Mechanism and Mechanistic Explanation

Review - 1

- Experiments provide the best evidence of a causal relation, but sometimes they are not possible
  - Because it is impossible physically or morally to manipulate the independent variable
- Two strategies
  - Prospective studies
    - Divide groups according to the **independent variable** and investigate correlation with the dependent variable
  - Retrospective studies
    - Divide group according to the **dependent variable** and investigate correlation with the independent variable

Clicker Question

Researchers are concerned about confounds because

- They show that the dependent variable is not the cause of the independent variable
- They, rather than the dependent variable, might be the cause of the independent variable
- They, rather than the independent variable, might be the cause of the dependent variable
- Are concerns only in retrospective studies

Review - 2

- All studies of causation are beset by confounds
  - Factors correlated with the independent variable that may themselves be the cause of the change in the dependent variable
- By manipulating the independent variable in an experiment, researchers reduce the risk of confounds
  - Researchers can randomize or match subjects or lock (control) procedural variables to minimize confounds
- Prospective and retrospective experiments do not allow manipulation
  - Greater risk of subject confounds. Try to reduce the risk by
    - matching subjects
    - measuring possible confounds

Clicker Question

A retrospective study differs from a prospective study

In that it involves manipulating the independent variable

In that it involves manipulating the dependent variable

It divides subjects by their value on the independent variable

It divides subjects by their value on the dependent variable

Two limitations of focusing only on causes

- Individual causal relations do not accomplish much
  - It often requires a coordinated system of causes to get something done
- Establishing a causal relation does not explain what relates causes to their effects
  - Typically there are processes intervening between causes and their effects

Much of science is concerned not with demonstrating specific causal relations, but with discovering **mechanisms** and explaining phenomena in terms of them

Mechanisms consist of **parts (entities) and causal operations (causal activities) organized to produce a phenomenon**

Mechanisms are appealed to

To explain causal relations

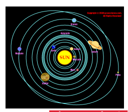
And appeal to causal relations between their parts

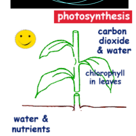
Clicker Question

Imagine someone has traveled in time from 1885 to 2011 and is trying to figure out how a car works. They do a series of experiments from the driver's seat, without ever looking under the hood of the car, and conclude that turning the ignition key explains why the car runs. What is a major limitation of their experiments?

- The person failed to control for subject confounds
- The person failed to control for procedural confounds
- The person missed the causal intermediaries that explain how the car worked
- The person failed to consider more ultimate variables such as the refinement of gasoline

The Ubiquity of Mechanisms in Science

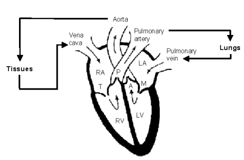




- Mechanisms in physical sciences
  - Solar system mechanics
  - Mechanisms of chemical reactions
- Mechanisms in biological sciences
  - Mechanisms of photosynthesis
  - Mechanisms of reproduction
- Mechanisms in behavioral sciences
  - Mechanisms of memory encoding
  - Mechanisms of decision making
- Mechanisms in social sciences
  - Mechanisms of consensus formation

Mechanisms as Coordinated Causation

- Mechanisms consist of **parts** whose **operations cause** changes in other parts, enabling mechanisms to **cause** changes in yet other things
- Muscles in heart contract while valves open and shut, **enabling**
  - The heart to move blood through arteries and veins



- Understanding a mechanism requires experimental procedures designed to figure out the parts, their causal operation, and how these operations are **coordinated (organized)** so that the mechanism can produce its effect

Clicker Question

When a scientist is interested in the mechanism responsible for the causal effect of aspirin on pain, she is

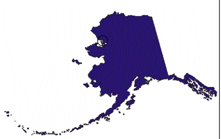
- Expressing skepticism that aspirin really affects pain
- Trying to understand how aspirin affects pain
- Trying to eliminate any confounds in experiments studying the affects of aspirin on pain
- Trying to determine whether aspirin does affect pain

Designing Mechanisms vs. Discovering Mechanisms

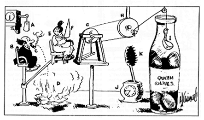
- The challenge in engineering is to design new mechanisms that produce the phenomena we are interested in
  - Typically, engineers begin with a goal and recruit parts already known to perform operations
  - Their challenge is to discover new modes of organization that enable the parts to together do something new
- Scientists do not have access to the design manuals of the mechanisms operative in the natural world
  - They must **reverse engineer** them—discover the parts, the operations, and the organization

Designing Mechanisms in Your Life

- Design a mechanism (set of operations) for making a beef taco
- Design a mechanism (set of operations) for getting to Kotzebue, Alaska
- Design a mechanism (set of operations) for making sure you get to class on time



Fish an Olive Out of a Long-Necked Bottle



At 6:30 weight (A) automatically drops on head of dwarf (B), causing him to yell and drop cigar (C), which sets fire to paper (D). Heat from fire angers dwarf's wife (E). She sharpens potato knife (F) on grindstone (G) which turns wheel (H) causing olive spoon (I) to dip repeatedly into olives. If spoon does not lift an olive in 15 minutes, clock (J) automatically pushes glass-cutter (K) against bottle and takes out a chunk of glass big enough for you to stick your finger in and pull out an olive.

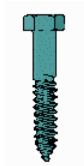
An Automatic Back Scratcher

Flame from lamp (A) catches on curtain (B) and fire department sends stream of water (C) through window. Dwarf (D) thinks it is raining and reaches for umbrella (E), pulling string (F) and lifting end of platform (G). Iron ball (H) falls and pulls string (I), causing hammer (J) to hit plate of glass (K). Crashof glass wakes up pup (L) and mother dog (M) rocks him to sleep in cradle (N), causing attached wooden hand (O) to move up and down along your back.

Early machines: Putting Shape to Work

Wedge

Ramp

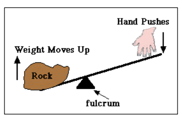


Screw

Early simple machines used human energy but extended its capacity

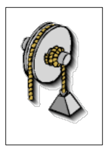
- In these cases, shape and spatial layout explain the causal efficacy

Early machines: Organizing Parts



Lever

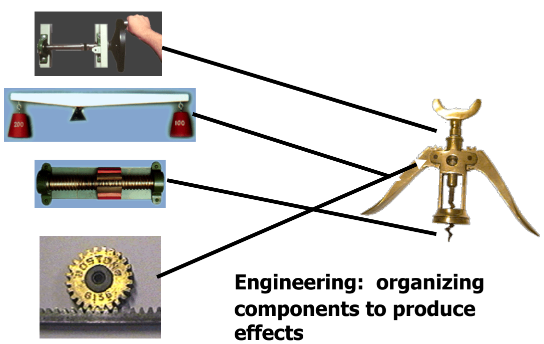
Wheel



Pulley

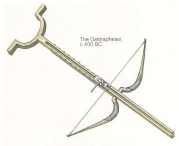
In these cases, shape and layout together with coordination of parts explains the effect

Combining simple mechanisms



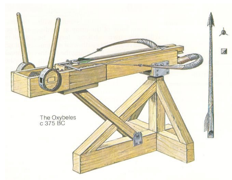
Engineering: organizing components to produce effects

Common force for creating new machines: warfare

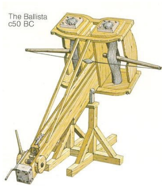


The Gastrophetes or belly bow, introduced around 400 BCE, designed to launch arrows further and more accurately than the traditional bow

The Oxybeles, introduced around 375 BCE, provided ever greater power and accuracy

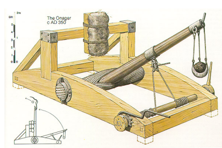


Common force for creating new machines: warfare



Ballista, introduced around 50 BCE, used more for throwing stones than arrows

Onager, developed around 350 CE, was a low cost way of launching projectiles such as clay balls with Greek fire inside

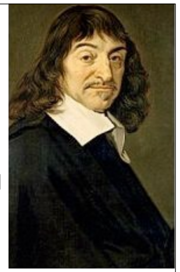


Evolution of a Design: The "modern" Trebuchet

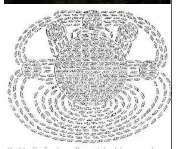
As in biology, so with human machines

- Once a basic design is shown to work
- It tends to be preserved
- With new additions added

Nature as a machine: Rene Descartes



"I have described this earth and indeed the whole universe as if it were a machine: I have considered only the various **shapes** and **movements** of its parts" (Principia IV 188).



All action in the physical universe due to shape and motion of physical matter

- No vacuum
- No action at a distance

Magnetism: Screw-shaped particles (formed in vortices) fit into threads in iron.

Descartes: Animals as machines

Automated garden figures and main driving mechanism in the grottoes of the royal gardens at Saint-Germain-en-Laye. From engravings in Salomon de Caus, *Les raisons des forces mouvantes avec diverses machines tant utilles que plaisantes ausquelles sont adjoints plusieurs desseings de grotes et fontaines*, Frankfurt, J. Norton, 1615. This grotto is described by Descartes on page 13 of the French text.

Impressed by the statuary in the Royal Gardens that moved by hydraulic principles

- Animal bodies are purely mechanical devices

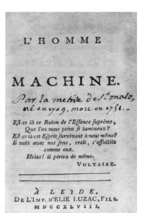
Circulation of blood due to heating in the heart, causing the expansion of droplets of blood, which then forced their way through the arteries

Nerve transmission and brain activity purely mechanical (albeit influenced by the mind in humans)

Humans as machines

Descartes could not conceive of a mechanism that could think or use language

- Accordingly, held that the human capacity for thought was not due to a mechanism
- Rather, thought due to a non-material mind



L'HOMME

MACHINE.

Par la metrie de St malo, né en 1709, mort en 1751.

Est-ce là ce Raion de l'Essence suprême,
Que l'on nous peint si lumineux?
Est-ce là cet Esprit survivant à nous même?
Il naît avec nos sens, croît, s'affoiblit comme eux.
Helas! il périra de même.

VOLTAIRE.

À LEIDE,
DE L'IMP. D'ELIE LUZAC, FILS.
MDCCXLVIII.

Julien Offray de La Mettrie objected that Descartes did not go far enough—all human activities, including thinking explained in mechanical terms

- *Man the Machine* in 1748

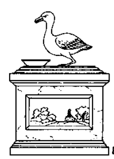
Clicker Question

In treating animal (and human) bodies as machines, Descartes was

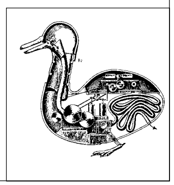
- Maintaining that they consisted of metallic parts that moved like the parts of a clock
- Denying the possibility of causal explanation of the behavior of animal bodies
- Claiming that their behavior could be explained in terms of the organized causal activities of their parts
- Claiming that it was easy to explain how animals worked

Jacques de Vaucanson (1709-1782): "Moving Anatomy"

- Mechanical duck
  - could move in the typical, wagging way of a duck
  - eat and digest fish
  - excrete the remains in a "natural" way
- Mechanism was driven by a weight
- Consisted of more than a thousand moving parts, concealed inside the duck and the base on which the bird stood
- Besides the duck, a flute and tambourine player

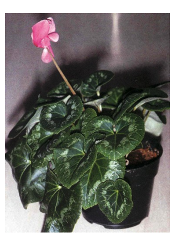


B1



Applying mechanical ideas to living organisms

- Living things seem to behave in complex ways that defy simple mechanical explanation
- Vitalists (anti-mechanists) maintained that the complexity and purposiveness of biological processes made mechanical explanation impossible
- Mechanists developed more complex conceptions of mechanisms



Tropism

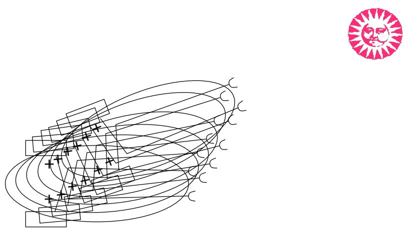
Two principles of Jacques Loeb:

(i) The movements of an organism to or from a center of a stimulus are caused by action of the stimulus on the receptors, and through these on the organs of locomotion, in consequence of which the animal turns until its body is symmetrically stimulated and an equilibrium obtained between the two sides.

(ii) These movements occur mechanically, as a result of physical and chemical changes in the receptors and effectors, with no real effort on the part of the organism.

Designing a tropistic machine

Designing a tropistic machine



Tasks in Developing a Mechanistic Explanation

1. Describe the phenomenon
2. Identify the working parts
3. Identify the operations the parts perform
4. Discover how the parts are organized

Task 1: Describing the Phenomenon

- Before setting out to explain a phenomenon, need to characterize it as accurately as possible
  - Otherwise one risks trying to explain something that might not be possible
- An important role for purely **observational research**
  - Before seeking a mechanism by which the universe continues to expand, make sure it is
  - Before seeking a mechanism to explain global warming, make sure it is really occurring
- But the description of the phenomena may be **revised** in the process of figuring out the mechanism

Task 2: Identify the ***working*** parts

To understand a mechanism, one must **decompose** it—take it apart

- Literally—actually remove the parts to study them in isolation
- Figuratively—figure out what the parts are and what they do

In identifying components, focus both on their

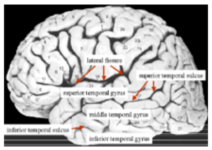
- Structure—parts
- Function—operations

Different tools for identifying parts and operations

What are the parts of the brain?

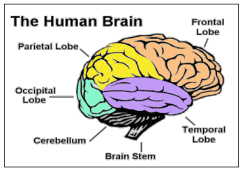
Open up the skull, and you see a hunk of grey matter highly convoluted

What are the **working** parts of the brain?



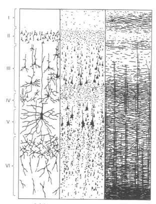
Sulci and Gyri?

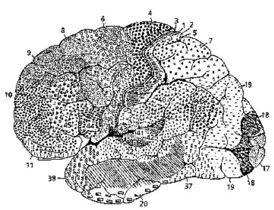
Lobes?



What are the working parts of the brain?

Korbinian Brodmann (1909) assumed differences in neuron type, density, and layering were probably related to function





Delineated areas in the brains of humans and many other species

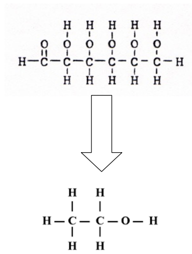
Task 3: What operations do the components perform?

Often one must reason backwards from what the whole mechanism does to what operations are needed to perform that activity

Often these operations are not obvious. Researchers must engage in reverse engineering

- Advance hypotheses as to what tasks need to be performed to produce the phenomenon
- Using information about the type of operations that have been previously identified in similar systems
- Drawing upon analogies with machines made by humans

What are the operations in fermentation?

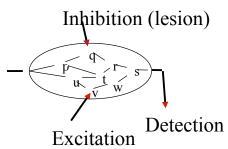


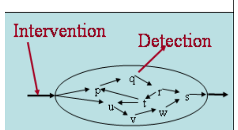
Ethyl alcohol
C_2H_5OH

Strategies of discovering intermediate operations

Operations in a mechanism are causal processes

- Accordingly, they are typically investigated my manipulating components to determine their effects
  - Inhibit possible intermediate processes to see if that stops the reaction—**lesion experiment**
  - Insert possible intermediaries to see if they could produce the end product—**excitation experiment**
  - Record from possible intermediates as the mechanism is operating to determine what they respond to—**recording experiment**





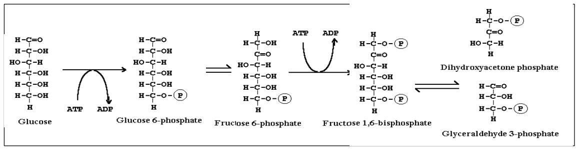
Clicker Question

The goal in decomposing a mechanism is

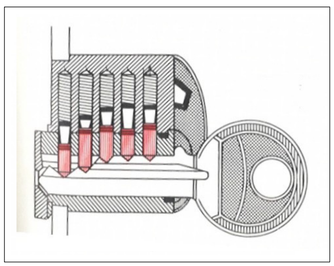
To find out how the parts are organized to produce the phenomenon of interest
To render the mechanism inoperable
To identify the parts and operations in the mechanism
To show that the mechanism doesn’t do what it is claimed to do

Task 4: Discover How the Parts are Organized

- The third feature of mechanisms is that they are organized and that the organization matters
- Grains of sand in a sand pile are not organized: you can recombine the grains at will and nothing happens
- In mechanisms, the operation of one part depends on that of others, so organization is crucial



Organization is critical to the operation of a lock



Using diagrams to portray organization

It is very difficult to understand the organization of a complex system from a verbal description

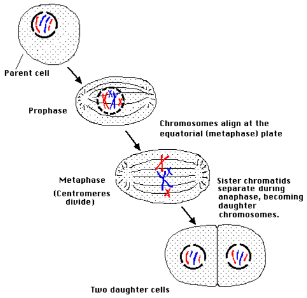
Diagrams are able to show in two dimensions the spatial layout of a mechanism

Often, though, diagrams must also show the activity of the mechanism

- This is often done through arrows
- Sometimes through sequences of diagrams
- Increasingly, by animating diagrams

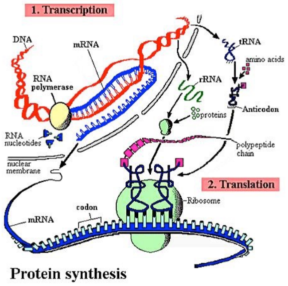
Diagramming steps in a process in separate diagrams

- Show organization at successive stages in the process of cell division
- Use arrows to reflect the progression of stages



Diagramming steps in a process in a common diagram

- Use arrows to trace the movement of components from one location to another: here, move various RNAs from the DNA of the nucleus to the ribosomes in the cytoplasm



Protein synthesis