"SCIENCE SEEKS TO DISCOVER and formulate in general terms the conditions under which events occur," writes Ernest Nagel. Note that there is no limit on the kinds of events scientists investigate, nor on what procedures are essentially scientific, nor on the scope of science. It is convenient to divide science into branches, which are differentiated by their methods and focus of interest. The branches may encounter different problems: the astronomer cannot experiment; the geneticist can predict only probabilities; the atomic physicist must postulate entities he can never observe; the scientific psychologist can sometimes find nothing to measure; the political scientist may have to examine his own motives in explaining other people's actions; the sociologist finds that his predictions may be self-fulfilling or self-defeating; the anthropologist may be unwittingly altering the phenomena he is investigating. But none of these peculiarities makes astronomy, genetics, atomic physics, psychology, political science, sociology, or anthropology inherently unreliable, nor excludes them from the realm of science. We should forget the stereotype of the scientist as the man in a white coat mixing chemicals in test tubes. There is no single scientific method other than the unremitting criticism of evidence and reasoning in every way possible.

Let us also note that scientists are human beings. That means that their judgment may be biased, their selection of problems may be whimsical, their assessment of the evidence may be faulty, their determination of the facts may be subjective, their motivations may be suspect, and their observations may be distorted by their values. But these factors may all be made explicit, and controlled. Science is a social and self-corrective enterprise.

But science is entirely a human enterprise. The objectives of science are to describe, explain, understand, investigate, predict, and control, and these are characteristically human goals. The ideals of science are reliability, definiteness, precision, objectivity or intersubjectivity, testability, self-correctiveness, comprehensiveness or universality, and systematic coherence. Human
welfare is not as such an objective of science; for this reason, science needs to be supplemented by philosophy. The functions of a scientific theory may be variously stated: to inform ("All men by nature desire to know"-Aristotle); to predict ("Savoir c'est prevoir"-Comte); to control (Bacon, James, Dewey); to summarize the data economically (Mach). Wittgenstein calls a scientific theory a system of coordinates, not itself either true or false (since it makes no substantial assertions about the world), but more like a mesh used to cover a surface; a coarse square mesh might cover more than a fine triangular mesh, and vice versa. (Beware the fisherman who uses a net with two-inch openings and declares that all the fish in the ocean are larger than two inches!) But Nagel makes it clear, in The Structure of Science, that disputes over whether a theory should be said to be literally true or false, or rather to be a logical instrument for organizing experience, or a compendious summary of data are only conflicts over preferred modes of speech.

**Selection of a Theory**

According to Whitehead, science tries "to see what is general in what is particular." But there's the rub! The particular thing always has more than one general aspect or property. Gomperz offers the following descriptions of the flight of a sparrow:

There goes a sparrow.
This bird is flying.
Here is an animal.
Something here is moving.
Energy here is being transformed.
This is not a case of perpetual motion.
The poor thing is frightened.

No description can succeed in telling all that can be told about a particular thing or event; "fact is richer than diction" (Chapter 2). When human actions are being characterized, varying descriptions will result in different imputations of responsibility (Chapter 20). A theory, like a description, is not mechanically dictated by the facts, but is selected in order to advance our objectives. It is the product of human ingenuity and creativity. A theory is arrived at neither by automatic induction, nor by generalization, nor by observation of obvious regularities, but by a leap of the imagination to a new unifying idea. All the facts of biological evolution-variation, natural selection, the struggle for
existence—were known before Darwin and Wallace, but it was they who proposed a theory of open-ended natural selection (Chapter 13). As Einstein put it:

Given to us are merely the data of our consciousness. . . . There is only one way from [them] to "reality," to wit, the way of conscious or unconscious intellectual construction, which proceeds completely free and arbitrarily .... We are free to choose which elements we wish to apply in the construction of physical reality. The justification of our choice lies exclusively in our success.

Facts

I began this chapter by indicating that different areas of scientific inquiry run into varying problems in getting at the facts. There is no one criterion for scientific methodology, and there are at least six constituents which enter into the determination of what is a fact:

1. The human organism. In discussing our knowledge of the external world (Chapter 3), I showed how the human sensory apparatus determines the range of facts. Note also the relevance of the human life span. Would a race of intelligent animals that live for only an hour be likely ever to discover that glaciers drift? or that a melody is being played on a phonograph record revolving once a century?

2. The scientific instruments available. "Fact" is relative to the methods and conditions of observation—to the accuracy of thermometers, yardsticks, and clocks. Operationalism emphasizes that things do not have a "size" which is independent of the instruments used to measure it. (And of course instruments cannot dispense with the human observer; even a computer print-out must be read at some point by a person.)

3. Memory. One can be aware of repetition or of generality only if one now has a sense of what has occurred in the past.

4. The personality, aims, and bias of the individual scientist. This factor is usually (perhaps not always?) corrected for by other scientists.

5. Language. The observer can describe the world only in the language available to him. "Fact" has a linguistic constituent. As B. L. Whorf has shown, speakers of languages that do not have a word for "wave" will see not waves but only changing undulating surfaces. The Navahos use one word for blue and green, whereas the Bororö of Brazil have no single word for
parrot. In Arabic a wind may be described as sarsar, which means both cold and whistling. The language of Tierra del Fuego has a useful word, mamihlapinatapai; it means, roughly, the state of mind in which two people regard each other when both want a certain thing to be done but neither wants to be the first to do it. How many lovely facts are available to them! Of course La Rochefoucauld said a long time ago, "Il y a des gens qui n'auraient jamais été amoureux, s'ils n'avaient jamais entendu parler d'amour" (There are people who would never have fallen in love if they had not heard love spoken about). Cassirer and Sapir argue that the forms of language predetermine the modes of observation and interpretation; Wittgenstein said that "if we spoke a different language, we would perceive a somewhat different world." Waismann's metaphor is "language is the knife with which we cut out facts." There is no "fact of the matter" outside language.

Most significantly, fact is relative to hypothesis. There are no "raw facts." The human eye is not a camera, unfocused, automatically and unselectively recording impressions. Facts are not found haphazardly, nor in isolation. The scientist is not a passive observer of a self-evident structure (as we saw in Chapter 4). Malinowski tells of the young anthropologist who went out in the field to record a certain tribal ritual. He dutifully photographed everything in sight, only to realize later that the significant part of the ceremony was taking place somewhere else. The scientist must know what to look for (aren't the "facts" of cancer all there?). He must select; he must evaluate; he works from an implicit paradigm which determines what he will consider as a relevant fact. Consider whether the following propositions are statements of fact: a glass of water has the same temperature all over; the universe is expanding; nothing can get colder than -273°C.; the unemployment rate has dropped; Bert is accident-prone; a Christian Scientist feels no pain; Henry Moore's sculptural forms draw on the racial unconscious: perception is possible outside the senses; Bert saw a UFO. To decide whether these statements report facts requires not observation alone, but clarification of a hypothesis. James said, "Animal magnetism wasn't a fact until the theory of hypnosis permitted it." Kant put it, "Knowledge of the world demands more than just seeing the world. One must know what to look for in foreign countries." According to Poincare, "Science is built up of facts, as a house
is built up of stones; but an accumulation of facts is no more a science than a heap of stones is a house." Eddington paradoxically remarked, "Never accept a fact until it is verified by a theory!" But of course Aristotle knew this when he said that all knowledge arises out of previous knowledge. To ask for "nothing but the facts!" is to demand a map drawn to no particular scale.

**Hypotheses**

It is the hypothesis, which guides us in the determination of the facts, that is of the essence. In order to be of maximum usefulness in acquiring and organizing knowledge, a hypothesis must meet eight conditions:

1. It must be *falsifiable*; that is, it cannot be an analytic statement (which will remain true regardless of what occurs).
2. The explanatory hypothesis must of course be *true*. I have read that "lost persons travel in circles because spiral movement is a property of all living matter in motion."
   "Please, would you tell me," said Alice, "why your cat grins like that?"
   "It's a Cheshire cat," said the Duchess, "and that's why."
3. The hypothesis must be *simple* "even if," as Nagel maintains, "the simplicity tacitly demanded cannot be articulated precisely, may be almost entirely a psychological matter, and is likely to change as mathematical techniques ... improve."

Simplicity is always relative to a conceptual scheme (compare
figuring a 10% tip in American dollars and in English pounds, shillings, and pence). Even in mathematics, simplicity cannot be defined; it may depend on conventional or cultural factors. The simplicity may be in the concepts employed, or in the laws in which they are used. It may be linguistic (in structure or in notation), or ontological (that is, in the extralinguistic entities postulated). Is Copernicus' heliocentrism simpler than Ptolemy's geocentrism, if Copernicus requires that the earth move? The decision was not easy to make. Is a corpuscular

theory of light simpler than a wave theory? If the simpler (or more parsimonious) hypothesis is the one with the fewer parameters, then it will automatically also be more probable since a wider range of subsequent findings will be considered as confirming evidence. The requirement of simplicity is explained by Nelson Goodman thus:

[The world] is neither simple nor complex except relative to-as organised under-a given system. The world has many different degrees of complexity, as it has many different structures; and it has as many different structures as there are different true ways of describing it. Without science, or some other mode of organisation, there is no simplicity or complexity .... We must not ignore the facts; but truth and simplicity often contend with one another, and truth cannot always win ... simplicity not only functions as a test of truth but sometimes outweighs truth.

4. The hypothesis must be elegant, or beautiful. The physicist Dirac says, "it is more important to have beauty in one's equations than to have them fit the experiment ... fundamental physical laws are described in terms of mathematical theory of great beauty and power." Sometimes the criterion of beauty takes the form of a demand for symmetry; it is for this reason that physicists first postulated the existence of so-called antimatter.

5. The hypothesis must be as general as possible; it must avoid names and arbitrary or unreasonable restrictions of time and place. Other things being equal, the wider the scope of the hypothesis, and the greater its range and variety of predictive power, the better. Yet generality and simplicity may sometimes conflict. In economics, for example, "perfect competition" is more simple as an explanatory hypothesis, but "imperfect competition" is more general.

6. The hypothesis, if possible, ought not to be purely statistical
or probabilistic. There are some areas of science, however, quantum mechanics, for example (Chapter 12), and genetics, in which only probabilities can be predicted. No one can state when the next alpha particle will be emitted, but only how many particles on the average will be emitted in a given time interval; no one can state whether the next baby born in a given family will be blue-eyed or brown-eyed, but only what the probabilities are in a large number of births. This is the basis for the dissatisfaction of some physicists with present-day quantum theory, and their search for what they call "hidden parameters." Einstein summarized his opposition to purely statistical hypotheses in a famous remark, "God does not play dice with the universe." In the social sciences, explanatory hypotheses are usually probabilistic. We may explain that there was a riot in Attica prison because confinement and frustration tend to breed aggression, but this hypothesis does not permit us to predict the time and place of the next prison riot.

7. The hypothesis should bring out analogies where possible. The scientist may use a model for this purpose (for example, of the atom or of the solar system). The model of course is never an exact replica; it is either much larger or much smaller than, and omits certain features of, whatever it represents. If the scientist offers a hypothesis that electricity "flows along a wire like water in a pipe," or that molecules interact "like billiard balls colliding," this aids us in grasping the hypothesis, as does a diagram drawn to prove theorems in geometry; but the model must not be confused with the hypothesis itself.

8. The hypothesis should, finally, satisfy certain criteria that can best be described as metaphysical: that there is no infinite regress of explanatory causes; that there is continuity in the world ("Nature makes no leaps," said Leibniz); that the world be regarded as stable; even that the world be properly anthropomorphic. Max Planck said of the "Principle of Least Action" (which is, loosely, that a physical system undergoing change chooses the process for which the action will turn out to be a minimum) that it "creates the impression in every unbiased mind that Nature is ruled by a rational purposive will."

Perhaps an example will clarify some of the variety of considerations in selecting a hypothesis. In economics, the business cycle has been explained by at least six theories, each citing different
factors: monetary changes, such as the contraction and expansion of bank credit (Friedman); technological innovations and in-
ventions, such as railroads (Schumpeter, Hansen); psychological attitudes and expectations (Pigou, Bagehot); variations in con-
sumption and savings (Hobson, Sweezy); variations in investment (Hayek, Mises); and sunspots and the weather (Jevons). Each of these hypotheses will uniquely determine the facts.