Inductive Inference and Paradigms

Which theory is best supported by the evidence?

Inductive Inference

- The *basic* format is:

  H predicts E
  E

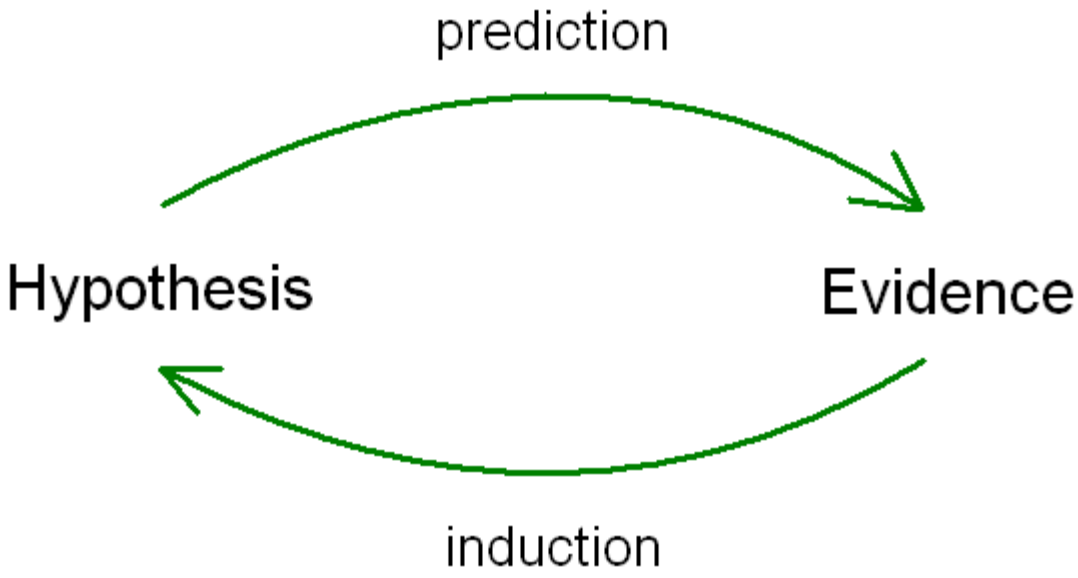
  $\therefore$ H

  H = some hypothesis, model, theory
  E = some evidence, data, observation

- Of course more premises are needed to make the inference reasonable, things like:
  - "H is a plausible theory"
  - "Other theories that predict E are implausible"

Induction and Prediction

- In general, *induction is the reverse of prediction*. We inductively infer a hypothesis from which the data can be predicted.

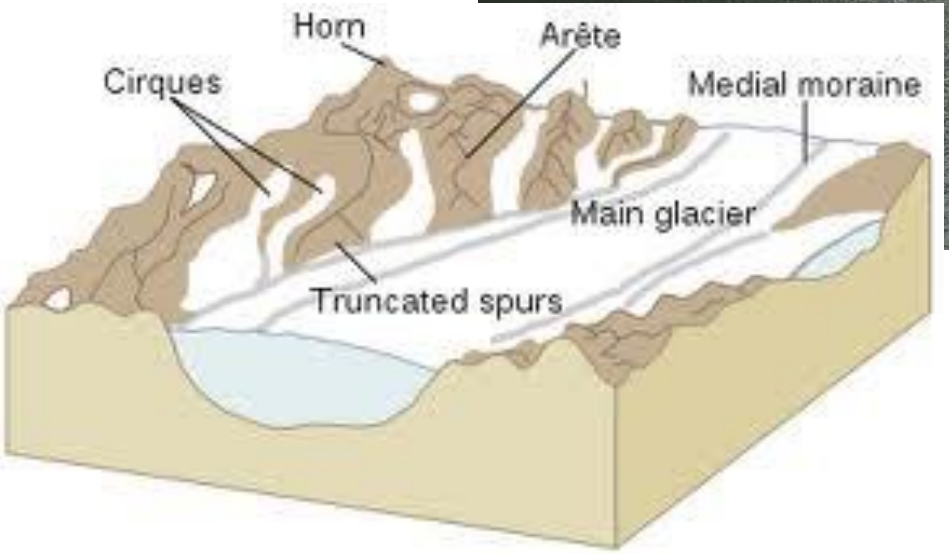


- E.g.

1. (This valley was formed by a glacier) predicts (This valley is U-shaped)
2. This valley is observed to be U-shaped

∴ This valley was formed by a glacier

hypothesis



evidence

H predicts E

E

∴ H

Question: Is this a *valid* inference?

(I.e. is the conclusion *guaranteed* to be true, given the premises?)

- No. It's an *invalid argument*. (Known to logicians as "affirming the consequent".)

- In an *inductive* inference the conclusion isn't guaranteed, or certain, even if all the premises are true. It would be possible to have premises that are all true, and a false conclusion. The data may be entirely correct, and yet the hypothesis is wrong.

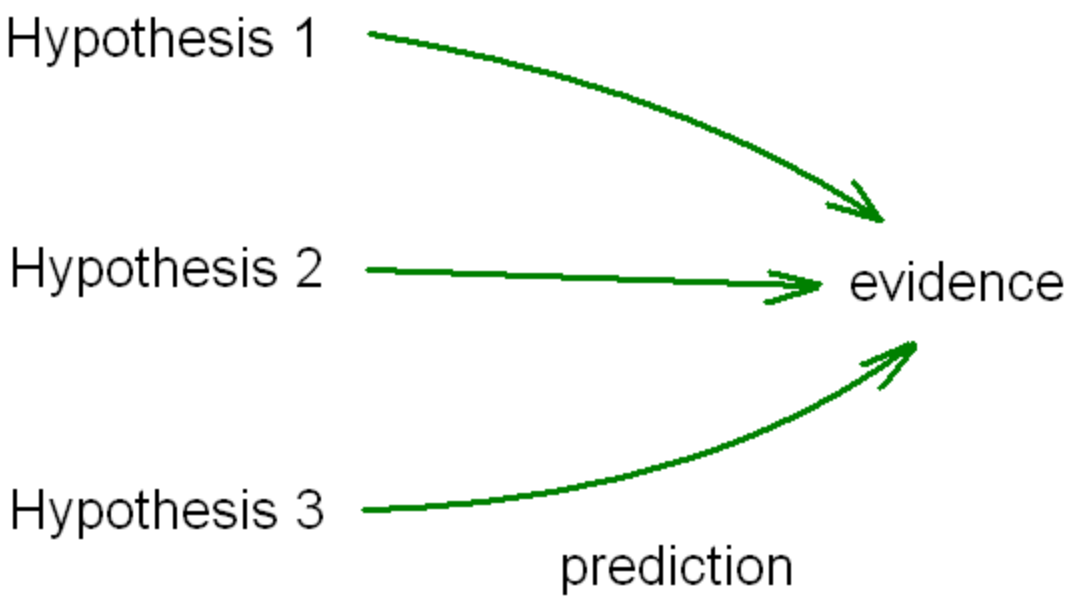
- Maybe God carved that valley directly, thousands of years ago. It's U-shaped because God happens to like the look of it.

- Or maybe it was formed by some bizarre physical process that no one has even imagined yet.

- Can we be *sure* something like this isn't true?

Many possible causes

- For any observed data, we can imagine many possible causes of it.
- If (say) three hypothesis all predict the observed data, then which hypothesis do you (inductively) infer *from* the data?

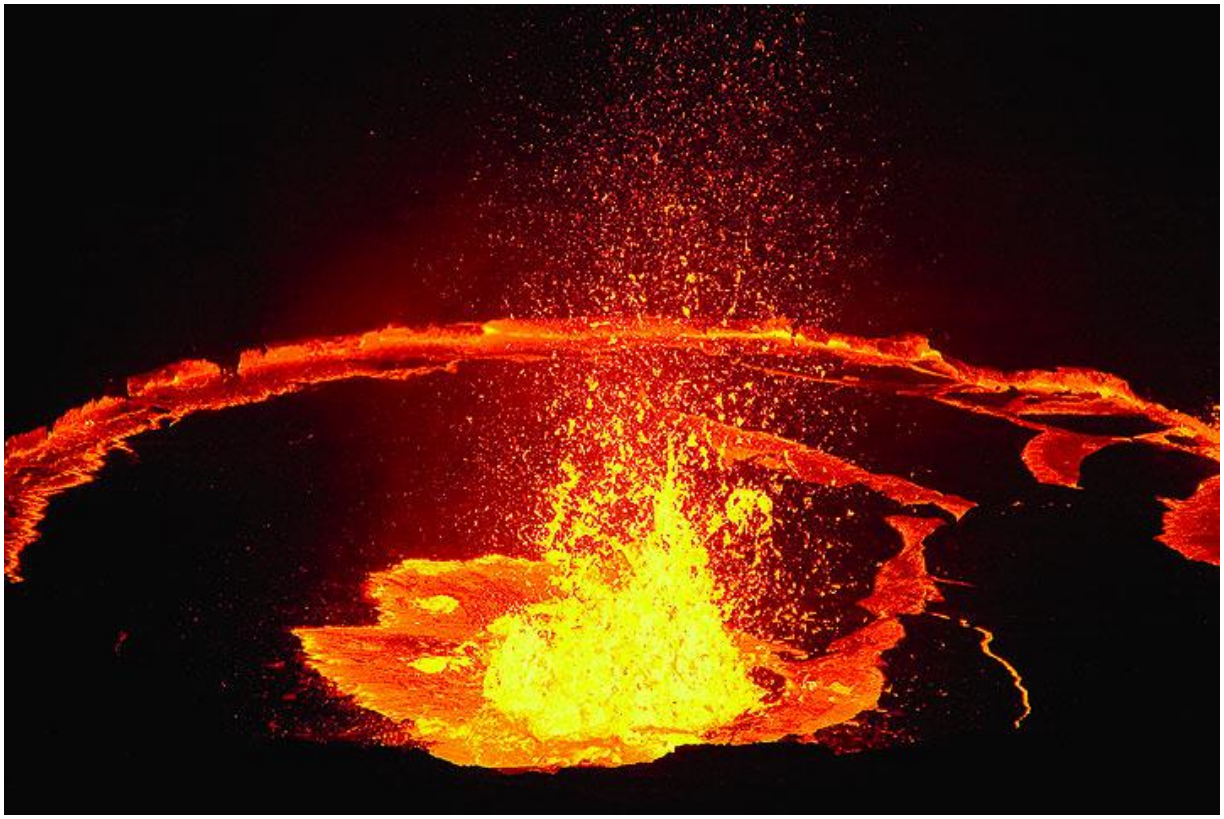


Example: Why did the dinosaurs die out?

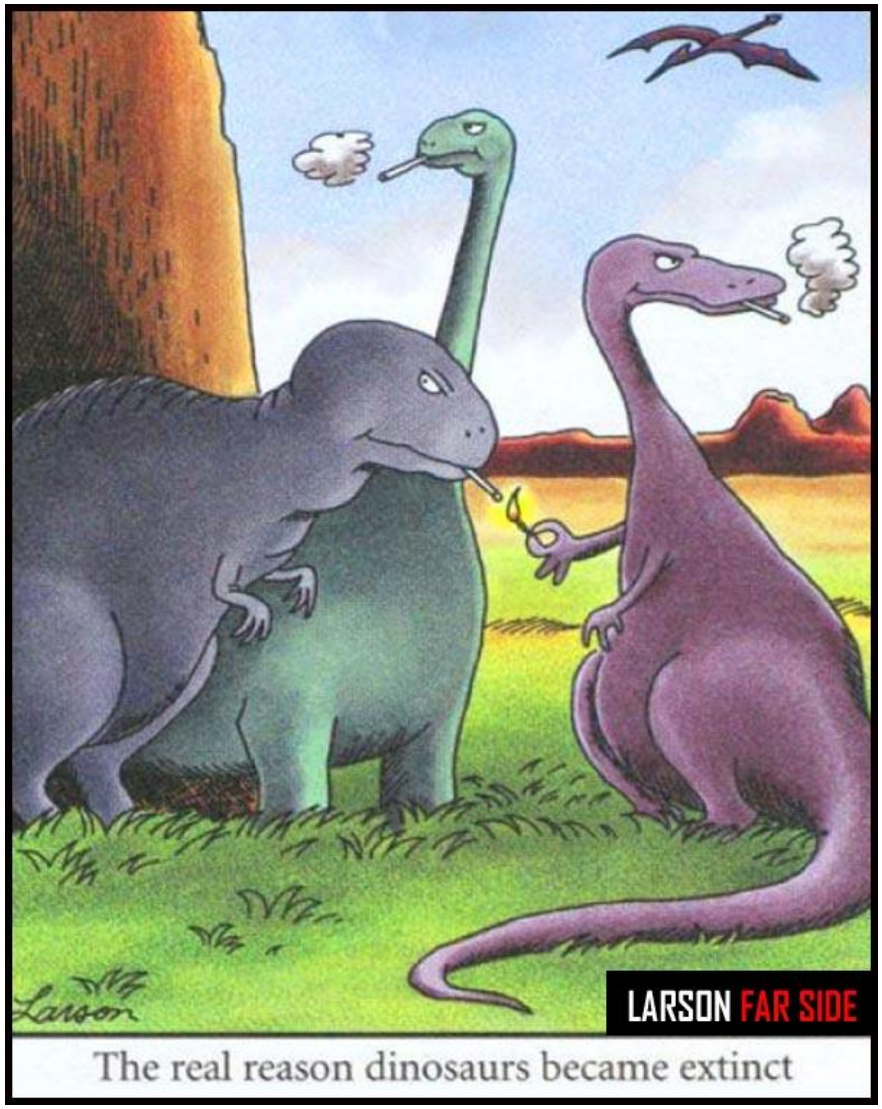
Data: in Cretaceous rocks, there are dinosaur fossils. In Tertiary rocks (the next layer up) there are no dinosaur fossils.

Hypothesis 1: Asteroid impact, leading to dust cloud blocking the sun, massive fireball reducing oxygen levels, etc.

Hypothesis 2: Volcanic Activity. The Deccan Traps formed at the end of the Cretaceous period, erupting for thousands of years, and releasing poisonous gases that cooled the climate.



Hypothesis 3 …



- The fact that there are many possible hypotheses, to explain a given set of data, doesn't mean that they're all equally good.

- Some hypotheses are *strong*, others *weak*, given the data available.

“Inductively Strong”

- An inductively strong argument is one whose conclusion is *probable*, given the premises.

- In other words, someone who believes the premises (with certainty) ought to believe the conclusion to a high degree (though perhaps not with certainty.

“Deductively Valid”

- The extreme case of an inductively strong argument is where the conclusion is *certain*, given the premises. Such an argument is said to be “deductively valid”, or just “valid”.

- E.g. All Canadian people are polite

  Don Cherry is a Canadian person

  ∴ Don Cherry is polite

Examples

(i) Eric has been convicted of 4 separate murders

∴ Eric has killed someone.

(ii) Rob is a member of Canada's armed forces

∴ Rob has shot and killed someone.

(iii) All metals conduct electricity, but mercury doesn't conduct electricity. So mercury isn't a metal.

(iv) Mike leads his varsity hockey team in hits and penalty minutes, so he must be pretty tough.

(v) Kim is good at presenting arguments, so she must be a lawyer.

“Background Knowledge”

- Notice how, in evaluating the strength of an inductive inference, we have to use our background knowledge.

- This is pretty unavoidable, I think. (Can you think of any exceptions?)

Michael Gershon, Columbia University, talking about the hypothesis that the MMR vaccine causes autism.

“From the point of view of the physiology of the bowel, blood circulation and the brain, this theory of the link between MMR and autism is implausible. For the theory to be correct a series of miracles would have to occur.

The liver would have to forget to function as a filter. It normally removes foreign molecules from the blood. Autistic patients, however, are not jaundiced so there's no reason to suspect liver failure. The blood-brain barrier, which is impermeable to large molecules, would have to part, like the Red Sea did for Moses and the Israelites, to let toxins from the bowel into the brain. Once there they'd have to do something to the human brain that they've never even been demonstrated to do in animals.”

4. Jim offers the following argument that wearing a bike helmet reduces the likelihood of a fatal accident.

"In this city, we have found that 40% of cyclists wear helmets while riding their bikes. But, in all cases where cyclists have been killed while riding, only 10% of them were wearing helmets at the time. So, clearly, wearing a helmet while riding a bike significantly reduces the chance of being killed."

In evaluating the inductive strength of this argument, it is useful to imagine **other hypotheses** that would explain the same data. Write down (one or two) alternative explanations of this evidence.

Hypothesis 1: Wearing a bicycle helmet protects the head from injury, and so reduces the chance of being killed in a bike accident.

Hypothesis 2: Some people are more cautious than others. Cautious people are more likely to wear helmets, and also more likely to ride carefully, on less busy streets, obey traffic laws, etc., leading to a lower chance of death.

- In assessing which of these explanations is the best, what background ideas come into play?

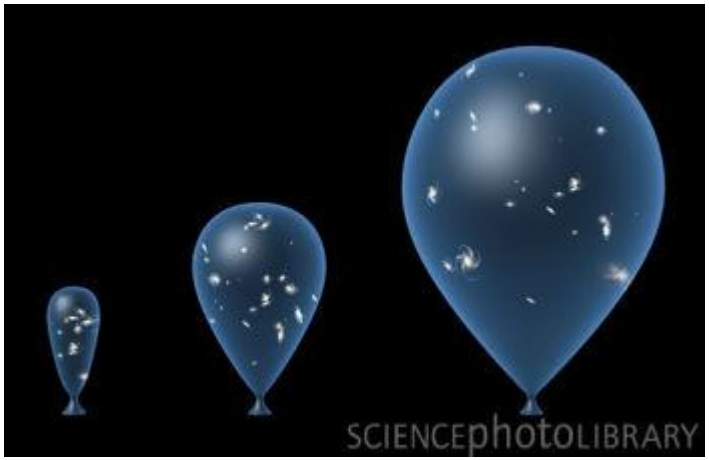
Relevant background beliefs

- Putting a layer of foam around the head ought to cushion it from impacts, reducing brain damage.
- Some people are more cautious than others.
- Cautious people are more likely to wear helmets
- Cautious people are less likely to ride on busy streets.
- Serious accidents are more likely to occur on busy streets.

(Etc.)

Example: The Big Bang Theory

- In 1916 Albert Einstein published a theory of gravity called *General Relativity* (GR). In this theory space-time and matter are tied together into a single dynamical system.
- The universe, according to GR, can be pictured as a balloon, with the skin of the balloon representing space itself.



“The Cosmological Constant”

- One puzzle for GR was why the whole universe doesn’t collapse in on itself, under its own gravity.
- In order to keep the universe in a steady state, Einstein added a force of repulsion to his equations, known as the ‘cosmological constant’.

The Big Bang Theory

- In 1927, however,, another solution to the problem was spotted by Georges Lemaître, a physicist and Catholic priest.

- Lemaître proposed that the universe was rapidly *expanding*, so that its outward momentum prevented it from collapsing inwards.

- One obvious consequence of an expanding universe was that the universe must have been smaller and smaller the further back in time you go. At some definite point in the past, all matter (and space itself) was compressed into a tiny volume.

Relevant background ideas

- Lemaître's theory was scientific. It was a mathematical solution to Einstein's "field equations" of GR. It made predictions (e.g. concerning Doppler shifts of distant galaxies) that were later observed.
- But some physicists were initially reluctant to accept the Big Bang model, on the grounds that it smelled of religion. The idea of a beginning to time *itself* suggested the need for something outside the physical universe to create it.

Relevant background ideas

- By the mid 1960s the Big Bang theory gained mainstream acceptance, thanks to a number of supporting observations.

- Prior to those observations, however, religious scientists tended to find the theory more plausible than secular scientists did. Secular scientists preferred to think that the universe was eternal, with no beginning.

E.g.

"While many of us may be OK with the idea of the big bang simply starting everything, physicists, including Hawking, tend to shy away from cosmic genesis.

> "A point of creation would be a place where science broke down. One would have to appeal to religion and the hand of God",

Hawking told the meeting, at the University of Cambridge, in a pre-recorded speech."

(*New Scientist*, "Why physicists can't avoid a creation event", January 2012.)

The most radical ideas are those that are perceived to support religion, specifically Judaism and Christianity. When I was a student at MIT in the late 1960s, I audited a course in cosmology from the physics Nobelist Steven Weinberg. He told his class that of the theories of cosmology, he preferred the Steady State Theory because “it least resembled the account in Genesis”

Frank Tipler, “Refereed Journals: Do They Insure Quality or Enforce Orthodoxy?”

Who's the thief?

At a certain bank, money has often gone missing, and the branch manager suspects that one of her employees is stealing it. She compiles the following table, showing which of her five employees were at work each day, and the amount of money that went missing that day.

	March 4	5	6	7	8	11	12
Jan	✓		✓	✓		✓	✓
Mike		✓	✓	✓	✓	✓	
Hazel	✓	✓		✓	✓		✓
Curtis	✓	✓		✓	✓	✓	
Dan	✓		✓		✓	✓	✓
	$210	$0	$0	$90	$130	$0	$75

Paradigms

- It looks like Hazel, since she's the only person who was present on every day when money went missing. (On March 5 Hazel didn't steal, for some unknown reason.)

- But here we're *assuming* that there's just one thief. What if two (or more) people are working together? Any other hypotheses?

Paradigms

- If we assume that there are *two* thieves, then a decent hypothesis is that Jan and Dan are working together, and (rather cleverly) trying to make it look as if Hazel is the thief!

- In general, a scientific hypothesis is grounded upon some framework of assumptions, or *paradigm*.

The geocentric *paradigm*

- Suppose we try to construct a universe that explains the known facts of astronomy. We need a paradigm to begin with. Let's suppose that *the earth is stationary, and that the planets are all orbiting the earth*. Suppose further that we order the planets by their apparent speed.
- What kind of universe do we get?

- We get something like Ptolemy's universe, in its basic structure. (Remember that Ptolemy's actual model was quite complicated, with minor epicyles, eccentric orbits and equants.)

- We've seen that scientific inferences are *inductive*, in the sense that the premises (empirical data) do not guarantee that the conclusion is true. More precisely, the conclusion offers one possible explanation of the data, perhaps the best explanation, but not the only possible explanation.
- Also, what one judges to the best explanation of the data depends on the *paradigm* that one is working in.

Inductive Inference

- Hence inductive inference might be represented as follows:

H predicts E

E

Paradigm

$\therefore$ H

What is a paradigm?

- The term is used rather loosely, with a variety of meanings (even by Kuhn himself). The following give the basic idea. A paradigm provides:

  -- a *framework* within which specific hypotheses can be constructed.

  -- a *basic picture* of the thing being investigated

  -- a *set of methods and tools* for the investigation

- A paradigm achieves these things largely through a “canon” of accepted solutions to problems. In trying to solve a new problem (within a paradigm) researchers try to extend the methods that have been used successfully in the past.

Examples

- The Ptolemaic paradigm for map-making included the basic assumption of a spherical earth. It also included *methods* for determining the longitude and latitude of a place.
- The paradigm of *oxygen chemistry* includes the basic picture that metals are elements, that metal ores are compounds of metals with oxygen, etc. It includes the use of an accurate balance to weigh the reactants and products of a reaction, and the use of a pneumatic trough.

- The Copernican paradigm for astronomy includes the idea that the sun is stationary, and the earth spins on its axis and orbits the earth.
- The telescope became (in the hands of Galileo) a major tool.

(Darwinian) evolution is a *paradigm*?

- Olivia Judson, New York Times, July 15, 2008:

  "I'd like to abolish the insidious terms *Darwinism*, *Darwinist and Darwinian*. They suggest a false narrowness to the field of modern evolutionary biology, as though it was the brainchild of a single person 150 years ago, rather than a vast, complex and evolving subject to which many other great figures have contributed."

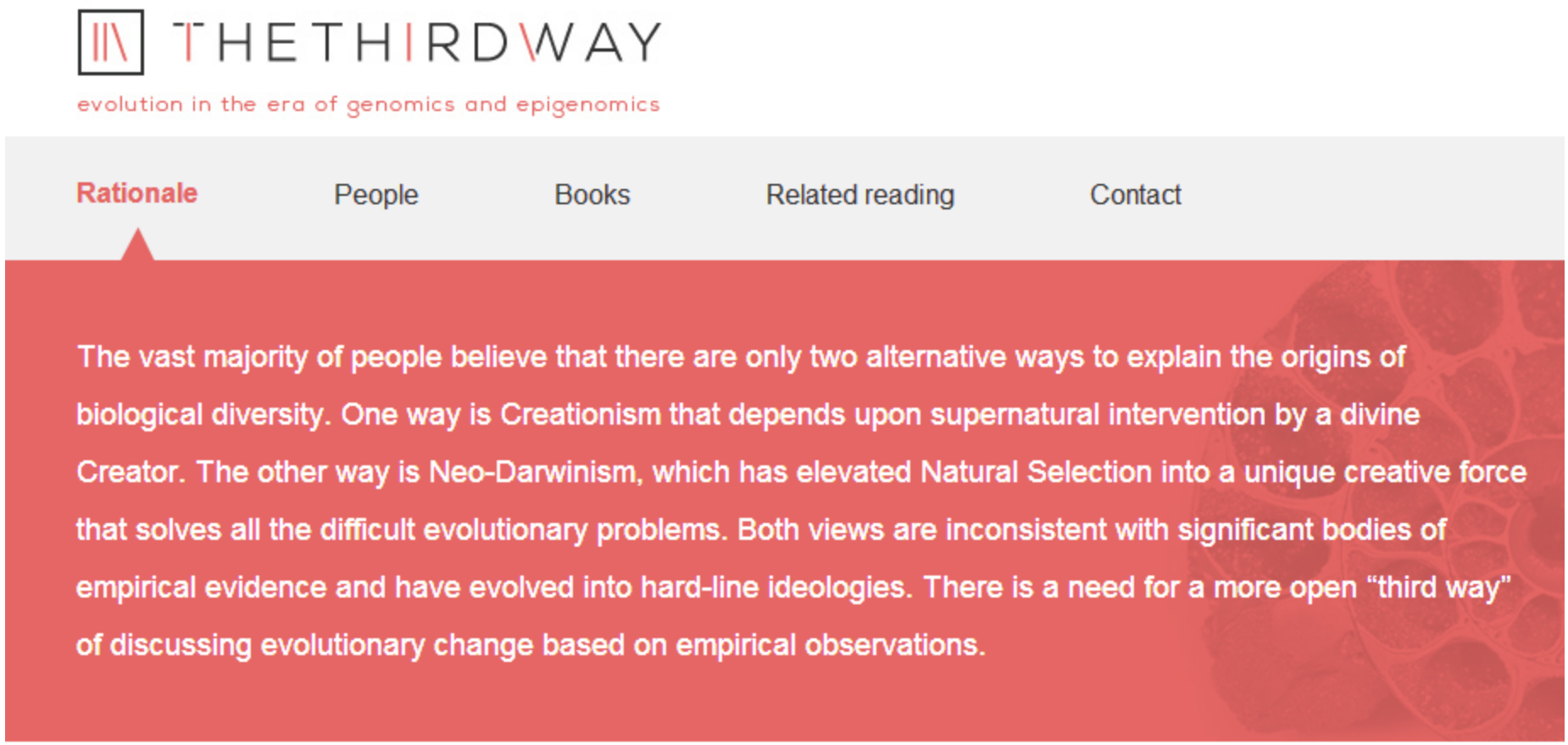
“Although several of his ideas — natural and sexual selection among them — remain cornerstones of modern evolutionary biology, the field as a whole has been transformed.”

“For although **natural selection is the only creative force in evolution** — the only one that can produce complex structures such as wings and eyes — it is not the only force that affects which genes will spread, and which will vanish.”

(My emphasis)

- Judson is right that evolutionary biology has come a long way since Darwin. For example, natural selection isn't the only driver of evolutionary change. (There is also drift, symbiogenesis, lateral gene transfer, etc.)
- But (unlike e.g. Newtonian physics) some of Darwin's *core* ideas about evolution are still accepted by most biologists.
- Moreover, some biologists are now questioning the importance of natural selection as a mechanism for evolution. These biologists are not questioning 'evolution', so we need some separate term for what they're questioning.

E.g James Shapiro's "Third Way" group



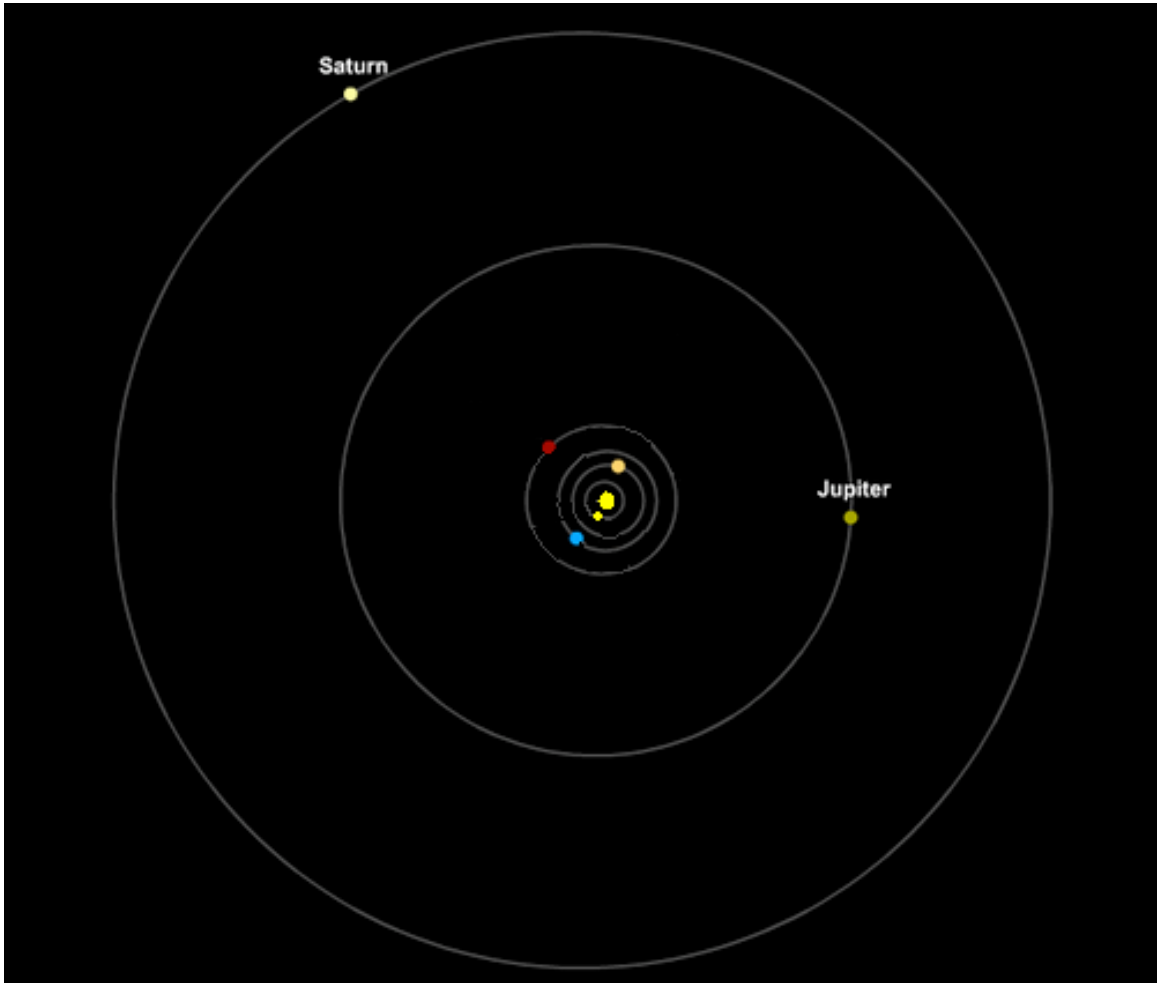
- People are in fact using “Darwinism” to refer to any theory of evolution (contemporary or otherwise) whose main mechanism is natural selection, operating on random variation.
- In particular, “Darwinism” refers to the idea that (among the mechanisms of evolution) only natural selection is “creative”, as Judson puts it. “…natural selection is the only [force] that can produce complex structures such as wings and eyes”. (Selection does not merely prune.)

- Used in this way, “Darwinism” is better seen as a paradigm rather than a hypothesis, as it is a “broad tent” that will include many different specific hypotheses. It is a general approach to evolutionary biology, rather than a specific hypothesis.
- If, at some point in the future, natural selection is seen as having only a minor role in evolution (e.g. as being conservative rather than creative) this would certainly count as a major “paradigm shift”, in Kuhn’s sense.

“Irrelevant Details”

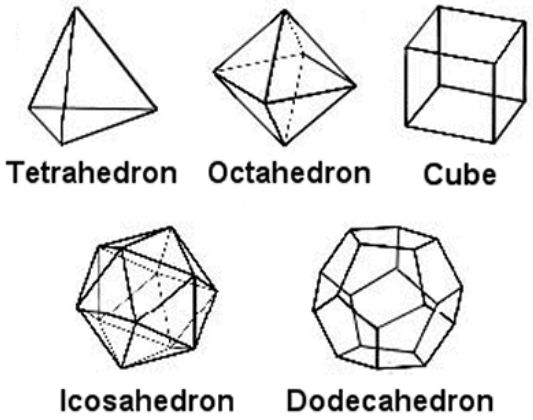
- Notice how, on the Duck paradigm, the PCI was an irrelevant detail. Asking “What is the PCI for?” is a mistake. It’s a bad question.
- Today, “Why are there 8 planets?” is a bad question. There’s no particular reason why there are 8 planets. There just are. It doesn’t “call for an explanation”.

- Problem for Kepler: How do you explain that there are exactly 6 planets, with the *orbital sizes* they have?



Kepler's explanation!

A **Platonic solid** is a regular, convex polyhedron with congruent faces of regular polygons and the same number of faces meeting at each vertex. *There are only 5 of these*.



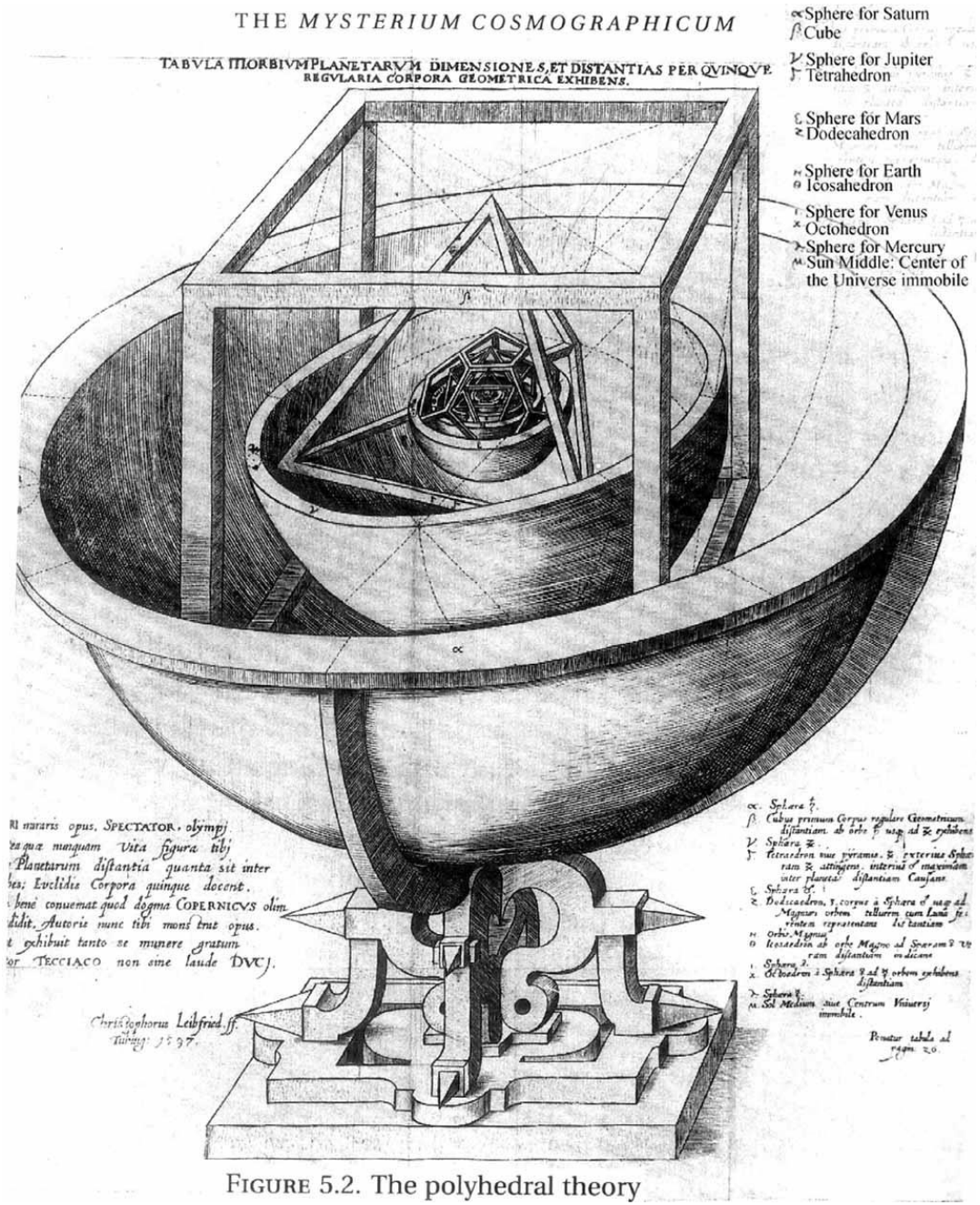


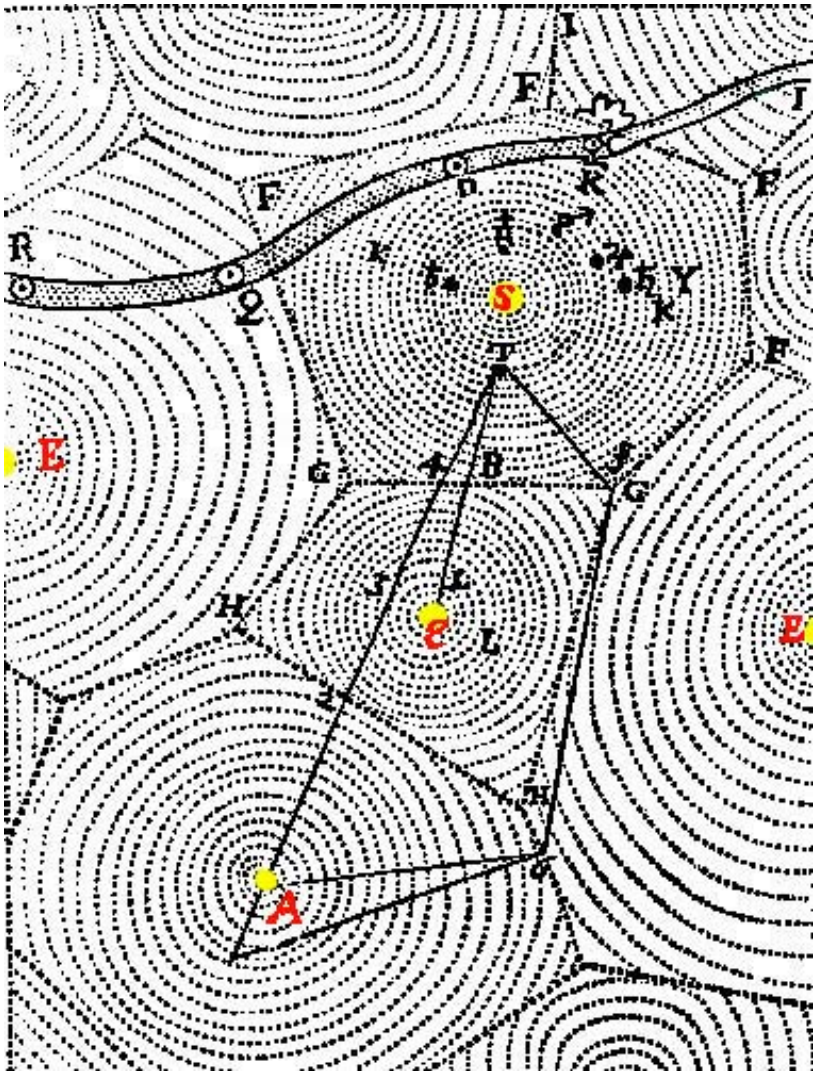
FIGURE 5.2. The polyhedral theory

Another irrelevant detail? *Why do the planets all go the same way?*

- Descartes considered this very significant, a vital clue to understanding the *mechanics* of planetary motion.

- He explained it with his “vortex” theory, that each star (including the sun) drives the matter around it into a swirling vortex. This vortex pushes the planets around their orbits.

Descartes' Vortex Theory



- Descartes' rival, Isaac Newton, had a different theory of why the planets move the way they do. His theory held that the planets are moving through empty space, under the influence of the sun's gravity. There is no vortex, and *there's no reason why the planets all move in the same direction*. They just do.

- It doesn't call for a *mechanical* explanation, but a historical one. (It arises from how the solar system was formed.)

The Problem of Induction

- The reliance of inductive inferences on background assumptions, or a “paradigm”, shows that there is no possibility of deriving a hypothesis from data, using pure logical inference.
- In the absence of background assumptions, logic won’t even tell us that a hypothesis is *probably* true, given the known data.
- (E.g. Copernicus and Kepler assumed that the universe will be simple, rational, economical, etc.)

Empiricism and Induction

- Some philosophers (known as empiricists) believe that all our knowledge comes from experience.
- In that case, it seems that Copernicus and Kepler *could not know* that the universe will be simple, or that mathematical harmony is a guide to truth.
- Hence (David Hume argued for example) the inferences of Copernicus and Kepler are not rationally justified!