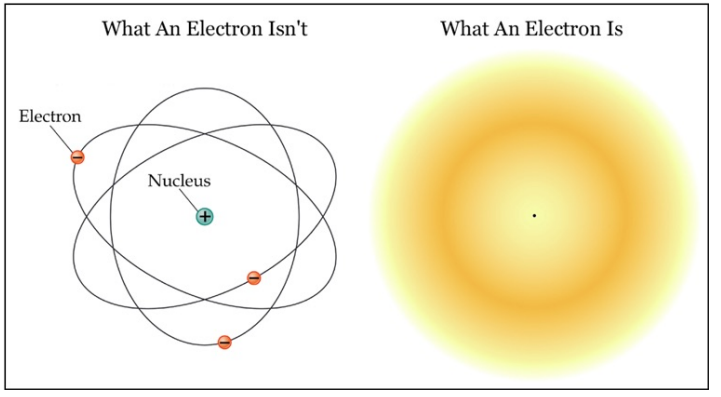
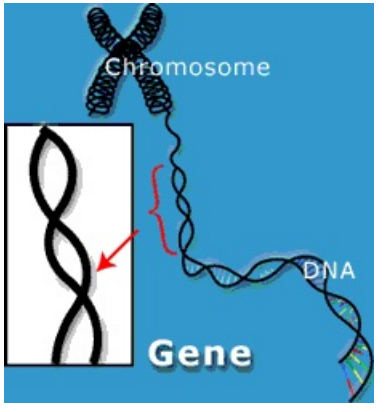
1. Scientific Realism



- What does the world consist of?
  - *electrons, chemical elements, genes, etc.*

- Was the world of one thousand years ago a world of electrons, genes, etc.?



  - <u>*Scientific realist*</u>: Yes, although nobody knew it back then.

  - <u>*Scientific anti-realist*</u>: No, the concepts of electron, gene, etc., were the product of debates and experiments in specific historical contexts (contingencies). These concepts are subject to change in future theories.

A. Types of Realism

Common-sense Realism: We inhabit a common reality, which has a structure that exists independently of what people think and say about it, except insofar as reality is comprised of, or is causally effected by, thoughts, theories, and other symbols.

- Could science tell us that common-sense realism is false?

Ex. 1: Quantum mechanics.

- Two ways a QM state can change:

  1. In absence of measurement, a state changes via the Schrödinger equation.

$$|\psi(t_1)\rangle \xrightarrow[\substack{Schrödinger\\ evolution}]{} |\psi(t_2)\rangle$$

  2. In presence of measurement, states change *via* the *Projection Postulate*:

> When a measurement of property B is made on a state $|\psi\rangle = a_1|b_1\rangle + ... + a_N|b_N\rangle$ expanded in the eigenvector basis of B with result b_i, then $|\psi\rangle$ collapses to $|b_i\rangle$:

$$|\psi\rangle \xrightarrow[collapse]{} |b_i\rangle$$

- What is a *measurement*? *When* is the Projection Postulate supposed to take over from the Schrödinger dynamics?

  - *When a conscious observer looks at a measuring device?*
  - *When a macroscopic system interacts with a microscopic system?*
  - *There is no Projection Postulate: when a measurement occurs, the world splits into as many duplicate worlds as there are possible outcomes of the measurement.*

Eugene Wigner

Hugh Everett

A. Types of Realism

Common-sense Realism: We inhabit a common reality, which has a structure that exists independently of what people think and say about it, except insofar as reality is comprised of, or is causally effected by, thoughts, theories, and other symbols.

- Could science tell us that common-sense realism is false?

Common-sense Realism Naturalized: We inhabit a common reality, which has a structure that exists independently of what people think and say about it, except insofar as reality is comprised of, or is causally effected by, thoughts, theories, and other symbols, and except insofar as reality is dependent on thoughts, theories, and other symbols in ways that might be uncovered by science.

Scientific Realism:

1. Common-sense realism naturalized.
2. One actual and reasonable aim of science is to give us accurate descriptions (and other representations) of what reality is like, including aspects of reality that are unobservable.

- *Optimistic Scientific Realism*: We can be confident that science is successful in this aim.

- *Pessimistic Scientific Realism*: We can hope that science is successful in this aim, although it is very difficult.

  - *Ex: Kuhn (pessimistic scientific realist): We try to 'force' nature into 'boxes' but nature resists. All paradigms are doomed to fail eventually.*

Pessimistic Meta-Induction: All theories in the history of science have been wrong, so current and future theories must and will be wrong, too.

Past theories now thought wrong:
- Aristotle's theory of motion.
- Humoral theory of disease.
- Caloric theory of heat.
- Phlogiston theory of chemical reactions.
- Aether theories of optics and electromagnetism.
- Vital force theories in physiology.
- Newton's theory of motion.

- *Basic Issue*: What level of confidence should we have in our current theories?

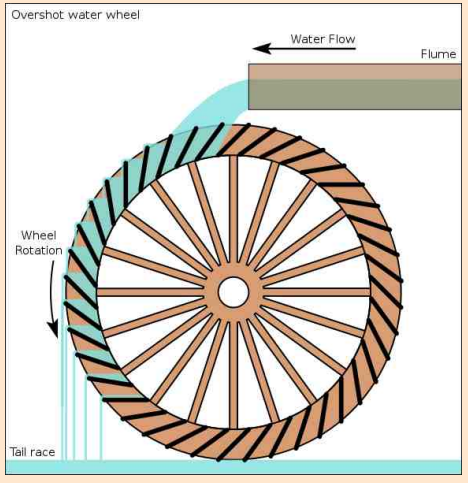
Miracle Argument: Realism is the only philosophy of science that does not make the success of science a miracle.

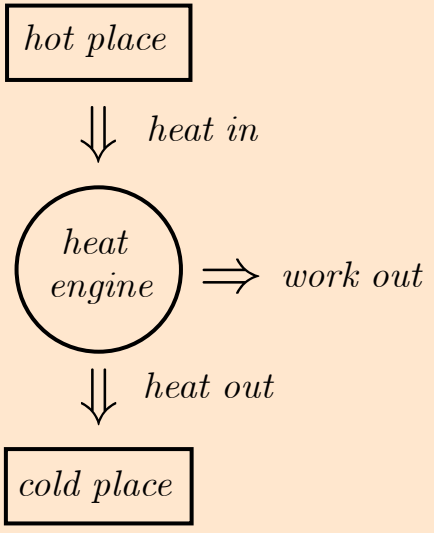
- *But*: There are many kinds of ways in which the link between theory and reality can generate success.
  - *Accurate representation* of the world is not the only way.

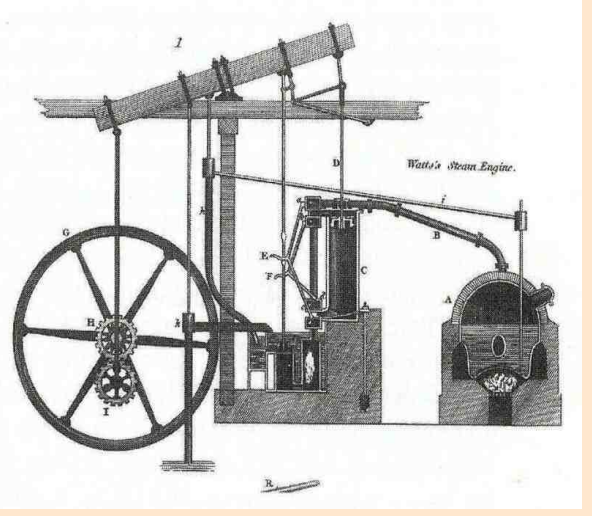
Ex. 2: Carnot, S. (1824) "Reflections on the Motive Power of Fire"

Sadi Carnot
1796-1832

- *Idea*: Treat heat in analogy with water as a substance ("caloric") that produces mechanical effect (work) when it "falls" from a hot place to a cold place.







- *Important question*: What is the *maximally efficient* heat engine?

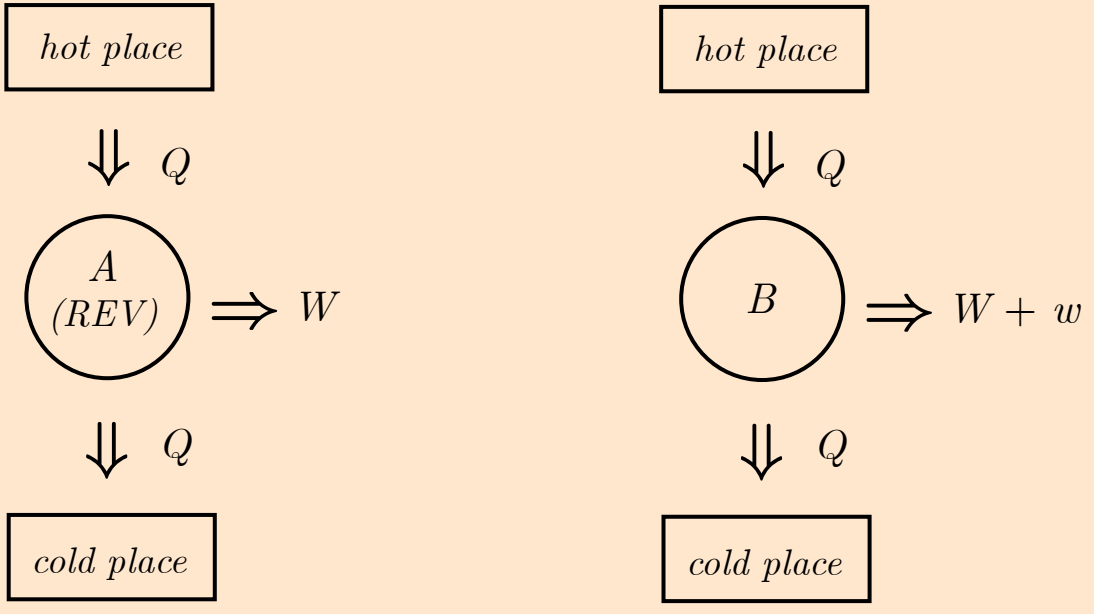
Maximum efficiency is obtained when heat-flow between hot place and engine, and engine and cold place, occurs at *equal temperatures*.

- *Analogy with water-wheel:* Maximum efficiency obtained when water-flow between stream and water-wheel occurs at *equal heights* (minimizes splashing).

Claim: The maximum efficiency of *any* heat engine is equal to that of a reversible heat engine operating between the same hot and cold places.

Proof:

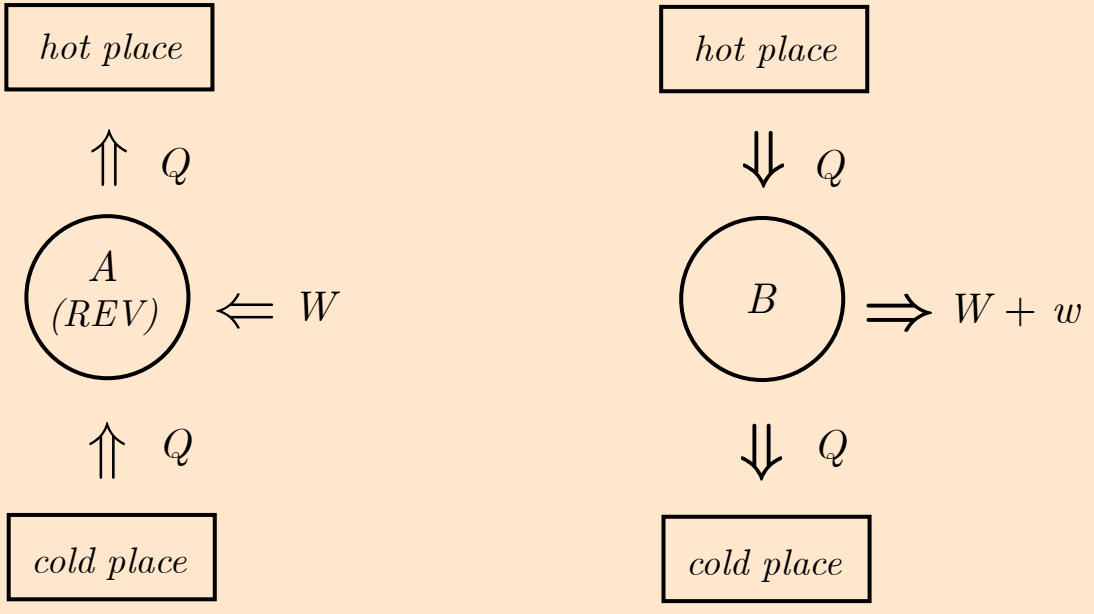
- Suppose we have a reversible engine A that produces work W.
- Suppose there is a more efficient engine B between the same hot and cold places (B uses the same heat as A and produces more work).
- Now reverse A and hook it up to B.



Claim: The maximum efficiency of *any* heat engine is equal to that of a reversible heat engine operating between the same hot and cold places.

Proof:

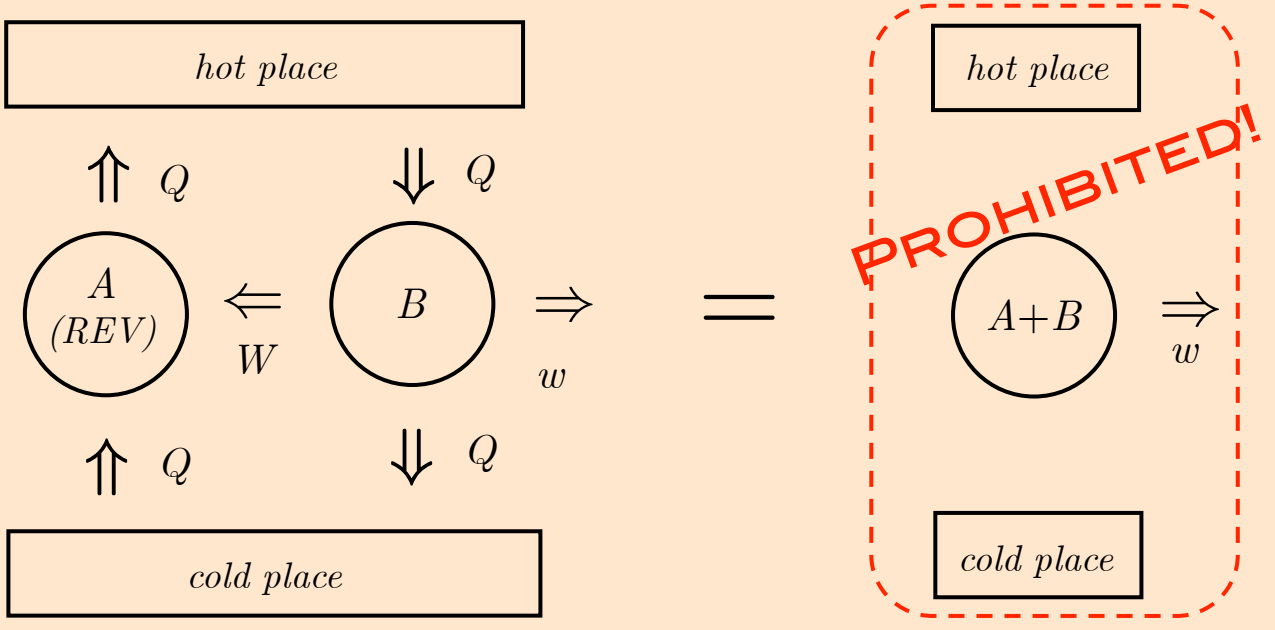
- Suppose we have a reversible engine A that produces work W.
- Suppose there is a more efficient engine B between the same hot and cold places (B uses the same heat as A and produces more work).
- Now reverse A and hook it up to B.



Claim: The maximum efficiency of *any* heat engine is equal to that of a reversible heat engine operating between the same hot and cold places.

Proof:

- Suppose we have a reversible engine A that produces work W.
- Suppose there is a more efficient engine B between the same hot and cold places (B uses the same heat as A and produces more work).
- Now reverse A and hook it up to B.
- Engine (A+B) does work w for free (no net fall of heat required)! But, sez Carnot, this is impossible: a perpetual motion machine!



Ex. 3: Maxwell, J. (1861) "On Physical Lines of Force"

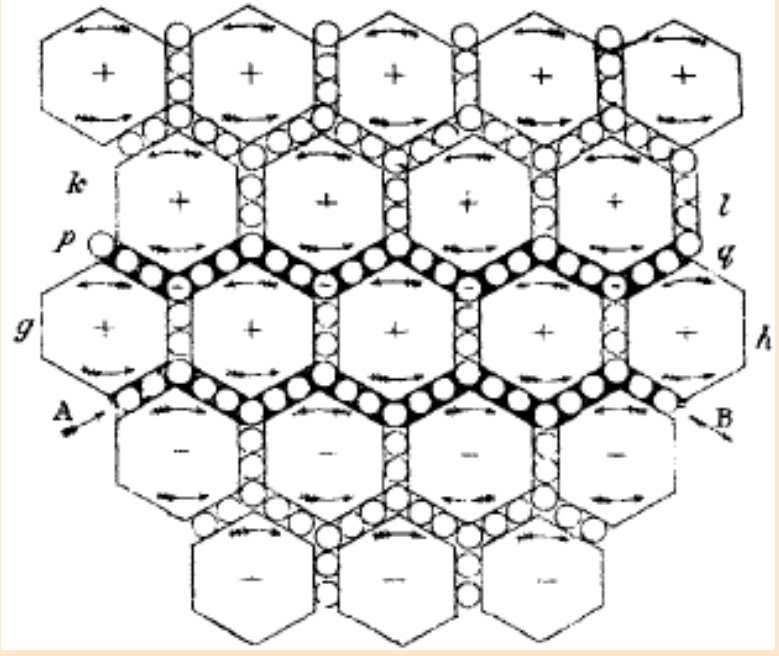
James Clerk Maxwell
(1831-1879)

- *Idea*: Treat electromagnetism as a mechanical effect of an "aether" made up of vortices and idle wheels.

(a) *Ampère's Law*: $\mathbf{J} = \nabla \times \mathbf{H}$. Current density ($\mathbf{J}$) in a wire generates a magnetic intensity ($\mathbf{H}$) around the wire.

(b) *Faraday's Law*: $-\partial\mu\mathbf{H}/\partial t = \nabla \times \mathbf{E}$. A changing magnetic intensity ($-\partial\mu\mathbf{H}/\partial t$) through a wire loop generates an electric field ($\mathbf{E}$), around the loop.

Suppose the aether consists of a (3-dim) array of spinning "vortex" cells separated by moving idle wheels:



Purely mechanical results:

(a) (*flux of idle-wheels*) $= \nabla \times$ (*angular velocity of vortices*).

(b) (*change in angular momentum of vortices*) $= \nabla \times$ (*tangential force of idle-wheels on vortices*)

Let $\mathbf{J}$ = *flux of idle-wheels*
$\mathbf{H}$ = *angular velocity of vortices*
μ = *density of aether*
$\mathbf{E}$ = *tangential force of idle-wheels on vortices*

B. Objections to Realism

1. Traditional Empiricism

> *Underdetermination*: There will always be a range of alternative theories compatible with all possible evidence; thus we never have good empirical grounds for choosing one over the others and regarding it as representing how the world really is.

Underdetermination of interpretations of a single theory:

- Should evidence for general relativity count as evidence for
  - *the existence of spacetime as a real substance independent of physical objects?*
  - *the existence of spacetime as certain relations between physical objects?*

- Should evidence for quantum mechanics count as evidence for
  - *observer-dependent measurement outcomes?*
  - *many worlds?*
  - *many minds?*
  - *etc.*

B. Objections to Realism

1. Traditional Empiricism

> *Underdetermination*: There will always be a range of alternative theories compatible with all possible evidence; thus we never have good empirical grounds for choosing one over the others and regarding it as representing how the world really is.

Underdetermination of theories by evidence:

- Should evidence for Newton's law of gravity count as evidence for
  - *Newtonian gravity as a force in flat Neo-Newtonian spacetime?*
  - *Newtonain gravity as an effect of the curvature of Newton-Cartan spacetime?*

- Should (fledgling) evidence for quantum gravity effects count as evidence for
  - *canoncial quantum gravity?*
  - *string theory?*
  - *causal set theory?*
  - *etc.*

2. Metaphysical Constructivism

Metaphysical Constructivism: The world, in some sense, is created or constructed by scientific theorizing.

- Kuhn, Strong Programme, ANT.
- *Recall*: Modified versions of Kant?
  - *Noumenal world ("raw data") versus phenomenal world ("filtered data").*
  - *Kant's claim*: Filters (categories) are universal and absolute: There's only one way we construct the phenomenal world from the noumenal world.
  - *Kuhn/Strong Programme/ANT*: Filters are the products of culture and society and are not absolute and universal.
- *Objection to realism*: "There is a real world (the noumenal world) *constraining* what we believe but in a way that does not permit our knowing or representing this world."

Problem: Is this *really* incompatible with (pessimistic) scientific realism?

3. *Constructive Empiricism*

Van Frassen, B. (1980) *The Scientific Image*

- An *empirically adequate* theory accurately describes the *observable* parts of the world.
- A *true* theory accurately describes both the observable and unobservable parts of the world.

Constructive Empiricism: The aim of science is to provide empirically adequate theories. To accept a theory is to

1. believe (provisionally) that the theory is empirically adequate, and
2. use the concepts the theory provides when thinking about further problems and when trying to extend and refine the theory.

- *So*: A theory can be accepted while remaining agnostic about its truth.
- *And*: Why risk anything more epistemically?

Problem: How is the distinction between observable and unobservable parts of the world to be made?

- *Realist*: "...there is a continuum, rather than a sharp distinction, between the observable and the unobservable".

2. Scientific Explanation

Instrumentalism: Scientific theories are devices for helping us deal with experience. They are instruments ("black boxes") used to make and test predictions.

- *But*: Isn't there more to science than prediction? Doesn't science aim at explaining phenomena?
- What is it for a scientific theory to explain something?

Terminology:
- *Expanandum* = whatever is being explained.
- *Explanans* = the thing that is doing the explaining.

A. Covering Law Account

Covering Law Account: To explain something is to show how to derive it in a logical argument that makes use of a law of nature, such that:

(a) *The conclusion is the explanandum.*

(b) *The premises are the explanans.*

(c) *The premises contain at least one statement of a law of nature.*

(d) *The premises are true.*

(e) *The argument can be either deductive or inductive (when deductive, this type of explanation is called "deductive-nomological")*

explanans	$L_1, L_2, \ldots$	*law(s)*
	$C_1, C_2, \ldots$	*conditions underwhich laws are applicable*
explanandum	$\therefore O_1, O_2, \ldots$	*observed phenomena*

- *Nomic expectability*: To explain something is to show that it is nomically (lawfully) expected.

Ex. 1: Why does an ice skater spin faster as he brings his arms in towards his body?

1.	Angular momentum is conserved.	$(L_i = L_f)$	*law*
2.	Skater doesn't interact with external objects.	$(L_i = I_i\omega_i;\ L_f = I_f\omega_f)$	*conditions*
3.	Skater has non-zero initial angular momentum.	$(L_i \neq 0)$	
4.	Skater brings arms in towards body.	$(I_f < I_i)$	
$\therefore$	Skater spins faster.	$(\omega_i > \omega_f)$	*observed phenomenon*

- *Note*: If we only knew the law and conditions in the premises, we could *predict* the observed phenomenon.

Symmetry thesis: Every *covering law* explanation is a potential prediction. Every prediction is a potential *covering law* explanation.

Problem: Not every prediction is a potential *scientific* explanation.

Ex. 2: Why does the shadow of this flagpole have length l?

1.	Light propagates linearly.	*law*
2.	Sun is at certain elevation.	*conditions*
3.	*<Relevant trigonometic relations>*.	
4.	Flagpole has height h.	
$\therefore$	Shadow has length l.	*observed phenomenon*

- *Now*: Consider the following *prediction* of the height of a flagpole, given it's shadow has length l and various conditions hold:

1.	Light propagates linearly.	*law*
2.	Sun is at certain elevation.	*conditions*
3.	*<Relevant trigonometic relations>*.	
4.	Shadow has length l.	
$\therefore$	Flagpole has height h.	*observed phenomenon*

- Does this prediction count as a scientific *explanation* of the flagpole's height?
  - *Why does this flagpole have height h? Because it's shadow has length l?*

B. Causal Account

- *Intuition*: The flagpole *caused* the shadow, and thus can explain it. The shadow did not *cause* the flagpole, and thus cannot explain it.

Causal Account: To explain something is to describe what caused it.

Ex. 3: Why do automatic sliding doors open when you approach them?
- *Because when you approach an automatic sliding door, you step into the beam of an optical sensor, and this causes a circuit to be broken, which subsequently causes a mechanism to open the door.*

Problems:
- Causation is not entirely understood.
- Purely theoretical explanations occur in science.

Ex. 4: Why can't you fit a left-handed glove on your right hand?
- *Because a left-handed glove and your right-hand are topologically inequivalent in 3-dim Euclidean space (they are enantiomorphs).*

C. Unification Account

- *Intuition*: To explain is to connect a diverse set of facts by subsuming them under a set of basic patterns and principles.

> *Unification Account*: To explain something is to demonstrate how it belongs to the most *unifying systematization* of the set of claims currently endorsed by the scientific community.

- A *systematization* Σ of a set of claims is a subset of those claims from which the rest can be derived.

- Σ is *unifying* if it maximizes scope, simplicity and stringency.
  - *Scope measures the number of conclusions that can be drawn from* Σ.
  - *Simplicity measures the size of* Σ.
  - *Stringency measures the range of applicability of* Σ.

Ex. 5: Unification as a goal in physics.
- *Maxwell's theory of electromagnetism provides unifying explanations of electric and magnetic phenomena.*
- *The Standard Model provides unifying explanations of phenomena that experience the electromagnetic, strong, and weak forces.*

D. Contextual Pluralism

Contextual Pluralist: Science aims at explaning phenomena, but the standards of a good explanation depend on the scientific context.

"It is a mistake to think there is one basic relation that is *the* explanatory relation..." (Godfrey-Smith 2003, pg. 197.)

- Standards of explanation vary between scientific disciplines at any given time, and within disciplines at different times.

Ex. 6: Synchronic and diachronic contextual pluralism

- *Synchronic: Explanations in biology (causes/mechanisms) versus explanations in theoretical physics (unifying).*
- *Diachronic: Aristotelian explanations (occult forms) versus Cartesian explanations (causes/mechanisms).*