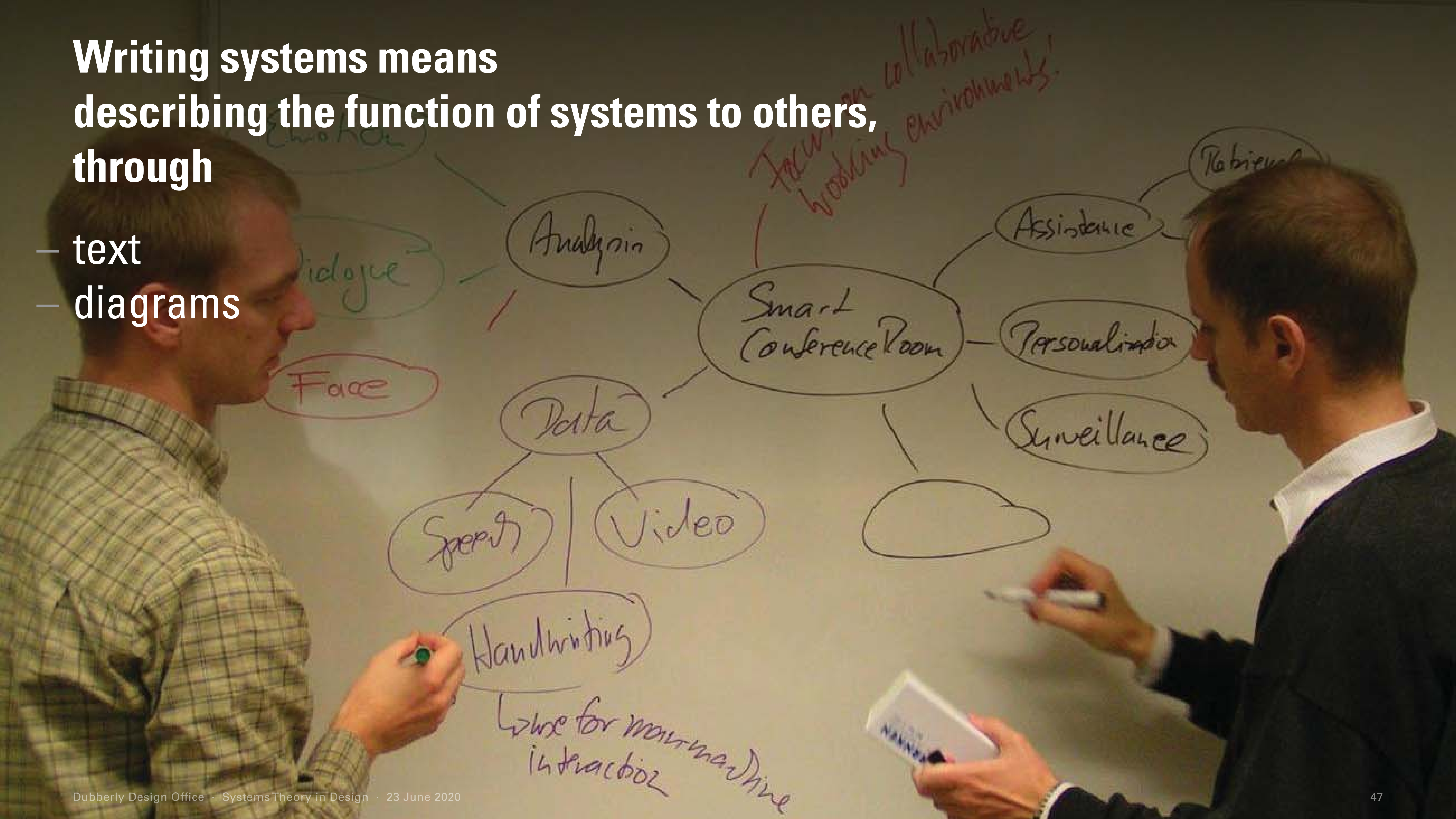
agreement, (mis-)understanding
“an agreement over an understanding”
learning, conversation
bio-cost, bio-gain
back-talk

structure, organization,
co-evolution, drift

black box
explanatory principle
“organizational closure”
self-reference, reflexive
ethical imperative
“generosity in design”
structural coupling
“consensual co-ordination of consensual co-ordination”
“conservation of a manner of living”

Writing systems means describing the function of systems to others, through

- text
- diagrams



Systems literacy is enriched with:

- **literature:**
  a canon of key works of theory and criticism
- **history:**
  context, sources, and development of key ideas
- **connections:**
  conversations among and between disciplines
  e.g., design methods and management science

Schedule overview

Systems Theory in Design— in three phases:

1.0 – Fundamentals of systems thinking
Holidays (August)
2.0 – Advanced perspectives
3.0 – Applications

1.0 – Fundamentals of systems thinking

23 June	1.1 – Overview
30 June	1.2 – Models: what, how, and why + cases
07 July	1.3 – Design systems
14 July	1.4 – Nodes, links, and networks
21 July	1.5 – Systems dynamics
28 July	1.6 – Feedback, control, and cybernetics
04 August	1.7 – Emergence
Holidays	

2.0 – Advanced perspectives

08 September	2.1 – Requisite variety
15 September	2.2 – Feed-forward
22 September	2.3 – Second-order systems + learning
29 September	2.4 – Third-order systems + bootstrapping
06 October	2.5 – Conversation
13 October	2.6 – Evolution
20 October	2.7 – Ethics from a systems perspective

3.0 – Applications

27 October	3.1 – Stacks
03 November	3.2 – Platforms
10 November	3.3 – Smart, connected products
17 November	3.4 – Data refineries
24 November	3.5 – Digital twins
01 December	3.6 – Prediction
08 December	3.7 – Self-driving organizations

PART ONE

Fundamentals

Models: what, how, and why + cases

Text can describe a system's function, linking it to a common pattern.

But text descriptions require mental gymnastics from readers—*imagining* both the behavior of the system and the abstract functional pattern—*and* then linking the two.

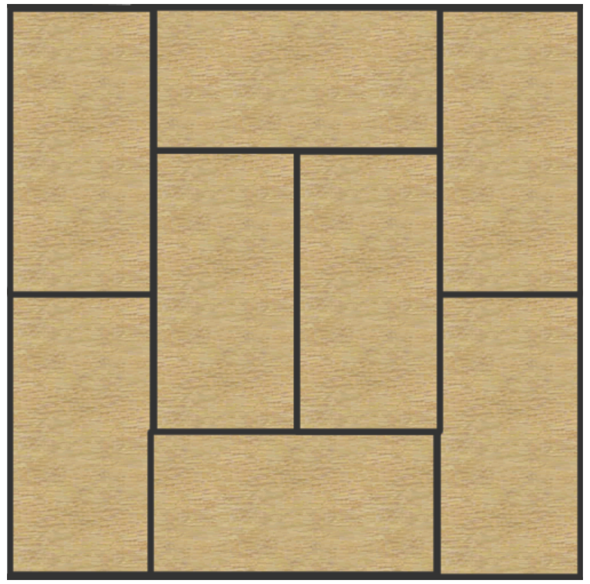
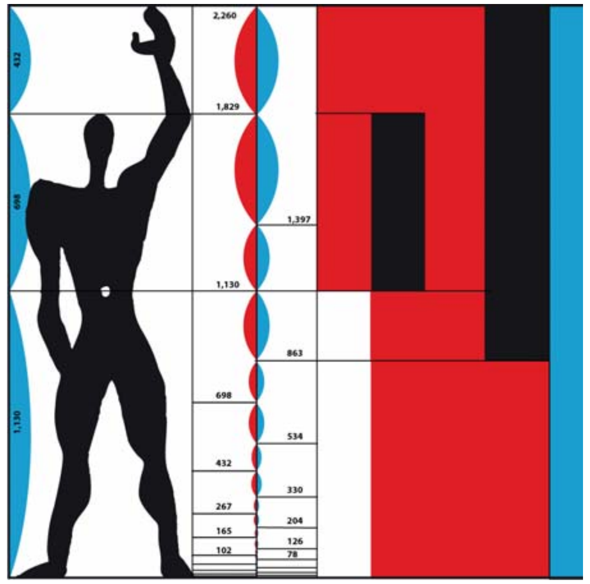
"Sentential representations are sequential, like the propositions in a text. Diagrammatic representations are indexed by location in a plane. Diagrammatic representations also typically display information that is only implicit in sentential representation and that therefore has to be computed, sometimes at great cost, to make it explicit for use."

—Herbert Simon
"Why a diagram is (sometimes) worth ten thousand words", 1987

Design systems

Designers tend to think of systems in formal terms,
a theme and rules for variation and extension.



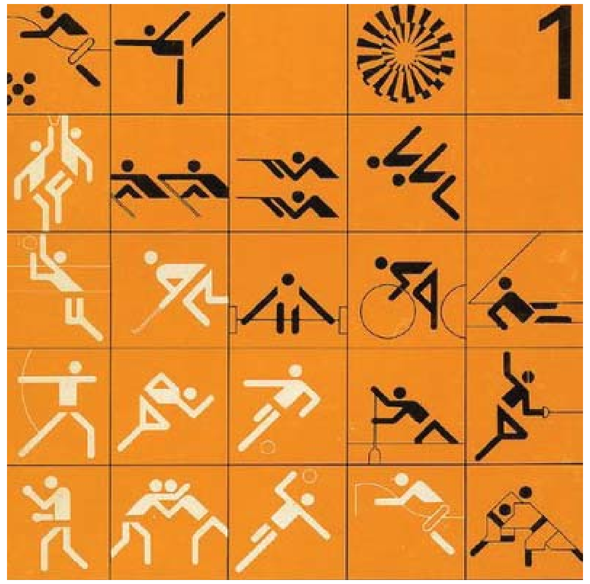
—

The Alhambra
Granada, ~1250

Münster Cathedral Cloister
Basel, ~1421

Tatami mats
Japan, ~1650

Le Modulor
Le Corbusier, 1950


—

Univers
Adrian Frutiger, 1957

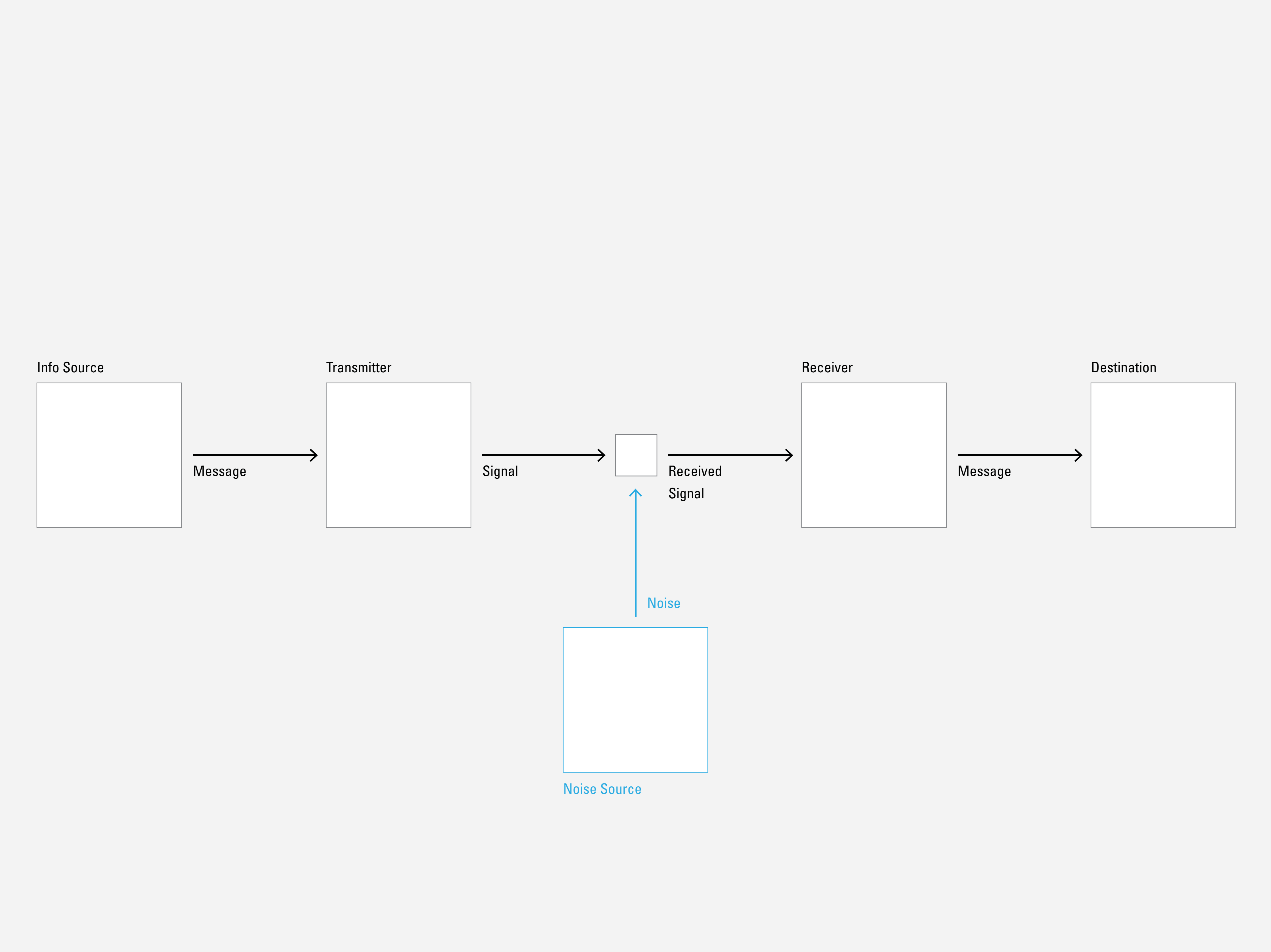
Schiphol airport signage system
Benno Wissing, 1967

Münich Olympics graphic standards
Otl Aicher, 1972

Oxo Good Grips
Sam Farber, 1989

Nodes, links, and networks

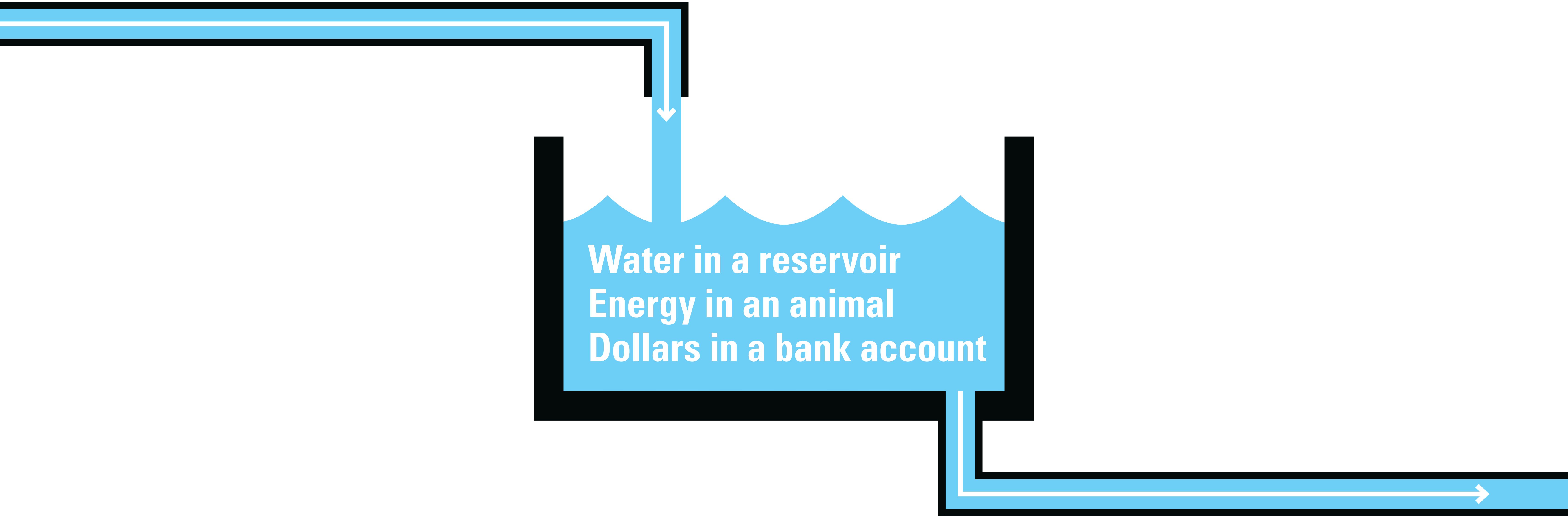
Mathematical Model of Communication



Systems dynamics

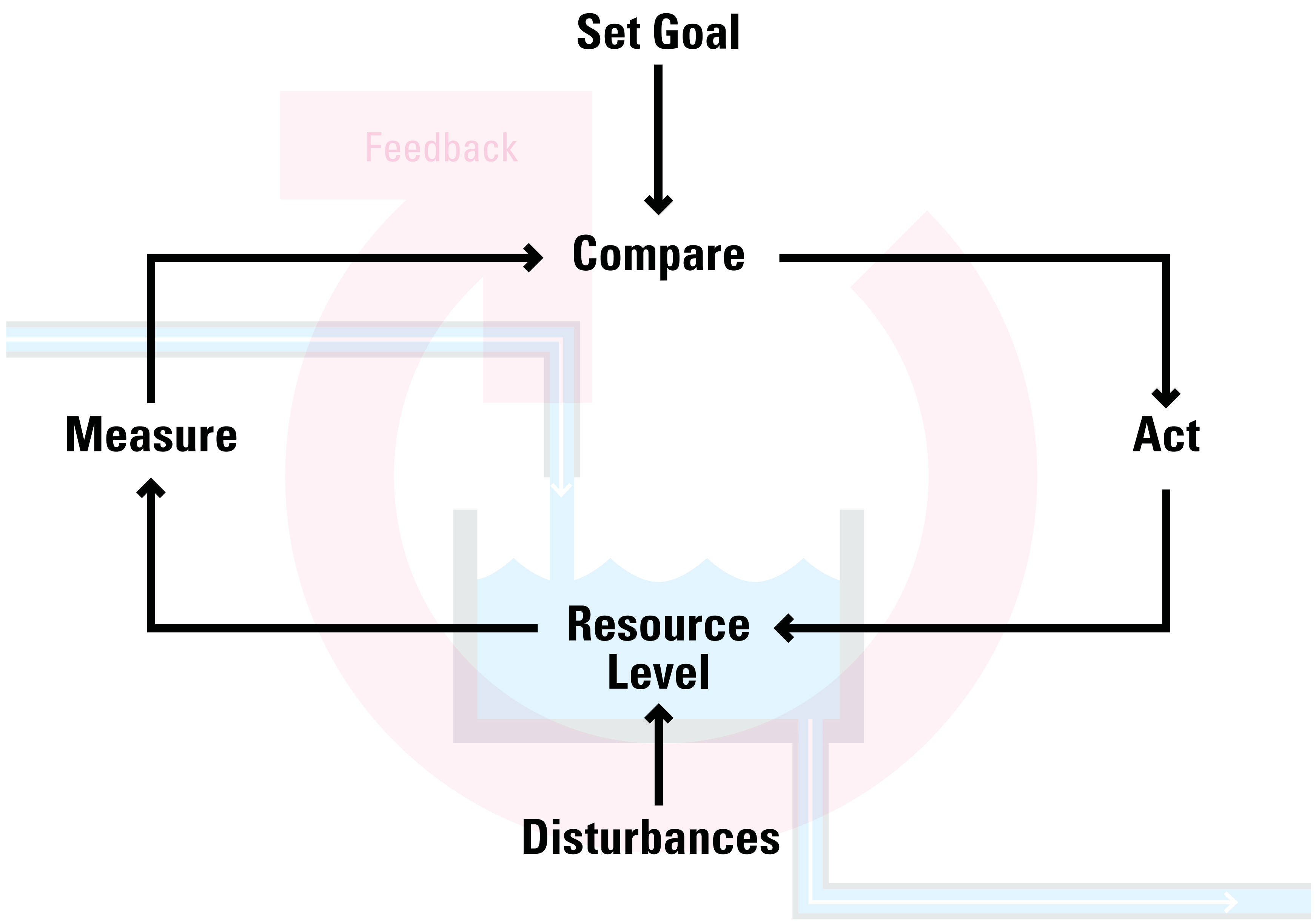
Stocks + flows, sources + sinks, lag, dynamic equilibrium
Resource cycles

Dynamic equilibrium is a state of balance—
a resource that stays at the same level
even as it flows through a system.



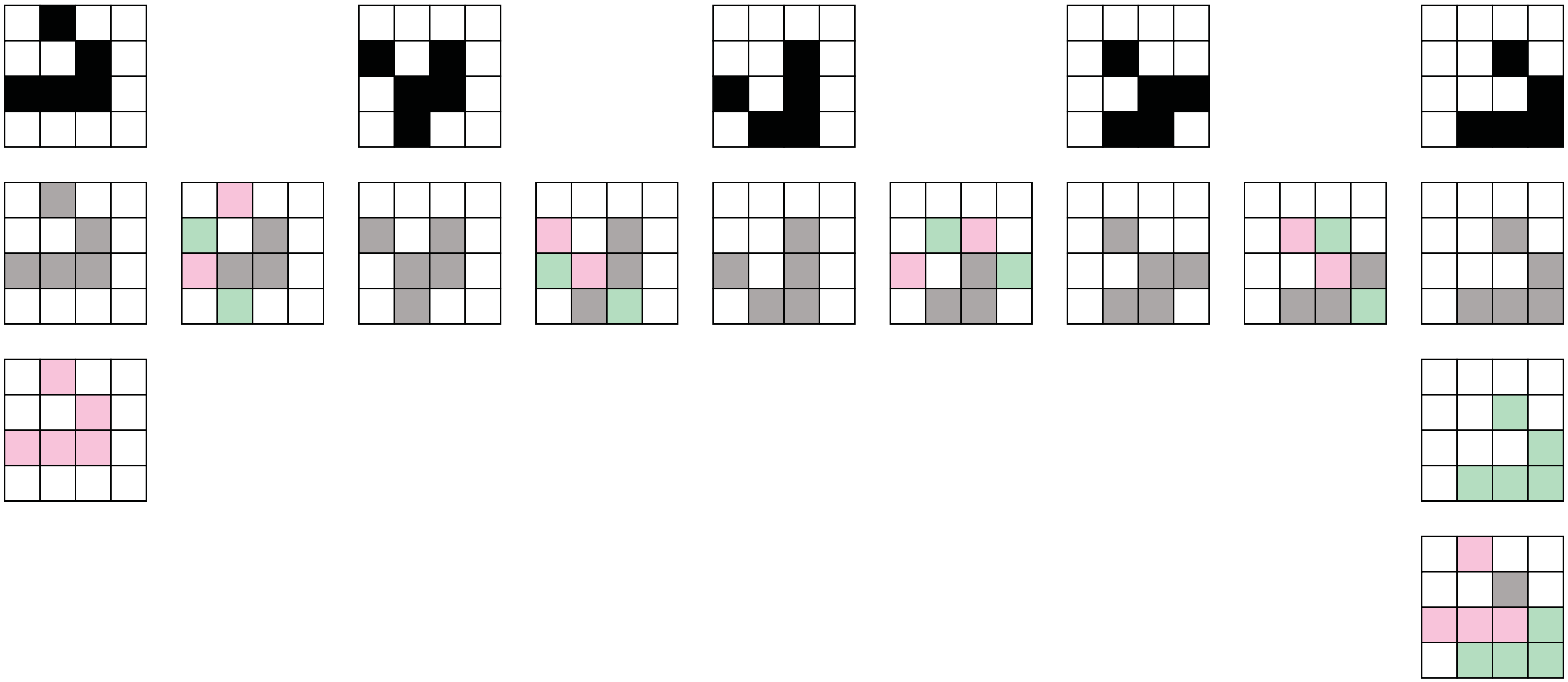
Feedback, control, and cybernetics

Self regulation is a process of maintaining balance— using feedback to control the resource level, e.g., governing how much flows in or out.



Emergence

For example, steps in a cellular automata glider path

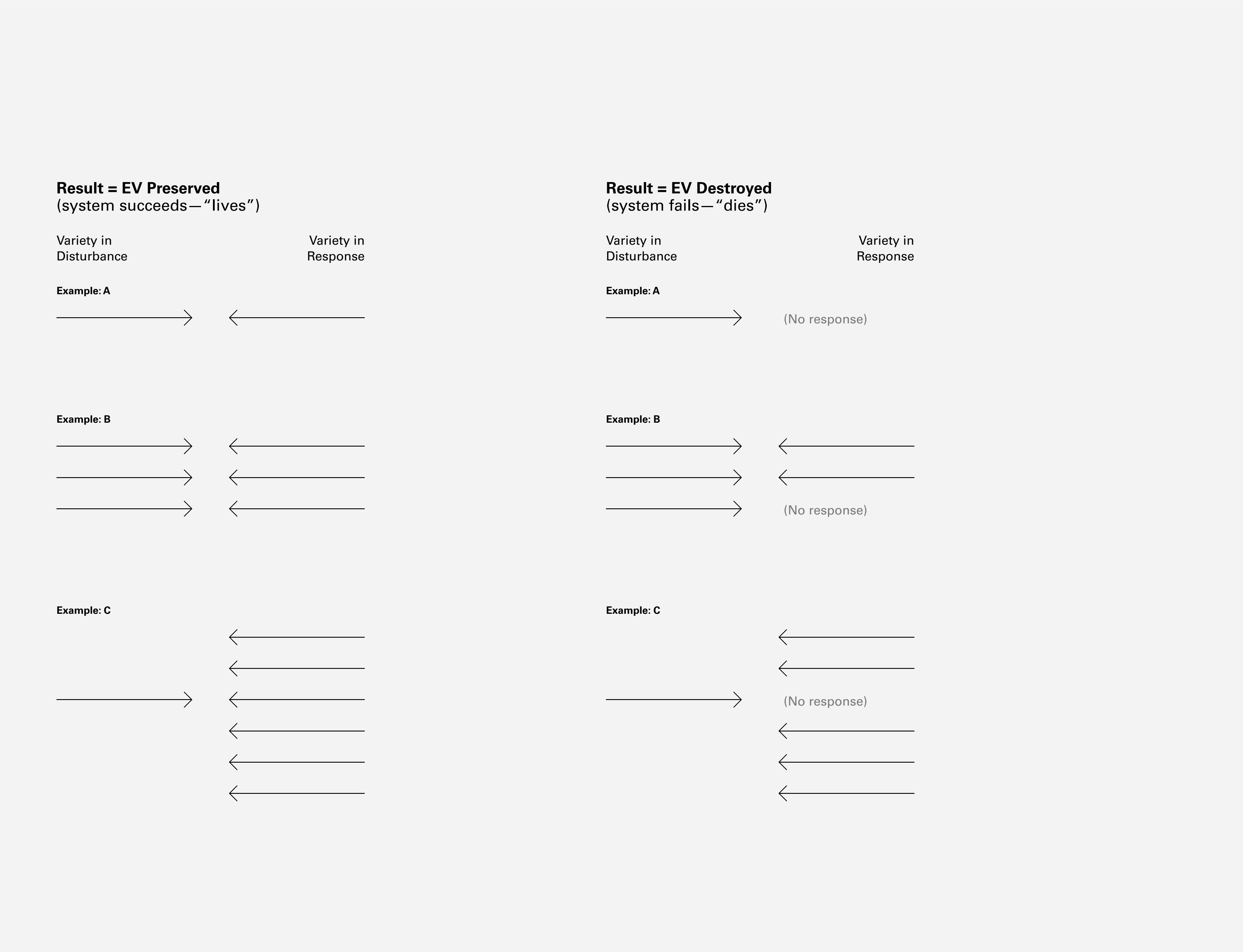


Advanced perspectives

Requisite variety

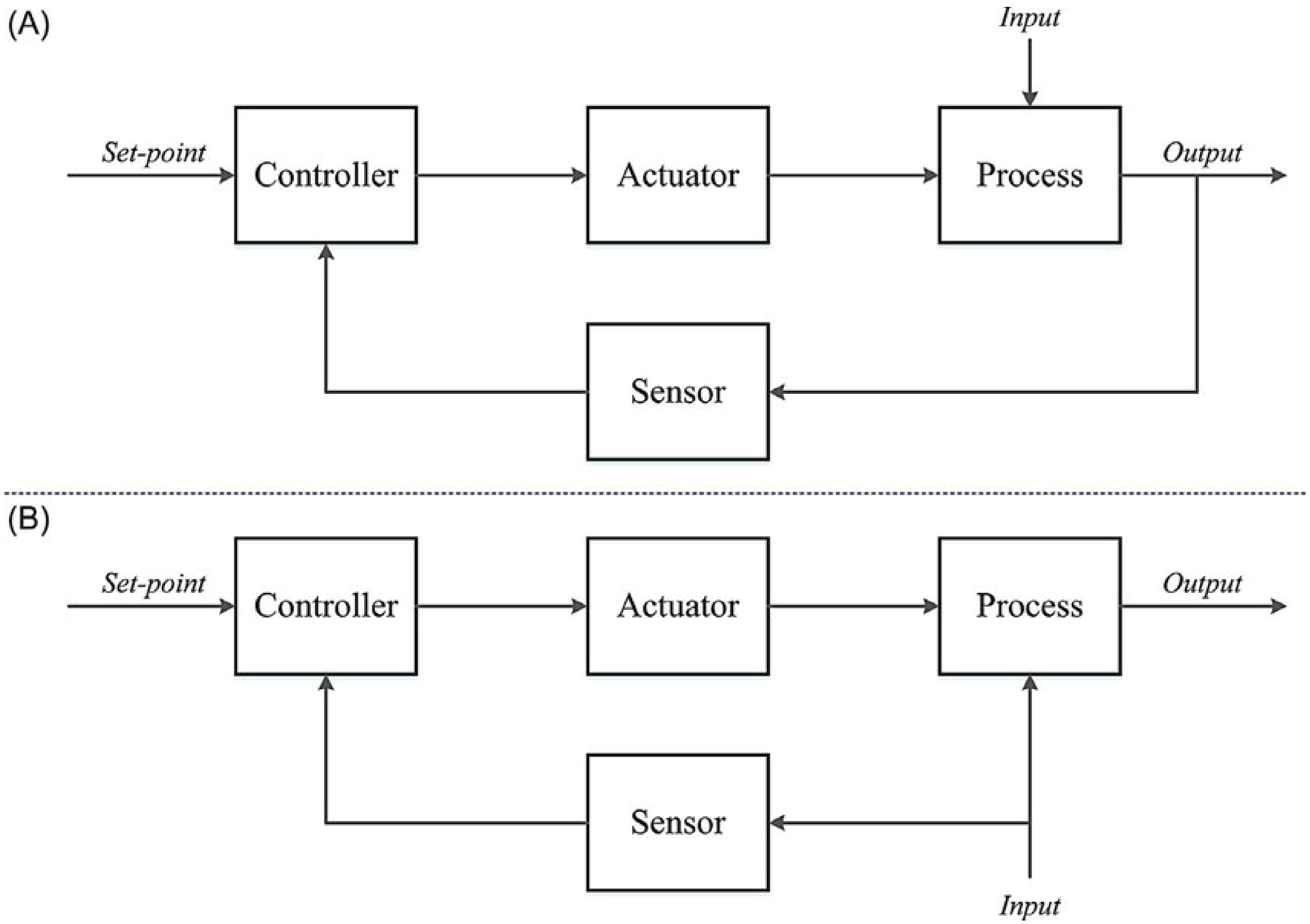
Diversity as information
Benefits + costs

Variety counters variety.



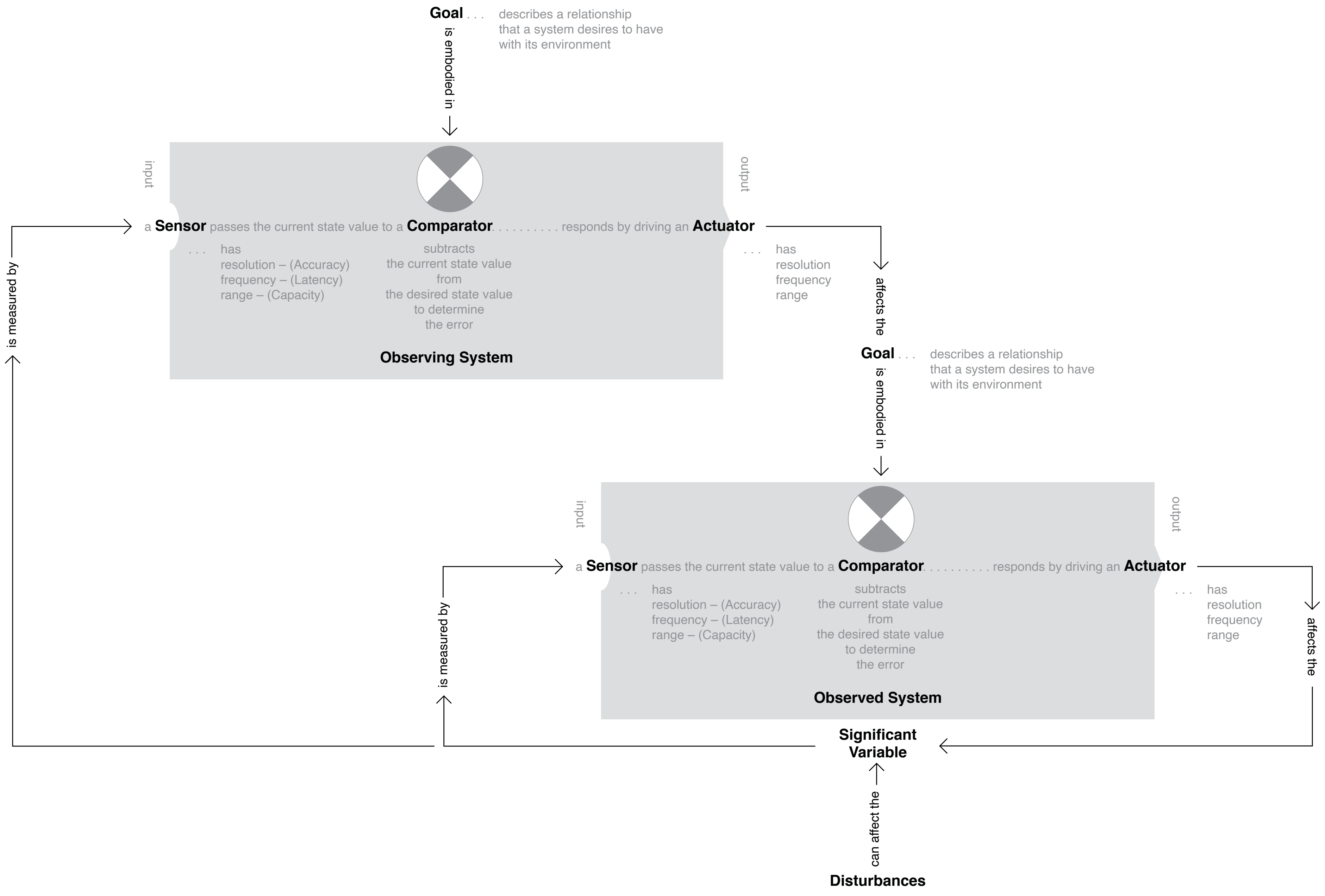
Feed-forward

Feed-forward measures an input signal and acts to modify it before the main process.



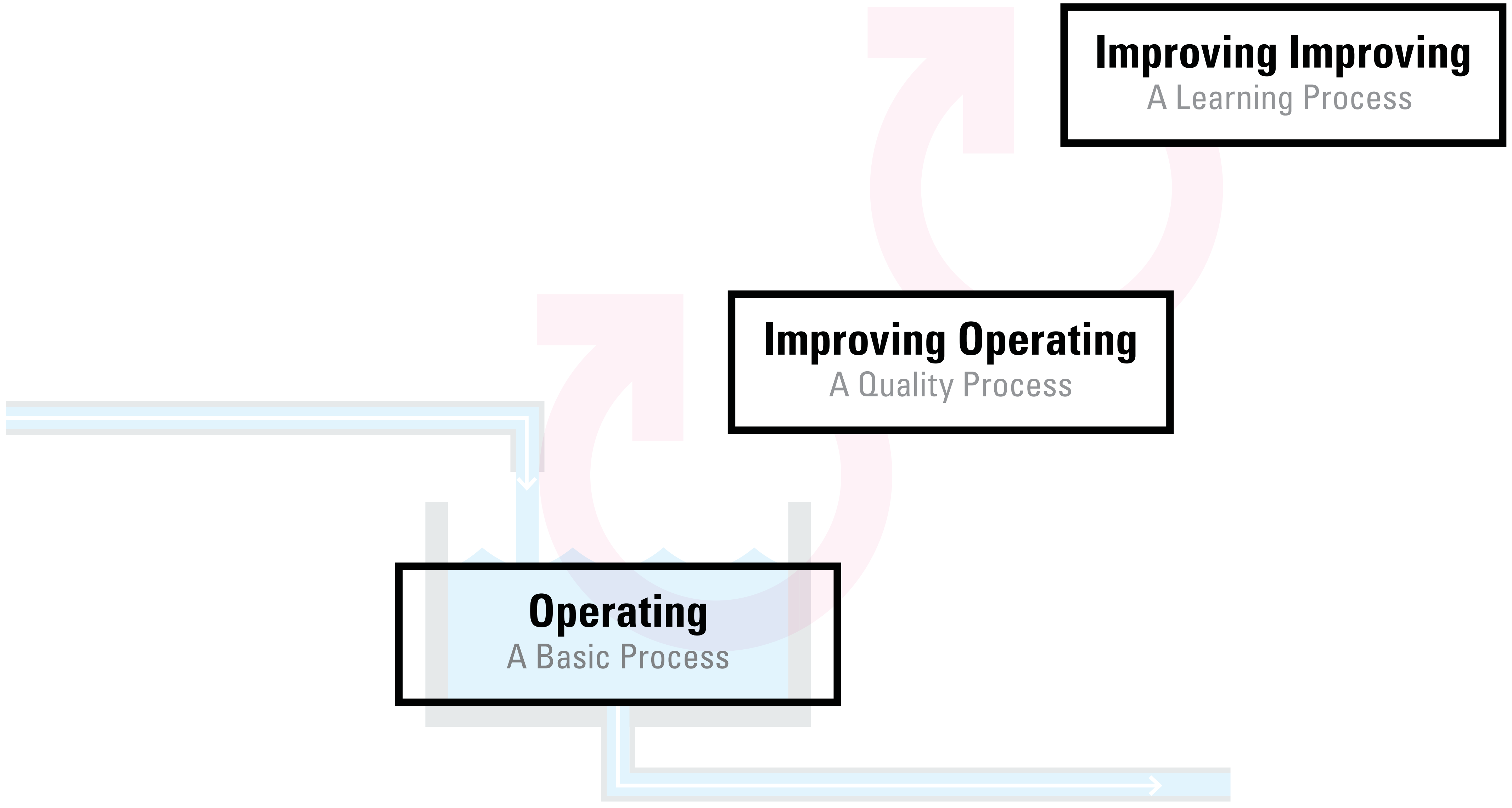
Second-order systems + learning

A second-order systems sets the goals of a first-order system.



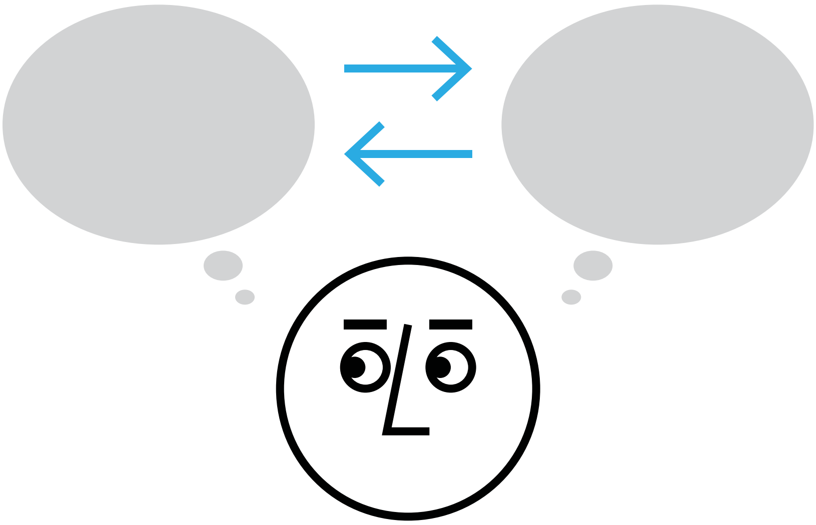
Third-order systems + bootstrapping

Boot-strapping is a process of self-improvement—
studying a basic process to improve it
and in turn studying the improvement process to improve it.

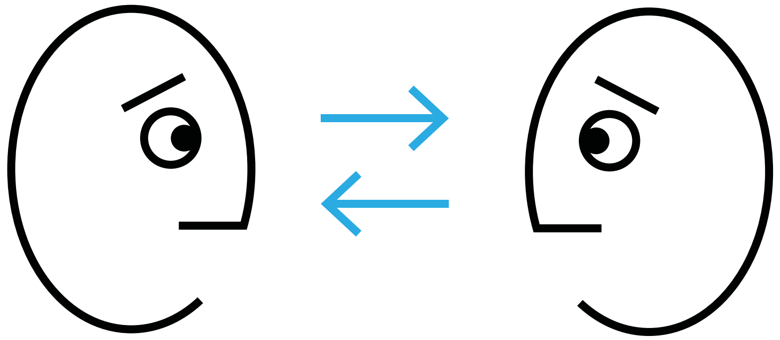


Conversation

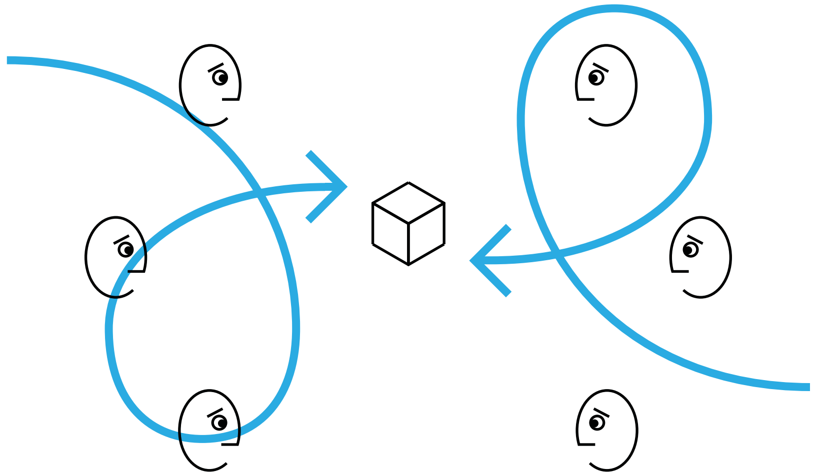
Conversation takes place in **three domains**



Between you and yourself,
e.g., a soccer player weighs options for a kick



Between you and another person,
e.g., two players pass the ball back and forth



Between one group and another,
e.g., two teams interact throughout a match

Evolution

Evolution involves:

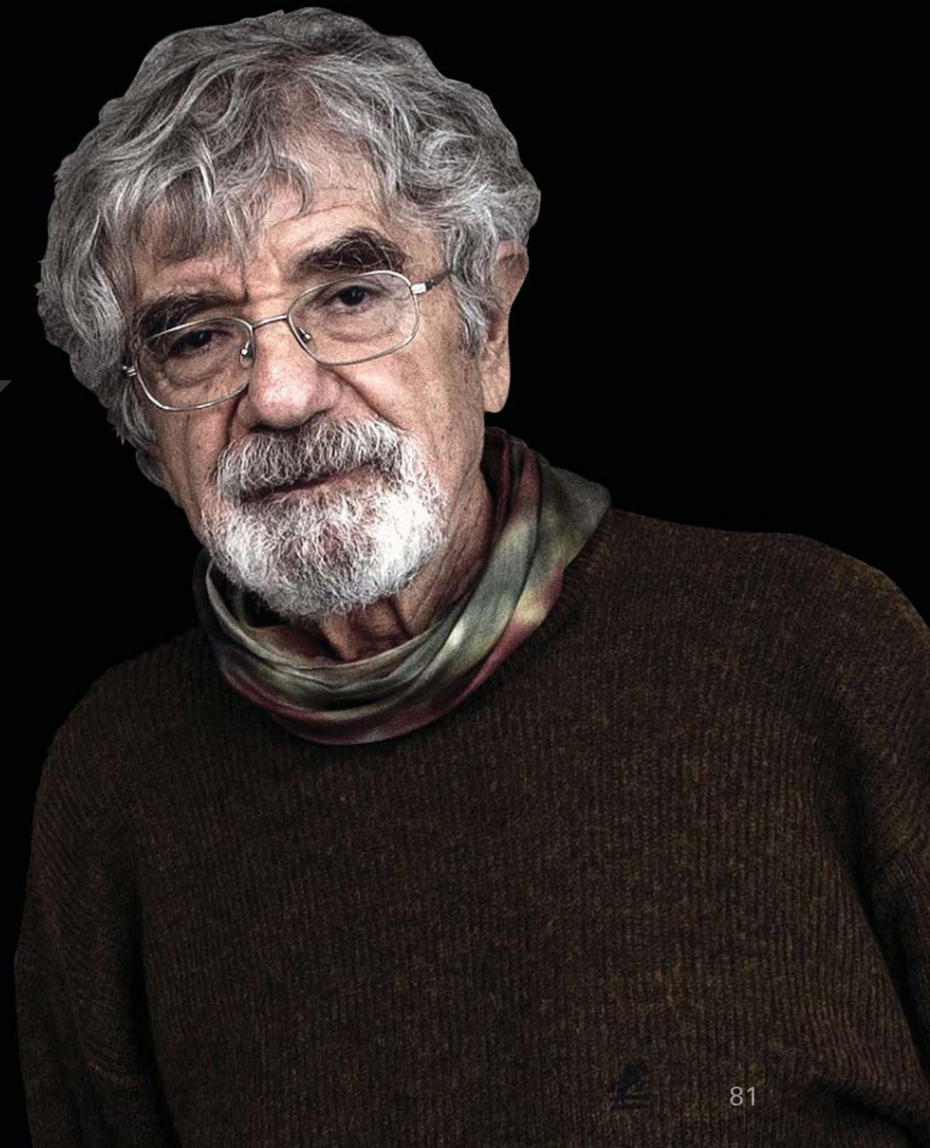
Variation + selection,
based on competition + cooperation,
in a cycle of iteration,
in the context of a changing environment,
i.e., increasing or decreasing resources or threats

Ethics from a systems perspective

"We human beings can do whatever we imagine if we respect the structural coherences of the domain in which we operate.

But we do not have to do all that we imagine, we can choose, and it is there where our behavior as socially conscious human beings matters."

— Humberto Maturana, 1997



PART THREE

Applications

Stacks

A stack is a series of layers, separated by clearly defined APIs, which enable one layer to change independent of the others.

Local Documents	.doc, .xls, .ppt, etc.
PC Apps	Word, Excel, PowerPoint, etc.
Operating System (OS)	Windows
Processor	8086, 80286, 80386, etc.

Platforms

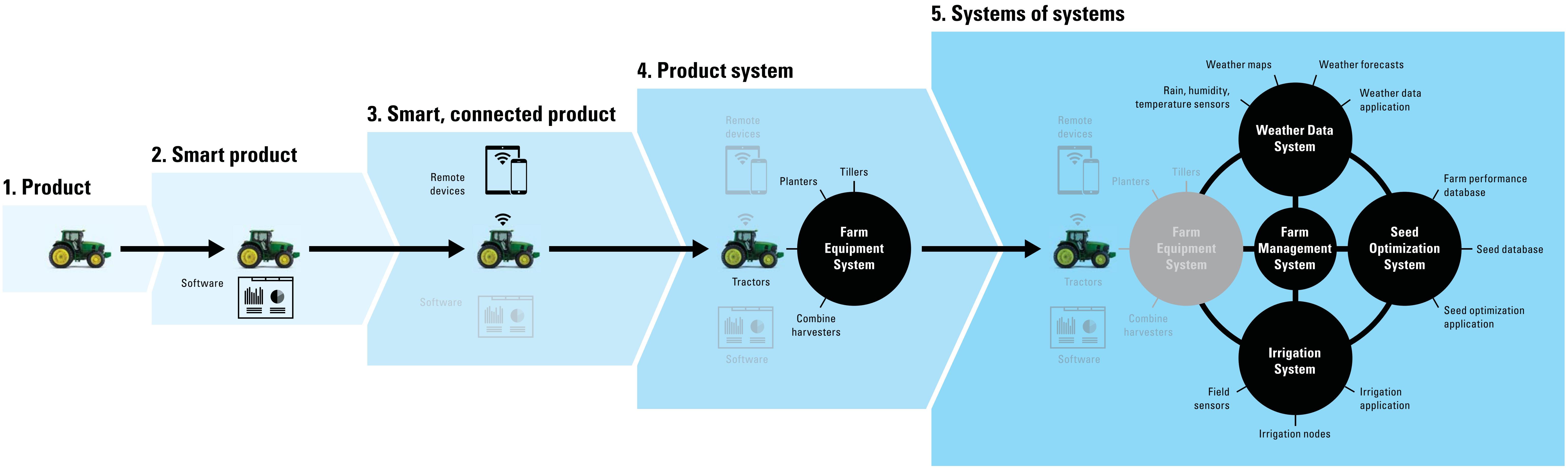
What's a platform?

"A 'platform' is a system that can be programmed and therefore customized by outside developers—users—and in that way, adapted to countless needs and niches that the platform's original developers could not have possibly contemplated, much less had time to accommodate."

—Marc Andreessen, co-founder of Netscape and Andreessen-Horowitz

Smart, connected products

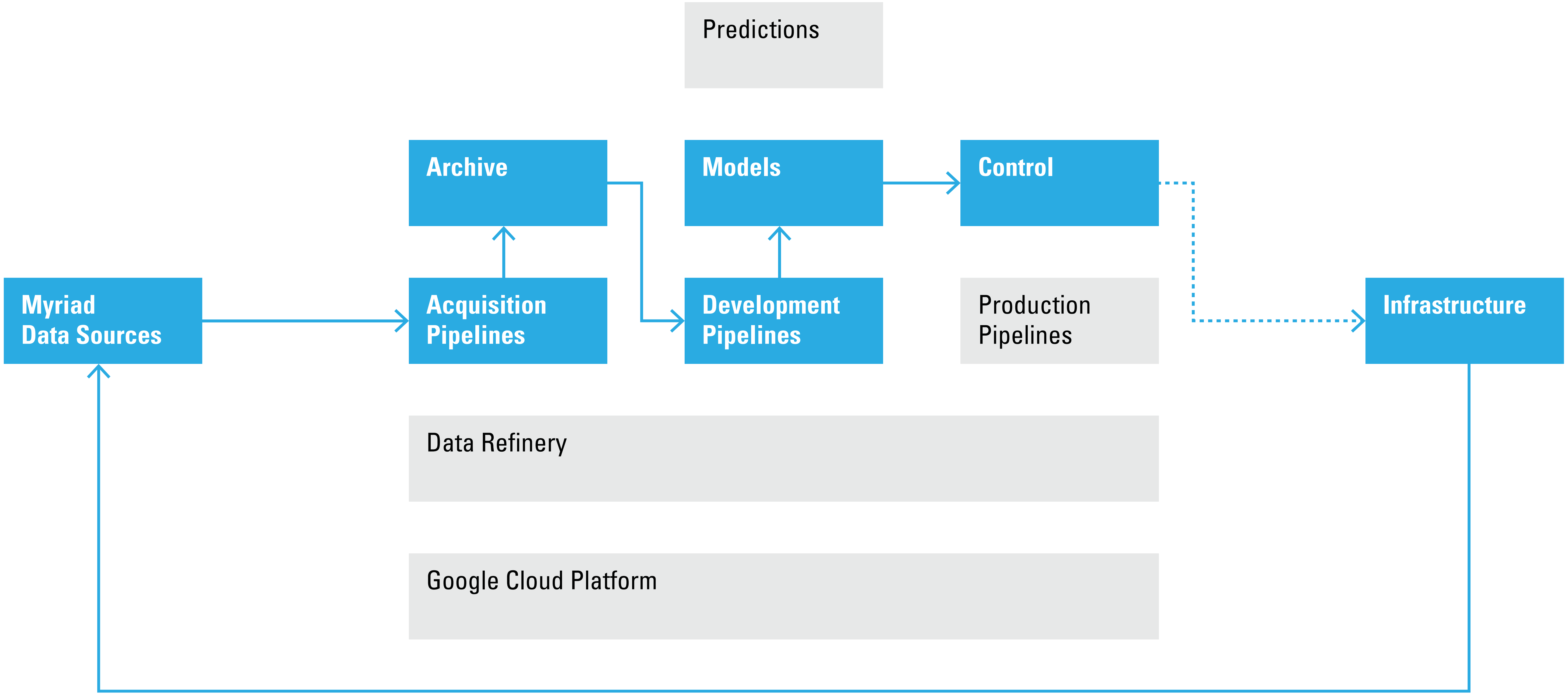
"Smart, connected products are transforming competition" and "redefining industry boundaries."



— **Michael Porter**, HBR, 2014

Data refineries

As production systems accumulate data and results, they improve their models — effectively “learning“.



Digital twins

The term "digital twin" seems to arise from NASA research.

"If various best-physics
(i.e., the most accurate, physically realistic and robust)
models can be integrated with one another and
with on-board sensor suites,
they will form a basis for certification of vehicles by
simulation and for real-time, continuous, health management
of those vehicles during their missions.
They will form the foundation of a Digital Twin."

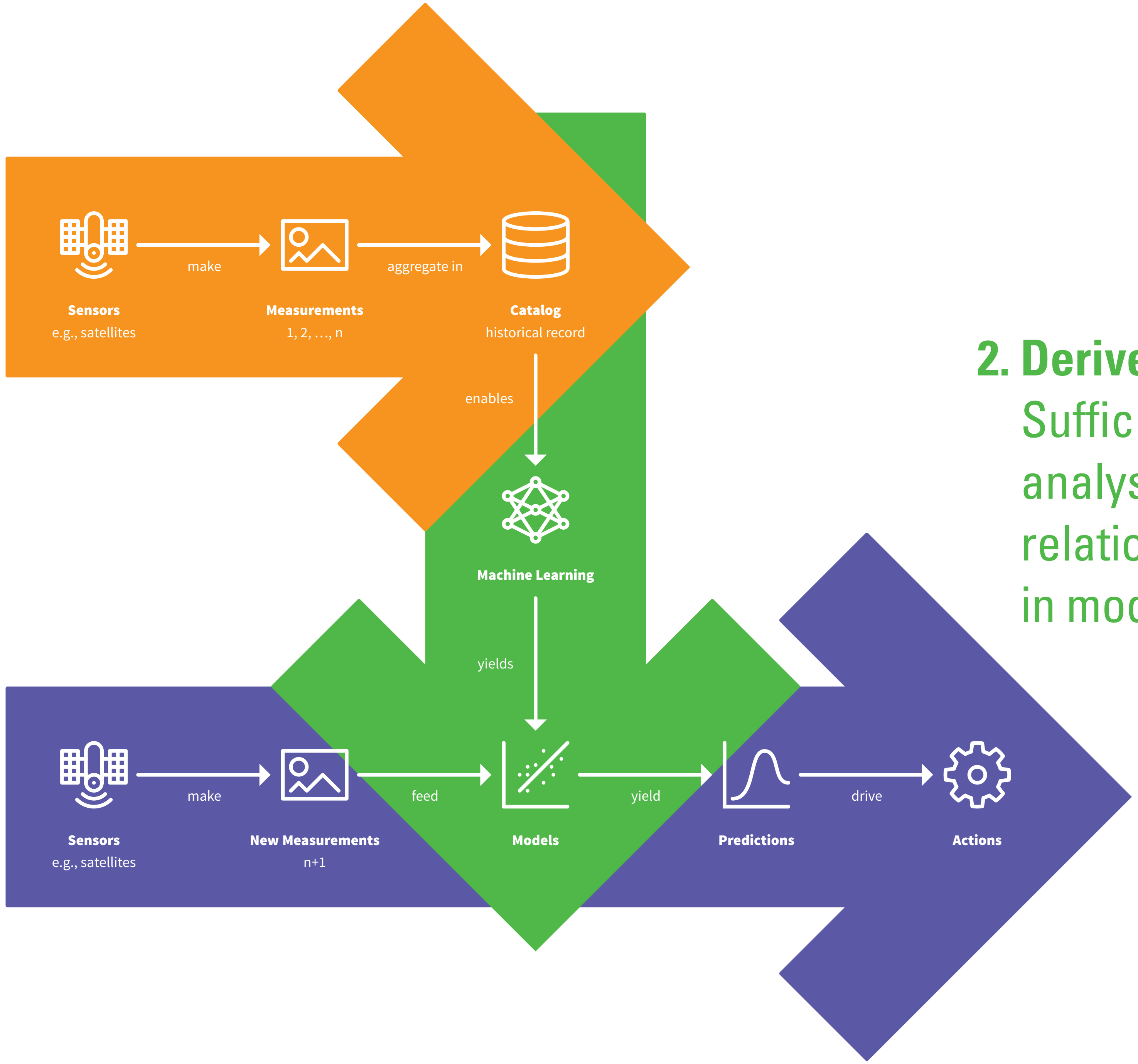
— **Stargel and Glaessgen**, The Digital Twin Paradigm for Future NASA and U.S. Air Force Vehicles, 2012

Prediction

Pattern-finding software (AI: DL, ML, CV, NLP), algorithms making sense of measurements.

1. Gather histories

Sensors make a series of point in time measurements. As measurements accumulate, a historical record emerges.



2. Derive models

Sufficient historical data enables analysts to discover patterns and relationships—these are codified in models.

3. Predict futures

Once trained, new measurements are fed through the model to predict the future—enabling us to act today.

Self-driving organizations

The first semi-autonomous organizations are already here.

amazon

Google

NETFLIX

facebook

Cambridge Analytica

Internet Research Agency

Special thanks to
Firat Toroglu
Connor Upton
Jamie Ikeda

hugh@dubberly.com

Presentation posted at
systems.dubberly.com/overview.pdf