

# Laws of nature

Christian Wüthrich

<http://www.wuthrich.net/>

**MA Seminar: General Philosophy of Science**

# What is a law of nature?

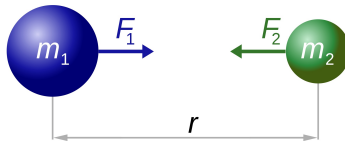


Alex Rosenberg (2012). Why laws explain. In his *Philosophy of Science: A Contemporary Introduction*, Routledge: New York and London, 61-79.

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](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

⇒ Triumph?

- Not quite...:
  - Neptune is discovered in 1846 at a location far off from where Bode's Law predicted (where, however, Pluto is 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

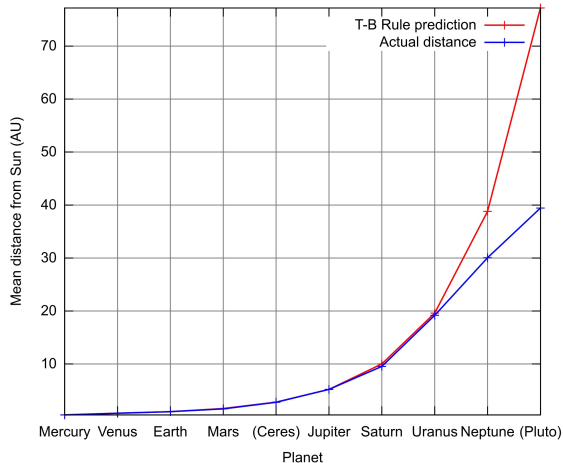
Planet	k	T-B rule distance (AU)	Real distance (AU)	% error (using real distance as the accepted value)
Mercury	0	0.4	0.39	2.56%
Venus	1	0.7	0.72	2.78%
Earth	2	1.0	1.00	0.00%
Mars	4	1.6	1.52	5.26%
Ceres <sup>1</sup>	8	2.8	2.77	1.08%
Jupiter	16	5.2	5.20	0.00%
Saturn	32	10.0	9.54	4.82%
Uranus	64	19.6	19.2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

<sup>1</sup> 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](#).

<sup>2</sup> 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](http://en.wikipedia.org/wiki/Titius-Bode_law)

# Distances of planets in the Solar System



from Wikipedia at [http://en.wikipedia.org/wiki/Titius-Bode\\_law](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

# 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.
- ⇒ 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!)

# Humean vs non-Humean analyses

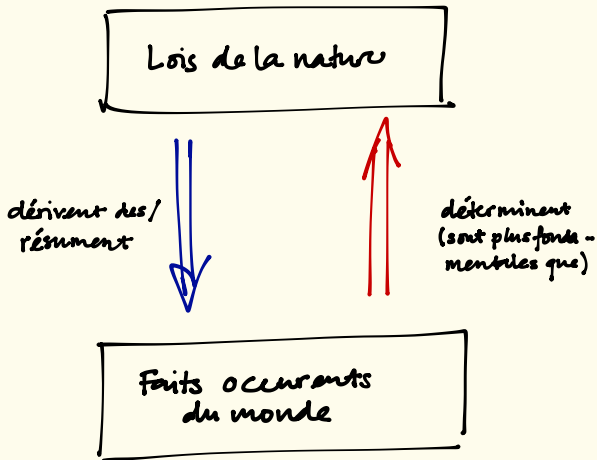
Alyssa Ney. *Metaphysics: An Introduction*. Routledge: Abingdon and New York, 2014.

## Position (Humeanism about laws)

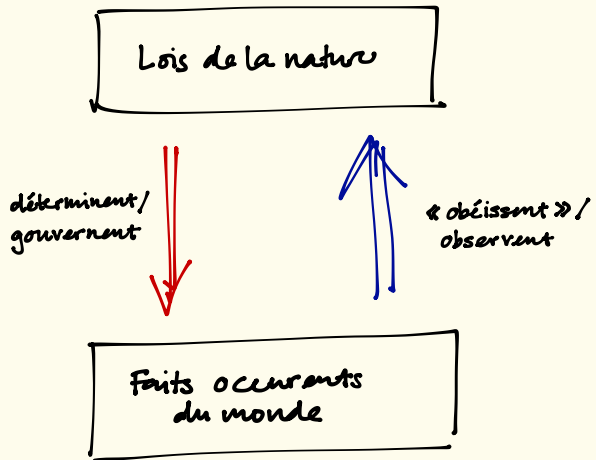
*"Humeans believe that the facts about what the laws are are ultimately explainable in terms of or reducible to facts about what happens at a world, that is facts about what kinds of objects and events there are and how that are distributed over space-time. Anti-Humeans think that the facts about what the laws are are not reducible to facts about what happens. Rather the facts about what the laws are are additional facts over and above what happens at a world. The facts about the laws instead **explain** what happens.*

*"Humeanism is named after David Hume because it was he who held there were no necessary connections between distinct entities. Since if laws were fundamental, this would mean there are fundamental, necessary connections between the events that take place; the Humeans would want to explain what appear to be necessary connections in terms of more basic facts about what happens just as a matter of fact (not as a matter of necessity)." (Ney, 248)*

# Humean analyses



# Non-Humean analyses



# Humean analyses

## Position (Humeanism about laws)

*"Humeanism about laws [is] the view that the facts about the laws of nature are reducible to facts about regularities in what happens in our universe." (Ney, 284)*

# Humean supervenience

David Lewis. *Philosophical Papers: Volume II*. Oxford University Press: Oxford, 1986.

## Thesis (Humean supervenience)

*"Humean supervenience... is the doctrine that all there is to the world is a vast mosaic of local matters of particular fact, just one little thing after another... We have geometry: a system of external relations of spatiotemporal distance between points. Maybe point of spacetime itself, maybe point-sized bits of matter or aether or fields, maybe both. And at those points we have local qualities: perfectly natural intrinsic properties which need nothing bigger than a point at which to be instantiated. For short: we have an arrangement of qualities. And that is all. There is no difference without difference in the arrangement of qualities. All else supervenes on that." (Lewis, ix f)*

## Main challenges: (1) explanatory circularity

David Armstrong. *What is a Law of Nature?*. Cambridge University Press: Cambridge, 1983.  
Cambridge Philosophy Classics 2016.

*“Suppose that a number of Fs have all been observed, and that each is a G. No F that is not a G has been observed. We might ask an explanation of this fact. One possible explanation is that it is a law that Fs are Gs... Laws... explain uniformities. Even if we take the Humean uniformity itself, that all Fs are Gs, it seems to be an explanation of this uniformity that it is a law that all Fs are Gs. But, given the Regularity Theory, this would involving using the law to explain itself. We need to put some ‘distance’ between the law and its manifestation if the law is to explain the manifestation.” (Armstrong, 37f)*



## Main challenges: (2) falsity of Humean supervenience

Tim Maudlin. *The Metaphysics Within Physics*. Oxford University Press: Oxford, 2007.

“Lewis’s Humeanism comprises two logically independent doctrines...:

### Thesis (Separability)

*“The complete physical state of the world is determined by (supervenes on) the intrinsic nature physical state of each spacetime point (or each pointlike object) and the spatio-temporal relations between those points.*

...[and]:

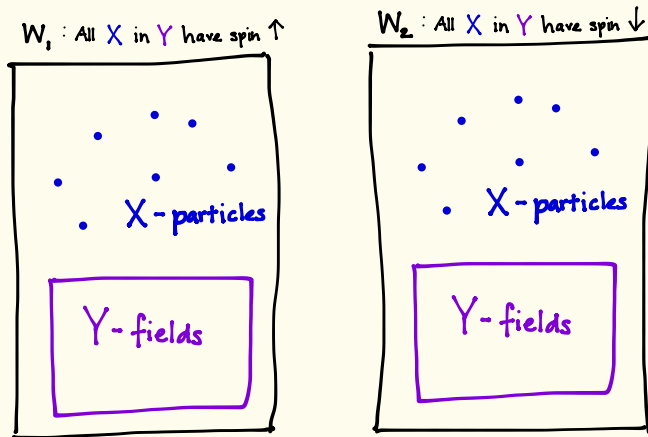
### Thesis (Physical Statism)

*“All facts about a world including modal and nomological facts, are determined by its total physical state.” (Maudlin, 51)*

## Main challenges: (2) falsity of Humean supervenience

- Maudlin and many others have argued that 'Separability' is shown to be false by quantum entanglement.
- Again, Maudlin and many others have argued that 'Physical Statism' contravenes scientific practice.
- Maudlin, John Carroll, Michael Tooley, and others have produced arguments of the following kind to show the falsity of 'Physical Statism':

## Two worlds that differ only in their laws:



- Helen Beebe: Humeans should not accept that these are distinct metaphysical possibilities.

# Best-systems analysis of laws

**SIMPLICITY**

**STRENGTH**

# 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  $F$ s are  $G$ s.  $F$ -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?)

## Armstrong: 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**
- Armstrong’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