Mechanism and Mechanistic Explanation

Does anyone belong to clicker numbers?
9B92F9F0
974232E7
89B44578
82A3DCFD
8524B011

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

A possible confounding variable is

- A variable correlated with the dependent variable that might be a cause of the independent variable
- A variable correlated with the independent variable that might be a cause of the dependent variable
- A bias of experimenters to see positive results
- A reason to prefer retrospective studies as providing stronger evidence

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 confounds. Try to reduce the risk by
    - matching subjects
    - measuring possible confounds

Clicker Question

What is the major advantage of a randomized experiment over a prospective study?

- In an experiment one manipulates the independent variable
- Randomizing can control for unknown subject confounds
- Randomizing can control for unknown procedural confounds
- There is no experimenter bias in a randomized experiment

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

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
- What relates causes to their effects?
  - Typically there are processes intervening between causes and their effects

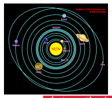
Much of science is concerned not with demonstrating specific causal relations, but with discovering **mechanisms** and explaining phenomena in terms of them

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

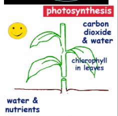
Mechanisms are appealed to

- To explain causal relations
- And appeal to causal relations between their parts

The Ubiquity of Mechanisms in Science

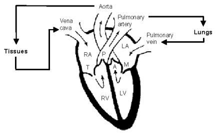


- Mechanisms in physical sciences
  - Solar system mechanics
  - Mechanisms of chemical reactions
- Mechanisms in biological sciences
  - Mechanisms of photosynthesis
  - Mechanisms of reproduction
- Mechanisms in behavioral sciences
  - Mechanisms of memory encoding
  - Mechanisms of decision making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

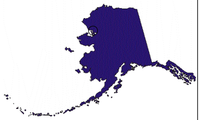
- Expressing skepticism that aspirin really affects pain
- Trying to understand how aspirin affects pain
- Trying to eliminate any confounds in experiments studying the affects of aspirin on pain
- Trying to determine whether aspirin does affect pain

Designing Mechanisms vs. Discovering Mechanisms

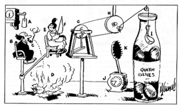
- The challenge in engineering is to design new mechanisms that produce the phenomena we are interested in
  - Typically, engineers begin with an objective and recruit parts already known to perform operations
  - Their challenge is to discover new modes of organization that enable the parts to together 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

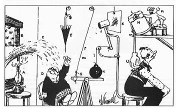


Fish an Olive Out of a Long-Necked Bottle



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

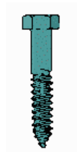


Flame from lamp (A) catches on curtain (B) and fire department sends stream of water (C) through window. Dwarf (D) thinks it is raining and reaches for umbrella (E), pulling string (F) and lifting end of platform (G). Iron ball (H) falls and pulls string (I), causing hammer (J) to hit plate of glass (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

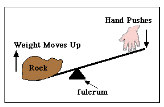


Screw

Early simple machines used human energy but extended its capacity

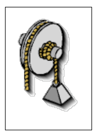
- In these cases, shape and spatial layout explain the causal efficacy

Early machines: Organizing Parts



Lever

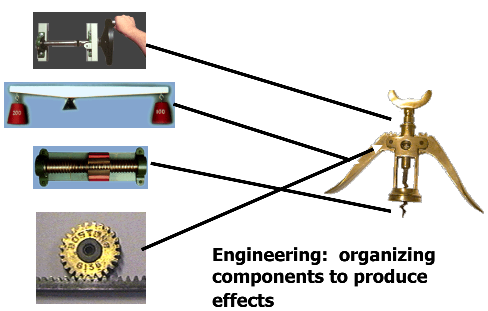
Wheel



Pulley

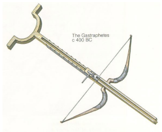
In these cases, shape and layout together with coordination of parts explains the effect

Combining simple mechanisms



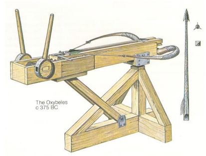
Engineering: organizing components to produce effects

Common force for creating new machines: warfare

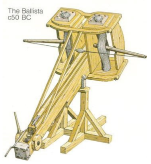


The Gastrophetes or belly bow, introduced around 400 BCE, designed to launch arrows further and more accurately than the traditional bow

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

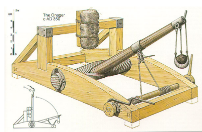


Common force for creating new machines: warfare



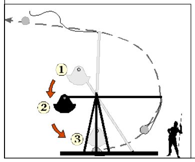
Ballista, introduced around 50 BCE, used more for throwing stones than arrows

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



Common force for creating new machines: warfare

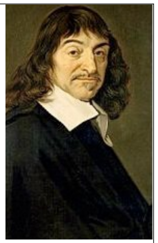
Trebuchet: a counterweighted catapult designed to throw heavy projectiles



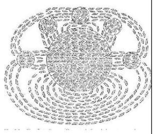
Such as pianos!

- Chris throwing Maggie's piano in Northern Exposure

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).

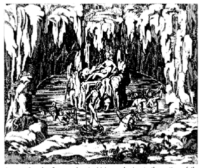


All action in the physical universe due to shape and motion of physical matter

- 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 dessings 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)

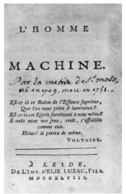
Humans as machines

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

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



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.

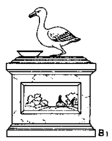
Clicker Question

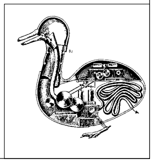
In treating animal (and human) bodies as machines, Descartes was

- 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 their parts, operations, and organization
- Claiming that it was easy to explain how animals worked

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

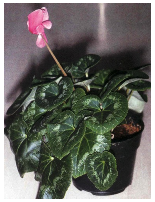
- Mechanical duck
  - could move in the typical, wagging way of a duck
  - eat and digest fish
  - excrete the remains in a "natural" way
- Mechanism was driven by a weight
- Consisted of more than a thousand moving parts, concealed inside the duck and the base on which the bird stood
- Besides the duck,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





Applying mechanical ideas to living organisms

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



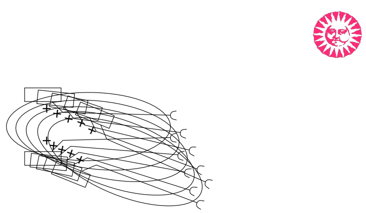
Tropism

Two principles of Jacques Loeb:

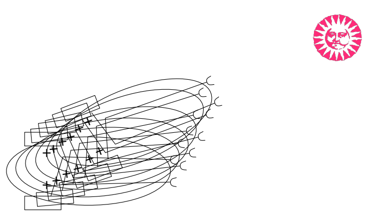
(i) The movements of an organism to or from a center of a stimulus are caused by action of the stimulus on the receptors, and through these on the organs of locomotion, in consequence of which the animal turns until its body is symmetrically stimulated and an equilibrium obtained between the two sides.

(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

Describe the phenomenon
Identify the working parts
Identify the operations the parts perform
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

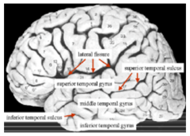
- Structure—parts
- Function—operations

Different tools for identifying parts and operations

What are the parts of the brain?

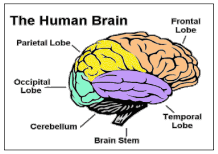
Open up the skull, and you see a hunk of grey matter highly convoluted

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



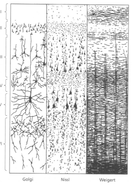
Sulci and Gyri?

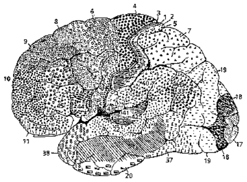
Lobes?



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

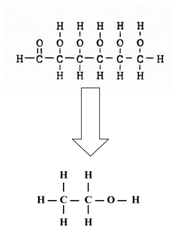
- Reverse engineering
- Figuring out what task needs to be performed
- Using information about the type of operations that have been previously identified in similar systems
- Drawing upon analogies with machines made by humans

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

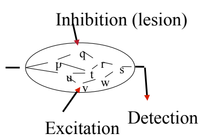
What are the operations in fermentation?

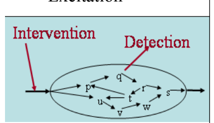


Strategies of discovering intermediate operations

Isolate possible intermediaries

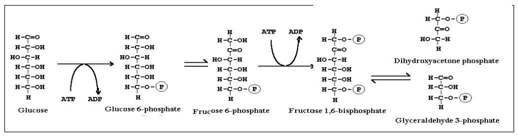
- Inhibit possible intermediate processes to see if that stops the reaction—**lesion experiment**
- Insert possible intermediaries to see if they could produce the end product—**excitation experiment**
- Record from possible intermediates as the mechanism is operating to determine what they respond to—**recording experiment**



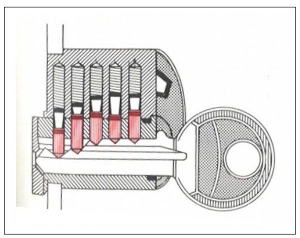


Task 4: Discover How the Parts are Organized

- 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



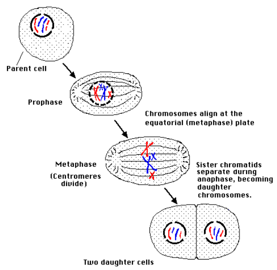
Using diagrams to portray organization

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

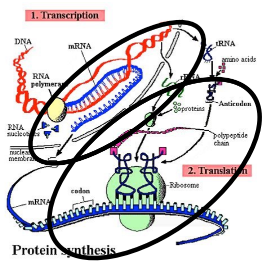
Diagramming steps in a process in separate diagrams

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



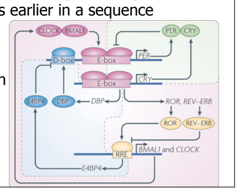
Diagramming steps in a process in a common diagram

- 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



Beyond Sequential Organization

- Negative Feedback
  - In many mechanisms, operations later in a sequence serve to inhibit (subsequent iterations) of operations earlier in a sequence
    - Important for maintaining system in desired condition
- Positive Feedback
  - It is also common for operations later in a sequence to promote (subsequent iterations) of operations earlier in a sequence
- Integrated Systems
  - Such organization renders a set of operations into a cohesive, and often stably enduring systems--organisms
    - The heart
    - A circadian clock



Clicker Question

A general use of negative feedback is

- To raise the number of negative outcomes
- To insure maximal efficiency in the operation of a mechanism
- To keep the operation of a mechanism within boundaries
- To make sure that predators don't destroy their prey

Organization creates systems

If the organization is appropriate, the components comprise a new entity

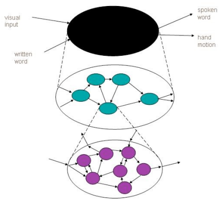
- One that operates as a unit
- Exists at a higher-level of organization than the components

Often it is cyclic organization, involving later reactions influencing ones earlier in a pathway, that turn a set of operations into a system—a recognizable entity that does something

- Nervous system
- Circulatory system

Levels of mechanism

- The system as a whole engages its environment by performing its activity
- That system is comprised of components that perform different operations
- Those components may in turn be comprised of components that perform yet different operations



Holism versus reductionism

Tension:

- Emphasizing organization focuses on the integration of the components into a whole system (holism)
- Emphasizing components focuses on the decomposition of the system into separate components (reductionism)

As a result, holism (vitalism) and reductionism are often pitted against each other

- Holists charge that reductionists fail to consider the consequences of organization
- Reductionists charge that holists fails to provide explanations

Mechanistic explanations: both reductionist and holist

To understand a mechanism you must be both a holist and a reductionist

Look both

- Upwards to higher levels of organization at which the mechanism is an organized systems that performs its activity and thereby interacts with other entities

and

- Downwards to lower levels of organization in which parts perform their operations in interaction with other parts

Clicker Question

A reductionist, in contrast to a holist,

- Focuses on how the components of the system fit into an integrated whole
- Denies any importance to discovering the parts of the mechanism
- Denies that organization plays any role in the operation of a mechanism
- Emphasizes the discovery of components as the key to understanding how a mechanism behaves

Clicker Question

A holist, in contrast to a reductionist,

- Places greater emphasis on the organization of the whole than on the identification of the parts
- Thinks that the parts don't matter; all that matters is how they are organized
- Denies that the parts of a mechanism are relevant to explaining what the mechanism does
- Places primary emphasis on discovering the parts of a mechanism