The Scientific Enterprise

7. On Types of Laws

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On the Notion of Laws

The idea that the universe is ordered in some fundamental way could have arisen in the human mind by the apparent regularity of sunrise and sunset, the waxing and waning of the moon, and the periodicities of planets. Vedic thinkers in ancient India introduced the notion of *rta* to refer to this cosmic order, and the idea extended to the moral plane as *dharma*. In ancient Greece Heraclitus introduced the term *logos* to refer to a similar principle. There the term was extended to mean 'rational discourse'. The Stoics of ancient Greece, like Hindu thinkers, imagined this to have a divine origin. The link between what is correct and orderly and what is morally right and proper in human behavior may be seen in the dual meaning of the word *right* in English: Something is right when it is logically correct and also morally proper (as in, that's the right thing to do). Such lines of thought led to the notion of a law as a guiding principle that should dictate the actions and functions of systems.

Human-made Laws

From the most ancient times human beings have regulated life and society by adhering to certain well-defined patterns of conduct. This has been achieved by the enactment of laws which all the members of a society agree to adhere to. Over the ages, innumerable human-made laws have arisen in this manner in various cultures and nations. They are at the basis of civilized nations.

Human-made laws, also called 'statutory laws', are generally arrived at by common consensus, and are found in the various statute books of the world. They prescribe the constraints under which the members of any society should interact with one another. The constraints are generally meant (in socially evolved societies) to safeguard the interests of all people, rather than to promote those of a few. Obedience to such laws thus has two implications: On the one hand, a certain amount of personal freedom will have to be sacrificed on the part of every individual. On the other hand, it ensures that there will not be any inconsiderate use by another person of his or her own freedom in such a way as to affect others in a negative way.

Laws of Nature

Careful observations reveal that all phenomena arise from specific patterns of behavior of the phenomenal world. That is to say, the physical world at large, of which whatever we see and experience are only specific parts, functions in uniform ways. Even when and where there seems to be apparent chaos, one has been able to discover underlying regularities. Such patterns of behavior of the natural world are referred to as *laws of nature* or *physical laws*. We shall use these two terms interchangeably. It is important to realize that laws of nature don't always direct human behavior. They only govern physical phenomena.

The word *law* arose from the notion that God imposed the regularities on nature. However, inasmuch as these laws are stated by humans on the basis of human observations – which are limited by several constraints – all the laws of nature are, in principle, subject to conceptual modification. From this point of view there is nothing inexorable about them. Nevertheless, the ultimate aim of science is the discovery of physical laws. It is in terms of such laws that processes and occurrences in the phenomenal world become intelligible.

Philosophers of science have given a variety of definitions for a law of nature. As with other fundamental concepts, there is no universally accepted definition or even view among philosophers on what a scientific law is. But some have talked about the essential characteristics of any law, such as that it must be true, universal, and contingent (J Carroll, *Laws of Nature*, 1994). To say that a law is contingent, as distinct from necessary, means that the contrary could well have been the case without violating any principle of logic.

Built-in Uncertainty and Cautionary Claim

Whatever definition one may adopt, at any given point of time it would be difficult, if not impossible, to assert whether a given statement, in spite of all its concordance with observed facts, is in fact a law or not. Take, for example, the relationship between the pressure and the volume of a given amount of gas at a specified temperature. This relationship, generally known as Boyle's Law, was taken to be true until more careful observations at high pressures revealed discrepancies between the law as stated and results of observations. Similarly, Dulong and Petit's Law of specific heats of solids was accepted as true for many decades until precise experiments at very low temperatures proved it to be invalid there. Examples of this kind may be found in many contexts throughout the history of science. In many instances one way out of the difficulty is to state right away that the experimentally observed (deduced) law in question holds only within a well-specified range of observations. In case of laws which are not derived directly from experiments, even this would be impossible.

In view of this, one may adopt the following cautious description: A law of nature is a suspicion of a certain pattern of behavior in a certain aspect of nature. As long as there is no reason to believe that the suspicion is mistaken, it may be considered as reflecting an intrinsic aspect of the world. From this point of view, a law may be exploited for theoretical satisfaction as well as for practical purposes.

This definition raises an important question: Is scientific knowledge, much of which is condensed in the statements of the various laws of nature, merely a subjective matter, as seems to be suggested in this definition? For the word *suspicion* implies what we think, rather than what is out there. Science seems to lose its great virtue of objectivity in this view. In answer to this, we will simply note an important lesson from the history of science: No law of nature, as stated by humans, can be regarded as unmodifiably true. So many laws, once categorized as being inexorably true, have been found to be either only approximations or even totally wrong in the long run, that it is wise to be cautious in our assertions. Also, a suspicion of a state of affairs does not necessarily deprive that state of all objective existence. It is just possible that the suspicion is right.

The Criterion of Simplicity

We just saw that one of the characteristics of scientific language is its conciseness. This is related to a basic attitude of the scientist: by which, of different possible explanations of a phenomenon, the simplest is to be preferred. This rests on the belief that there is an element of intrinsic simplicity in the behavior of nature. Already in the 14th century, William of Ockham enunciated a principle of parsimony which was stated in a variety of forms: *Pluralitas non est ponenda sine necessitate*: Plurality is not to be assumed without necessity. In other words, as Newton put it, "it is vain to do with more what can be done with less". For this and other views Ockham was accused of heresy and excommunicated by Pope John XXII in 1324. Ockham's works show that it was the Pope who had been heretical! (Marilyn Adams, *William Ockham,* 1987.) In any event, Ockham's principle became a matter of much philosophical and theological controversy. Over the centuries a number of philosophers of science have analyzed this concept in detail, and tried to provide a logical justification for it: But it has always appealed to the scientist's mind. (Roger Ariew, *Ockham's Razor: A Historical and Philosophical Analysis of Ockham's Principle of Parsimony,* 1976.)

The criterion of simplicity may be justified on at least two grounds. First, it reflects the efficiency of a scientific theory or explanation. For it accomplishes more with less. Secondly, we must remember that the hypotheses underlying a theory are unconfirmed statements on what is not directly observed or observable. Hence, the simpler and the less the number of such claims, the more acceptable they should be. After all, the hypotheses of a theory are a little like a commission we have to pay for the purchase of an article. The less this amount, the better.

There is also a third reason, partly theological, for accepting the principle. It is that God would not make a universe governed by complicated laws. Pierre Duhem, writing in 1906, regarded such an attitude as obsolete. "There was a time," he wrote, "when physicists supposed the intelligence of a Creator to be tainted with the same debility, when the simplicity of these laws was imposed as an indisputable dogma in the name of which any experimental law expressing too complicated an algebraic equation was rejected, when simplicity seemed to confer on a law a certainty and scope transcending those of the experimental method which supplied it... That time no longer exists. We are no longer dupes of the charm which simple formulas exert on us; we no longer take the charm as evidence of a greater certainty". (*The aim and structure of physical theories*, 1954 ed.). But the criterion has certainly not been given up since Duhem's time.

Perhaps the best known example of the application of this principle in the course of the 20th century is in the *Theory of General Relativity* of Einstein. As J G Kemeny pointed out, "...after years of research, he (Einstein) arrived at a particular equation which, on the one hand, explained all known facts and, on the other hand, was considerably simpler than any other equation that explained these facts. When he reached this point he said to himself that God would not have passed up this opportunity to make nature this simple..." (Quoted in Hugh G Gauch Jr,, *Scientific method in practice,* p.275, 2003.)

The paradox here is that to those who have not been formally initiated into the intricacies of the scientific enterprise, science does seem to be quite a complicated business. Yet, those who have devoted some time and effort to the systematic study and practice of science also discover that at the core everything is indeed simple. Once the mystery has been unraveled, the underlying principles are seen to have an enchanting simplicity. The time and ingenuity needed to track down the planetary orbits may be considerable. But once this has been accomplished and the intrinsic harmonies laid bare, precessions and elliptical orbits seem simple and uncomplicated.

It must be pointed out – and herein lies the solution to the paradox mentioned above – that by *simplicity* in physical theories we do not mean something trivial, something that is understandable to anyone and to everyone. Rather, one refers by this term to the harmony and logic of the relationships, to the elegance and balance of the conceptual structures used in analyzing the world. This is why the General Theory of Relativity, which is based on much sophisticated mathematics, is still extolled for its simplicity, but only by those who understand it. As Einstein once quipped, "Everything should be made as simple as possible but not simpler."

Moral Laws

Between the human-made laws of statute-books and the physical laws of science text-books there are certain kinds of laws whose status has been the subject of much controversy among philosophers. These are the so-called moral laws. They arise from a unique characteristic of man in a culturally evolved state. Human beings experience what is called conscience: which is an intangible pointer that seems to indicate the difference between good and bad, between right and wrong action. External and preached principles of good and bad behavior may be questioned or discarded, but the inner impulses for right action and the deeper personal feelings of guilt are often inescapable. This may suggest that they too have some kind of objective status, somewhat like the laws of nature.

On the other hand, it is also true that the inner ethical directives do not always point to the same direction in all individuals, let alone in peoples under different cultural influences. Anthropologists and behavioral psychologists have traced the origins of some of our motivating ethical principles to inculcation of value systems from our remotest infancy, by mother, father, friend, preceptor, and the cultural environment at large. Already in the 17th century, Thomas Hobbes, imbued as he was by the mechanistic scientific philosophy of the time, suggested that good and bad were purely relative concepts, and did not have the kind of absolute validity that traditional religions claim for them. (*The elements of law, natural and political*, 1650.) What is more, Hobbes went on to say that the so-called virtuous behavior arises on final analysis essentially from selfish motives.

And yet one may argue that human beings, even with completely different cultural upbringings, do have certain common criteria of right and wrong conduct. Consider the following extreme cases: The cruel torture of a wounded, invalid, blind four year old child who is gasping for breath would be regarded as a wrong act by normal human beings in almost any society. (This statement is not based on any anthropological research.) Similarly, practically any normal human being will consider it a preferable (good) gesture to offer some water to a sick, old, man dying of thirst rather than take away whatever water may be within his reach. These examples suggest that perhaps there are absolutes in moral principles to which the human spirit is subject, exactly as the physical world is governed by strict laws of nature. Such considerations led Immanuel Kant to declare: “Two things fill the mind with ever new and increasing admiration and awe, the oftener and the more we reflect on them: the starry heavens above, and the moral law within.” (*Critique of practical reason*, 1788.)

Whether moral laws have the same standing as physical laws or not, they do have one important resemblance to human-made laws: They can be violated without performing a miracle. Those who are inclined to give objective validity to moral laws invoke a new idea in response to this possibility. They maintain that there also operate in the universe (by which they simply mean in this context the world of humans) certain inescapable laws of action and consequences governing our behavior. Invariably and inevitably, our actions will be rewarded or punished by a divine arbiter, whether via the law of karma or on judgment day or through some other means.

The Biblical statement (Galatians VI), "Whatsoever a man soweth, that shall he also reap" is a metaphorical expression of this idea.

Some have seen in this a parallel with the physical law according to which every action has an equal and opposite reaction, which is a total misunderstanding of the physical law, in which it is the target of the force that exerts the reaction, and not some supernatural entity, and where the notions of good and bad are entirely absent.

Conceptual Limitations of Physical Laws

There are also some fundamental difficulties in accepting the so-called physical laws as giving us the whole truth, i.e., in accepting these to be eternal characteristics of the universe. Whatever physical laws we hold to be true, we have become aware of them only through our experiences on this planet (and, since recently, in some other sections of our solar system); and these are but infinitesimal parts of a grand universe that seems to stretch to billions of light years. Also, these experiences have been during a very short time span in the considerably longer history of the cosmos. The question that then arises is the following: Are we justified, on the basis of these very limited spatio-temporal experiences, in imagining that these laws have operated all through time and are valid in every nook and niche of the universe?

Before the rise of modern science there used to be a clear-cut distinction in the minds of investigators between the physics on the terrestrial plane and the physics of the heavens. It was believed that in the celestial spheres entirely different laws operated: there, for example, all motion took place only in perfectly circular orbits, no changes ever occurred, and matter never decayed. We no longer hold such views. Indeed, a necessary step in the development of modern science was the recognition of the universality of the laws of nature here and beyond. Although the Copernican Revolution was generally looked upon as removing humans from the coveted center of the universe, thus humiliating their ego, one could just as well regard it as resulting in the merger of our abode into the heavens.

On the other hand, one could also argue that from a purely logical point of view, the older Aristotelian world view was more sound: for according to it, extrapolation of our limited experiences into the domain of the totally unknown and (apparently) unreachable was not justified. For example, suppose that we had known in precise quantitative terms that all falling bodies accelerate at a certain rate here on earth, but were unaware of the law of gravitation. Could we have concluded from this that bodies on Jupiter or on the moon would also fall down with the same acceleration? Yet, in a sense this is precisely what we do in certain contexts of modern physics.

Thus, at least at the quantitative level, things do not seem to behave in quite the same manner everywhere in the universe. We now know that the explanation for this lies in the fact that the rate of fall depends on the mass of the planetary body: the greater the mass, the faster the fall. But there is also another parameter which determines the rate of fall. And that is the gravitational constant G. We believe that this has the same value on the moon, on Jupiter, and everywhere in the universe. The gravitational constant is only one of many other such constants that seem to play a fundamental role in determining the general features of the world we live in.

In connection with the fundamental constants also, one may raise certain important questions. To see this, consider the following: There are a number of physical laws whose quantitative aspects involve the fundamental constants: such as the velocity of light, the charge on the electron, etc. We do not know why these constants have the specific values they have. The situation could well be compared to pre-Newtonian physics when the acceleration due to gravity was known, but one did not understand why it had that particular value. Now if it turns out that these fundamental constants have the observed values because of some local properties of the galaxies, it is conceivable that we may have to restrict some of our ideas as to the universality of physical laws.

Indeed, we already know that the second law of thermodynamics, for example, has no meaning in the context of a very small number of particles and at very small dimensions – a fact which was not as apparent when the law was first formulated in the middle of the nineteenth century. Likewise, for extremely short time intervals, the principle of energy conservation may be broken. More generally, we know that the laws governing the microcosm are in many ways different from those at the much larger scale. And if the universe is indeed oscillating (expanding and contracting, only to be re-formed and to re-expand) it could well be that in each phase of its existence it is governed by an entirely different set of laws.

There are other considerations from which we may recognize that we can never be absolutely certain about the eternal and universal validity of physical laws. However, two things must be borne in mind while considering these imperfections of science: First, they arise from the human being's inherent limitations as an organism in the physical universe, and thus are part of every other competing effort to interpret the world of experience. Secondly, humans have been able to accomplish much, both intellectually and practically, in spite of these constraints. The all too human limitations of science have not lessened its productivity.

Thus, we must be clear about two aspects of the scientific enterprise. It does not aim at, nor pretend to, absolutely certain knowledge. But science does offer proofs for whatever tentative knowledge it proclaims. In religious doctrines, on the other hand, while one is assured of the eternal veracity of the views, one is not always given logical or evidential supports. Hence the statement that science gives proof without certainty, whereas religion offers certainty without proof.

Scientific knowledge may be an illusion, but so is all human endeavor: Art is aesthetic illusion, literature is fanciful illusion, democracy and communism are ideological illusions, philosophy is intellectual illusion, and science is fruitful illusion.

On the Breaking of Laws

A law of nature cannot be broken, even in principle. If a law of nature seems to be violated, the scientific community will examine the situation with great care and interest. And if the violation persists, the law itself will be modified or declared to be invalid.

Moral laws can be – often are – violated. Violators of moral laws are described as sinful in the religious framework, and are expected to be punished in some way or other by supernatural principles.

Violations of human-made laws are called crimes or felonies. A violation of a law of nature is called a miracle. Miracles are not allowed in the world of science. Ironically those who are believed to break a law of nature (God-made law) are revered and proclaimed as saintly individuals in the religious framework.

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Resonance, Vol.13, p.596, p.778, p.885, p.1074; Vol.14, p.90, p.386.

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