Laws of nature

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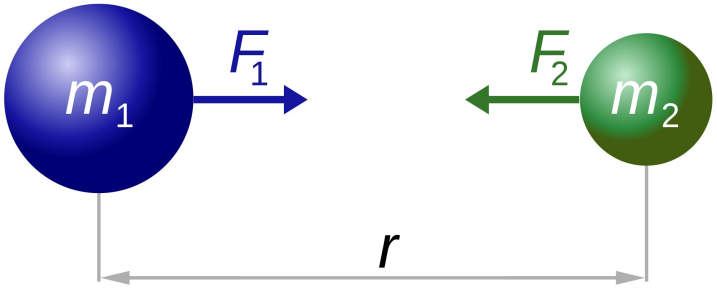
What is a law of nature?

Alex Rosenberg (2012). Why laws explain. In his *Philosophy of Science: A Contemporary Introduction*, Routledge: New York and London, 61-79.

Laws do important explanatory work—but just what is a law?

- first pass: true generalization, universal statement
- not merely true by definition, makes contingent claims about nature, not about merely local facts
- need to distinguish generalizations that are accidentally true from 'laws'
- example of accidental truth: 'All faculty members of the Department of Philosophy are right-handed', 'All fruits in the garden are apples'
- example of law: 'All gases expand when heated under constant pressure'

Newton's Law of Universal Gravitation



$$F_1 = F_2 = G\frac{m_1 \times m_2}{r^2}$$

"Every point mass attracts every single other point mass by a force pointing along the line intersecting both points. The force is proportional to the product of the two masses and inversely proportional to the square of the distance between them."

(Proposition 75, Theorem 35, p. 956)

Newton, *Principia*. I.Bernard Cohen and Anne Whitman (trans.), University of California Press, 1999.

Bode's Law

Johann Elert Bode (1747-1826)

"This latter point seems in particular to follow from the astonishing relation which the known six planets observe in their distances from the Sun. Let the distance from the Sun to Saturn be taken as 100, then Mercury is separated by 4 such parts from the Sun. Venus is 4+3=7. The Earth 4+6=10. Mars 4+12=16. Now comes a gap in this so orderly progression. After Mars there follows a space of 4+24=28 parts, in which no planet has yet been seen. Can one believe that the Founder of the universe had left this space empty? Certainly not. From here we come to the distance of Jupiter by 4+48=52 parts, and finally to that of Saturn by 4+96=100 parts."

Johann Elert Bode (1772). *Anleitung zur Kenntniss des gestirnten Himmels.*

Bode's Law

Law ((Titius-) Bode)

"The law relates the semi-major axis a of each planet outward from the Sun in units such that the Earth's semi-major axis is equal to 10:

$$a = 4 + n$$

where $n = 0, 3, 6, 12, 24, 48...$ *with each value of* $n > 3$ *twice the previous value."*

(`http://en.wikipedia.org/wiki/Titius-Bode_law`*, accessed 16 October 2013)*

Bode's 'Law'?

- You might be inclined to dismiss this as pure coincidence...
- ... but then
  - William Herschel discovered Uranus in 1781—at about a distance from the sun by $4 + 192 = 196$ parts!
  - And in 1801, Ceres is found at the location predicted by Bode, i.e., at $4 + 24 = 28$ parts

$\Rightarrow$ Triumph?

- Not quite...:
  - Neptune is discovered in 1846 at a location far off from where Bode's Law predicted (where, however, Pluto in found in 1930!).
  - And many objects other than Ceres are found in the Asteroid Belt, disrobing Ceres from status as planet.

Distances of planets in the Solar System

Planet	k	T-B rule distance (AU)	Real distance (AU)	% error (using real distance as the accepted value)
Mercury	0	0.4	0.39	2.56%
Venus	1	0.7	0.72	2.78%
Earth	2	1.0	1.00	0.00%
Mars	4	1.6	1.52	5.26%
Ceres[1]	8	2.8	2.77	1.08%
Jupiter	16	5.2	5.20	0.00%
Saturn	32	10.0	9.54	4.82%
Uranus	64	19.6	19.2	2.08%
Neptune	128	38.8	30.06	29.08%
Pluto[2]	256	77.2[2]	39.44	95.75%

[1] Ceres was considered a planet from 1801 until the 1860s. Pluto was considered a planet from 1930 to 2006. Both are now classified as dwarf planets.

[2] While the difference between the T-B rule distance and real distance seems very large here, if Neptune is 'skipped,' the T-B rule's distance of 38.8 is quite close to Pluto's real distance with an error of only 1.62%.

from Wikipedia at `http://en.wikipedia.org/wiki/Titius-Bode_law`

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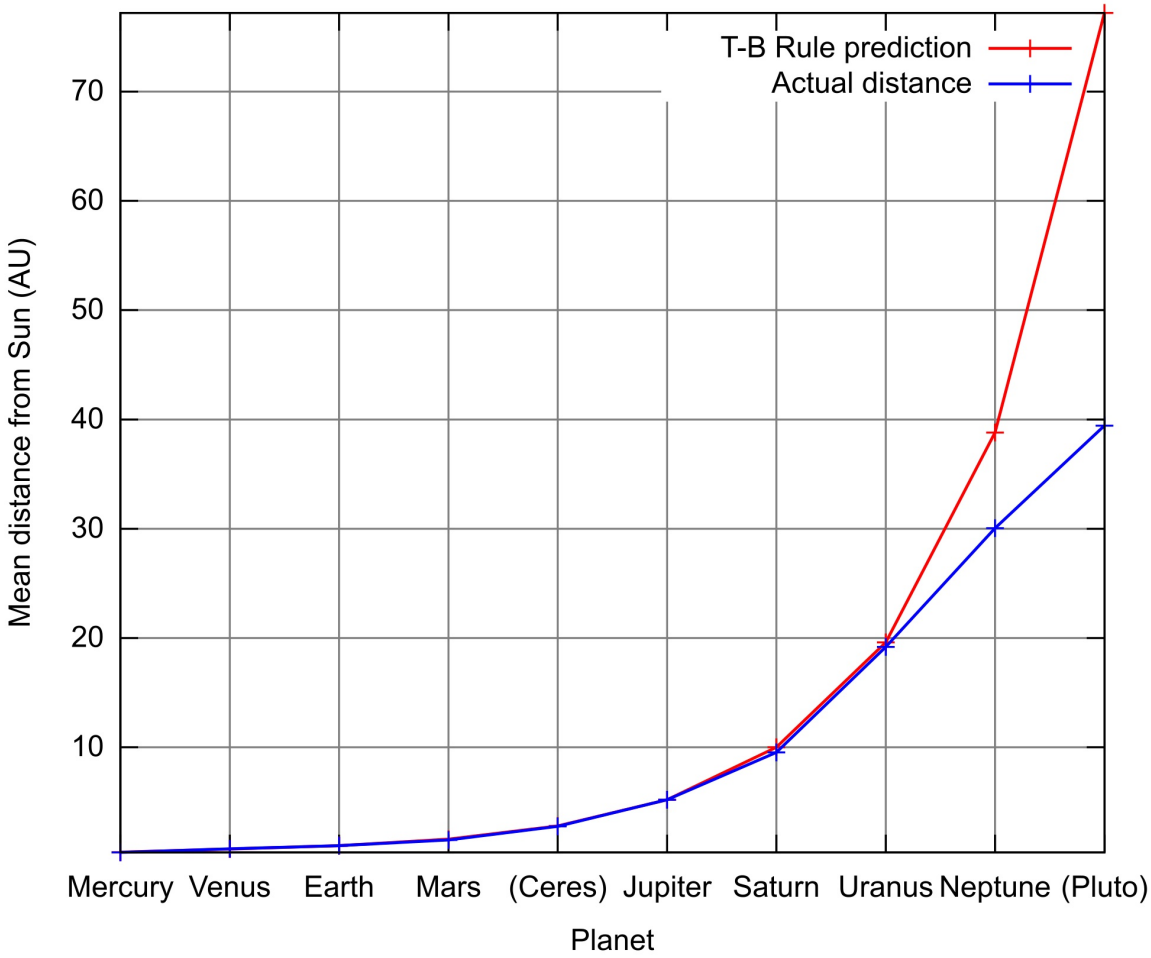

from Wikipedia at `http://en.wikipedia.org/wiki/Titius-Bode_law`

Counterfactual support as a symptom of the necessity of laws

- Hempel: 'counterfactual support' is diagnostic of lawhood, but philosophically hard to capture
- Rosenberg: laws have to have some sort of 'necessity'
- second pass: law = true, exceptionless generalization describing regularity PLUS some additional, yet unspecified conditions

Compare:

"All solid spherical masses of pure plutonium weigh less than 100,000 kilograms.

All solid spherical masses of pure gold weigh less than 100,000 kilograms." (Rosenberg, 63)

- Both statements seem true, but for very different reasons: explanations of both require laws, but only the latter must also include boundary or initial conditions

Conditionals: 'If *p*, then *q*.'

Terminology

If ANTECEDENT, then CONSEQUENT.

Definition (Types of conditionals)

A counterfactual conditional is a conditional of which the antecedent is not true, expressing (in the subjunctive tense) what would be the case, if something were the case that is not. An indicative conditional is a conditional of which the antecedent may or may not be true, expressing what is in fact the case, if its antecedent is in fact true.

On the difference between indicative and counterfactual conditionals

You can accept 'If Oswald didn't kill Kennedy, someone else did' as true, while rejecting 'If Oswald hadn't killed Kennedy, someone else would have' as false.

Adams, E. W. (1970). Subjunctive and indicative conditionals. *Foundations of Language* **6**: 89-94.

A litmus test for lawhood: counterfactual support

Consider the following two counterfactuals, of which both antecedents (and both consequents) are false:

1. "If it were the case that the Moon is made of pure plutonium, it would be the case that it weighs less than 100,000 kilos." (63)
2. "If it were the case that the Moon is made of pure gold, it would be the case that it weighs less than 100,000 kilos." (64)

- First counterfactual seems clearly true, while the second seems false. But what underwrites this difference?
- The first is supported by the universal truth about plutonium, but the second isn't supported by the universal truth about gold.

$\Rightarrow$ counterfactual support is indicative of lawhood—but this doesn't explain difference yet!

- Rosenberg: difference is found in physical or nomic necessity (not in logical!)

The causal connection

- Nomic necessity seems to be closely tied to causal connection we noticed before and which the logical positivists tried to avoid—it's metaphysics!
- But if it is something like this necessity which is responsible for the difference between explanatory laws and merely accidental generalizations, metaphysics cannot be avoided!
- recall: Humean vs. non-Humean accounts of laws of nature
- example of Humean approach: best-systems analysis
- example of non-Humean approach: universalism

A bit of terminology

Definition (Proposition)

A proposition is a 'thought' or the 'content' of a meaningful declarative sentence. Propositions are truthbearers, and, if true, typically express facts obtaining in a world.

Three reasons to think that propositions and sentences are distinct:

1. The sentences 'Schnee ist weiss', 'La neige est blanche', and 'La nieve es blanca' all express the same proposition, viz. that snow is white.
2. Some sentences are ambiguous and express more than one proposition (e.g. 'Flying aeroplanes can be dangerous').
3. Grammatically well-formed sentences such as 'Colorless green ideas sleep furiously' do not express any proposition.

A bit more terminology

- Many philosophers think that there are not only objects ('ontology'), but also properties (and perhaps relations, 'ideology').
- distinction between properties and words that name them ('predicates'), somewhat analogous to that between propositions and sentences
- Three reasons to think that properties and predicates are distinct:
  1. The predicates 'rot', 'rouge', and 'rojo' all refer to the same property, that of being red.
  2. Some predicates are ambiguous and refer to more than one property (e.g. 'square').
  3. Seemingly meaningful predicates such as 'is a square circle', 'is the universal set', 'is non-self-exemplifying' do not denote properties.

What are properties?

- Plato: property 'red' shared by all red things is an abstract entity, a 'form', which has an existence independent of its instances
- Universals vs. particulars: a universal is what similar things have in common, e.g. their redness, i.e., a universal is a recurrent entity which can be multiply exemplified in particular objects, i.e., in 'particulars'
- But there are rival theories of properties (notably, 'nominalism')

Best-systems analysis of laws

Best-system analysis of laws

Position (Best-system analysis)

A universal proposition is a law if and only if it is an axiom or a theorem in that true deductive system that best combines simplicity (e.g., least number of axioms) and strength (e.g., most informational content) (or, in the case of a tie, which is an axiom or a theorem in all 'best' systems).

- John S Mill, Frank Ramsey, David Lewis, John Earman
- metaphysically lean, Humean: doesn't require undetectable 'glue'
- reduces nomic necessity to logical necessity
- gives a principled distinction between nomic and accidental generalizations
- allows for a link to counterfactuals: what we take to be true counterfactuals is given by our best theories

Problems

1. Main problem: What is simple? What is strength? These seem to be language-dependent, perhaps subjective criteria.
2. Generally, there will not be a shared maximum for both criteria $\Rightarrow$ needs balance between them. But how do we balance them?

Necessitarian theories: David Armstrong

Characterization (Armstrong's universals approach)

"Suppose it to be a law that Fs are Gs. F-ness and G-ness are taken to be universals. A certain relation, a relation of non-logical or contingent necessitation, holds between F-ness and G-ness. This state of affairs may be symbolized as '$N(F, G)$'." (*David Armstrong,* What Is a Law of Nature?*, Cambridge: Cambridge University Press, 1983, 85; my emphasis)*

- view is also called 'universalism' (why?)

Amstrong: comments and justification

- Example: "being uranium does necessitate being less than one mile in diameter, but being gold does not" (Carroll 2008, Sec. 3)
- law not just universal generalization, but relation between two universals
- Amstrong's account has the following attractions:
  1. necessitation not mind-dependent $\Rightarrow$ objective nomicity
  2. rules out 'gruesome' predicates (cf. 'Induction and confirmation')
  3. good account of vacuous laws

Problems of the universals approach

Bas van Fraassen, *Laws and Symmetry*, Oxford, Clarendon, 1989, 96.

1. Identification problem: what is the lawmaking relation, the universal *N*?
2. Inference problem: "Does *N*'s holding between *F* and *G* entail that *F*s are *G*s? Does it support counterfactuals?" (Carroll 2008, Sec. 3)

No laws: Nancy Cartwright

- "What we think of as a law is really a simplification that ignores all the other myriad dispositions a thing has, in order to explain its behavior to a good approximation. But really there are no laws..." (76)
- objects have dispositions, i.e., properties that the object does not presently manifest
- dispositions support counterfactuals
- 'nomic necessity' derives from necessary connection between a disposition and its manifestation