4 Laws of nature

4.1 Law or accident?

In 1766, a mathematics professor, Titius, described the distances of the planetary orbits from the Sun as falling into a simple pattern. If the distance between the Sun and Saturn's orbit is divided into100 equal units, then Mercury's orbit is 4 of those units from the sun, Venus 4 + 3, Earth 4 + 6, and Mars 4 + 12. As far as Titius knew, there was a gap at 4 + 24 units, but Jupiter is at 4 + 48 and Saturn, of course, is at 4 + 96 units. This numerical progression doesn't reflect the distances perfectly. Its accuracy depends on such things as what point of the planet's orbit (closest, farthest, or average distance from the Sun) is chosen. Nevertheless, it is easy enough for us to appreciate why Titius was impressed by the pattern.

A controversy emerged: an astronomer, Bode, promoted the principle. His position was strengthened by the discovery of Uranus at approximately 4 + 192 units and the discovery of the asteroid Ceres (taken to be a minor planet) at 4 + 24 units. Critics of the principle included Gauss, Delambre, and Laplace. Delambre and Laplace are reported to have called it a "mere game with numbers."[1]

What exactly was at issue? On one reasonable understanding of this episode in the history of astronomy, these scientists disagreed about whether Titius had discovered a *law of nature*. Science includes many principles that were at least once thought to be laws. Famous examples include Newton's law of gravitation, his three laws of motion, the ideal gas laws, Einstein's principle that no signals travel faster than light, Mendel's laws, the economic laws of supply and demand, and more. In essence, the controversy was whether Titius' principle was on a par with these scientific

[1] For further discussion, see Jaki, "The Early History of the Titius-Bode Law."

propositions. Does the principle reflect something fundamental about how the universe works? Or does it describe an accident of nature, just saying something about how the orbits of the planets happen to be spaced?

Laws of nature are not just important to scientists. They are also a matter of great interest to us metaphysicians. We aren't so much concerned with discovering laws. We are not in the business of figuring out *what the laws are*. We leave that to the scientists. Metaphysicians care about *what it is to be a law*, about *lawhood*, about whatever it is that is the essential difference between something's being a law and something's not being a law. That's exactly what this fourth chapter is about.

We have already encountered some good reasons for undertaking this investigation. Lawhood is pretty clearly a part of our scientific conceptual framework. So it is the job of philosophers of science, if not also us metaphysicians, to understand lawhood better. But, in earlier chapters, we have come across some reasons why metaphysicians in particular definitely should engage with this concept. As we saw in Chapter 3, lawhood is critical to the standard formulation of Determinism; Determinism holds if the state of the universe at any one time together with the *laws of nature* determine what the state of the universe will be all other times. As a result, lawhood is also central to the philosophical puzzles that arise about freedom and responsibility. In Chapter 2, we saw that lawhood is thought by some to be to a key element of plausible accounts of causation; for example, according to NS Condition, a cause's occurring must be a necessary part of a condition that together with the *laws of nature* is sufficient for the effect to occur. Let's see what we can find out about what it is to be a law.

4.2 Starting points

We begin this investigation by highlighting some plausible assumptions that have greatly shaped current discussions of laws of nature.

In our daily inquiries, we take ourselves to be seeking, and sometimes finding, truth. It would be surprising if scientists – our most revered investigators – sought less. So to the extent that laws are one object of scientific discovery, it is natural to think that *all laws are true*. This connection between lawhood and truth is reflected in the historical episode described at the start of this chapter. Despite its accuracy about Ceres and the seven major planets nearest to the Sun, the numerical progression proposed by

Titius clearly is not in line with the orbital distances of Neptune and Pluto. Titius' principle (in its 1766 formulation and some other formulations) was jettisoned after Neptune was discovered in 1846. Astronomers judged it not to be a law. Why? Obviously, this judgment was made because, in order for something to be a law of nature, it must be true. The determination of Neptune's orbital distance from the Sun showed Titius' principle to be false, and so not a law of nature.

The assumption that all laws are true can lead to some confusion. Strictly speaking, many propositions that are called 'laws' are not really laws. For example, though it is false, Titius' principle is commonly known as Bode's law or the Titius–Bode law. While a good approximation, Newton's law of gravity is false and so not really a law. Why are these principles still called 'laws'? This may be because the propositions were given *names* including the word 'law' when they were believed to be laws, or because of a tendency to use the word 'law' to describe any general proposition or any proposition at one time taken to be a law by scientists. One should be wary of this confusion because, for expository reasons, we will frequently rely on simple and familiar generalizations from the history of science (or on even simpler, wholly fictitious examples) that are no longer (or perhaps never were) believed to be true.

Something else important is suggested by the examples of laws of nature provided so far: *that all laws are generalizations*. They all make a claim to the effect that all things or events have a certain property, usually a certain conditional property. For example, that no signals travel faster than light says about every individual thing in our universe that if it is a signal then it is traveling at a speed less than or equal to the speed of light. The Titius–Bode law says about every individual thing that if it is a planet orbiting the Sun then its orbital distance from the Sun falls in the progression described above. Note that we are reluctant to accept anything but general propositions as laws. For instance, it would be strange to think that some singular fact (e.g., that the Earth has mass 5.98×10^{24} kilograms) could be a law of nature, no matter how interesting or scientifically important it might be.

As was the case with the idea that truth is a necessary condition of lawhood, we should be careful about the assumption that generality is one too. In taking laws to be generalizations, we are not thereby denying that laws sometimes refer to specific objects, times, or places. (Generalizations referring to specific material objects will be discussed in 4.3.) Nor do we thereby deny either that there might be certain probabilistic laws or even what philosophers sometimes call *ceteris paribus laws*. The probabilistic generalizations that all uranium atoms have a half-life of 1,500 years or that all silver atoms exposed to a non-homogeneous magnetic field have a 50 percent chance of having spin up are perfectly good candidates to be laws of nature. They are generalizations despite including an element of probability. Similarly, if it is true that, ceteris paribus (i.e., other things being equal), price is inversely proportional to supply, we do not intend anything we have said to disqualify this (hedged) generalization from being a law.

Suppose that it's a law that all copper expands when heated. Then consider any bit of copper *b* that, in fact, is not heated. Even if particular circumstances had been different, even if *b* were heated, the laws governing our world surely would be unchanged. Thus, we naturally accept the counterfactual conditional that, if *b* were (still) copper and heated, then *b* would expand. It is very natural to think that *all laws of nature support counterfactual conditionals*; they are somehow or other part of what makes a wide range of counterfactuals true.

Most have correctly recognized that lawhood is somehow conceptually entwined with the counterfactual conditional. Indeed, it is the account of counterfactuals in terms of lawhood championed by Roderick Chisholm[2] and Nelson Goodman[3] that provoked much of the recent philosophical interest in laws of nature. Very roughly, their account maintains that, if *P* were the case, then *Q* would be the case if and only if there is a valid argument of the form:

$L_1, \ldots, L_r$
$P, I_1, \ldots, I_k$
Q

where $L_1 – L_r$ are laws, and $I_1 – I_k$ are non-laws *cotenable* with *P*. Since 'cotenable' is a technical term, this account needs to be supplemented with some characterization of cotenability. Even so, it is clear how the account was intended to apply to cases like our case of *b*, that unheated bit of copper. Since the law that all copper expands when heated together with

[2] Chisholm, "The Contrary-to-Fact Conditional" and "Law Statements and Counterfactual Inference."

[3] Goodman, "The Problem of Counterfactual Conditionals."

the conjunction that *b* is heated and *b* is copper entails that *b* expands, there is the true counterfactual conditional that, if *b* were heated, it would expand.

David Lewis defended a different account in his book *Counterfactuals*. Like his approach to (metaphysical) necessity, it invokes possible worlds. He argued that what determines whether *Q* would be the case if *P* were the case has to do with what other 'nearby' possible worlds are like. Very roughly, what it depends on is whether *Q* is true in worlds that are otherwise most similar to the actual world but in which *P* is true. So to determine whether, if *P* were true, then *Q* would be true, ask yourself what the nearest *P*-is-true worlds are. Then check to see if, in those worlds, *Q* is also true. Laws of nature are important to Lewis's account because one factor identified by Lewis as very important to whether a world is similar to our world is whether the worlds are in agreement on their laws. So since it is true that in the worlds most similar to ours where *b* is copper and *b* is heated that all copper expands when heated, it is also true in those worlds that *b* expands. Thus, if *b* were copper and *b* were heated, then *b* would expand.

Metaphysicians have generally held that *some* (metaphysically) contingent propositions could be laws of nature. For example, any possible world that as a matter of law obeys the general principles of Newtonian physics is a world in which Newton's first law of motion – the generalization that all inertial bodies have no acceleration – is true. A possible world containing accelerating inertial bodies is a world in which Newton's first law is false. Two reasons can be given for believing that it is possible for a contingent proposition to be a law of nature. The first reason is the plausibility of judgments of possibility engendered by examples like the one just given regarding an inertial body with no acceleration. Just as there is a possible world in which it is raining in Paris now, there are possible worlds with accelerating inertial bodies. The second reason is that there are laws of nature that can only be discovered in an a posteriori manner. If necessity is always associated with laws of nature, then it is not clear why scientists cannot always get by with a priori methods.

Philosophers known as *Necessitarians* hold that *no* laws of nature are contingent.[4] They often argue that their position is a consequence of the

[4] See, for example, Shoemaker, "Causal and Metaphysical Necessity."