getting a cold by keeping him temporarily away from Billy, who has a cold. We want some basis for prediction, so that we will not always be taken by surprise at the next series of events with which nature confronts us. And often when we can predict, we can also control the course of events; at least we are in a better position to control if we can first make a reliable prediction. We can reliably predict eclipses, but we cannot control their occurrence; but in many cases we can control as a result of our prediction: if we can predict reliably that after heavy rains the river will flood, we can get out of the way of the flood, or even (if it happens repeatedly) build a dam.

Most of the regularities that we find have many exceptions: they are not invariants. There is a certain regularity to children getting colds when they play with other children who already have colds, but it doesn’t always happen that way. Chickens lay eggs and never cans of sardines, but how many eggs they do lay and at what intervals is extremely variable. Trees are more likely to fall during a severe storm, but they don’t always: some do and some don’t.

The scientific enterprise could be described as the search for genuine invariants in nature, for regularities without exception, so that we are enabled to say, “Whenever such-and-such conditions are fulfilled, this kind of thing always happens.” Many times we think we have found a genuine invariance, but we have not. We may have been sure that water always boils at 212°F, since we have tried it many times and it has always happened. But if we try it on a mountain top, we discover that the water there boils at a slightly lower temperature, so our hope that we had found a true invariance is upset. We try some more, however, and find that the temperature of water boiling depends not on the moisture in the air, not on the time of day, not on anything except the pressure of the surrounding air. We are thus able to say, “Water at the pressure found at sea level boils at 212°. Here at last we have a statement of genuine invariance; and behold, we have a law of nature.

Prescriptive v. descriptive laws. The word “law” is ambiguous, and the ambiguity can be extremely misleading if we are not aware of it.

1) In daily life we most often use the word “law” in the context of “passing a law,” the law prohibits you from . . . , and on. Law in this sense is prescriptive: it is a rule of behavior imposed by a monarch or passed by a legislative body, and enforced by the legal machinery of the state. Laws in this sense are not propositions, because they cannot be false (it is, however, true or false that certain laws have been passed); they are, rather, imperatives, in effect “Do this,” “Don’t do that.” The law does not state that anything is the case; rather, it issues a command, a prescription, usually with penalties attached for failure to obey. But this is not the sense of “law” that is involved in speaking of laws of nature.

2) Laws of nature are descriptive: they describe the way nature works. They do not prescribe anything: Kepler’s laws of planetary motion do not prescribe to the planets that they should move in such-and-such orbits, with penalties invoked if they fail; rather, Kepler’s laws describe how planets actually do
move. Laws in this sense describe certain uniformities that exist in the universe. Sometimes, for the sake of simplicity, they describe only what would happen under certain ideal conditions: Galileo's Law of Falling Bodies describes only the velocities at which bodies fall in a vacuum. But such a law is still descriptive: it describes our universe (not any logically possible universe), and it prescribes nothing. Only conscious beings can prescribe, since only they are capable of giving orders. But the uniformities of nature would still occur even if there were no human beings to describe them.

Several confusions can be avoided if we keep this distinction in mind. (1) "Laws should be obeyed." Whether or not you should obey all the laws of the land is a problem in ethics. But a law of nature is not the sort of thing you can obey or disobey, since it is not an order or command anyone has given. What could you do if someone said to you, "Obey the Law of Gravitation?" Your motions, along with those of stones and every particle of matter in the universe, are instances of this law; but since the law only tells us how matter does behave, and cannot prescribe how things should behave, you cannot be said either to obey or disobey it. A prescriptive law, moreover, could still be said to exist even if it were universally disobeyed. (2) "Where there's a law, there's a lawmaker." Again this applies clearly to prescriptive law: if a course of action is prescribed, someone must have prescribed it. But the same consideration does not apply to laws of nature. Did someone make the planets move in a certain way?... It is sufficient to observe that "law implies lawmaker" is not a necessary proposition in regard to descriptive law as it is with prescriptive law. (3) "Laws are discovered, not made." This applies only to descriptive laws: we discover how nature works, we do not make it work that way. But statute laws are made, devised, passed by human beings in positions of authority. Such laws do not exist but for human beings, but laws of nature— that is, the uniformities of nature would exist whether men were there to observe them or not, although the formulation of these uniformities is the work of men.

Laws of nature constitute a smaller class of propositions than empirical statements in general. Any statement whose truth can be tested by observation of the world is an empirical proposition. "Some chickens lay eggs," "World War I lasted from 1914 to 1918," "She fell ill with pneumonia yesterday," and "New York City contains approximately 8 million residents" are all empirical statements. Indeed, most of the statements we utter in daily life are empirical statements. But none of these is a law of nature: laws of nature are a special class of empirical statements. Since laws of nature are the very basis of the empirical sciences—physics, chemistry, astronomy, geology, biology, psychology, sociology, economics—it is important that we be clear about the principal defining characteristics of laws of nature.

The meaning of "law of nature." What, then, is a law of nature? What requirements must an empirical proposition fulfill in order to be a member of that select class of propositions which we call laws of nature?

1. It must be a true universal empirical proposition. To say that a proposition is universal is to say that it applies to all members of a given class without exception. That all iron rusts when exposed to oxygen is a universal proposition, but that this piece of iron rusts, or even that some iron rusts, is not a universal proposition.

a. A proposition about a single thing—"This piece of rock is metamorphic"—may be material for a law of nature, but it is not a law. Science does not consist of such singular propositions. Books on physics, the most developed of the empirical sciences, make no reference (except by way of example) to the motions of particular bodies, nor do chemistry books tell us about this piece of lead or that vessel of chlorine. But one does find many such references in psychology books (psychiatry division), for example in case-histories of patients. In this area few genuine laws have yet been discovered, so the psychologist must rely on individual case-histories as a means toward finding laws of human behavior. In this sense, psychology is still very much in a pre-scientific stage, a stage physics had already passed out of three centuries ago. But physics is in an advantageous position in that its laws are simpler—not in the sense of "easier to understand," for physics is more difficult for most students than any of the other empirical sciences, but in the sense that a law of physics can be stated in terms of the smallest number of conditions. In stating the velocity at which objects fall, one can ignore most of the universe: one can ignore the color of the object, its smell or taste, the temperature of the environment, the number of people watching the event, and so on for thousands of factors. By contrast, in dealing with human behavior it would be difficult to say what might not turn out to be relevant. A trivial event that occurred in your childhood, which neither you nor anyone else may remember, may still influence your behavior today and cause you to react differently to a given stimulus. The best we can do, usually, is to state certain general tendencies of human behavior, allowing for many exceptions. In psychology we hardly have laws at all, only tentative blueprints for laws; laws about human behavior that are both true and exceptionless have seldom been found.

The obvious examples of "laws of human nature" that come to mind all turn out on examination to be analytic. "People always act from the strongest motive" sounds like a plausible candidate for a law of human nature: people do a tremendous variety of things, but whatever they do, don't they always do what their strongest motive impels them to do? Waiving the fact that people don't always act from motives (they sometimes act from habit), the uncomfortable fact is that there seems to be no way of specifying what is meant by "strongest motive" except as the motive from which one acts. Thus: one acts from the motives from which one acts—true, but analytic. Similarly, "People always do what they most want to do" is either synthetic but false or true but analytic, depending on what one means by the sentence: in a familiar sense, we all do things (like coming to class) that we don't want to do; we often perform unpleasant chores even though we hate them. If one says even in these cases
that we always do what we want to do, we must mean "want" in some unusual sense—and indeed this sense is not far to seek: for the only criterion for knowing what we "really want" to do turns out to be what we actually do. So once again we have "We do what we do," which is true but analytic.

The universal proposition constituting the law must, then, be an empirical truth: it must not be analytic. "All A is B" is true in the case of "All triangles have three sides," but this statement, being analytic, is not a law of nature. Nor is "All gold is yellow," if being yellow is considered a defining characteristic of gold; in that case it would have to be yellow in order to be called gold in the first place, and the statement would be analytic. But if gold is defined by other means (such as atomic number), then it is a law of nature that everything having this property is also yellow. The B in "All A is B" must be connected with the A as a matter of contingent fact, not a priori or of necessity, if "All A is B" is to count as a law of nature.

b. Even true propositions about some members of a class are not usually considered laws of nature, though sometimes they are given the honorary title of "statistical laws." If 90 per cent of the A's there are are B's, there is a considerable regularity between the two, and the statement is far from useless as a basis for prediction. But, we are led to ask, if only 90 per cent of A's are B's and the remaining 10 per cent are not, why are the 90 per cent B's and not the others? What we want to find is some uniformity of a universal character underlying the statistical one. In daily life, however, we are constantly confronted by such regularities that are not universal: People with a cold usually have the sniffles, but not always; if one person hits another in the nose, the second person often gets a nosebleed, but not always. We have not yet formulated any universal statement about the precise conditions under which people get nosebleeds when struck on the nose, though we have a fairly adequate idea on what factors it depends. There is some regularity here (the harder you hit him, the more likely he is to get a nosebleed, and so on), but no invariant relationship.

2. These universal propositions are hypothetical in form. Now, universal propositions, both in logic and in science, are usually interpreted hypothetically—that is, as propositions of the "if...then..." form. "All iron rusts when exposed to oxygen" would thus be translated as "If there is iron, it will rust when exposed to oxygen." Thus formulated, the proposition does not tell us that there is any iron (it makes no existential claim), but only what happens under certain circumstances if there is. "All bodies freely falling in a vacuum accelerate at the rate of 16 feet per second per second" does not imply that there actually were or are any bodies falling in a vacuum. "At 99.9 per cent of the velocity of light, organisms grow old far more slowly than do those traveling at slower velocities" is a universal proposition that scientists believe to be true, but no one would declare that any organism is now traveling at that velocity.

The hypothetical interpretation of laws, however, can get us into trouble. The hypothetical "If p is true, then q is true" in logic is equivalent to "It is not the case that p is true, but q is false." For example, "If there is friction, then there is heat" (a law of nature) would be translated "It is not the case that there is friction but no heat." But now let us take the proposition "All unicorns are white." This is translatable into "It is not the case that there is a unicorn that is not white." And since there are no unicorns the proposition is true: there are no nonwhite unicorns, for the excellent reason that there are no unicorns at all. Moreover, by the same reasoning, "All unicorns are green" would also be true, since there are no nongreen unicorns. When p is false, then anything whatever follows, so we can put what we like into q.

Of course, "All unicorns are white" would never be counted as a law of nature; yet it is a universal proposition, construed as a hypothetical. Why would the proposition about unicorns not be considered a law, whereas the propositions about friction and organisms at almost the velocity of light are so considered? The difference lies in the fact that there is evidence from other laws that these laws are true. Indeed, the proposition about aging more slowly as one approaches the velocity of light is a logical consequence of (deducible from) Einstein's relativistic laws of time, whereas the proposition about unicorns is connected with no laws at all.

But even this is not sufficient to characterize laws of nature.

3. There are many true, universal propositions of hypothetical form that do not pass as laws of nature. Suppose I were to say, "All the dogs in this kennel are black," and that my statement were true: it would still not qualify as a law of nature. It is limited to a definite area in space and time—this kennel today. Even if its scope were broader ("All the dogs I've ever had in my kennels are black"), it still would say nothing about all dogs, or even all dogs of a certain breed. But if I say that all crows are black, I mean that all crows, wherever they may be, and whenever they may exist or have existed or have yet to exist, are, were, and will be black. (Blackness is not here considered defining of crows, else the proposition would be analytic.) The law is "open-ended": it has an infinite range, both in time and in space. This does not mean that there is an infinite number of crows—nor indeed that there are any crows at all—but that it is an open class, with no strictures of time and space operating to limit the scope of the law. There is no time or place at which the law will not hold true: considerations of when and where are irrelevant to the application of the proposition. By contrast, the proposition about the dogs in my kennel will not pass as a law because (1) though universal in form, the universality is restricted to a specifically delimited time and space; (2) the number of things covered by the proposition is not only finite, but this finiteness may be inferred from the terms in the proposition itself; this is not so for Kepler's laws of planetary motion, for example: though there are a finite number of planets, this fact cannot be deduced from the law; and (3) the evidence for the proposition exhausts its domain of application—the proposition is simply a summative report of what has been observed to be the case.

Since laws of nature apply to all places and all times, their claim extends into the future. This is perhaps the most important single feature of laws, for it enables them to be made the basis for prediction. If the proposition merely
read "All crows thus far have turned out to be black," one might say "So what?"—we could not deduce any predictions from it; but if we say that all A's, no matter when or where, are B's, we can deduce from it, plus the proposition that this is an A, that it will also be a B.

4. But even when all these conditions are met, a proposition may not be classified as a law of nature. "All crows are black" is unrestricted in time, place, and number of individuals in its domain of application. Yet it would generally not be counted as a law, because the only evidence for it is direct evidence, and a proposition is not usually accorded the status of a law unless there is some indirect evidence for it. This requires a word of explanation.

The laws of any science are not viewed in independence of one another. Together they form a vast body or system of laws, with each law fitting into a system including many other laws, each mutually reinforcing the others. The laws that scientists are most loath to abandon are those that form such an integral part of a system of laws that the abandonment of the one law would require the abandonment or alteration of a large number of other laws in the system. Thus an observation that directly confirms one law indirectly confirms a group of other laws, because of the interconnection of the laws in a system. (Physics is, again, the most systematized science. Biology was not very highly systematic until the present century: until then, it was for the most part a classificatory science, recording the properties of various species of creatures but discerning no interconnectedness among them. It was in much the state of chemistry before the rise of atomic theory.)

"All crows are mortal" is supported by much indirect evidence: the mortality of organisms in general, the biochemical deterioration of tissue, increase in auto-allergenic response, and so on. But "All crows are black" seems to relate to no other significant regularities, of either greater or lesser generality. A crow that was not black would change no other laws known to us; but a crow that was immortal (or even one that lived a thousand years) would excite considerable scientific surprise, because it might force us to reconsider the many other laws (about deterioration of tissue, etc.) with which it is interlocked. Whether or not something is called a law, then, depends to a large extent on how deeply embedded it is in a wider system of laws. A true universal proposition for which there was no indirect evidence would have little fundamentality in science: it could easily be abandoned without effect on the rest of the system. But "All metals are good conductors" is so fundamentally tied to other laws (of atomic structure) that a counterinstance would have far-reaching consequences.

5. Even when all this has been said, many propositions that satisfy all these criteria are often denied the status of laws. The difference seems to lie in the proposition's degree of generality. "All metals are good thermal conductors" and "Silver is a good thermal conductor" are both universal propositions, since both apply to all members of the given class; but the first statement is more general than the second, for it covers a wider scope. Universal propositions whose degree of generality is greater are more likely to pass as laws; thus the statement about metals is considered a law, but the statement about silver is not. While "All rare-earth metals have higher melting points than the halogens" may pass as a law, one would not likely hear the fact that tungsten melts at 3,370° C. referred to as a law but only as a fact.

Sometimes one of these conditions works against another, and the outcome is not certain. Einstein refers to the constancy of the velocity of light in a vacuum as a law of nature, and this is referred to as a law, in spite of its limited generality, because of the fundamentality of this item in the system of physical laws. On the other hand, while the mass of the electron is an elemental fact of physical science, its precise value remains largely independent of the main body of scientific theory, and therefore it is not accorded the status of a law. . . .