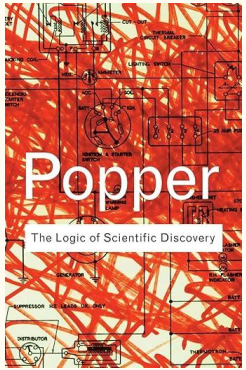
# LECTURE II

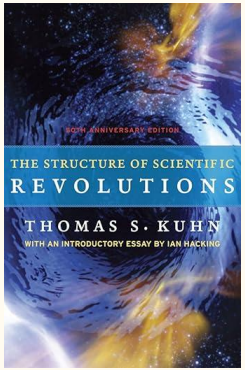
## COMPETING VISIONS OF SCIENCE

Foundations of Science I
Prof. Overbey
4/1/25

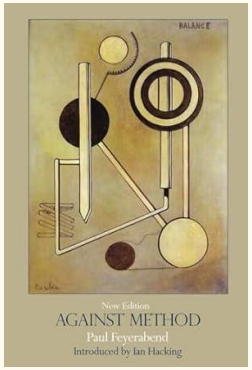
# CLASHING VISIONS

## How Should We Understand Science?



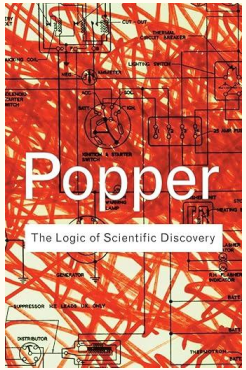



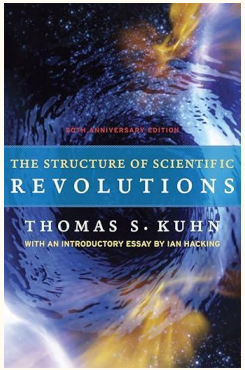




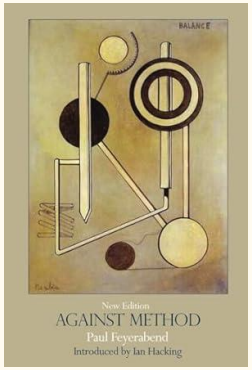
# CLASHING VISIONS

## Example: Theory of Evolution







# ON DARWINISM

## Popper

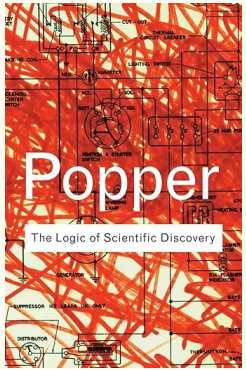
**“Darwinism is not a testable scientific theory but a metaphysical research programme. Its success is due to the fact that it is almost a tautology.”**
*— Karl Popper, "Unended Quest" (1976)*

Popper expressed concern that **natural selection** (i.e., “survival of the fittest”) was being used in a **circular** way—those who survive are the fittest, and the fittest are those who survive—**without independent criteria for “fitness.”**

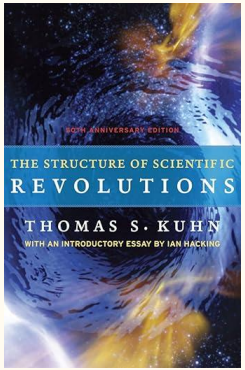
**“I have changed my mind about the testability and logical status of the theory of natural selection, and I am glad to have an opportunity to make a recantation.”**
*— Popper, in "Evolutionary Epistemology, Rationality, and the Sociology of Knowledge" (1980)*

# CLASHING VISIONS

## Example: Theory of Evolution

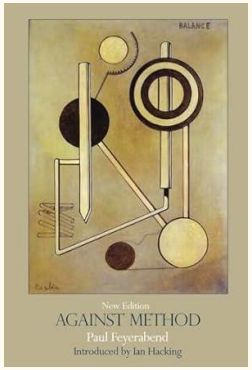



Initially criticized Darwinism as tautological, but later accepted it as a scientific theory with testable predictions about nature.




Viewed evolutionary theory as a strong scientific paradigm unlikely to be overturned without a major scientific revolution.


Framed Darwinism as a progressive research programme with a stable core and adaptable protective belt generating novel predictions.

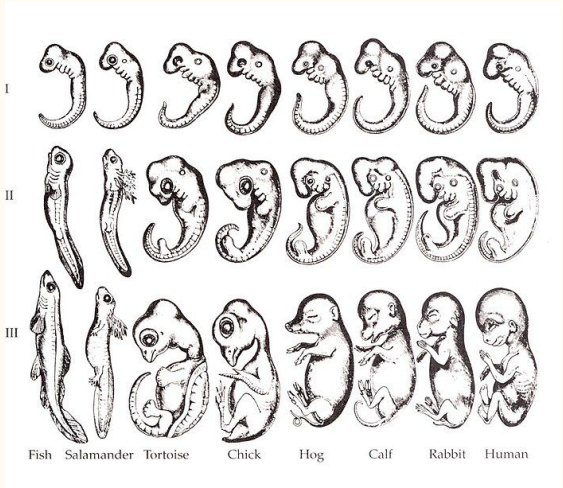


# EX: LAKATOS ADAPTIVE PROTECTIVE BELT

## Example: Recapitulation Theory

**The Theory (now rejected):**

- Proposed by **Ernst Haeckel**, this 19th-century idea claimed that the **embryonic development (ontogeny)** of an organism **literally repeats** the evolutionary history (phylogeny) of its species.
    - E.g., human embryos go through a “fish stage” with gill slits, then a “reptile stage,” etc.

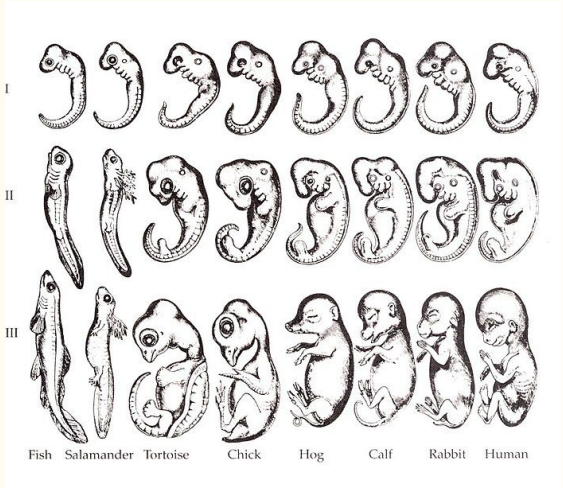


# EX: LAKATOS ADAPTIVE PROTECTIVE BELT

## Example: Recapitulation Theory

**What Happened:**

- The idea was appealing early on and **incorporated into evolutionary thinking** as part of the explanation for developmental biology.
- Over time, however, better embryological research showed:
    - The resemblance is **partial and symbolic**, not literal.
    - Haeckel even **exaggerated** some of his embryo drawings.
- The theory was **rejected** in its strong form.

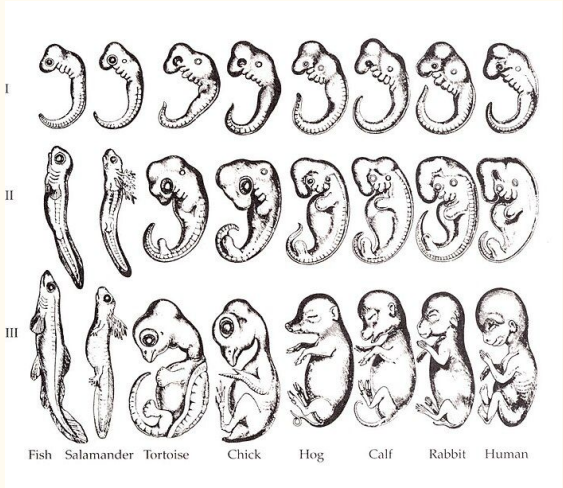


# EX: LAKATOS ADAPTIVE PROTECTIVE BELT

## Example: Recapitulation Theory

**In Lakatos' Terms:**

- **Hard core**: Evolution by natural selection and common descent.
- **Protective belt**: Recapitulation theory, as a specific developmental hypothesis.
- When it was falsified, the **protective belt was revised** (leading to Evo-Devo), but the **core theory remained intact**.



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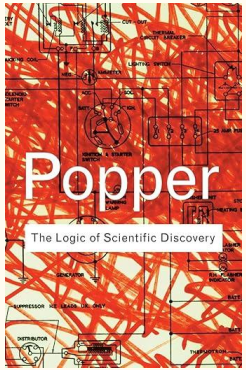


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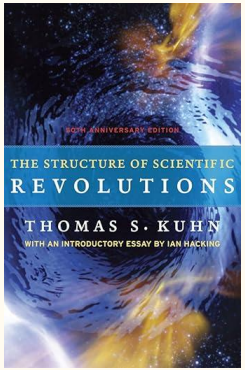


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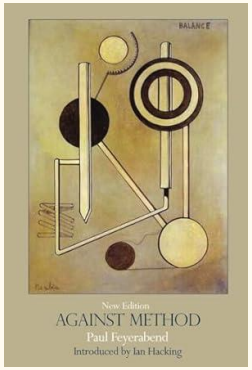


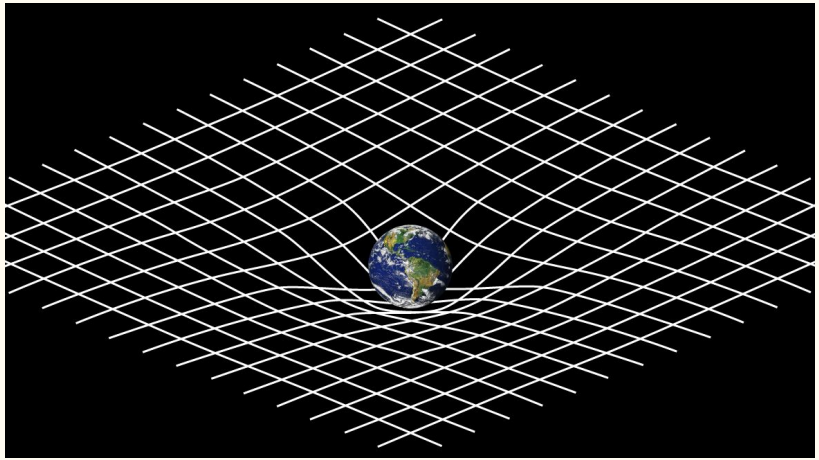

Feyerabend argued that science, while valuable, shouldn't be seen as the sole arbiter of truth or the ultimate authority in society. He believed that science, like any other ideology or social institution, could be used to oppress or marginalize other perspectives.

# CLASHING VISIONS

## Example: Einstein's General Theory of Relativity (GR)

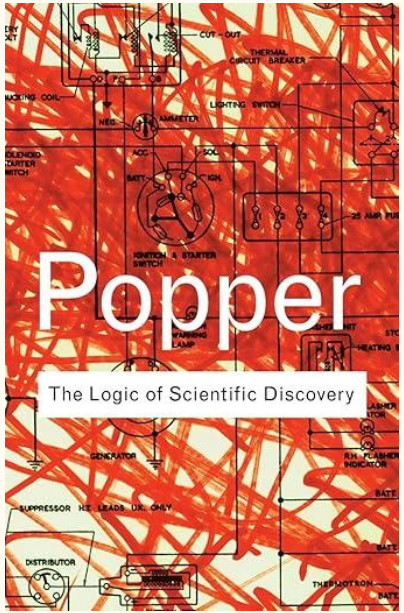
"Mass tells spacetime how to curve; curved spacetime tells mass how to move."

- Gravity isn't a force — it's the **curvature of spacetime**.
- Massive objects (like stars or planets) **bend spacetime**.
- Predicts:
  - Bending of light around stars
  - Gravitational time dilation
  - **Black holes**
  - **Gravitational waves** (confirmed in 2015!)



# CLASHING VISIONS

## Example: Einstein's General Theory of Relativity



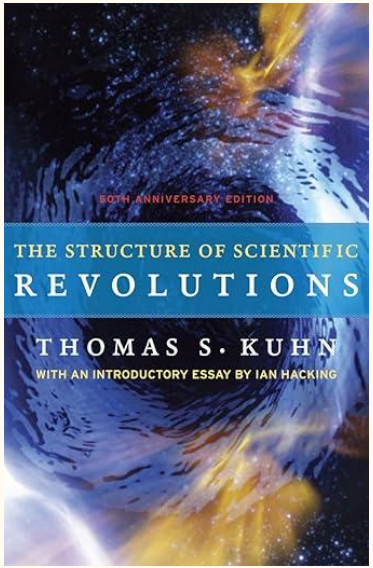

**View**: Relativity is a **model example of science** because it made **risky, testable predictions**.

**Why?**:

- GR predicted the **bending of starlight** near the sun—confirmed during the 1919 solar eclipse.
- Popper loved this because it was **falsifiable**—had the light not bent, GR would be refuted.

# CLASHING VISIONS

## Example: Einstein's General Theory of Relativity




**View**: GR represents a **paradigm shift**—a full-scale **scientific revolution** that displaced Newtonian mechanics.

**Why?**:

- GR and Newtonian physics are **incommensurable**: they rely on fundamentally different assumptions about space, time, and gravity.
- Kuhn would emphasize the **conceptual rupture** and the **social reorganization of science**.

**New paradigm replaces old—classic revolution**.

# CLASHING VISIONS

## Example: Einstein's General Theory of Relativity


**View**: GR is a **progressive research programme** that replaced Newtonian mechanics, which had become **degenerating**.

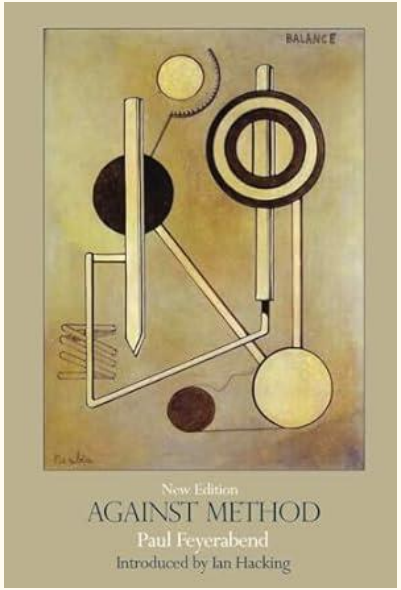
**Why?**:

- GR explains **more phenomena** (e.g., Mercury's perihelion precession) and unifies gravity with spacetime.
- GR offered **novel predictions**, while Newtonian mechanics had to introduce ad hoc fixes.

**A more progressive programme supplanted an older one**.

# CLASHING VISIONS

## Example: Einstein’s General Theory of Relativity




**View**: Likely to **challenge the idea** that GR's rise was purely rational or methodological.

**Why?**:

- Might highlight **Einstein's bold theoretical creativity** before experimental confirmation.
- Could argue that early acceptance of GR wasn’t entirely due to data but also **personal prestige**, mathematical elegance, and sociopolitical dynamics.
- Famous for saying: *"The only principle that does not inhibit progress is: anything goes."*

**Science progressed, but not purely through logic or falsifiability**—and that’s okay.

# CONCEPTUAL DEEP DIVE

| Concept | Popper | Kuhn | Lakatos | Feyerabend |
|---|---|---|---|---|
| How Science Progresses | | | | |
| Role of Failure | | | | |
| Rationality of Science | | | | |
| Flexibility of Method | | | | |

# CONCEPTUAL DEEP DIVE (CLASS ANSWERS)

| Concept | Popper | Kuhn | Lakatos | Feyerabend |
|---|---|---|---|---|
| **How Science Progresses** | Through falsification—testing bold hypotheses to weed out falsehoods | Through paradigm shifts after periods of normal science and crisis | Through progressive research programs that evolve while protecting core theories | Through methodological pluralism; science advances by breaking rules |
| **Role of Failure** | - Necessary and good to eliminate false ideas.<br>- Which hypotheses to reject | - Excited about failure because it can lead to a paradigm shift.<br>- Which paradigms to move away from<br>- Failures are proportionate to the size of the advancement/paradigm shift | - Failure was good because it can strip away weak parts of the protective belt<br>- Eliminate bad research programs<br>- Failure can effect a number of protective belts | - Failure is not a setback, its an opportunity<br>- Shows which methodologies not to use<br>- More focused on new discoveries |

# CONCEPTUAL DEEP DIVE (CLASS ANSWERS)

| Concept | Popper | Kuhn | Lakatos | Feyerabend |
|---|---|---|---|---|
| **Rationality of Science** | - Rationality is required for testability<br>- Reasonable assumptions or theories are less conducive than testing. (Testing over assumptions) | - Periods of less rationality lead to more revolutionary ideas<br>- New paradigms must be more rational than previous<br>- Revolution and crises can lead to departures from rationality | - Irrational programs will not be accepted or work out or degenerate<br>- Research projects will make excuses when protective belts fail<br>- Degree of rationality can be used as a marker of progressive or regressive capacity/state | - Less important because anything goes<br>- Rationality is based on new knowledge, not previous<br>- Creative, not rational |
| **Flexibility of Method** | - Not flexible<br>- Some flexibility on finding the right method to falsify; otherwise not flexible<br>- As long as you can determine falsifiability, the method doesn't matter | - Lots of flexibility to look for gaps and crises points<br>- More flexibility leads to more revolutionary ideas | - Incentives drive programs to progress or regress<br>- Some flexibility; but need to protect core theories limits flexibility | - Very flexible; anything goes<br>- 100% |

# CONCEPTUAL DEEP DIVE (INSTRUCTOR ANSWERS)

| Concept | Popper | Kuhn | Lakatos | Feyerabend |
|---|---|---|---|---|
| **How Science Progresses** | Through falsification—testing bold hypotheses to weed out falsehoods | Through paradigm shifts after periods of normal science and crisis | Through progressive research programs that evolve while protecting core theories | Through methodological pluralism; science advances by breaking rules |
| **Role of Failure** | Failure to pass a test leads to theory rejection (e.g., classical ether) | Failure signals a **crisis** in the current paradigm (e.g., anomalies in pre-relativity physics) | Failure leads to **auxiliary adjustments** unless the program becomes stagnant (e.g., modifying orbits in geocentric model) | Failure might be ignored or reframed; **failure can be productive** or even necessary (e.g., Galileo disobeying norms) |
| **Rationality of Science** | Rational because it follows a clear logic of conjecture and refutation | Rationality is **intra-paradigm** but **not guaranteed** during revolutions (e.g., accepting Einstein was partially social) | Rationality exists at the **program level**: compare which program makes more progress | Rationality is **overrated**; science is historical, messy, and **sometimes irrational** (e.g., no method fits all) |
| **Flexibility of Method** | Low—there is a proper way to test theories | Medium—method shifts with paradigms; puzzle-solving has rules, but revolutions break them | Medium-high—methods evolve within research programs, which are **protected and revised** | Very high—"Anything goes" if it leads to discovery; reject method dogma (e.g., using poetry or metaphysics if helpful) |

# PHYSICS THEORIES/HYPOTHESES

## Can be explored in reading week essays

### Mechanics & Classical Physics

- **Newtonian Mechanics** – Long-dominant framework, eventually challenged by relativity and quantum theory
- **Caloric Theory of Heat** – Superseded by the kinetic theory of gases and thermodynamics
- **Action-at-a-Distance** – Replaced by field theory in both gravity and electromagnetism

# PHYSICS THEORIES/HYPOTHESES

## Can be explored in reading week essays

### Electromagnetism

- **Maxwell's Equations** – Unified electricity, magnetism, and light; highly testable and predictive
- **Aether Theory** – Once thought necessary to carry electromagnetic waves; falsified by Michelson-Morley experiment
- **Faraday's Lines of Force** – Initially controversial, later foundational to field theory

# PHYSICS THEORIES/HYPOTHESES

## Can be explored in reading week essays

### Relativity

- **Special Relativity** – Radical shift in concepts of time and simultaneity; well-supported by experiment
- **General Relativity** – Paradigm shift from Newtonian gravity; predicts black holes, gravitational waves
- **Modified Newtonian Dynamics (MOND)** – Alternative to dark matter; not widely accepted but testable

# PHYSICS THEORIES/HYPOTHESES

## Can be explored in reading week essays

### Quantum Mechanics

- **Copenhagen Interpretation** – Dominant but philosophically controversial; challenges classical notions of reality
- **Many-Worlds Interpretation** – Elegant in some ways, but arguably unfalsifiable
- **Pilot-Wave Theory (Bohmian Mechanics)** – Deterministic alternative to standard QM; consistent but underappreciated
- **Quantum Field Theory (QFT)** – Highly successful but conceptually dense; unites QM and special relativity

# PHYSICS THEORIES/HYPOTHESES

## Can be explored in reading week essays

### Cosmology & Gravitation

- **Big Bang Theory** – Currently accepted model of the universe's origin; supported by cosmic microwave background and redshift
- **Steady State Theory** – Once serious competition to Big Bang; fell out of favor after new evidence
- **Inflationary Cosmology** – Adds rapid early expansion; not directly testable, but explains key features
- **String Theory** – Aiming to unify gravity with quantum mechanics; lacks direct experimental evidence
- **Loop Quantum Gravity** – Competing framework to string theory; also awaiting testable predictions

# PHYSICS THEORIES/HYPOTHESES

## Can be explored in reading week essays

### Thermodynamics & Energy

- **Laws of Thermodynamics** – Empirically grounded; foundational in physics and engineering
- **Maxwell's Demon** – A thought experiment that challenged the second law; now a basis for discussion on information and entropy
- **Zero-Point Energy** – Real in quantum theory, speculative in some exotic energy proposals
- **Perpetual Motion Machines** – Historically pursued, now ruled out by established physics (but useful in discussing falsifiability)