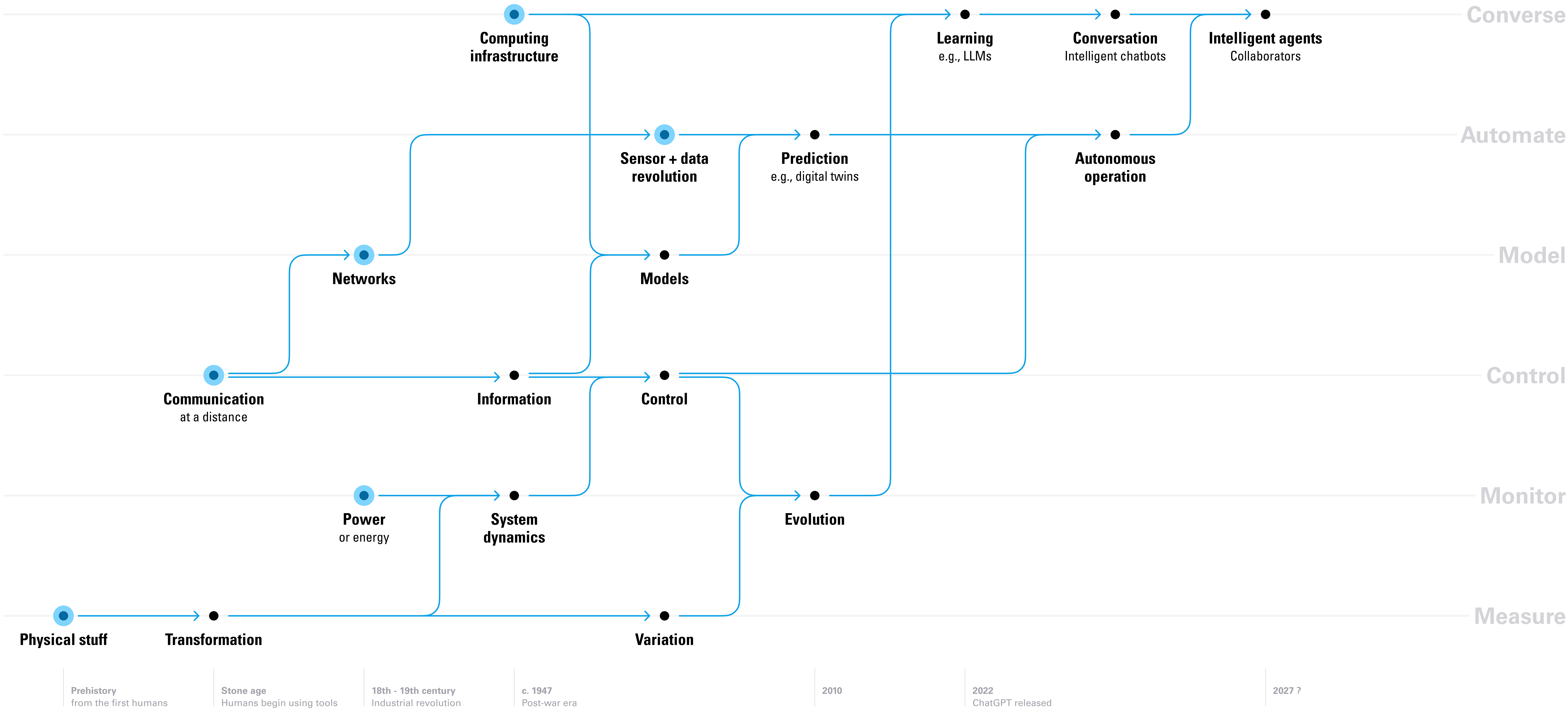
November 15, 2023

Core models for systems designers by week

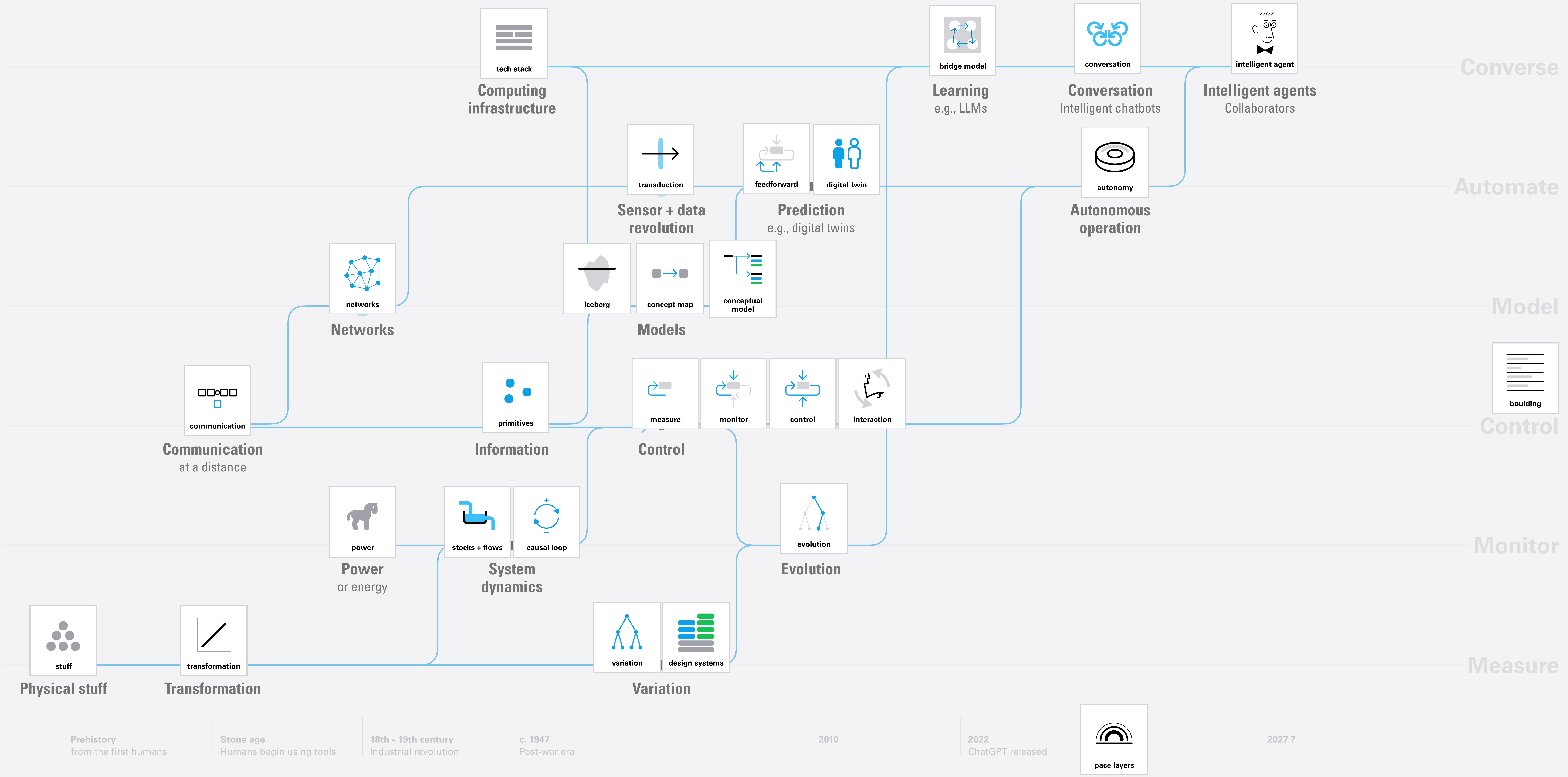
Version 2

Dubberly Design Office

Growth of system capabilities over time



Models of system capabilities



Core models for systems designers — by week

Week 1
- Iceberg Model
- Concept Maps
- Bridge Model

Week 2
- Boulding
- Pace Layers

Week 3
- Transform Function
- Communication
- Tech Stack

Week 4
- Information Structures
- Networks

Week 5
- Variation
- Evolution
- Design Systems

Week 6
- Physical Stuff
- Power
- Stocks & Flows
- Dynamic Equilibrium
- Causal Loop Diagrams

Week 7
- Measuring
- Transduction
- Monitoring

Week 8
- Control

Week 9
- Interaction
- User Conceptual Models

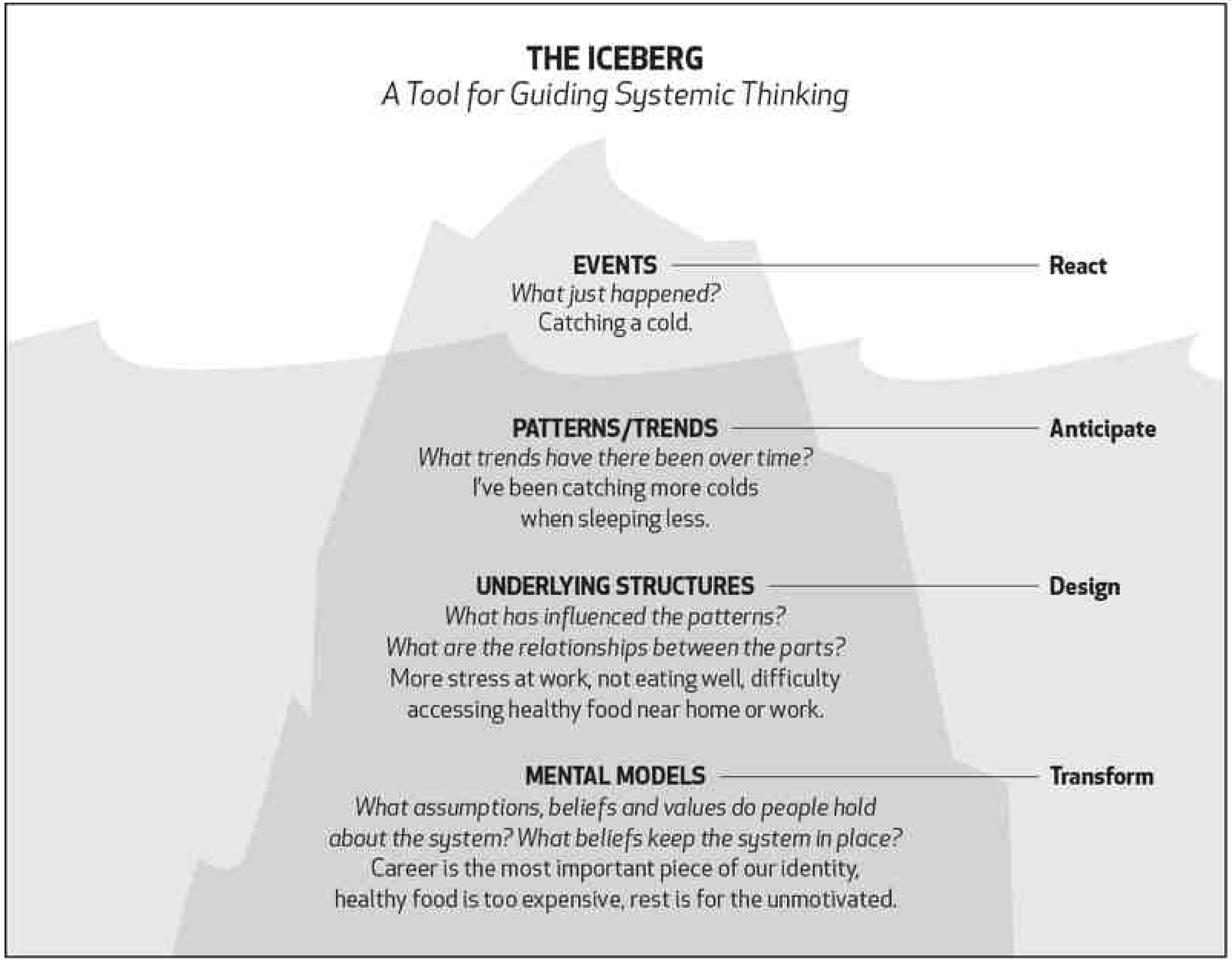
Week 10
- Learning
- Conversation

Week 11
- Feedforward
- Digital Twins
- Autonomous Operation

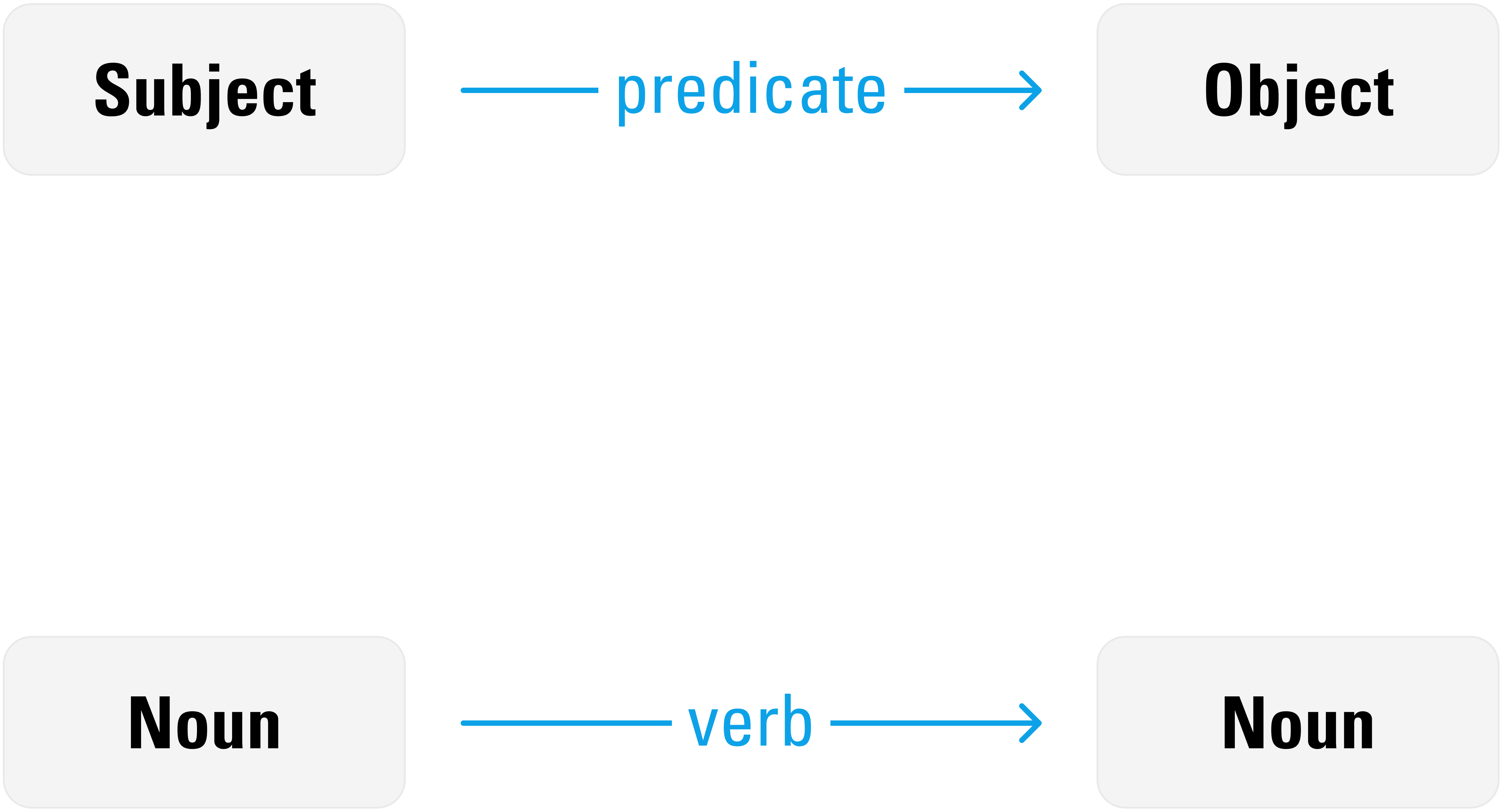
Week 12
- Intelligent Agents

Week 1: Models

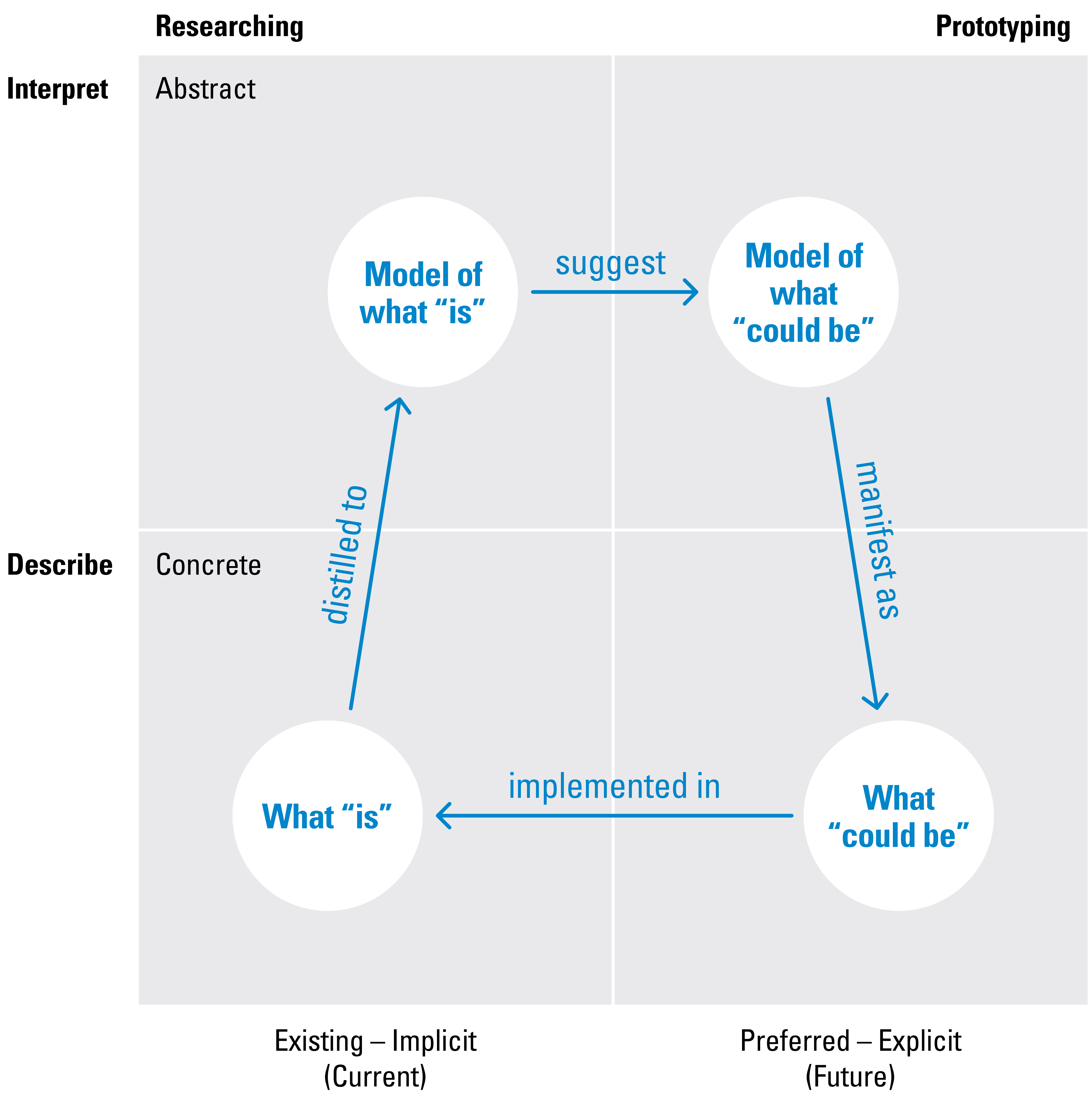
The Iceberg model breaks systems down into levels of thinking.



The basic form of concept maps: Verbs link terms to form propositions.



The Analysis-Synthesis Bridge model describes how models are tools designers use to bridge the gap between what is and what should be.

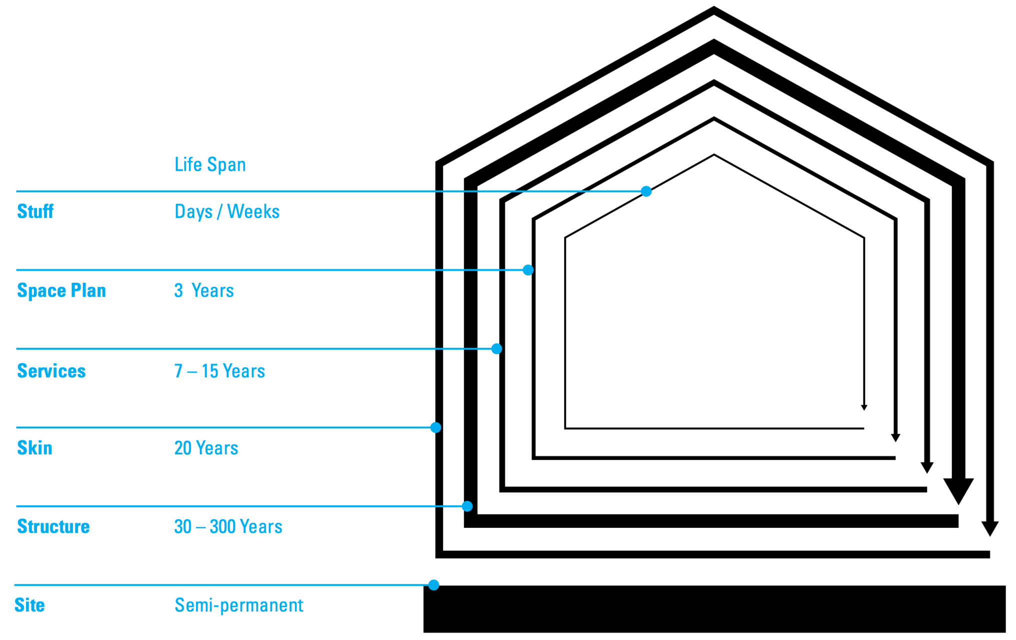


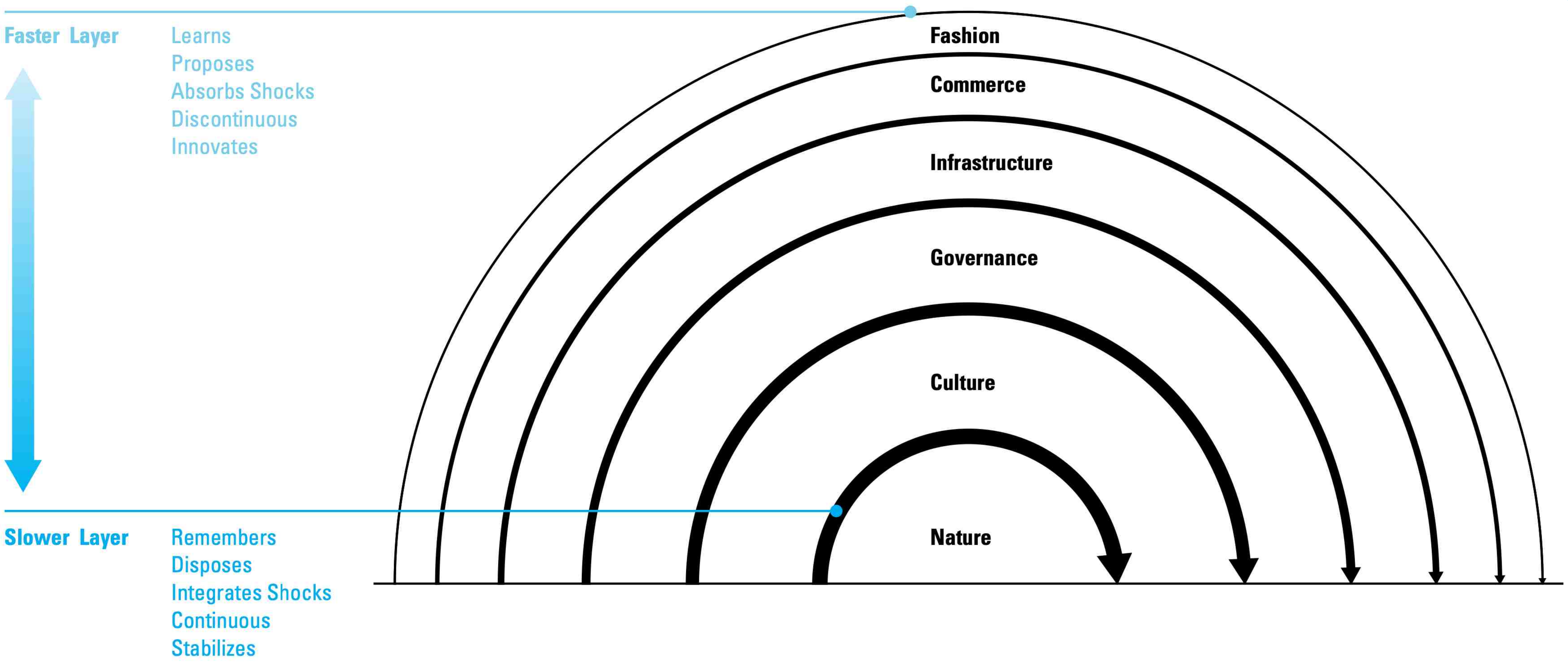
Week 2: Levels of systems

Kenneth Boulding distinguishes 9 types of systems.

1. 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.]
2. the level of **Clockworks**	Machines that are determined
3. the level of **Thermostats**	The level of control in mechanical and cybernetical [sic] systems
4. the level of the **Cell**	As an open and self-maintaining system, having a through-put that transforms unpredicted inputs into outputs [what Maturana, Varela, and Uribe later called an “autopoetic” system]
5. the **Genetic** and **Societal** level	Of plants and accumulated cells
6. the level of the **Animal**	Specialized receptors, a nervous system, and an “image”
7. the **Human** level	All of the previous six—plus self-consciousness. The system knows that it knows, and knows that it dies
8. 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
9. the level of **Transcendental Systems**	The “ultimates” and “absolutes” and the “inescapables” with systematic structure

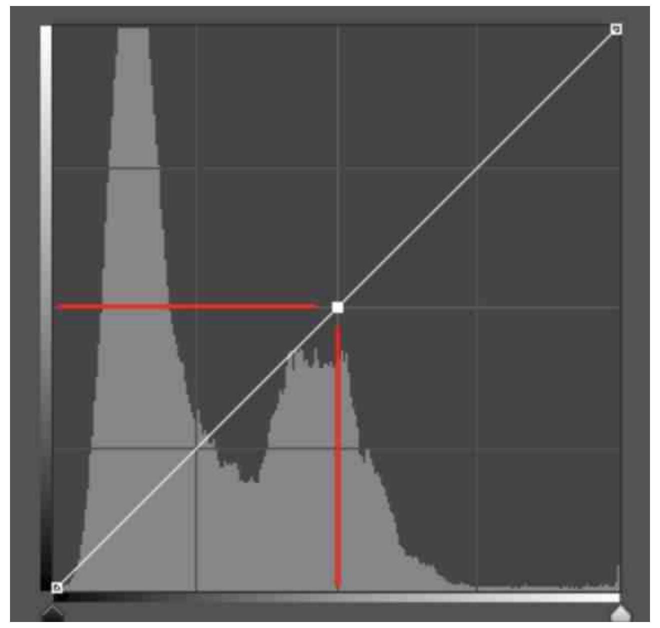
Steward Brand distinguishes systems in Pace Layers.

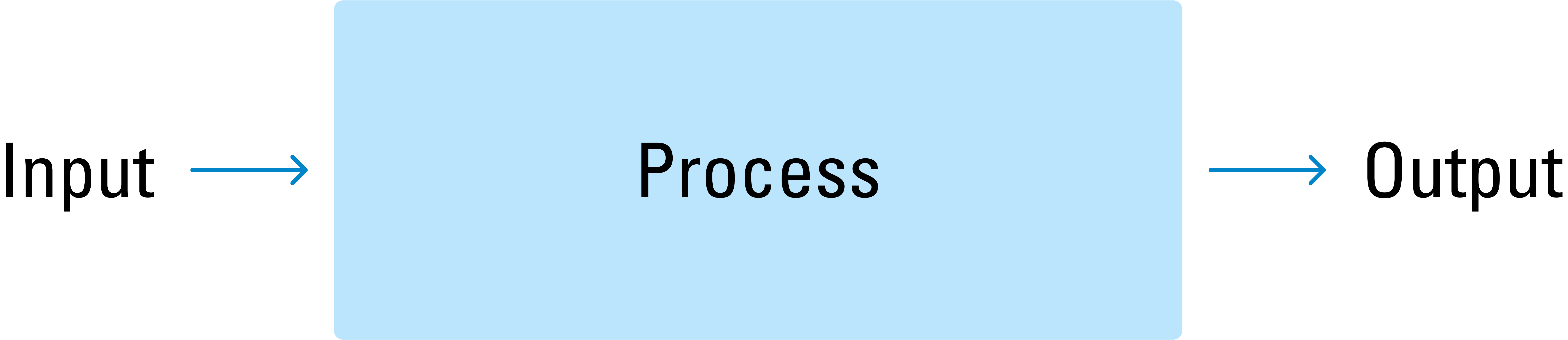




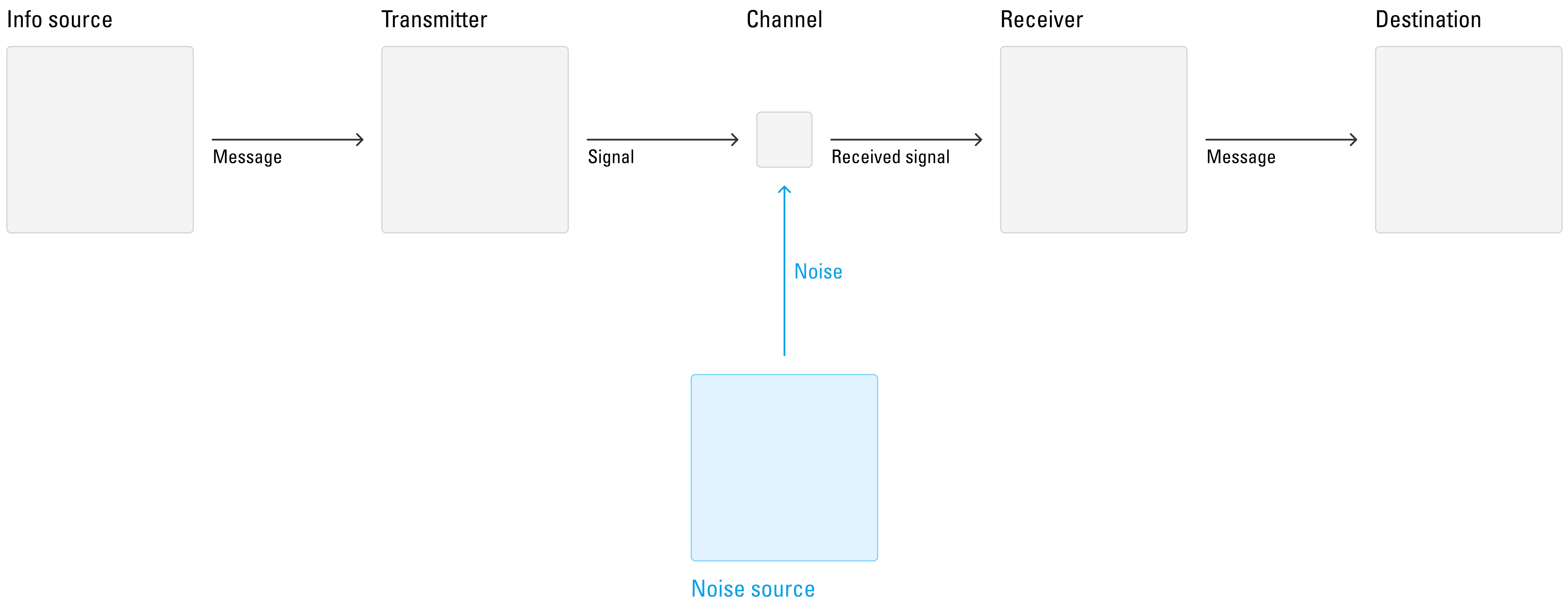
Week 3: Communication

A process may be represented by a node with inputs + outputs.
Taking an input and returning an output may also be thought of as a transform function or transformation.





Shannon’s model of communication represents the process of transmitting information as a series of transformations in which the output of the previous process provides the input for the next.

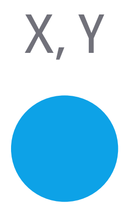


In software development, layers of a technology stack exchange information with one another.

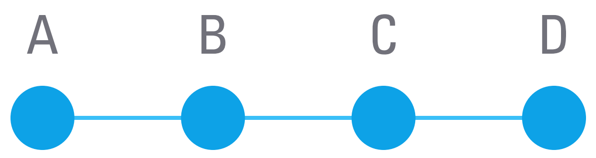
Web app		
Core application	**API**	**API**
Web browser	Chrome, Safari	
Operating system	Windows, macOS, Linux	
Hardware	Processor	

Week 4: Information

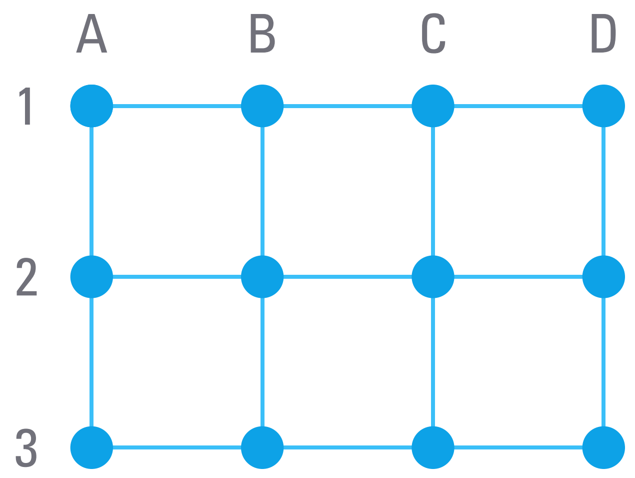
Information structures compose into 5 basic forms, or “primitives”.



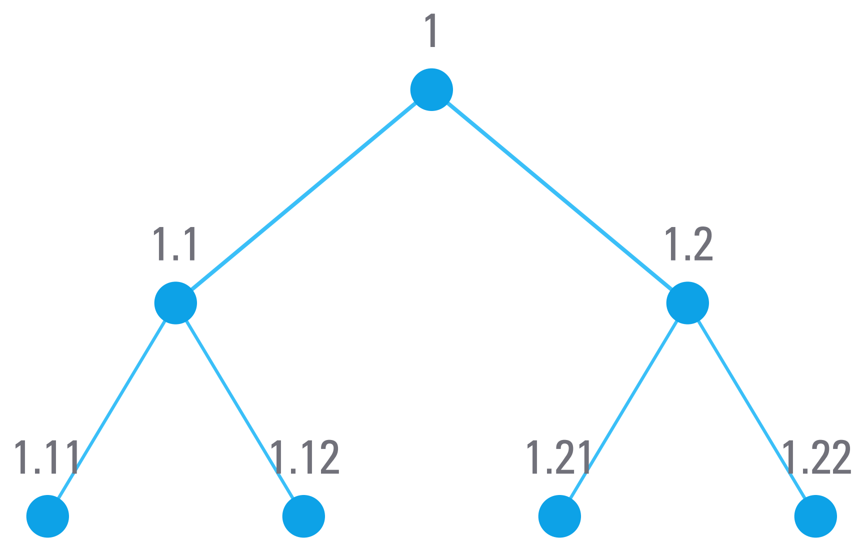
Name-value pair
Point



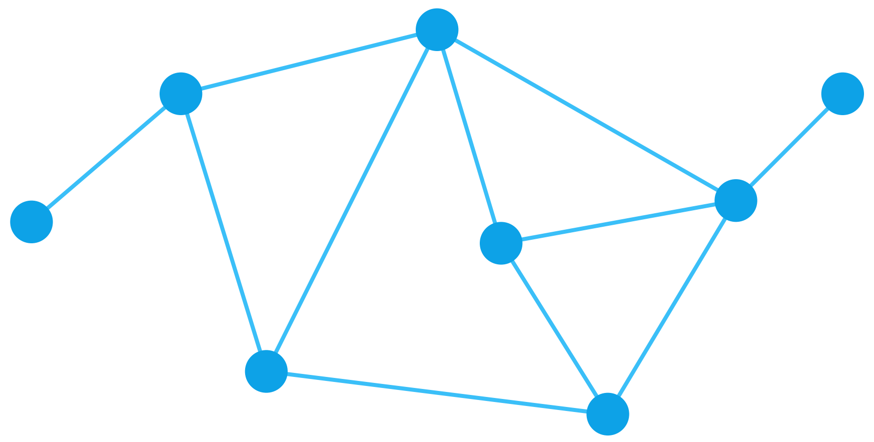
Array
String, List



Matrix
Table

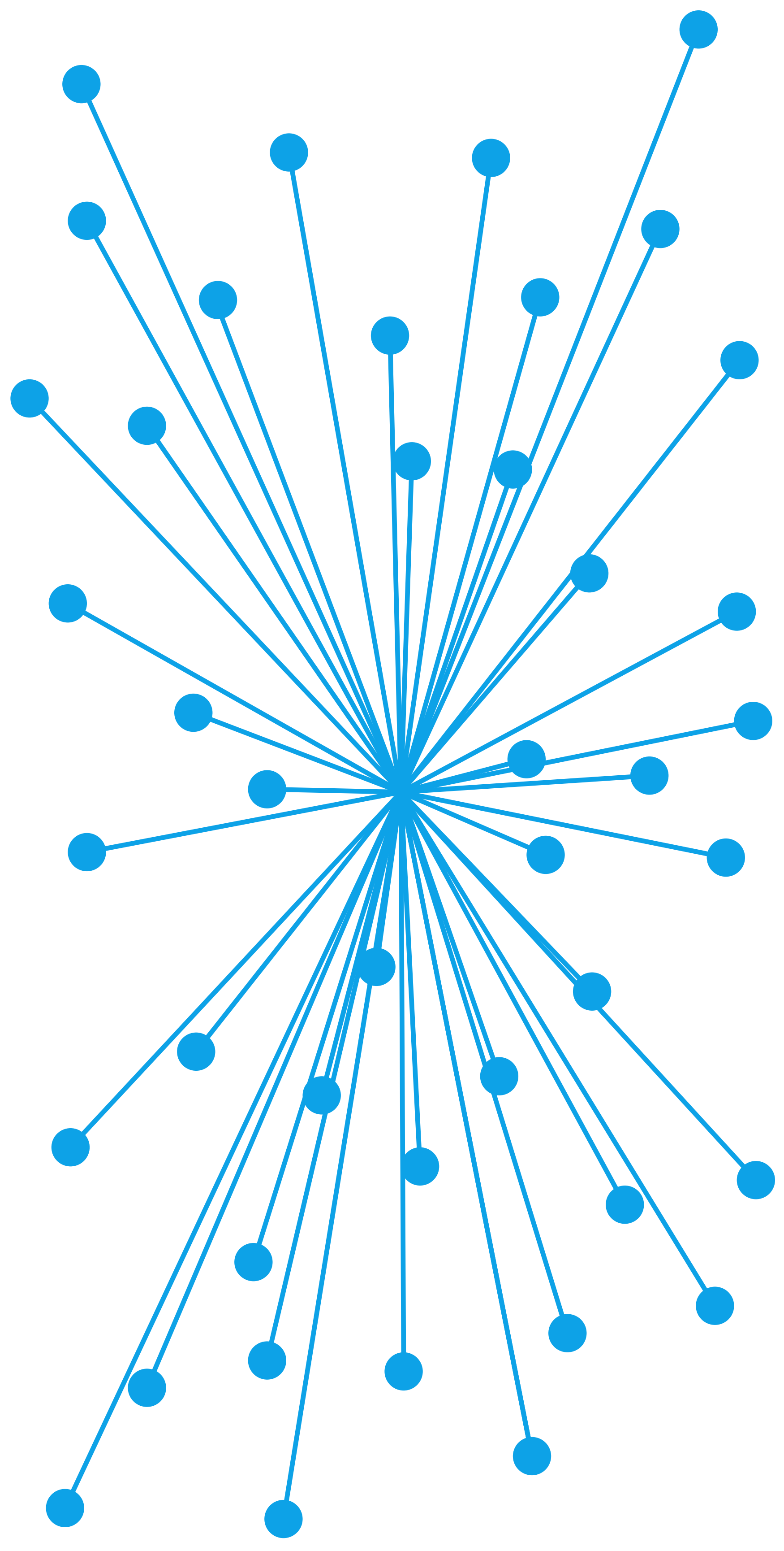


Tree
Hierarchy, Taxonomy

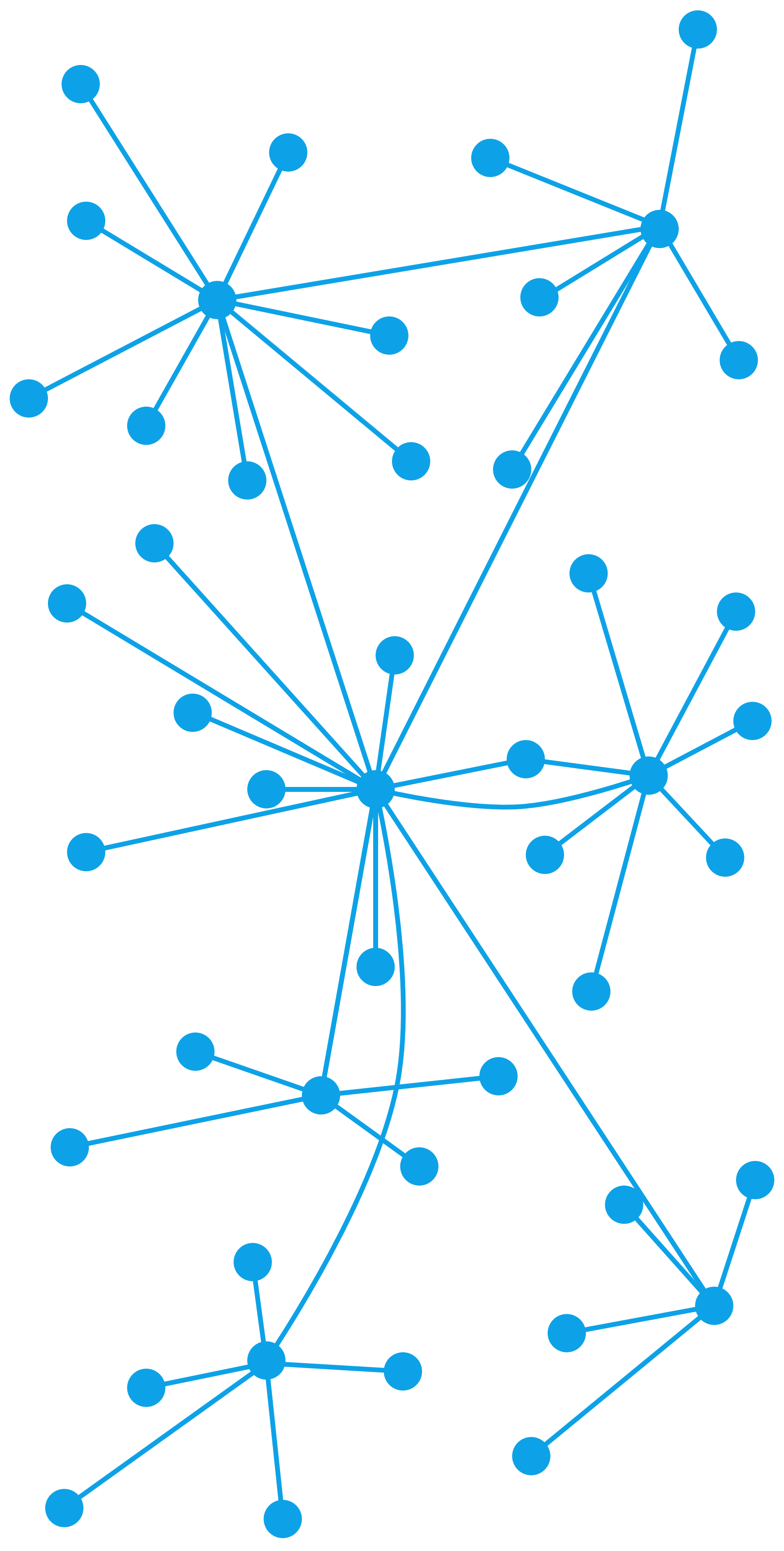


Web
Graph, Network

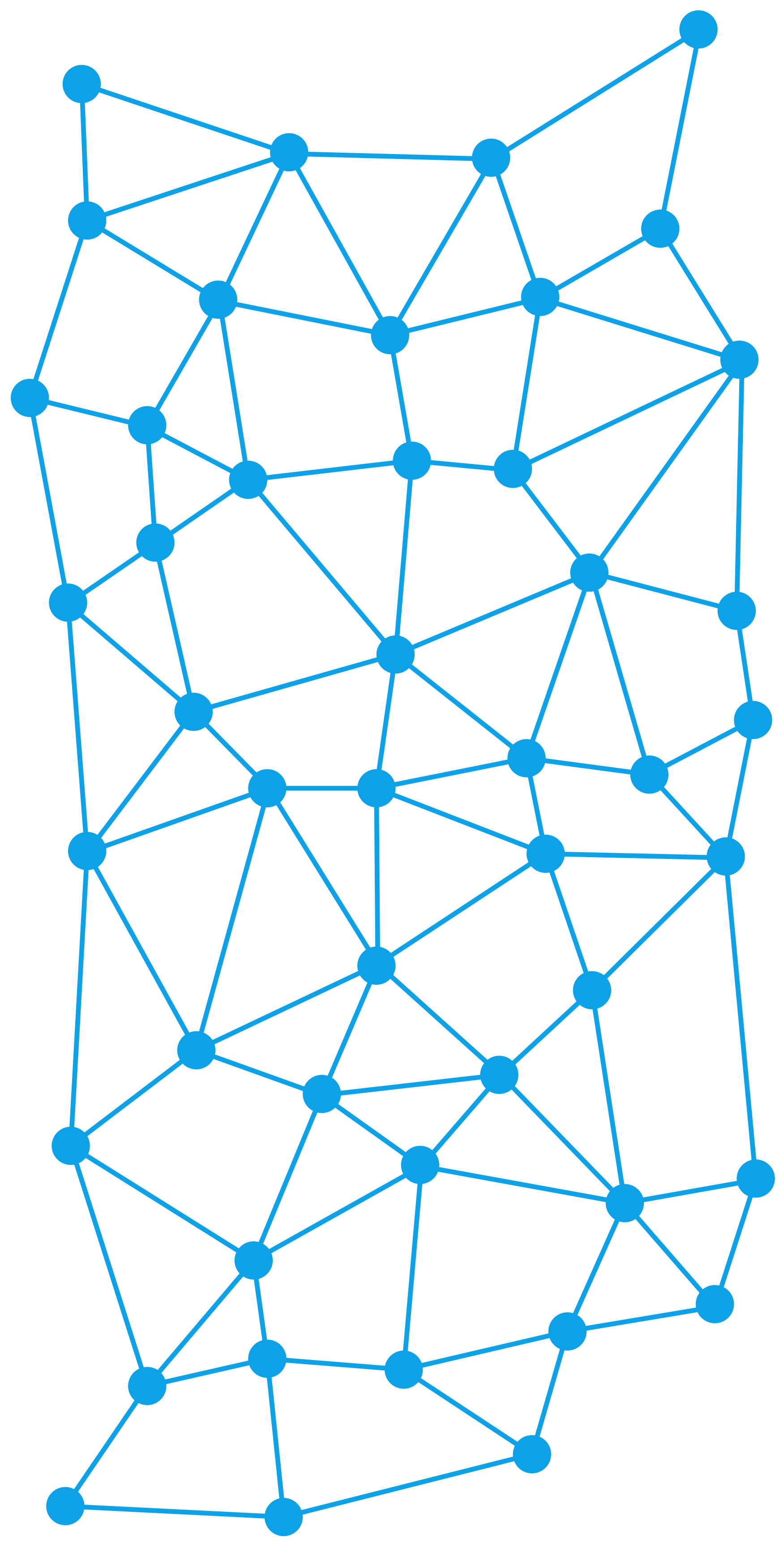
Networks may be centralized, decentralized, or distributed.



Centralized



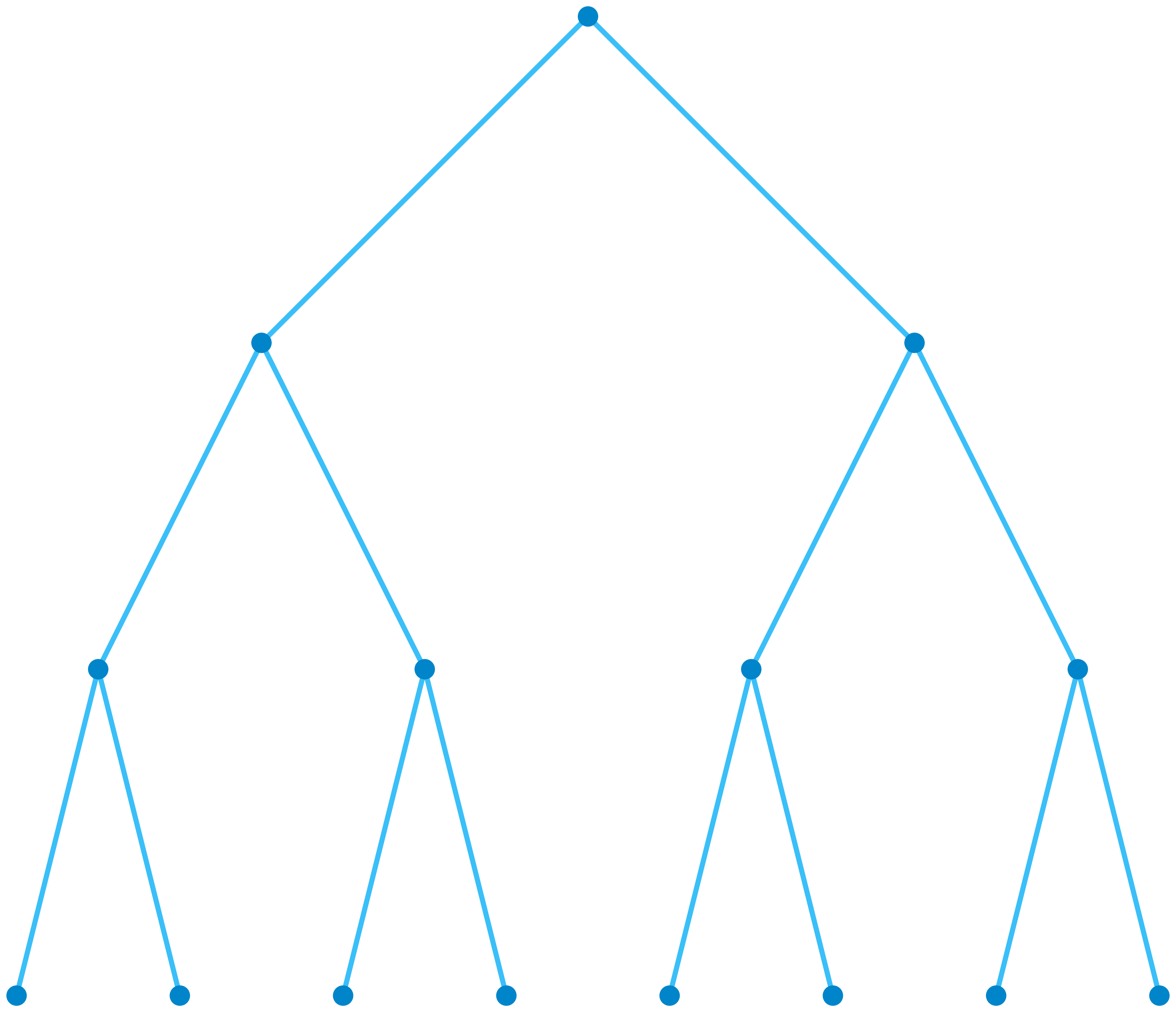
Decentralized



Distributed

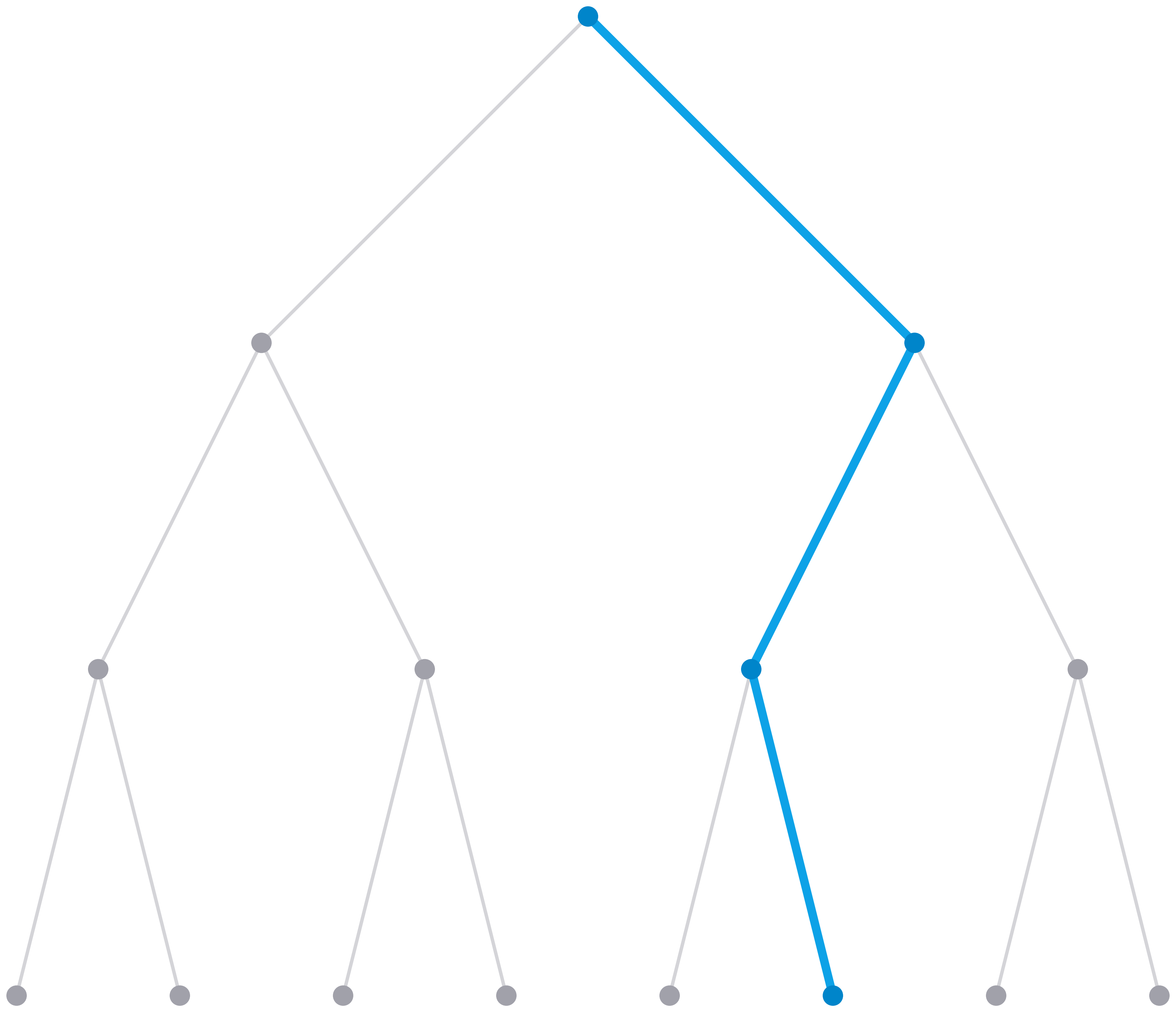
Week 5: Variation & Evolution

Variation



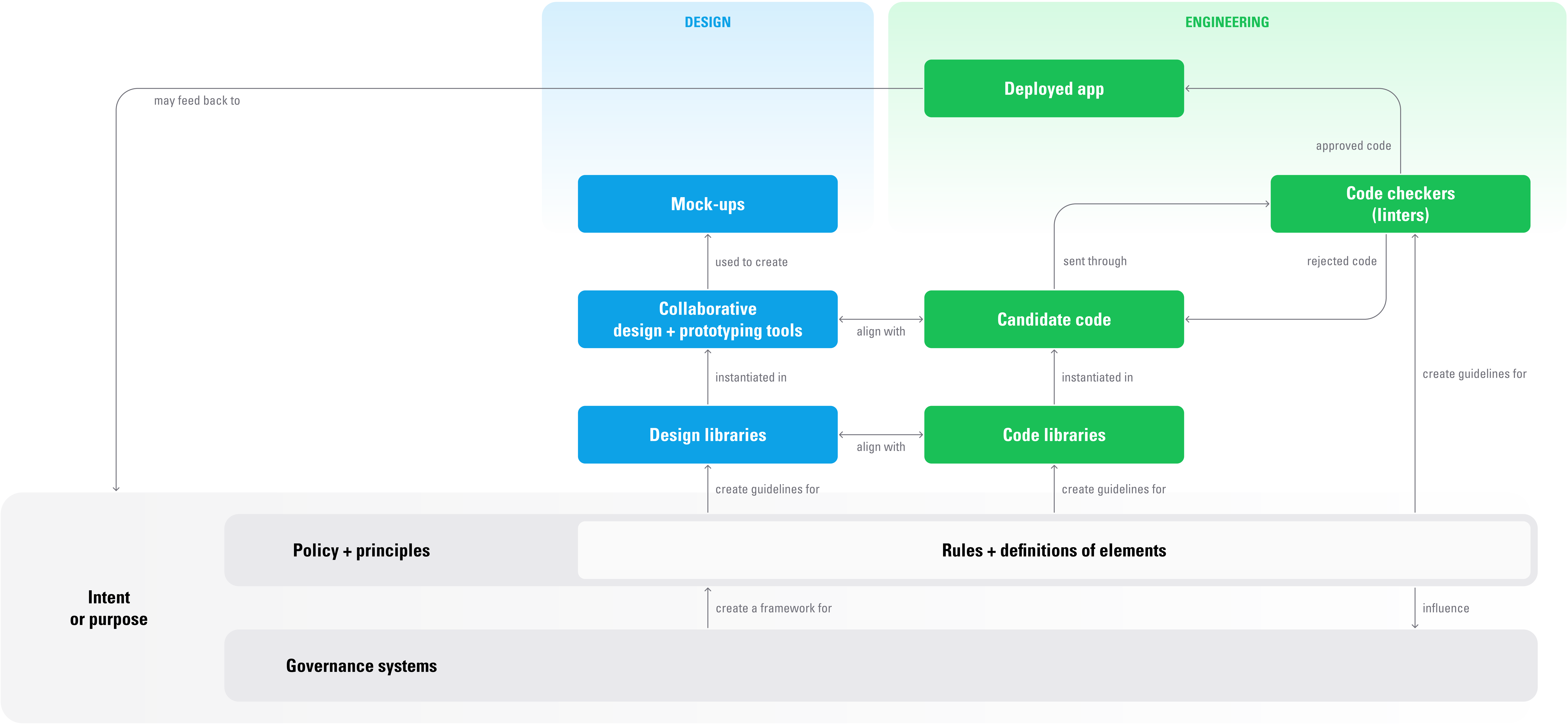
Variation

Evolution is a result of variation and selection.



Evolution

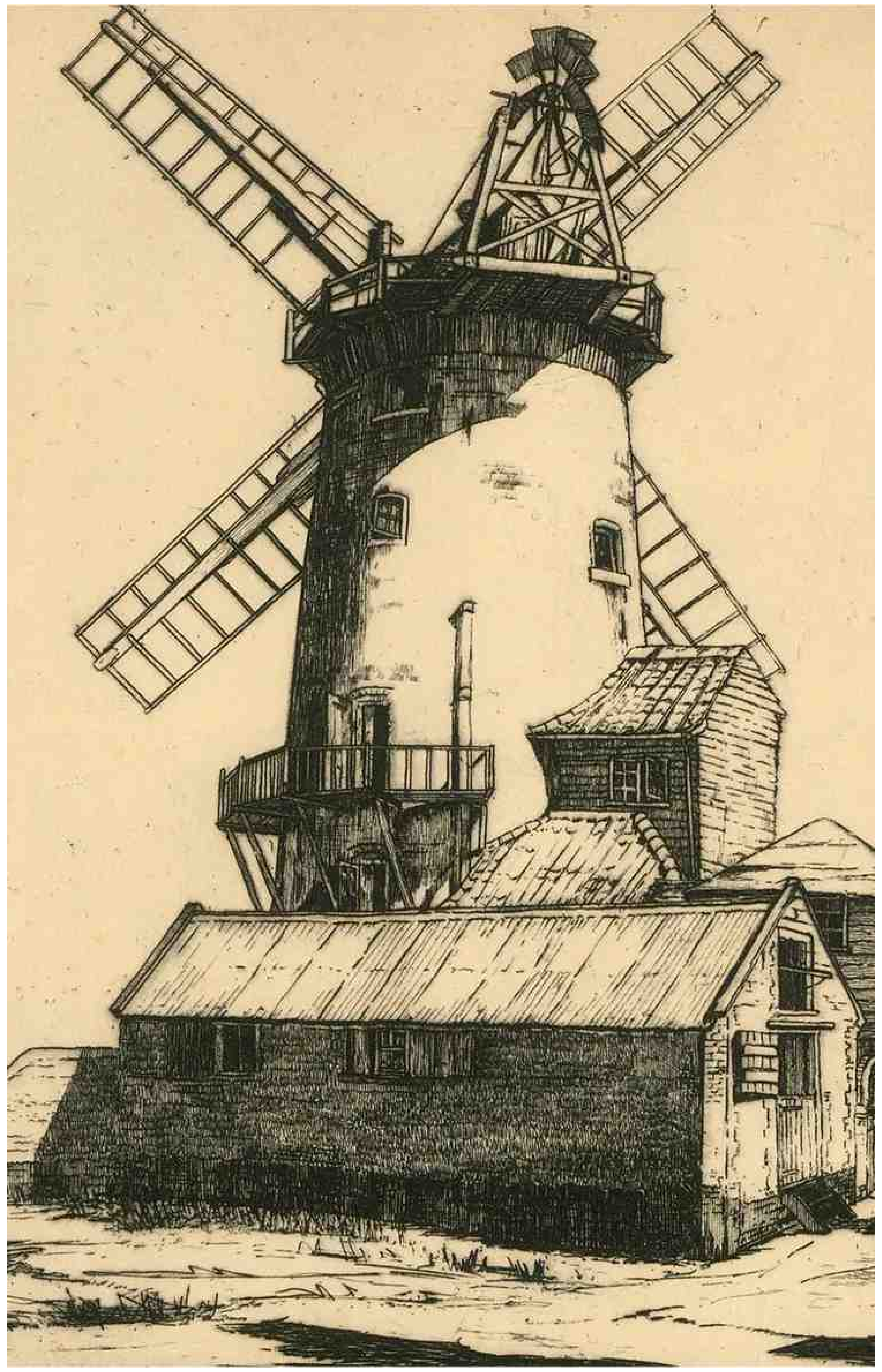
In software development, design systems create a framework for variation. Design systems may also evolve over time.

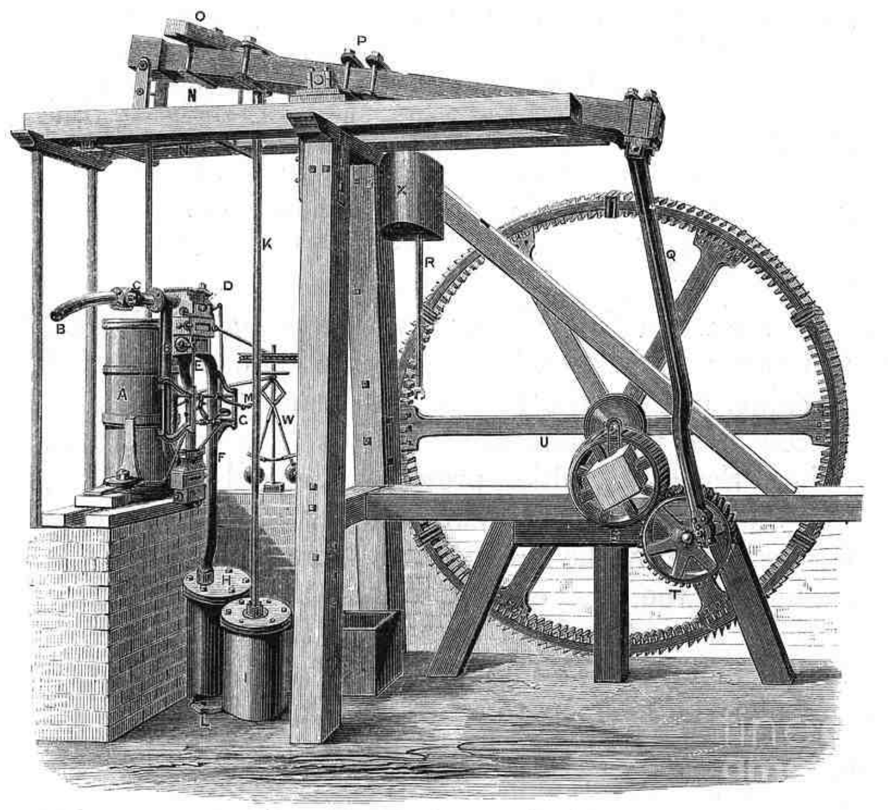


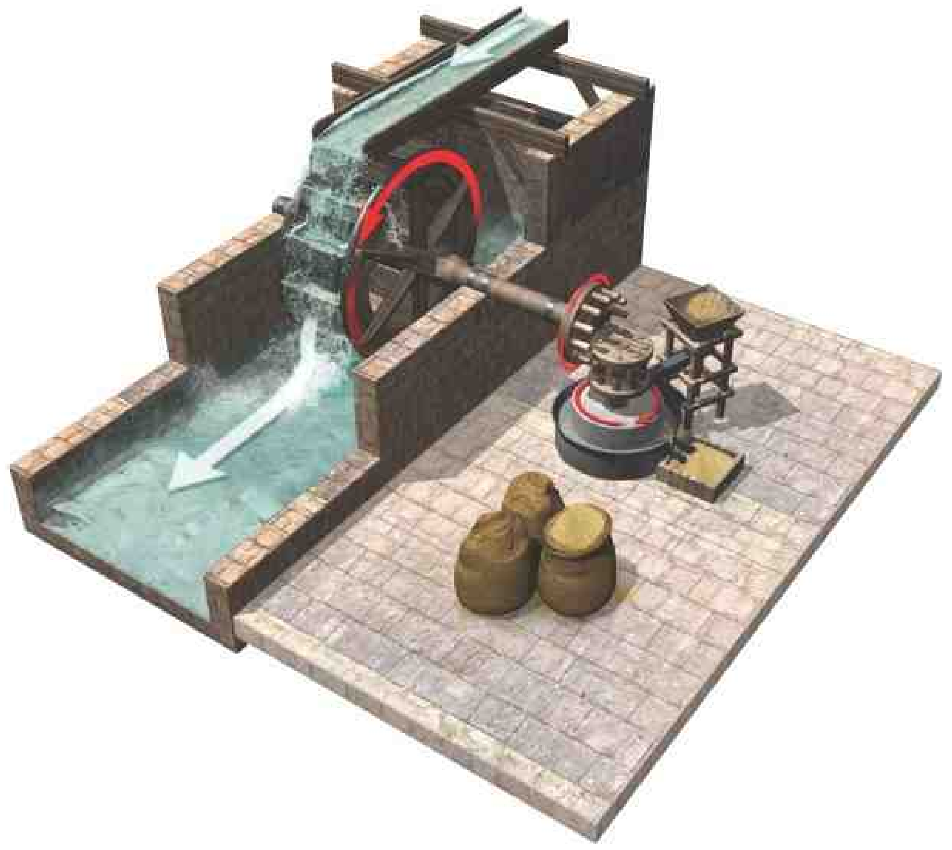
Week 6: System dynamics

Gathering materials (food, water, materials for shelter, etc.) is the root of augmentation.

Humans began to harness power or energy using things like livestock, wind, water, or fuel — harnessing power aids in gathering materials and transforming them.

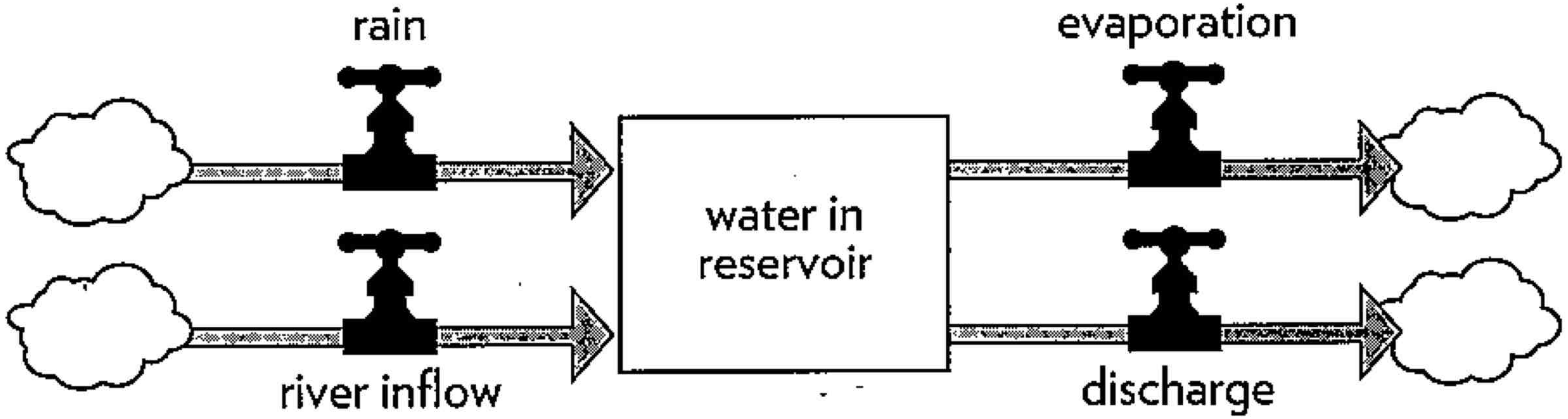






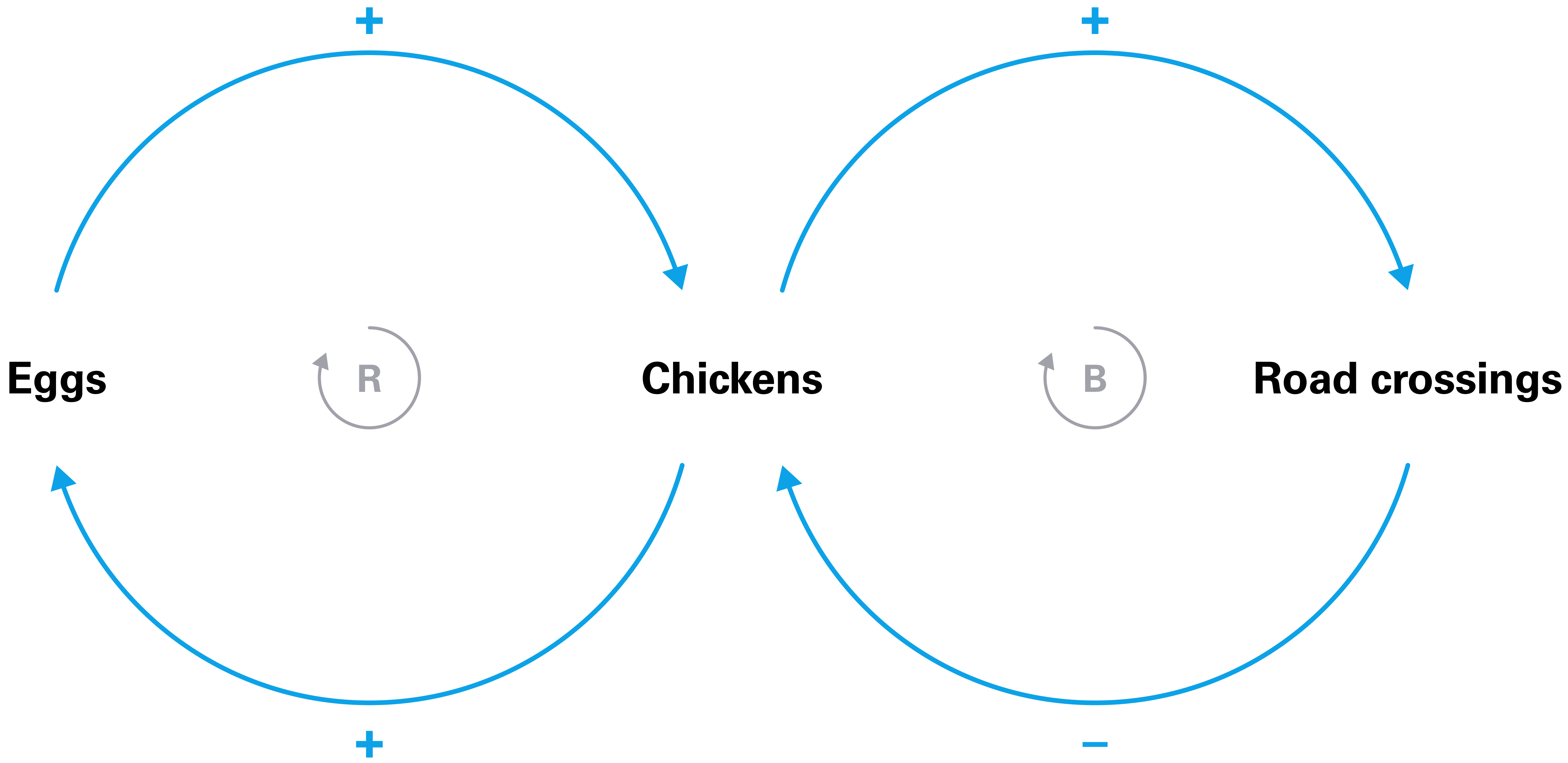
c. 1900 BC

Stocks (e.g., materials) change over time due to the actions of a flow.
System dynamics studies how stocks move through systems (via flows).



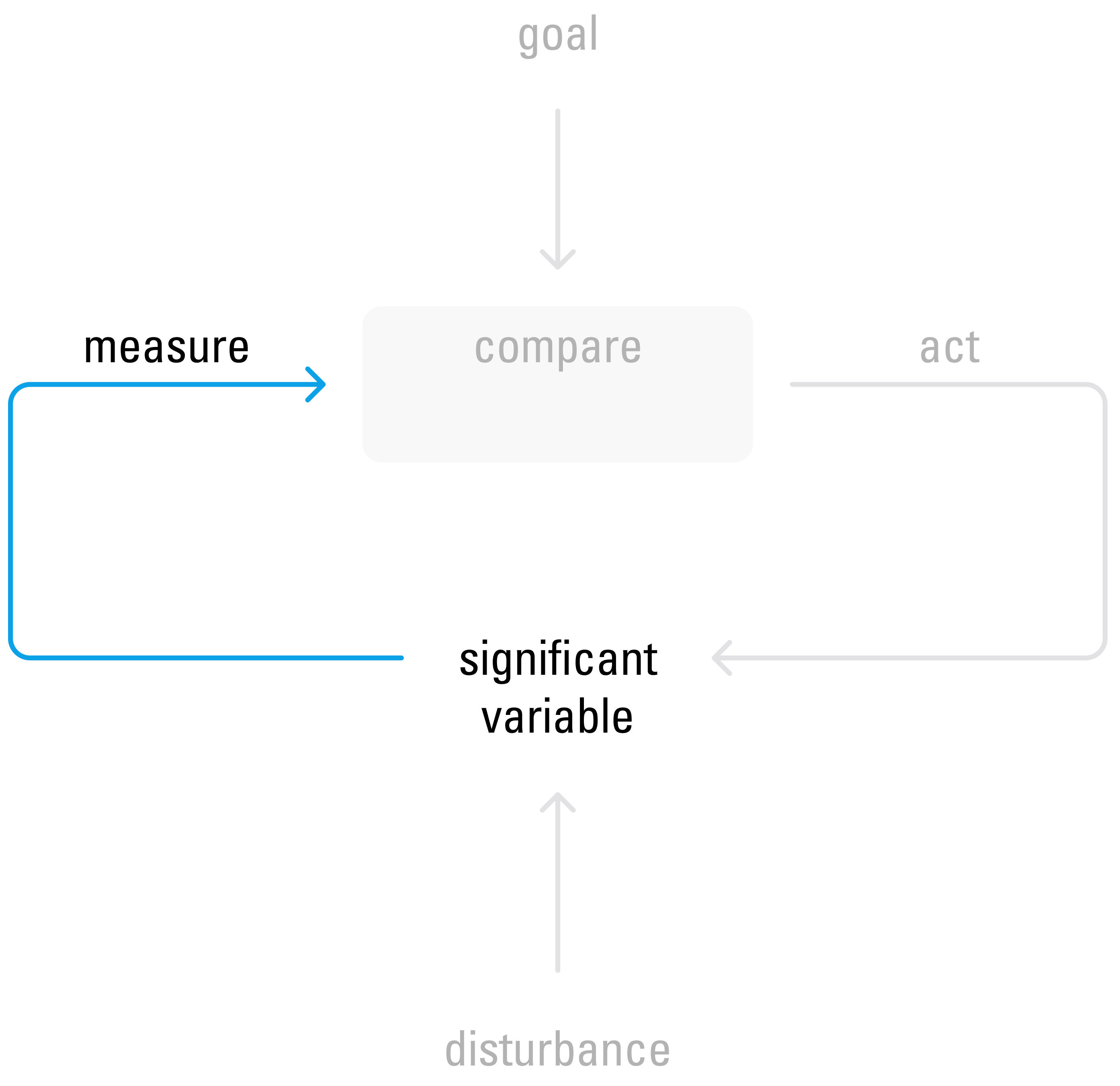
If the rate of inflow = the rate of outflow, the system is in a state of balance — dynamic equilibrium.

Causal loop diagrams can be used to model relationships between components in dynamic systems.
Reinforcing (R) and balancing (B) feedback loops can be identified as well.

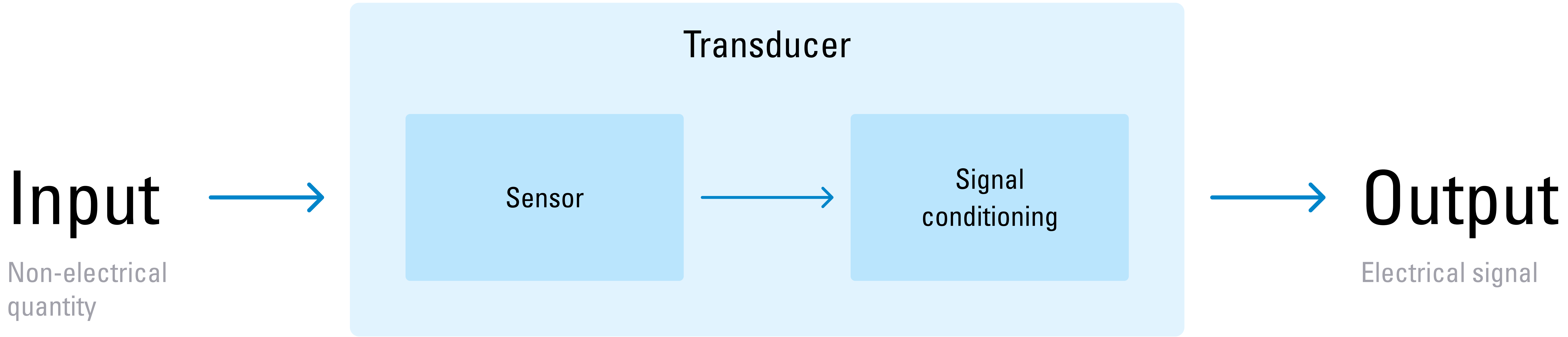


Week 7: Open-loop systems

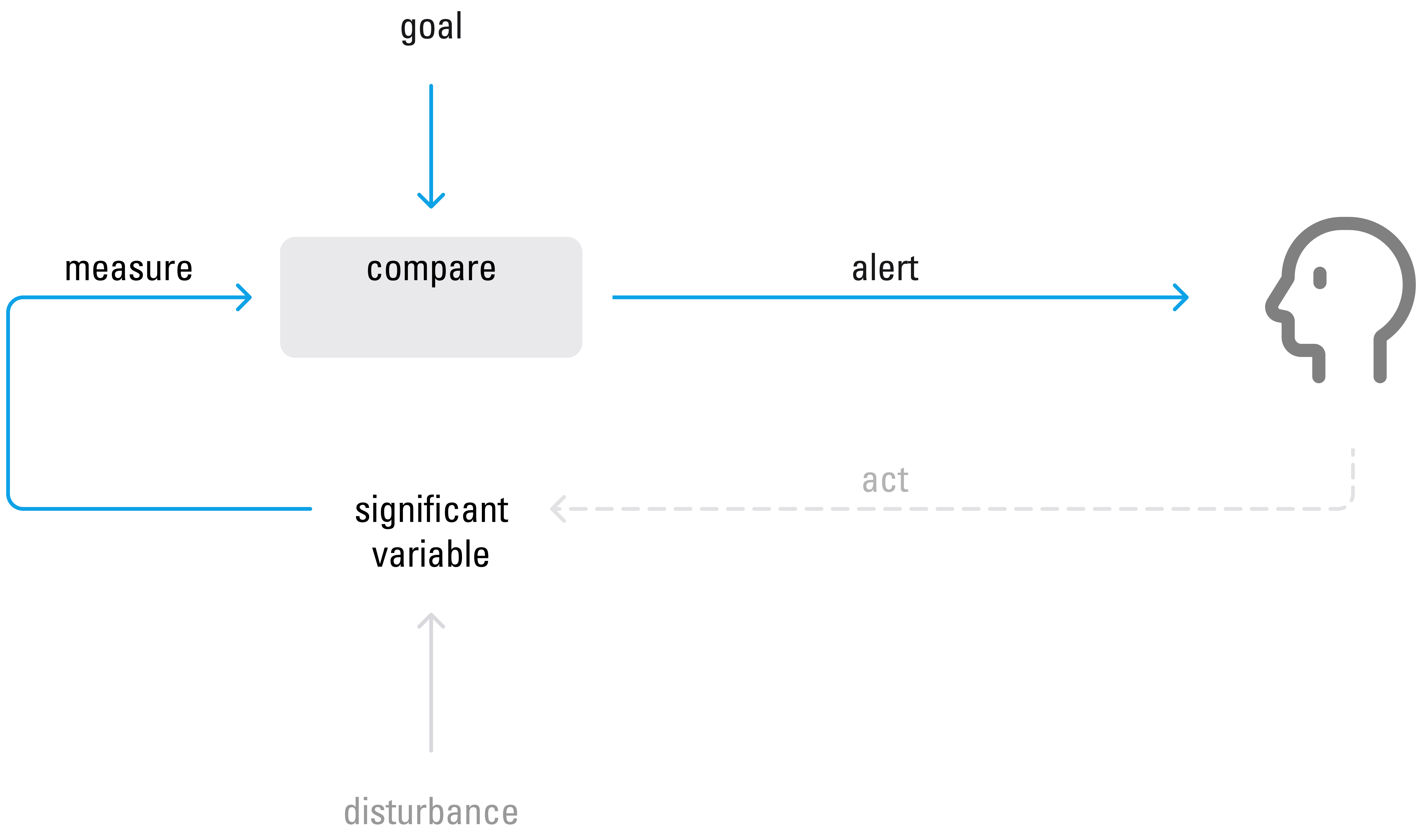
Control systems measure a significant variable in their environment.
The significant variable might be physical materials, energy, or information.



Sensors measure non-electrical quantities and transform them into usable electrical signals through transduction.

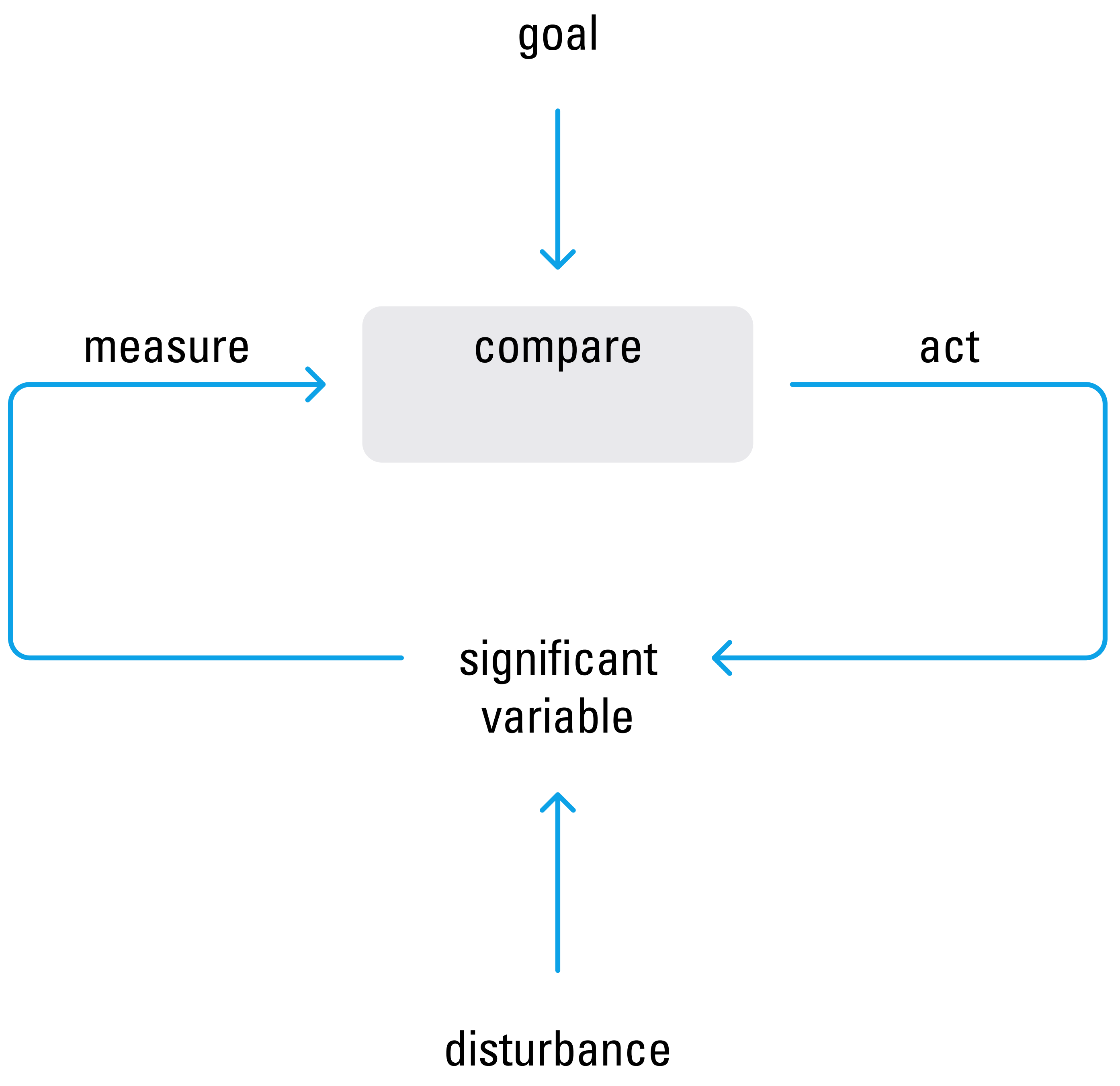


An open-loop system involves monitoring a variable and comparing the value to a threshold — then, the system might alert a human user if the variable exceeds the threshold.



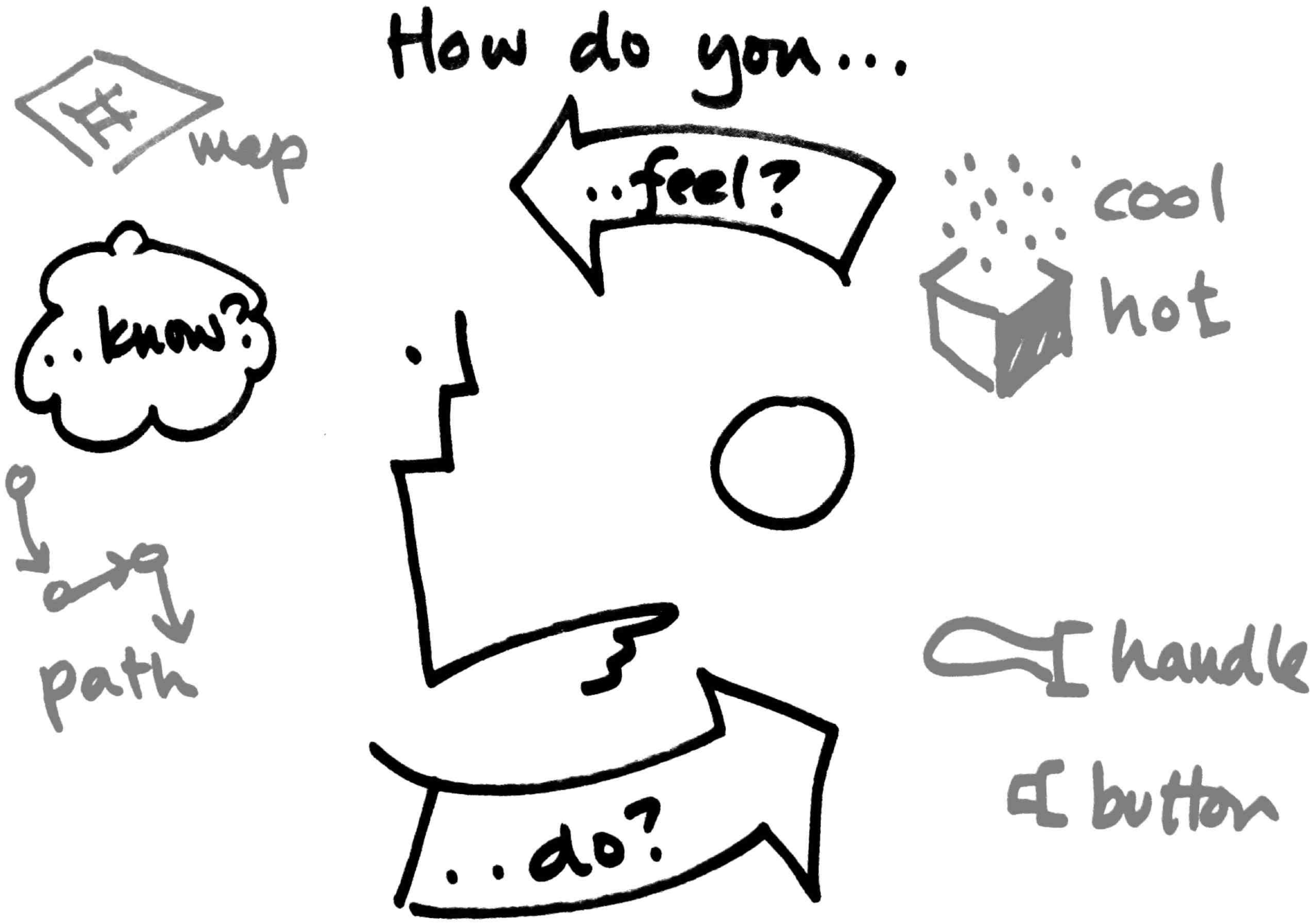
Week 8: Control

A control system 'closes the loop' and takes action to affect the significant variable. Control (i.e., "feedback") is required to maintain dynamic equilibrium.

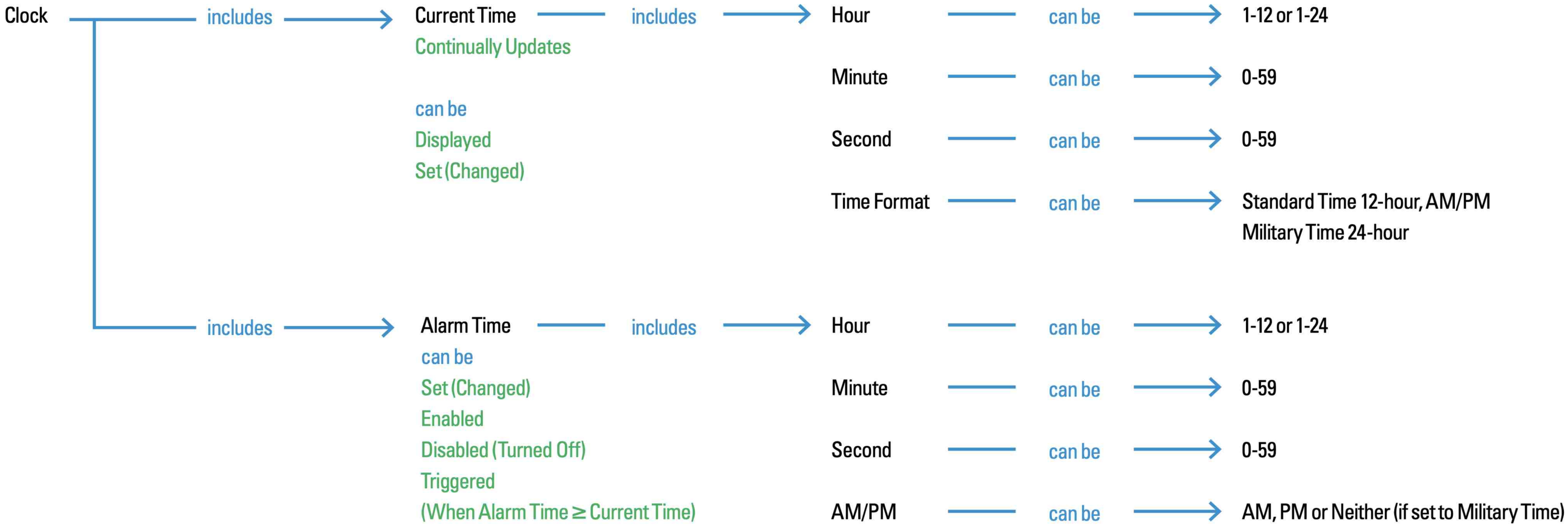


Week 9: Interaction

Bill Verplanck uses a feedback loop to describe how humans interact with systems like software applications.

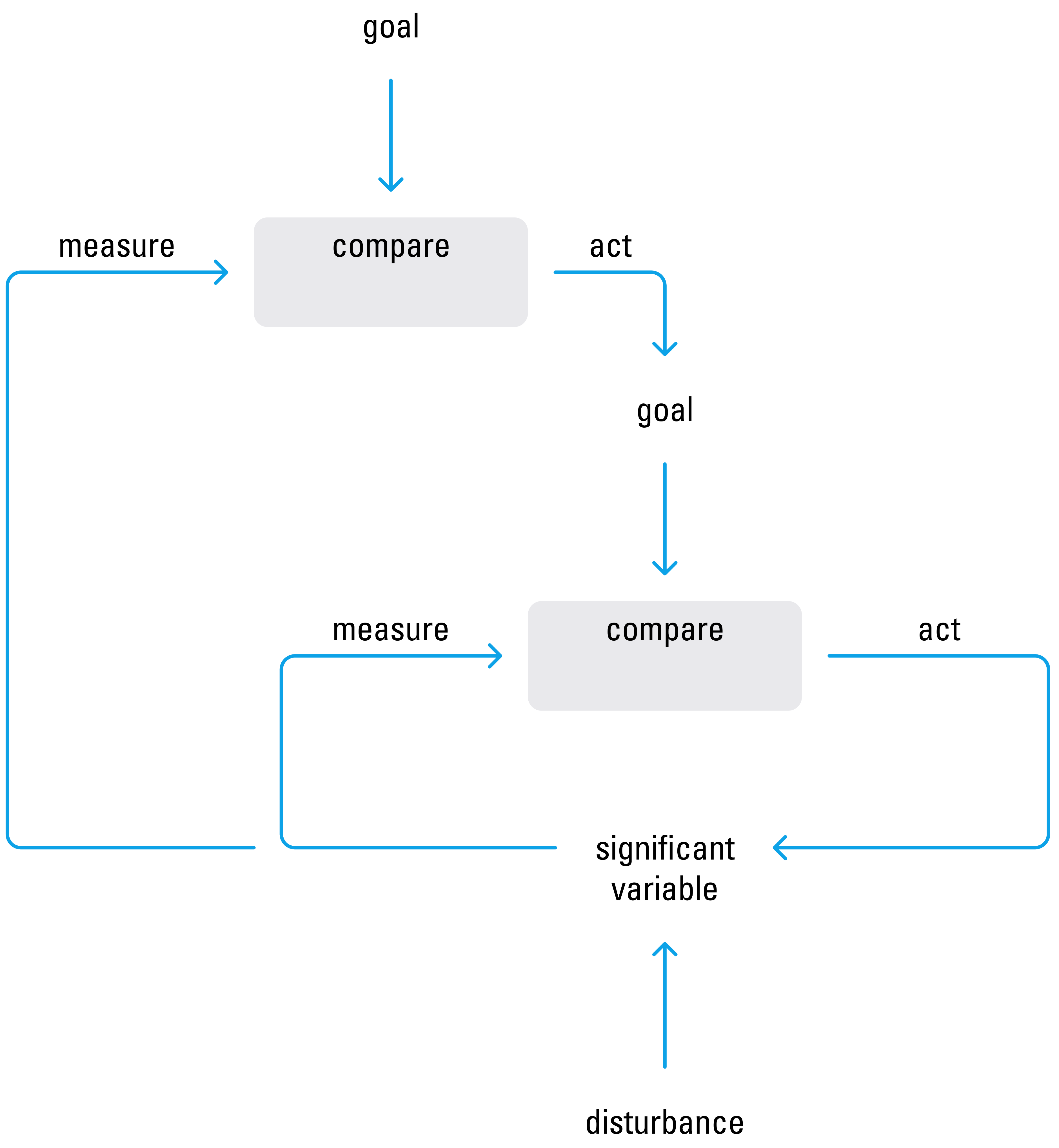


A key step in interaction design is to develop a user conceptual model — that is, a graph of data objects, their relationships, and actions that users can take on the objects.

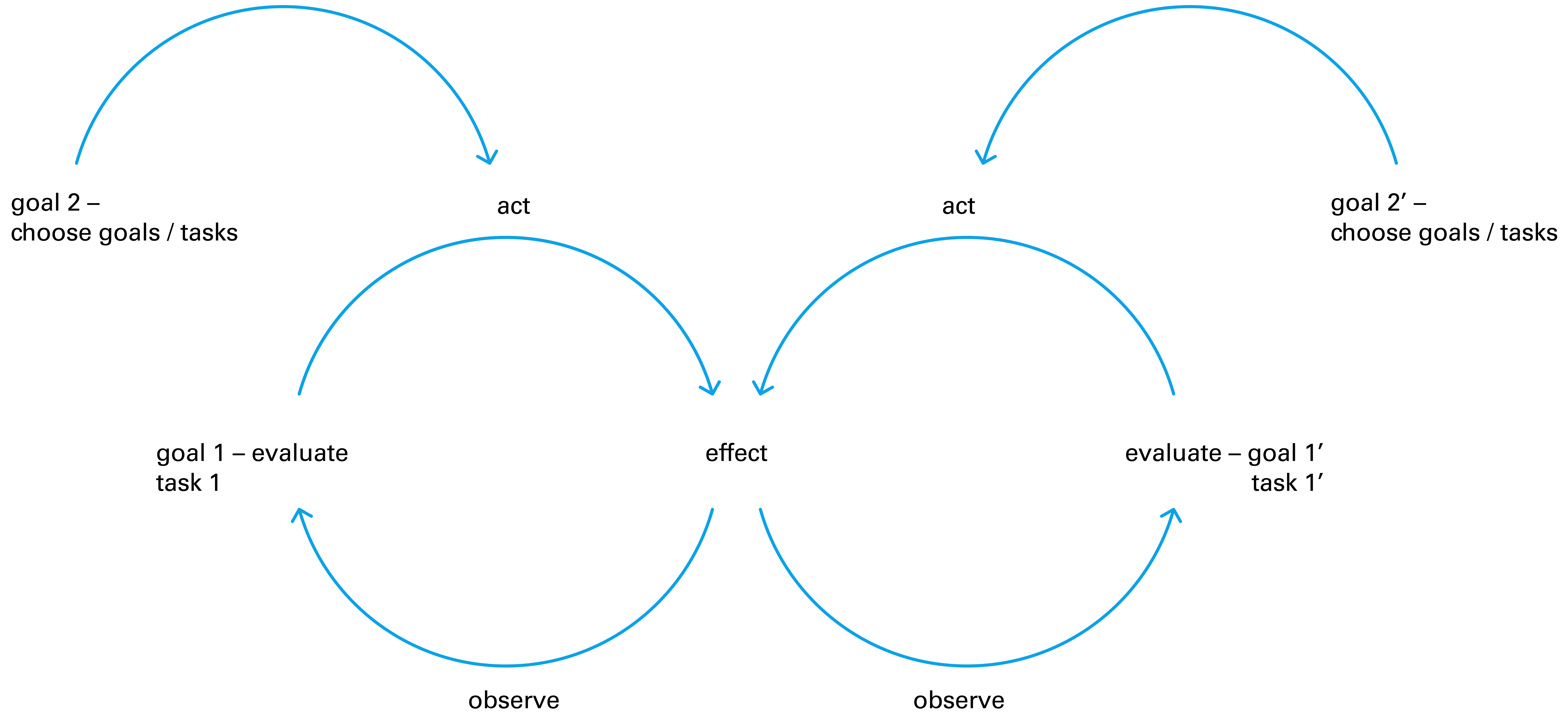


Week 10: Learning

**A ‘learning system’ is a control loop nested within a second-order control loop.
It observes the results of its actions, then adjusts the first-order loop to improve its performance.**

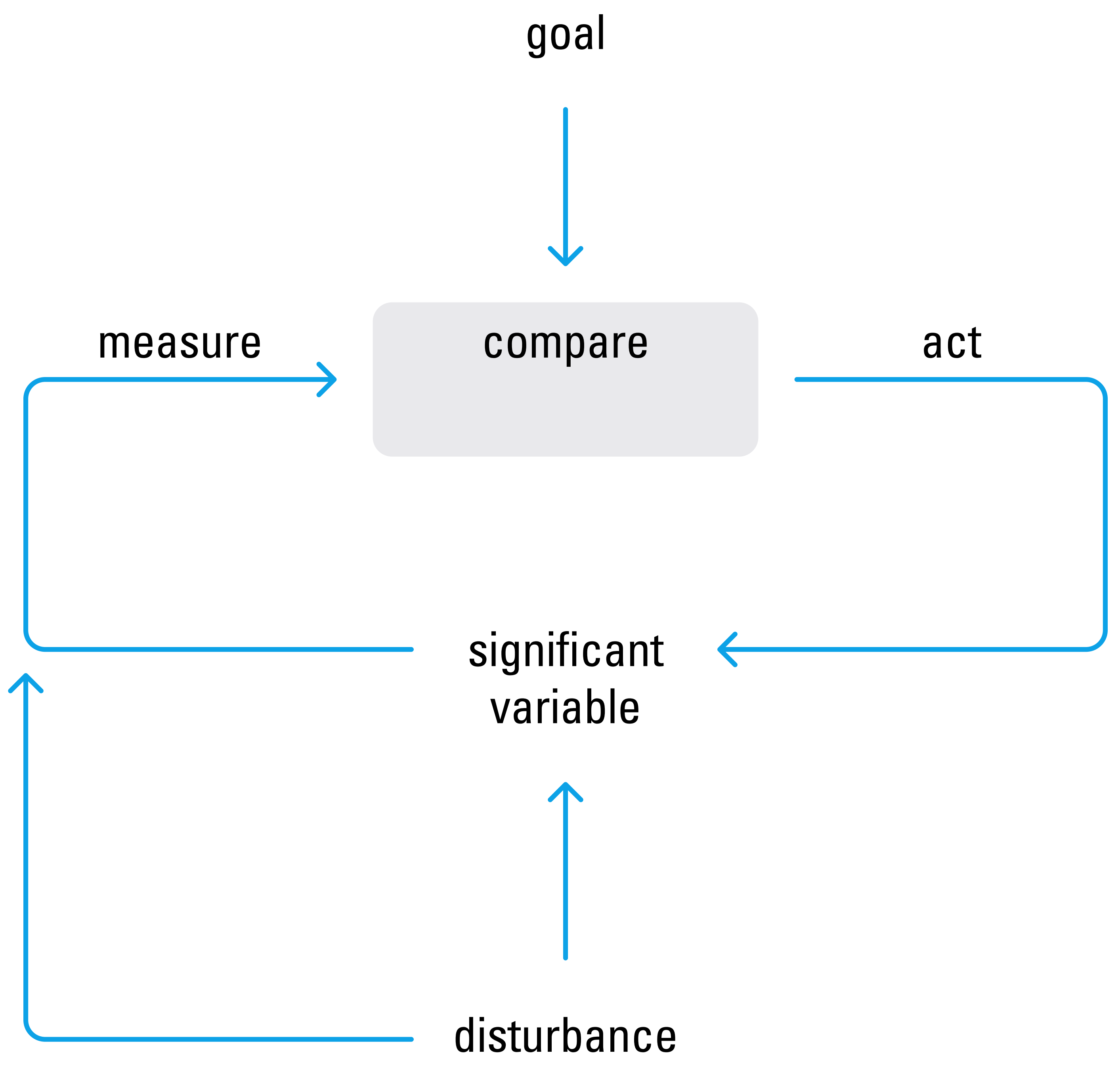


Conversation involves interaction between two second-order feedback system — the output of one system becomes the input for another.



Week 11: Digital twins

Feedforward involves measuring disturbances in the environment which affect the significant variable.
Feedforward can enable a system to anticipate larger changes,
by signaling the likely future state and acting in advance to control for it.

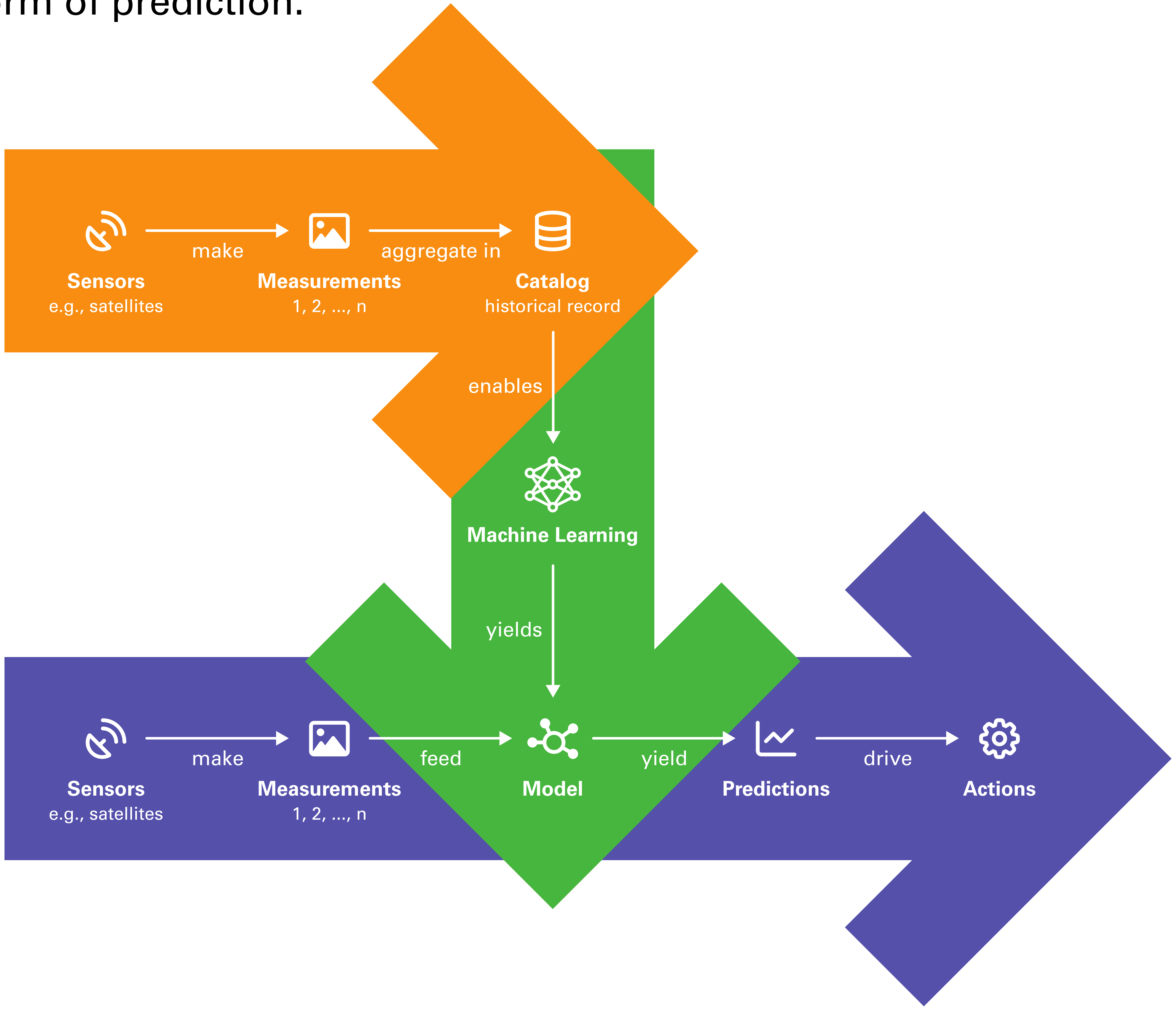


A digital twin is a virtual representation of a real object or system, which can be used to predict outcomes based on measurements collected by sensors.
Digital twins enable a sophisticated form of prediction.

1. Gather histories
Sensors make a series of point-in-time measurements. As measurements accumulate, an historical record emerges.

2. Derive models
Sufficient historical data enable 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.



Autonomous operation exists on a scale of complexity.

A Roomba is a simple autonomous system; the Longwall mining system is an example of a more complex one. Autonomous systems might use digital twins to anticipate changes in a dynamic environment.

iRobot Roomba

The Roomba navigates the home, can return to its charging station, and empty itself without human input.

Joy Longwall Mining System

The Joy mining system is able to operate autonomously far underground, overseen by a mine control center on the surface. Individual machines communicate wirelessly in order to coordinate operation with one another.

Simple → Complex

Week 12: Intelligent agents

Stuart Russell and Peter Norvig group agents into five classes based on their degree of perceived intelligence and capability:

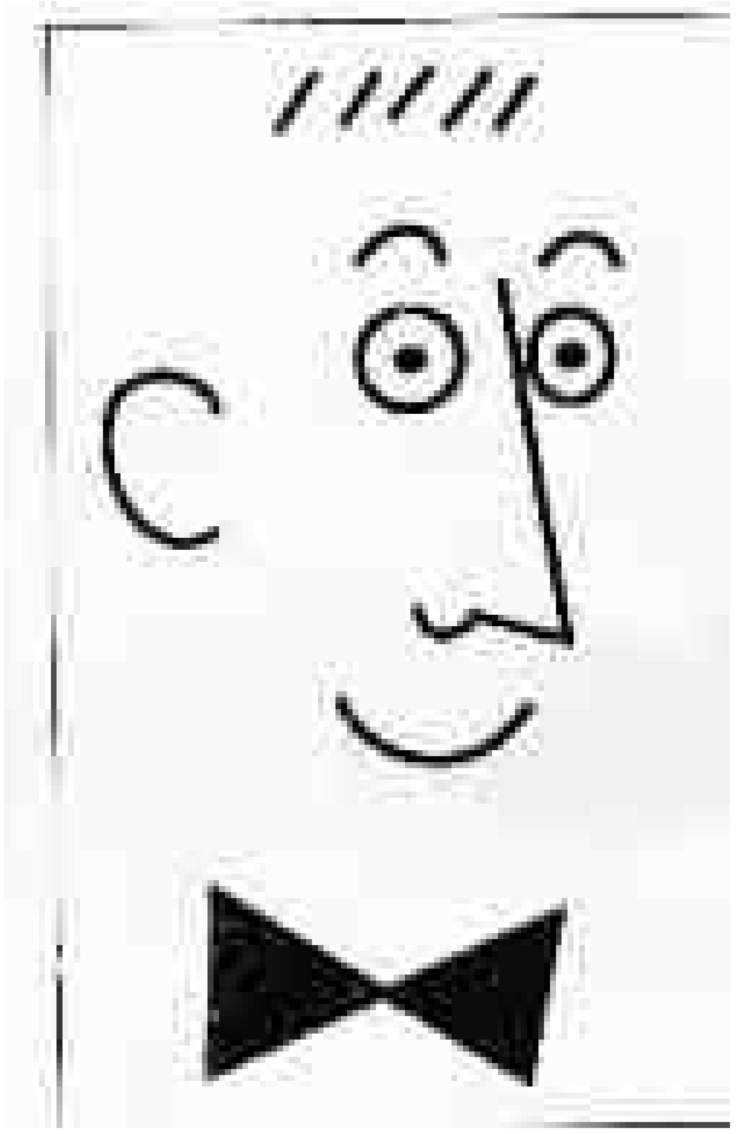
1 Simple reflex agents

2 Model-based reflex agents

3 Goal-based agents

4 Utility-based agents

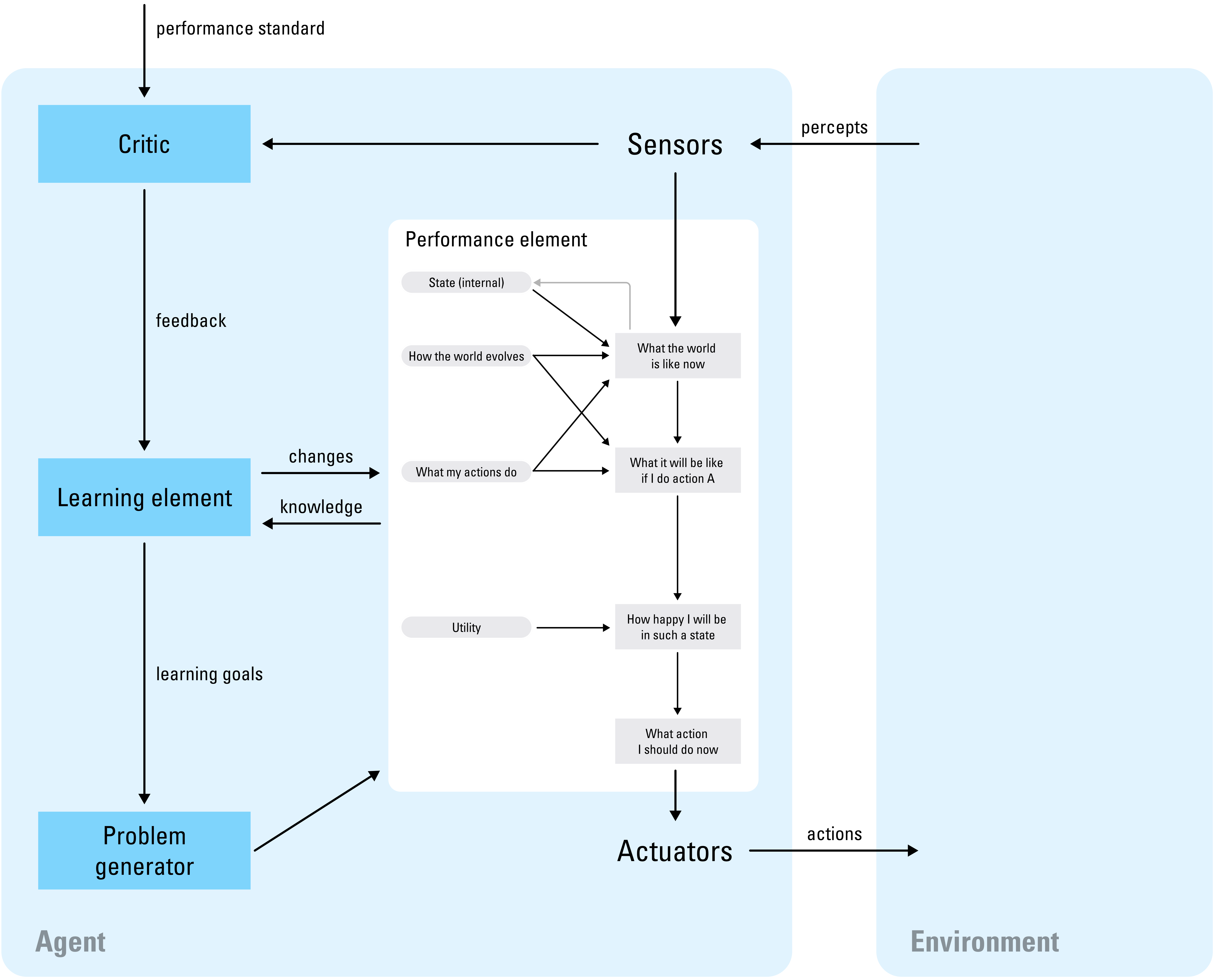
5 Learning agents



Russell & Norvig, ‘Artificial Intelligence: A Modern Approach’ (2003)
http://aima.cs.berkeley.edu/figures.pdf

Intelligent agents

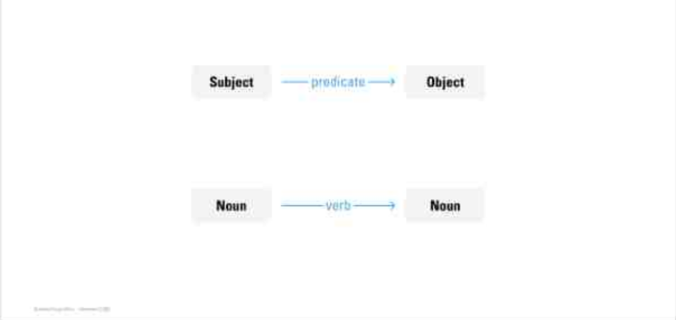
"A general learning agent. ***The 'performance element' box represents what we have previously considered to be the whole agent program.*** *Now, the 'learning element' box gets to modify that program to improve its performance."*



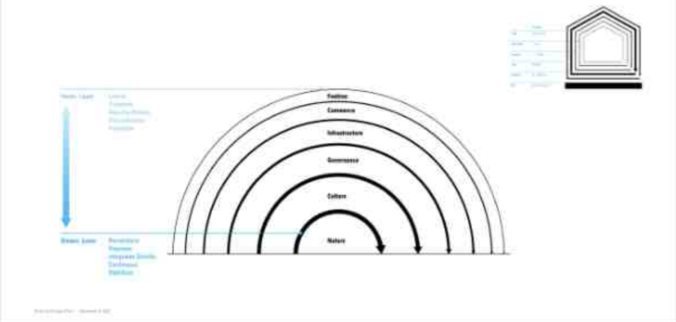
Summary

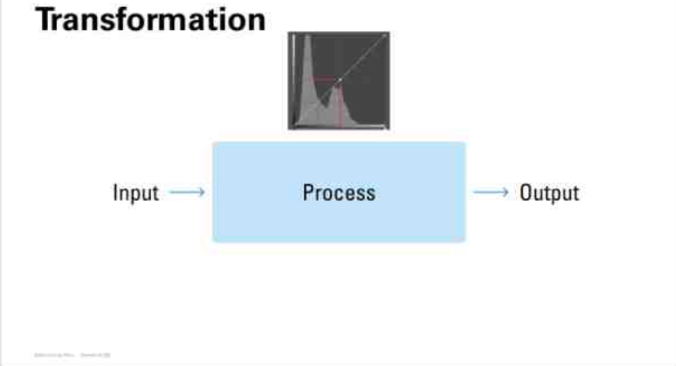
Iceberg model

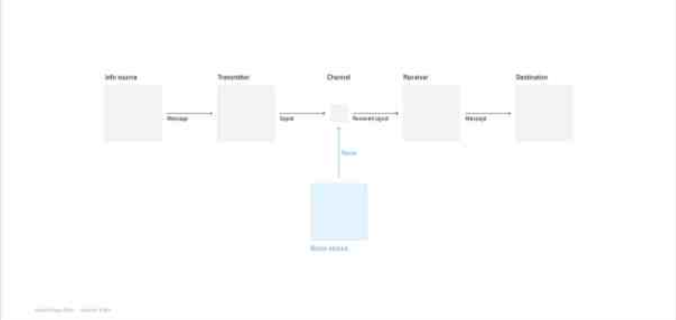

Bridge model

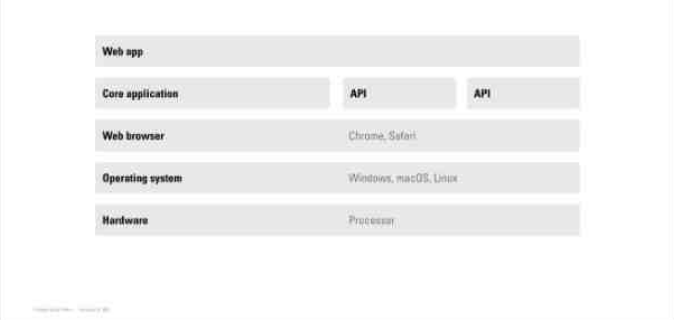

Concept maps


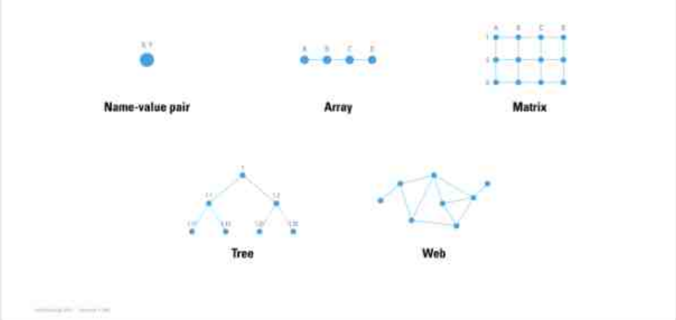
Boulding's levels of systems

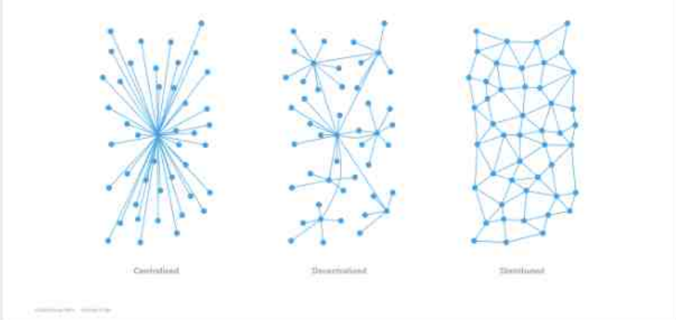

Pace layers


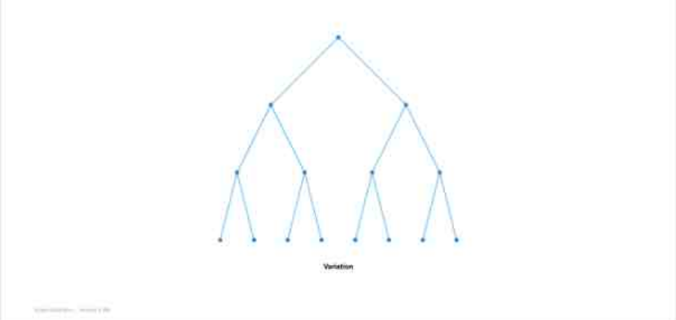
Transformation


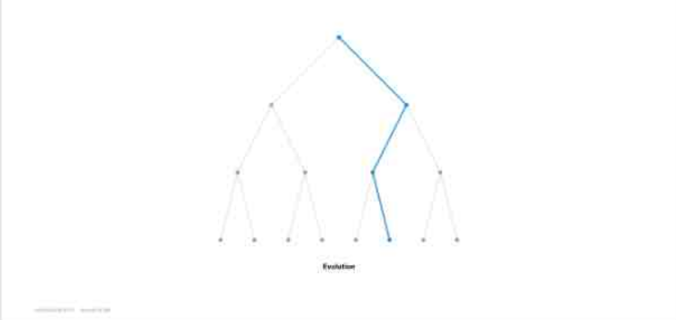
Communication


Stacks


Information primitives


Networks


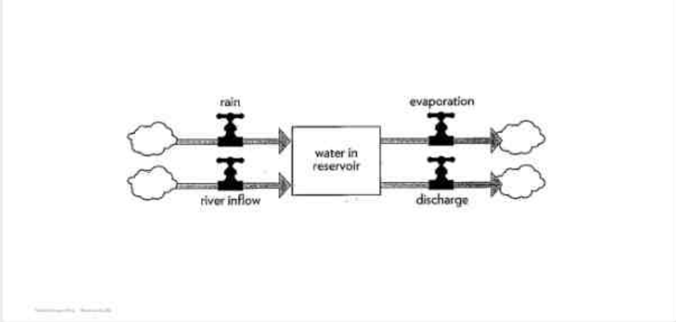
Variation


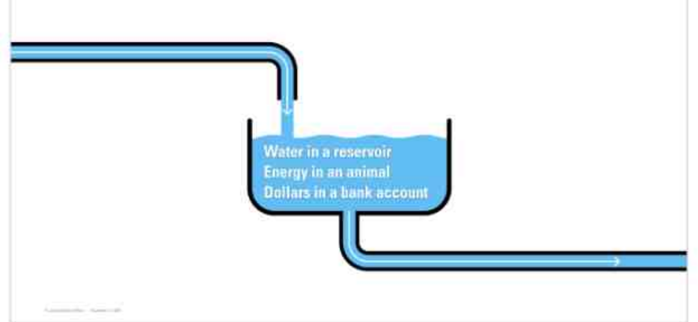
Evolution


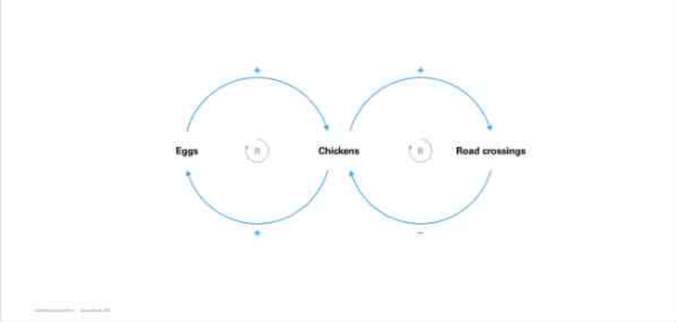
Design systems

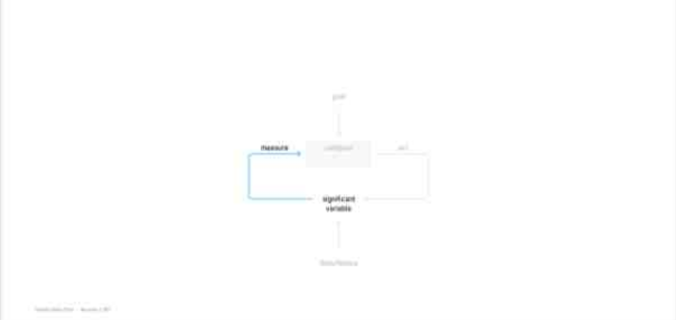

Physical stuff

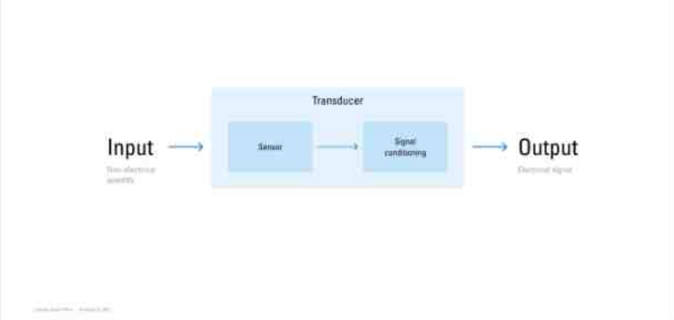

Power

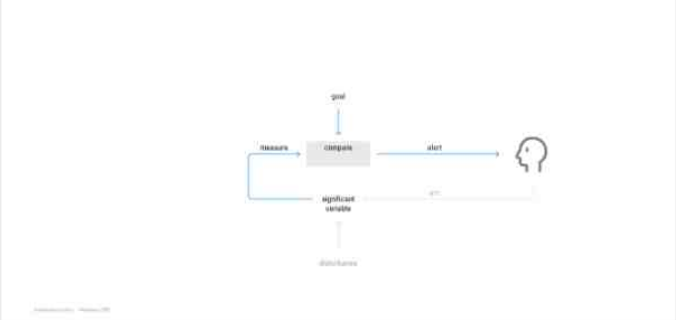

Stocks and flows


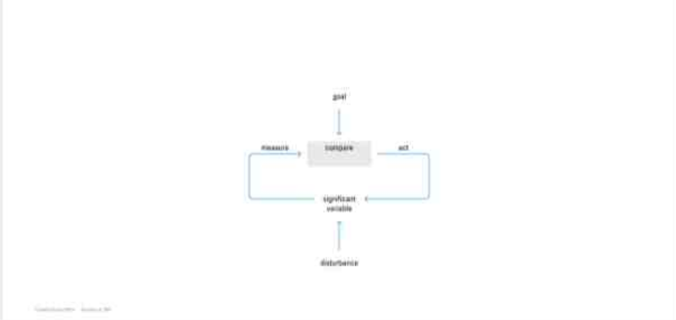
Dynamic Equilibrium


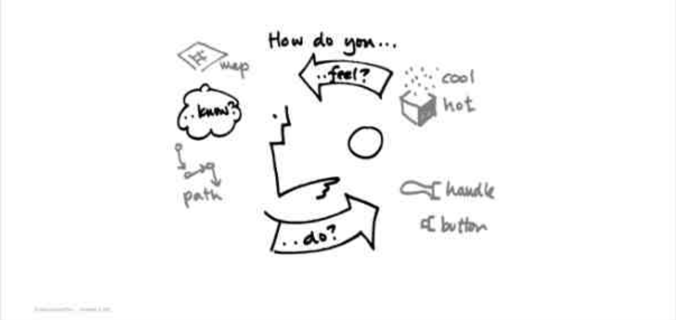
Causal-loop diagrams


Measuring


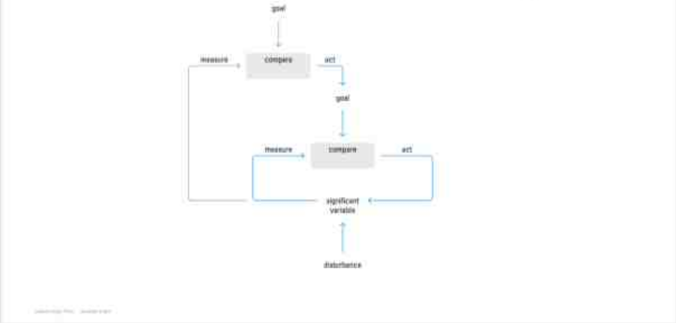
Transduction


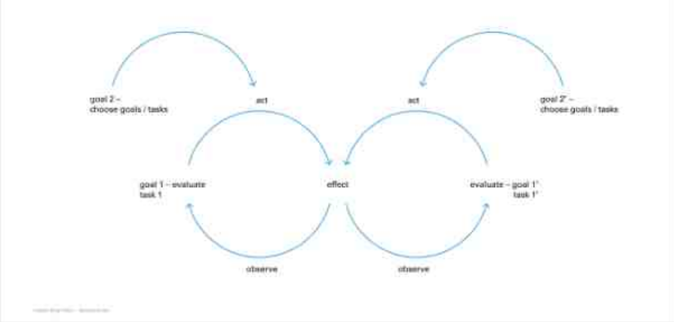
Monitoring (Open-loop)


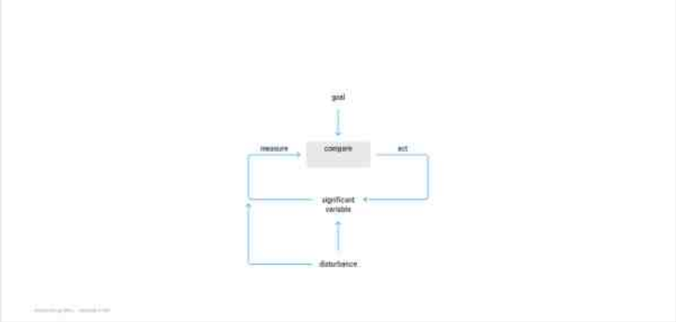
Control


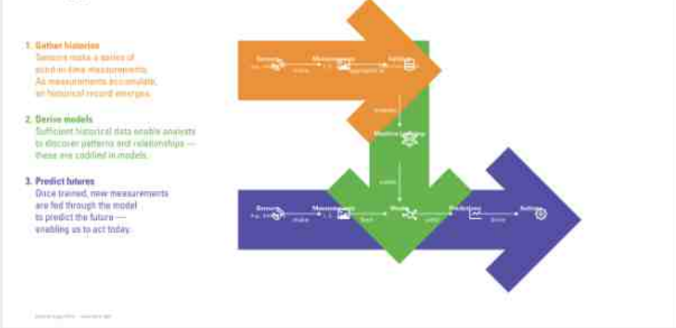
Interaction


User conceptual models

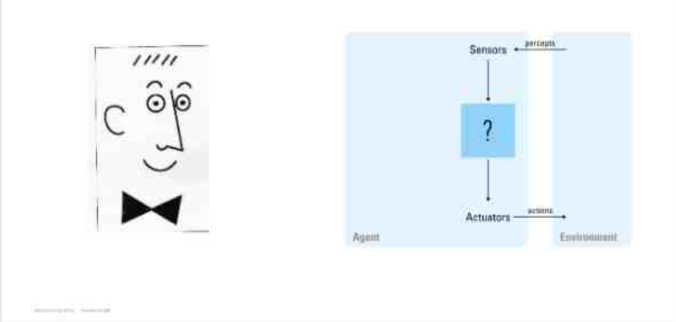

Second-order feedback (Learning)


Conversation


Feedforward


Digital twin


Autonomous operation


Intelligent agents


November 15, 2023

Core models
for systems designers

Dubberly Design Office