

**REVISED  
EDITION**

**VOLUME ONE**

# **Philosophy of SCIENCE**

**FROM PROBLEM  
TO THEORY**

**MARIO  
BUNGE**

# **Philosophy of SCIENCE**

**Science and Technology Studies**  
Mario Bunge, Series Editor

*Philosophy of Science, Volume 1: From Problem to Theory,*  
Mario Bunge

*Philosophy of Science, Volume 2: From Explanation to Justification,*  
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## **A Foretale of Five Philosophers of Science**

The five Wise Men of the Kingdom of \* were back from their long sojourn in the remote Republic of \*\*. They stood trembling before their terrible sovereign, the Queen of \*. They had to report on the Strange Beast that dwells in the land they had visited.

“Tell Us, O wise Protos, what does the Strange Beast look like?” the Queen asked the elder sage.

“The Strange Beast they call Science, your Majesty, can register and compress all facts. In fact Science is a Recorder and Compactor all in one”. Thus spake Protos.

“Off with his head!” shouted the Queen, purple with rage. “How could We believe that the Strange Beast is a mindless recorder if even We sometimes grope, doubt, and make the occasional mistake?” Whereupon she addressed Deuterios, the next oldest savant.

“Tell Us, O wise Deuterios, how the Strange Beast looks”.

“The Strange Beast, your Majesty, is an information processor. It takes in tons of raw data which it processes to order. Science, in short, is a huge Computer”. Thus spake Deuterios.

“Off with his head!” shouted the Queen, green with rage. “How could We believe that the Strange Beast is an automaton, if even We have dreams and whims?” Whereupon she addressed Tritos, the middle-aged sage.

“Tell us, O wise Tritos, what does the Strange Beast look like?”

“There is no such thing, your Majesty. Science is only a Game. Those who play it stipulate the rules, which they change from time to time in mysterious ways. Nobody knows what they play or to what purpose—except perhaps to gain power. Let us agree then that Science, just like football, is a Game”. Thus spake Tritos.

“Off with his head!” shouted the Queen, yellow with rage. “How could We believe that the Strange Beast could survive without taking

things seriously, if even my chambermaid does?" Whereupon she addressed Tetartos, the mature savant.

"Tell Us, O wise Tetartos, how does the Strange Beast look?"

"The Strange Beast, your Majesty, is a woman who meditates and fasts. She has visions, tries hard to prove them wrong, and feels no better when she fails. Science, I conjecture—and I challenge anyone to refute me—is a Flagellant Visionary". Thus spake Tetartos.

"Off with his head!" shouted the Queen, white with rage. "How could We believe that the Strange Beast cares neither for justification nor for gratification, if even We do?" Whereupon she turned to Pentos, the young sage.

But Pentos, fearing for his head, had just managed to escape. He ran for several days until he crossed the border. He then came to my office, where he has been working ever since. Pentos has finally completed his somewhat bulky *Report on the Strange Beast: Its Anatomy, Physiology, Behavior, and Inner Life*, which I have translated into English.

Haunted by his painful memories of the rude manners prevailing in the court of the Queen of \*, Pentos wishes to remain anonymous. He fears, perhaps rightly, that his account of the Strange Beast will be unpopular, fond as most people are of simple, white-and-black creeds that can be learned with ease and be held on to with certainty. His is, in effect, a much more complex view of Science than either the Recorder, the Computer, the Game, or the Flagellant Visionary models, although he acknowledges his indebtedness to all four of his unlucky late colleagues.

The above explains why the fifth report on the Strange Beast comes out under a different title and a different author's name. May this trick save Pentos from the wrath of the zealous followers of simple creeds.\*

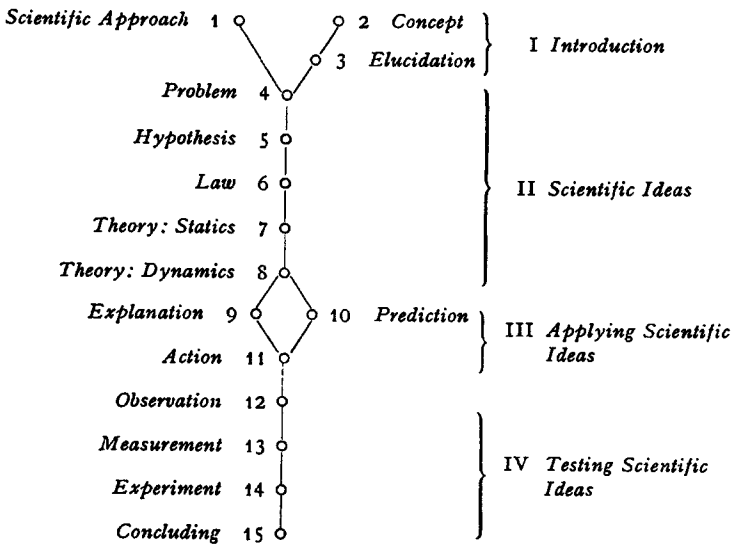
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\* *Note added in proof.* The Four Wise Men of \* are still alive. Protos and Deuteros survived because the executioner found no heads to cut. Tritos, because he grew himself a new skull by convention. Tetartos, because he figured a new brain for himself as soon as his former one was falsified.

## How to Use This Book

This is a treatise on the strategy and philosophy of science. It is an attempt to describe and analyze scientific research, as well as to disclose some of its philosophical presuppositions. This work may then be used as a map to identify the various stages in the road to scientific knowledge. It is an update of the author's *Scientific Research* (Berlin-Heidelberg-New York: Springer-Verlag, 1967, 1973).

This treatise is divided into two volumes of two parts each. Part I, the *Introduction*, offers a preview of the scheme of science (Ch. 1) and some logical and semantical tools (Chs. 2 and 3) that will be used in the sequel. The account of scientific research proper begins with Part II on *Scientific Ideas*. In the beginning was the problem—a subject studied in Ch. 4. Then comes the tentative solution to a problem—that is, a hypothesis (Ch. 5). Next, the hypothesis assumed to reproduce an objective pattern, i.e. the scientific law (Ch. 6). Finally the building and readjustment of systems of hypotheses—i.e., theories—are examined in Chs. 7 (with emphasis on structure and content) and 8 (with emphasis on construction). This closes Vol. 1, *From Problem to Theory*. Vol. 2 opens with Part III, *Applying Scientific Ideas*. Ch. 9 deals with the application of theories to explanation and Ch. 10 with their application to prediction and retrodiction. Ch. 11, on rational action, belongs to the philosophy of technology. Finally Part IV, *Testing Scientific Ideas*, opens with observation (Ch. 12) and goes on to measurement (Ch. 13) and experiment (Ch. 14). The jumping to conclusions from data to hypotheses and conversely (Ch. 15) completes Vol. 2, *From Explanation to Justification*. Look at the structure:



A look at the logical relationships among the chapters as displayed in the previous diagram should help the reader to use the book and understand the philosophy of science it proposes.

\*The paragraphs between asterisks may be skipped in a first reading\*. What should not be omitted are some of the problems appended to every section. Their purpose is threefold: to test the reader's understanding of the text, to shake his belief in it, and to invite him to advance the subject. There are more than a thousand such queries. Every problem set has been ordered roughly according to difficulty: the first few are usually exercises whereas some of the last are research problems. In assigning them the instructor should first appraise the background they require.

Quarrels with fellow metascientists have for the most part been avoided in the text and left to the problems. Bibliographical references, too, have been relegated to the problems and to lists at the end of every chapter. As a consequence every section resembles an uninterrupted lecture. With appropriate cuts each volume will cover one semester.

The book has been planned both for independent reading and reference, and for use in courses on Scientific Method and Philosophy of Science. Since the text oscillates between an introductory and an advanced level, it may suit a variety of purposes. For one thing, the book might be used as a substitute for formal lectures—which anyhow would

seem to have been rendered somewhat obsolete by Gutenberg. A lively discussion of the text and some of the problems, as well as of the results of exploring the suggested bibliography, should be more interesting and rewarding than a paraphrase.

Warning: Any book on our subject is apt to make irritating demands on its reader: he will be asked to sail back and forth between the Scylla of science and the Charibdis of philosophy. The author sympathizes with the traveller but he cannot offer apologies; instead, he will state the truism that shipwrecking can be avoided either by abstaining from sailing or by training in the skill. May the present book be of help to those who feel seasick at the mere thought of having to learn some science, and a rough guide for those who wish to take a closer look at the beast. Let it be recalled however that no travel guide can make the journey for us.

Department of Philosophy  
McGill University  
Montreal/Canada  
April 1997

Mario Bunge



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*To my wife Marta, who encouraged me to write this work,  
watched its gestation, and criticized it mercilessly,  
I dedicate it in friendship and love.*

## Special Symbols

$A \subseteq B$	the set $A$ is included in the set $B$
$A \cup B$	the union of the sets $A$ and $B$
$A \cap B$	the common part of the sets $A$ and $B$
$a \in A$	the individual $a$ as in (or belongs to) the set $A$
$\text{Card}(A)$	cardinality (numerosity) of the set $A$
$A \times B$	Cartesian product of the sets $A$ and $B$
$Cn(A)$	consequence(s) of the set $A$ of assumptions
$=_{df}$	equals by definition
$Df.$	definition
$(\exists x)$	some $x$ (or there is at least one $x$ such that)
$e$	empirical datum
$e^*$	translation of $e$ into a semiempirical, semitheoretical language
$h$	hypothesis
$m(\dot{r})$	measured value of the degree $\dot{r}$
$\bar{m}(\dot{r})$	average (or mean) value of a set of measured values of $\dot{r}$
$P \dashv T$	$T$ presupposes $P$
$p, q$	arbitrary (unspecified) propositions (statements)
$P(x)$	$x$ has the property $P$ (or $x$ is a $P$ )
$\{x P(x)\}$	set of the $x$ such that every $x$ is a $P$
$p \vee q$	$p$ and/or $q$ (inclusive disjunction)
$p \& q$	$p$ and $q$ (conjunction)
$p \rightarrow q$	if $p$ , then $q$ (conditional or implication)
$p \leftrightarrow q$	$p$ if and only if $q$ (biconditional or equivalence)
$\sum_i$	sum over $i$
$t$	theorem, testable consequence
$t^*$	translation of $t$ into a semiempirical, semitheoretical language
$T$	theory
$A \vdash t$	$A$ , therefore $t$ (or $A$ entails $t$ , or $t$ follows logically from $A$ )
$\emptyset$	the empty set
$U$	the universal set
$x$	arbitrary (unspecified) individual
$(x)$	for every $x$
$\langle x, y \rangle$	ordered pair of the elements $x$ and $y$

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# **Part I**

## **Approach and Tools**

- 1. The Scientific Approach**
- 2. Concept**
- 3. Elucidation**

*It will be convenient to start by taking a panoramic view of the means and ends peculiar to the scientific approach. Such a preview is given in Chapter 1. Like any other brief account of a rich subject this one will have to be presented in a somewhat dogmatic fashion, but it is hoped that the remainder of the book will provide a justification for it. Then we shall need a bridge between science and philosophy: this will be provided by Chapters 2 and 3, which discuss the semantics of scientific concepts and the logic of certain familiar yet tricky conceptual operations, such as classing and defining.*

# 1

## The Scientific Approach

Science is a style of thinking and acting—indeed, the most recent, universal, and rewarding of styles. As with all human creations, we should distinguish in science the work—research—from its end product—knowledge. In this Chapter we shall take a look both at the overall pattern of scientific research—the scientific method—and at its aim.

### 1.1. Knowledge: Ordinary and Scientific

Scientific research starts with the realization that the available fund of knowledge is insufficient to handle certain problems. It does not begin from scratch because investigation deals with problems and no question can be asked, let alone answered, outside some body of knowledge: only those who see something can see that something else is missing.

Part of the background knowledge from which every research starts is ordinary, i.e. nonspecialized knowledge, and part of it is scientific, i.e. it has been obtained by the method of science and can be rechecked, enriched, and eventually superseded by the same method. As research proceeds it corrects or even rejects portions of the fund of ordinary knowledge. Thereby the latter is enriched with the results of science: part of today's commonsense are yesterday's results of scientific research. Science, in short, grows from common knowledge and outgrows it: in fact, scientific research begins at the point where ordinary experience and ordinary thought fail to solve problems or even to pose them.

Science is not just a prolongation or even a mere refinement of

#### 4 Philosophy of Science

ordinary knowledge in the way that the microscope extends the reach of unaided vision. Science constitutes a knowledge of a special kind: it deals primarily, though not exclusively, with unobservable events unsuspected by the uneducated layman, such as the evolution of stars and the duplication of chromosomes; it invents and tries conjectures beyond common knowledge, such as the laws of quantum mechanics or those of conditioned reflexes; and it tests such assumptions with the help of special techniques, such as spectroscopy and the control of gastric juice, which in turn require special theories.

Consequently common sense cannot be an authoritative judge of science, and the attempt to evaluate scientific ideas and procedures in the light of ordinary knowledge alone is preposterous: science elaborates its own canons of validity and, in most subjects, is far ahead of common knowledge, which is more and more becoming fossil science. Imagine a physicist's wife rejecting her husband's theory of elementary particles because it is unintuitive, or a biologist sticking to the hypothesis of the inheritance of all acquired characters because it fits common experience concerning cultural evolution. The moral for philosophers should be clear: Do not try to bring science down to ordinary knowledge but rather learn some science before philosophizing about it.

The radical discontinuity between science and common knowledge in most respects, and particularly as regards method, should not blind us to their continuity in other respects, at least if common knowledge is limited to the opinions held by the so-called sound common sense. In fact, both sound common sense and science attempt to be *rational* and *objective*: they are critical and seek coherence (rationality), and they try to fit the facts (objectivity) rather than indulging in uncontrolled speculation.

But the ideal of rationality, namely the coherent systematization of grounded and testable statements, is achieved by theories—which are the core of science rather than of common knowledge, which is an accumulation of loosely related bits of information. And the ideal of objectivity, namely the building of true impersonal images of reality, can be realized only by transcending the narrow limits of daily life and private experience: by abandoning the anthropocentric viewpoint, by hypothesizing the existence of physical objects beyond our poor chaotic impressions, and by testing such assumptions via intersubjective (transpersonal) experiences planned and interpreted with the help of

theories. Common sense can achieve only a limited objectivity because it is much too closely tied to perception and action, and when it does transcend them it is often in the form of myth: science alone invents theories that, while not limited to summarizing our experiences, are tested by the latter.

An aspect of the objectivity shared by sound common sense and science is *naturalism*, i.e. the refusal to countenance nonnatural entities (e.g., disembodied thinking) and nonnatural sources or modes of cognition (e.g., metaphysical intuition). But common sense, suspicious as it is of the unobservable, has on occasion had a crippling effect on scientific imagination. Science, on the other hand, is not afraid of the unobservables it hypothesizes as long as it can keep them under control: indeed science has uncommon (yet neither esoteric nor infallible) means for testing such assumptions.

A consequence of critical alertness and of the naturalistic rejection of esoteric modes of cognition is *fallibilism*, i.e. the recognition that our knowledge of the world is provisional and uncertain—which does not exclude scientific progress but rather demands it. Scientific statements, no less than those of common experience, are opinions—only, enlightened (grounded and testable) opinions rather than arbitrary dicta or unchecked gossip. What can be proved beyond reasonable doubt are either theorems of logic and mathematics or trivial (particular and observational) statements of fact, such as “This tome is heavy”.

Statements covering immediate experience are not inherently incorrigible but are seldom worth doubting: although they are conjectural, in practice we handle them as if they were certain. Precisely for this reason they are scientifically uninteresting: if common sense can handle them why resort to science? This is the reason why there is no science of typewriting or of car driving. On the other hand, statements covering more than is immediately experienced are doubtful and therefore often worth being checked, rechecked and given a ground. Only, in science doubt is creative rather than paralyzing: it stimulates the search for ideas accounting for the facts in a more and more adequate way. In this way an array of scientific opinions with unequal weight is generated: some are better grounded and tested than others. Accordingly, the skeptic is right when he doubts anything in particular, wrong when he doubts everything alike.

In short, scientific opinions are rational and objective like those of sound common sense—only, much more so. What else, if anything,

gives science its superiority over common knowledge? Surely not the substance or subject matter, since one and the same object may be approached either nonscientifically, or even antiscientifically, or in the spirit of science. Thus, e.g., hypnosis may be dealt with ascientifically, as when case histories are described without the help of either theory or experiment. It may alternatively be regarded as a supernormal or even supernatural fact in which neither the sense organs nor the nervous system are involved: i.e., as a result of a direct intermind action. Finally, hypnosis may be approached scientifically, i.e. by framing conjectures about the physiological mechanism underlying hypnotic behavior, and by controlling such assumptions in the laboratory. In principle, then, the object or subject matter does not mark science off from non-science, even though certain problems, e.g. those of the structure of matter, can hardly be stated outside a scientific context.

If the “substance” (object) cannot be distinctive of all science, then it must be the “form” (procedure) that is: the peculiarity of science must reside in the way it operates to attain a certain end—i.e., in the scientific method and in the aim to which this method is directed. (Caution: ‘scientific method’ should not be construed as a set of mechanical and infallible instructions enabling the scientist to dispense with imagination: it is not to be interpreted either as a special technique for handling problems of a certain kind. The method of science is just the overall pattern of scientific research.) The *scientific approach*, then, is made up of the *scientific method* and of the *goal* of science.

Let us take a glimpse at the scientific approach—not, however, without first trying our forces on some of the following problems.

### **Problems**

1.1.1. Writers and humanists often complain that science is dehumanized because it eliminates the so-called human elements. Examine this view.

1.1.2. Is science objective to the point of excluding points of view, or does it rather limit the consideration of viewpoints to those which are somehow grounded and testable? For a recent criticism of the “myth” that science is objective, see R. Rorty, *Objectivity, Relativism, and Truth* (Cambridge: Cambridge University Press, 1991). For a coun-

terattack, see N. Rescher, *Objectivity* (Notre Dame: University of Notre Dame Press, 1997). Hint: Make sure to distinguish the psychology of research—concerned with the motives, biases, etc. of the individual investigator—from the methodology of research. See K. R. Popper, *The Open Society and its Enemies*, 4th ed. (London: Routledge & Kegan Paul, 1962), Ch. 23.

1.1.3. Examine the widespread opinion, shared by philosophers like K. Jaspers, that the conclusions of scientific research are conclusions proper, i.e. final and certain. *Alternate Problem*: Trace the history of the view that genuine science is infallible.

1.1.4. Elucidate the concepts of *opinion*, *belief*, *conviction*, and *knowledge*. *Alternate Problem*: Is there any logical relation between *naturalism* (an ontological doctrine) and *testability* (a methodological property of certain statements)? In particular is naturalism necessary, sufficient, necessary and sufficient, or neither for testability? Hints: Distinguish between testability in principle (conceivable testability) and effective testability (the property of a statement of being subjectible to test with the means at hand); and search for counterexamples to the first three theses, i.e., “ $T \rightarrow N$ ”, “ $N \rightarrow T$ ”, and “ $N \leftrightarrow T$ ”.

1.1.5. Traditional philosophy has retained the important distinction drawn by Plato (*Meno* 97, *Republic* V, 477, 478, *Timaeus* 29, etc.) between opinion or belief (*doxa*) and certain knowledge or science (*episteme*). Opinion, according to Plato, is characteristic of the vulgar as regards every subject matter but is also all we can achieve regarding things transient (physical objects), which *are* not in a complete way since they emerge, change, and pass away: only eternal objects (ideas) can be the subject of perfect knowledge. Discuss this view, distinguishing its relevance, if any, to formal science and to factual science.

1.1.6. Point out the similarities and differences between common knowledge and scientific knowledge. *Alternate Problem*: Given that scientific thinking is unnatural, i.e. comes with difficulty and to only a part of mankind, imagine what would become of scientific research in the aftermath of a nuclear war destroying all scientific centers.

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1.1.7. Discuss the view that science is nothing but a systematic continuation of ordinary knowledge. For this view see, e.g., R. Carnap, “Logical Foundations of the Unity of Science”, in *International Encyclopaedia of Unified Science* (Chicago: University of Chicago Press, 1938), I, p. 45, and A. J. Ayer, *Language, Truth, and Logic*, 2nd ed. (London: Gollancz, 1953), p. 49.

1.1.8. Philosophers of various shades, from certain medieval schoolmen through the Scottish common-sense realists to the language philosopher G. E. Moore, have claimed for common sense the right to evaluate scientific theories. Likewise, certain scientists have fought genetics, relativity physics and the quantum theories because they clash with common sense. Discuss this phenomenon. *Alternate Problem:* Freedom of opinion includes the right of everyone to criticize and even ridicule anything. But freedom of research—a companion to freedom of opinion—can be hampered by a hostile public opinion. Can this problem be solved?

1.1.9. L. Wittgenstein and the philosophers of the Vienna Circle have claimed that the criterion of demarcation between science and nonscience (particularly metaphysics) is the *meaningfulness* of the statements that make up science. Accordingly, an analysis of meaning would suffice to decide whether a discipline is scientific or not. Examine this view, see whether it does not upgrade bookbinding and accounting as sciences, and propose your own criterion of demarcation between science and nonscience.

1.1.10. G. W. Hegel and other philosophers have stated that all sciences except philosophy share the advantage of presupposing either their object or the method guiding the beginning and the ulterior march of investigation. Is it true that the object and the special method of every science are given in advance? Hint: look for counterexamples.

### 1.2. Scientific Method

A method is a procedure for handling a set of problems. Every kind of problems requires a set of special methods or techniques. The problems of knowledge, by contrast to those of language or action, require the invention or the application of special procedures bearing on the

various stages of problem handling, from the very statement of problems all the way down to the control of the proposed solutions. Examples of such *special methods* (or *techniques*) of science are triangulation (for the measurement of large distances) and the recording and analysis of brain waves (for the objectification of brain states).

Every special method of science, then, is relevant to some particular stage in the scientific investigation of problems of a certain kind. The *general method* of science, by contrast, is a procedure applying to the whole cycle of investigation into every problem of knowledge. The best way to learn how the scientific method works is to engage, with an inquisitive attitude, in some scientific research broad enough to ensure that the special methods or techniques do not overshadow the general pattern. (Becoming a specialist in some stage of scientific work, such as measuring, is far from sufficient to acquire a clear grasp of the scientific method: moreover, it may foster the idea that there is a plurality of disconnected methods rather than a single pattern underlying all the techniques.) The next to the best way is to become acquainted with a piece of research—not just with its more or less perishable outcome but with the whole process, starting with the questions that originally prompted the research.

Suppose we ask the question ‘Why do different human groups use more or less different languages?’. A simple answer to this question—i.e. an explanation of the empirical generalization that different human groups tend to speak differently—is provided by any myth such as, e.g., the original diversity of ready-made tongues. A scientific investigator of our problem will be suspicious of simple explanations and will start by critically examining the problem itself. In fact, the question presupposes an empirical generalization that might be in need of refinement: what groups are those that speak differently: ethnic groups, social groups, professional groups? Only a preliminary investigation into this prior question can lead us to a more precise formulation of our original problem.

Once such a more precise statement of the problem has been found, a number of guesses will be offered: some regarding the geographical determination of such language differences, others the biological factors, others the social ones, and so on. These various assumptions will then be tested by checking their observable consequences. Thus, e.g., if the kind of occupation is in fact a major determinant of linguistic differences (hypothesis), then occupational groups composed of other-

wise similar individuals should speak distinctive jargons (testable consequence).

A number of data will have to be gathered in order to decide which, if any of the above conjectures, is true. And, whenever possible, the data will have to be scientifically certifiable, i.e. obtained and re-checked if necessary by scientific means. For example, random samples of occupational groups will have to be studied in order to minimize the effects of possible bias on the choice of subjects. The merits of the various hypotheses so far proposed will then be evaluated, and in the process some new conjectures may be suggested.

Finally, if the investigation has been careful and imaginative, the solution to the original problem will raise a cluster of new problems. In fact, the most important pieces of research, like the best books, are the most thought-provoking rather than the most thought-blocking ones.

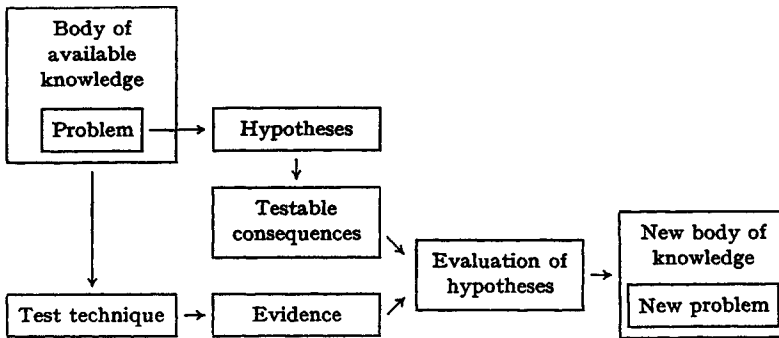
In the above example we may disclose the chief stages of the way of scientific research—i.e. the main steps in the application of the scientific method. We discern, in fact, the following ordered sequence of operations:

1. *Ask well-formulated and likely fruitful questions.*
2. *Devise hypotheses both grounded and testable to answer the questions.*
3. *Derive logical consequences of the assumptions.*
4. *Design techniques to test the assumptions.*
5. *Test the techniques for relevance and reliability.*
6. *Execute the tests and interpret their results.*
7. *Evaluate the truth claims of the assumptions and the fidelity of the techniques.*
8. *Determine the domains in which the assumptions and the techniques hold, and state the new problems raised by the research.*

This cycle is schematically represented in Fig. 1.1.

Are there rules for the adequate execution of the above operations? That is, are there effective directions for handling scientific problems? There certainly are some, though nobody has drawn an exhaustive list and everybody should be reluctant to do it after the failure of the philosophers who, from Bacon and Descartes onwards, have professed to know the infallible rules for the direction of inquiry. For the sake of illustration we shall mention and exemplify some quite obvious rules of scientific method; further rules will be found scattered in the rest of the book.

*R1. State your problem precisely and, in the beginning, specifically.* For example, do not ask just ‘What is learning?’, but pose a well-



**Fig. 1.1.** A research cycle. The importance of a scientific investigation is gauged by the changes it induces in our body of knowledge and/or by the new problems it poses.

circumscribed question such as, e.g., ‘Do albino rats learn maze tasks gradually or by little jumps?’

*R2. Try definite and somehow grounded conjectures rather than noncommittal or wild hunches:* risk hypothesizing definite relations among clearcut variables, and such that they do not conflict with most of our scientific heritage. For example, do not rest content with assuming that it is possible to learn on a single trial but assume, e.g., that one-trial learning of orientation in a T-maze has a definite probability.

*R3. Subject your assumptions to tough tests rather than to soft ones.* For example, in testing the single-trial learning hypothesis do not assign your subjects tasks for which they are already prepared and do not excuse negative results: assign new tasks and accept all the evidence.

*R4. Do not pronounce true a satisfactorily confirmed hypothesis: regard it as, at best, partially true.* For example, if you have obtained an empirical generalization concerning the probabilities of learning a given task on a single trial, on a second one, and so on, regard your statement as corrigible by further research.

*R5. Ask why the answer should be as it is and not otherwise:* do not stop on finding data-fitting generalizations but try to explain them in terms of stronger laws. For example, pose the problem of finding the neural mechanism responsible for learning on a first presentation: this will integrate your behavior research with biology.

These and other rules of scientific method are far from being infal-

lible and therefore in no need of improvement: they have grown along scientific research and are—let us hope—perfectible. Moreover, we must not expect the rules of scientific method to replace intelligence by patient drilling. The asking of astute and rewarding questions, the building of strong and deep theories, and the design of delicate and original tests are not rule-directed activities: if they were, as some philosophers have supposed, everyone could conduct scientific research and computers could be turned into investigators instead of being research tools. Scientific methodology can give some hints and it does supply means for spotting mistakes, but is no substitute for original creation and does not spare us all mistakes.

Table manners are more or less conventional and local; consequently it would be difficult to validate or invalidate them in an objective manner, although they are explainable in social and historical terms. What about research manners, i.e. the rules of scientific investigation? They are clearly universal: indeed there is nothing, not even philosophy, as universal as science. But are those rules justifiable? They certainly have a *pragmatic justification*: although they are not infallible, no other rules are known to be better conducive to attaining the goal of science—the building of the truest possible conceptual models of the patterns of things.

But surely that is a poor justification. First, because the application of the scientific method yields, in the best of cases, approximate truths. Second because a rule that is justified by its success but is not integrated with the body of scientific knowledge hangs in the air and cannot meet the challenge of nonscientific procedures—such as divination—for the advancement of knowledge. In other words, we would like a theoretical justification of the scientific method in addition to its pragmatic justification. By the *theoretical justification* of a rule (or norm, or prescription, or direction) we shall understand: (i) the validation of the rule's presuppositions—i.e., showing that what the rule takes for granted is consistent with the known laws; and (ii) showing that the given rule is compatible with the other members of the set of rules—in this case, the scientific method. In short, a rule will be regarded as theoretically justified if, and only if, it is both *grounded* and *systematic* (a member of a consistent system of rules).

In the case of the rules of the scientific method we want them to make up a system of norms based on, or at least consistent with, the laws of logic and the laws of science, not only with the desiderata of

research. Thus, the rule “State your problem precisely” clearly presupposes that unique (though perhaps many-membered) answers are being sought: if a plurality of mutually incompatible assumptions were acceptable, the preciseness condition would not be stipulated. In turn, the desideratum of unique solution is required by the logical principle of noncontradiction. At this point the justification of the given rule can stop, because logical principles are presupposed by scientific research, not questioned by it (see Sec. 5.9).

The justification of other rules of the scientific method will be more difficult and may involve tricky philosophical problems—such as whether the scientific analysis of a whole dissolves it without clarification—but anyhow it should be given and it promises to be an interesting work. Unfortunately no theoretical justification of the rules of the scientific method has been attempted: scientific methodology is still in a descriptive, pretheoretical stage. Largely responsible for this neglect seems to be the tacit assumption that anything is good if it works—a strange assumption to make in the case of the scientific method, which is not supposed to yield perfect results. At any rate here is an exciting problem for philosophers that care for living science.

Scientists have not been concerned with either the foundation or the systematization of the rules of scientific procedure: they do not even care to state all the rules they employ. In fact, discussions of scientific methodology seem to be alive only in the beginnings of a science: at least this was the case of astronomy in Ptolemy’s time, of physics in Galilei’s day, of psychology and sociology nowadays. In most cases scientists adopt a trial and error procedure with respect to the rules of research, and those rules that are found effective are silently built in the everyday routine, so that most researchers do not notice them. One does not become method-conscious until the prevailing method is shown to fail.

The scientific method and the goal to which it is applied (objective knowledge of the world) make all the difference between science and nonscience. Moreover, both method and goal are philosophically interesting, so that a neglect of either is unjustifiable. Yet it must not be forgotten that a tacit methodology, if sound, is more valuable than a wrong explicit methodology. This must be emphasized at a time when so much space is devoted by psychology and sociology journals to methodological discussions as how to best stop research by prohibit-

ing the use of concepts not applying to directly observable traits. In the face of such dogmatic (theoretically unjustified) and sterile methodological prescriptions it is best to keep in mind what is perhaps the sole golden rule of scientific work: *Audacity in conjecturing, cautiousness in testing.*

To sum up. The scientific method is a mark of science, whether pure or applied: no scientific method, no science. But it is neither infallible nor self-sufficient. The scientific method is fallible: it can be improved both by evaluating the results it leads to and by deliberate analysis. Nor is it self-sufficient: it cannot operate in a knowledge vacuum but requires some knowledge which can in turn be adjusted; and it must be implemented by special methods adapted to the peculiarities of the subject matter. To these techniques we turn next.

### **Problems**

1.2.1. Comment on the following characterization of method (in general) given by the famous Port Royal *Logic* (1662), in *Grammaire générale* [de Port Royal] (Paris: Delalain, 1830), p. 524: "In general we may call method the art of arranging a sequence of thoughts either to discover the truth when we ignore it or to prove it to others when we know it." The art of the discovery of truth was described as analysis or method of resolution; the art of showing the truth to others, synthesis or method of composition. *Alternate Problem:* Why was a new method for the discovery of truth so keenly searched for at the beginning of the modern era? And were the new proposals (such as Bacon's fact collecting and Descartes deduction from clear and distinct a priori principles) successful?

1.2.2. Examine the general characterization of method given by H. Mehlberg, *The Reach of Science* (Toronto: University of Toronto Press, 1958), p. 67: "A *method* is a statement or a set of statements describing a repeatable sequence of *operations*, such that each individual sequence of operations so described would enable a human individual or group to bring about, either infallibly or in a fair proportion of cases, a repeatable event called the *objective* of the method. [. . .] If the objective of the method is always an event occurring in some individual object, then the method is said to be *applied to this object*. Thus, in order to drive a nail into a piece of wood, one may hit the

head of the nail with a hammer several times in succession. The method consists, then, in a repeatable sequence of hits executed with the hammer in a specified way; the objective of the method is driving a nail into a piece of wood; the object of the method is any system consisting of a nail and a piece of wood". Does this apply to the method of science?

1.2.3. Comment on J. Dewey's characterization of the scientific method as "a method of changing beliefs by means of tested inquiry as well as of arriving at them". See *A Common Faith*, in D. Bronstein, Y. H. Krikorian and P. Wiener, Eds., *Basic Problems of Philosophy* (Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1955), p. 447.

1.2.4. Is *trial and error* a method proper? Be careful to distinguish, within the class of trial and error procedures, hit-or-miss from the methodical examination of possibilities (e.g., hypotheses).

1.2.5. Determine which if any of the following activities and disciplines employ the method of science: speleology (exploration and description of caves), star gazing and describing, bird watching and description, plant and animal collecting and pigeon-holing, personality diagnosis by techniques lacking a pragmatic and/or a theoretical justification, and computer programming and operation.

1.2.6. Analyze and exemplify the various stages in the procedure of a general practitioner faced with a sick patient.

1.2.7. Is sacrifice theoretically justified as a method for producing rain or passing examinations?

1.2.8. Examine the method employed by A. M. Ampère establish his law of the mutual action of electric currents. See his memoir of June 10, 1822 in *Mémoires sur l'électromagnétisme et l'électrodynamique* (Paris: Gauthier-Villars, s. d.), especially pp. 76—77. *Alternate Problem*: Study the possibility of finding a general methodology (praxiology) applying to all kinds of work, whether intellectual or physical. See T. Kotarbiński, "De la notion de methode", *Revue de métaphysique et de morale*, 62, 187 (1957).

1.2.9. Until recently it was universally taken for granted that the chief rule of scientific method is: "Relevant variables must be altered one at a time". It was assumed that no control of the various intervening factors was effective other than that. As recently as the 1930's it was realized that we never have an exhaustive knowledge of the relevant variables and, even if we did, we could not vary each of them, one at a time, freezing as it were all the others, because there are constant relations (laws) among some of them. Accordingly experiments involving the simultaneous changes of the values of a number of (possibly interacting) variables were planned (factorial design). See R. A. Fisher, *The Design of Experiments*, 6th ed. (London: Oliver and Boyd, 1951). Draw some moral concerning the mutability of the scientific method.

1.2.10. Examine whether, and if so to which extent, the following procedures are used in science. 1. The various methods of deduction. 2. Induction. 3. The hypothetico-deductive method, i.e. the procedure consisting in framing hypotheses and tracing their logical consequences. 4. Descartes' methodical doubt (to be distinguished from the skeptic's systematic doubt). 5. Husserl's phenomenological method. 6. Hegel's dialectical method. 7. Dilthey's empathic comprehension (*Verstehen*).

### **1.3. Scientific Tactics**

The scientific method is the strategy of scientific research: it bears on any whole research cycle and is independent of subject matter (see 1.2). The actual execution of every one of the strategic moves will, on the other hand, depend on the subject matter and on the state of our knowledge regarding that subject matter. Thus, e.g., determining the solubility of a substance in water requires an essentially different technique from the one needed to find out the degree of affinity between two biological species. And the actual solution to the first problem will depend on the state of the theory of solutions, just as the solution to the second one will depend on the state of evolution theory, ecology, serology, and other biological disciplines.

Every branch of science is characterized by an open (expanding) set of problems which it approaches with a set of tactics or techniques. These techniques change much more rapidly than the general method of science. Furthermore, they cannot always be exported to other fields:

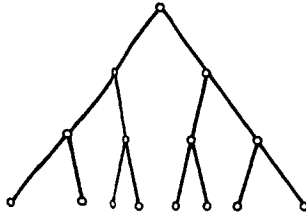
thus, the historian's craft of testing for the authenticity of a document has no use for the physicist. Yet both, the historian and the physicist, are after truth and search for it according to a single strategy: the scientific method.

In other words, there is no strategic difference among the sciences. The special sciences differ only by the tactics they use to solve their peculiar problems, but they all share the scientific method. This, rather than being an empirical finding, follows from the following *Definition*: A science is a discipline using the scientific method for the purpose of finding general patterns (laws).

Those disciplines which have no occasion to use the scientific method—e.g., because they limit themselves to data gathering—are not sciences, although they may supply science with raw material; this is the case of geography. Nor are sciences those doctrines and practices which, like psychoanalysis, refuse to employ the scientific method (see 1.6).

Scientific techniques may be classed into *conceptual* and *empirical*. Among the former we may mention the tactics for the precise stating of problems and conjectures of a certain kind, and the procedures (algorithms) for deducing consequences from the hypotheses and for checking whether the proposed hypotheses do solve the corresponding problems. (Mathematics provides, of course, the richest set of powerful tactics for stating problems and hypotheses in an accurate way, for deducing consequences from the assumptions, and for checking solutions. But it is of little help in finding problems or in conceiving the nuclei of new hypotheses in the factual sciences. Besides, in the more backward sciences our ideas are not yet clear enough to be susceptible to mathematical translation. Otherwise there is no limitation in principle to the application of mathematical concepts, theories and techniques in factual science: see Sec. 8.2.) As to the empirical techniques, we may recall those for designing experiments, performing measurements, and making instruments for the recording and processing of data. The mastering of most such techniques is a question of training: talent is needed to apply known techniques to problems of a new kind, to criticize the known techniques and, particularly, to invent better ones.

Certain techniques, though not as universal as the general method of science, are applicable in a number of fields. Let us review three such quasi-universal techniques: tree questioning, iteration, and sam-



**Fig. 1.2. Porphyry's tree questioning for an initial set of 8 objects: orderly subdivision into mutually exclusive alternatives.**

pling. They all have antecedents in ordinary life and are therefore easily comprehensible.

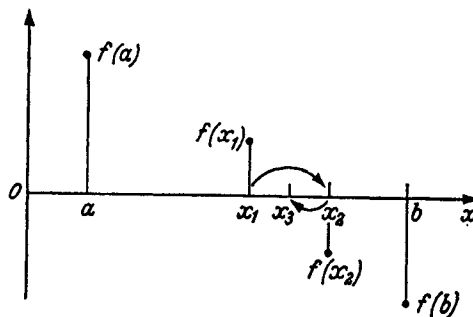
*Tree questioning* consists in surveying the set of possibilities (logical or physical, as the case may be) and dividing them step by step into mutually disjoint subsets until the wanted subset (or element) is reached. Suppose the problem consists in finding out which of eight objects has a certain property—e.g., which of the first eight digits has our playmate in mind or which among eight hypotheses is the most likely. If we proceed erratically, i.e. by random trial and error, we shall need a maximum of seven operations (e.g., questions). In using tree questioning, on the other hand, we proceed in the following way. We divide the field of possibilities (8 objects) into two equal parts and ask whether the wanted object is in the first subset. Since the problem is one of decision (yes or no answer), the reply to this single question will be enough to reduce our initial uncertainty to one-half. We then repeat the procedure until our initial uncertainty has been altogether removed. A total of three questions will solve the problem in our case, as shown in Fig. 1.2. Tree questioning is, then, *methodical trial and error*, to be contrasted with the blind hit-or-miss procedure. In general, for a set of  $N$  objects, random questioning requires a maximum of  $N-1$  and an average of  $N/2$  answers. Tree questioning, on the other hand, requires a maximum of  $H=\log_2 N$  bits of information. In our case,  $\log_2 8 = \log_2 2^3 = 3$ .

*Iterative procedures* are step by step trials in which a gradual improvement of an approximate solution is obtained: every solution is built upon (is a function of) the preceding one and is better (more accurate) than it. Often the initial stepping stone must somehow be surmised in order for the process to start. When there is no method for finding such a first rough solution (zero order approximation), experi-

ence, perseverance and insight will be needed—and a bit of good luck will not be amiss. A familiar example of an iterative procedure is shooting at a fixed target. The information concerning the deviation committed is fed back to the shooter, which enables him to correct the aim in successive steps until the target is hit. In the process the errors, far from accumulating, are used to improve the performance. Iterative procedures, then, are *self-improving*: they can be carried to any desired degree of accuracy, i.e. until the difference between two successive solutions is negligible.

Mathematics has *exact* iterative procedures, i.e. techniques that warrant a *uniform* increase in accuracy; famous examples are Newton's method for computing square roots and Picard's method for the approximate solution of differential equations. In every case a sequence of approximate solutions is built on the basis of a fixed relation among two or more members of the sequence, and the sequence has a definite limit. That is, mathematical iterative procedures are convergent.

Example: Find a solution of the equation  $f(x) = 0$ . Data:  $f(\ )$  is continuous and the values it takes at the points  $a$  and  $b$  have opposite signs (see Fig. 1.3.). Technique: the *dichotomic method*. First guess: the given function has a zero midway between  $a$  and  $b$ , i.e.  $x_1=(a+b)/2$ . Test: compute  $f(x_1)$ . There are two possibilities: either  $f(x_1)$  is zero, in which case the problem is solved, or it is different from zero. In the latter case there are again two possibilities: either  $f(x_1)$  has the sign of  $f(a)$  or that of  $f(b)$ . Suppose the former is the case; then the zero of the function will lie between  $x_1$  and  $b$ . Try the simplest guess:  $x_2=(x_1+b)/2$ . If  $f(x_2)=0$ , the problem is solved. Otherwise  $f(x_2)$  has either the sign



**Fig. 1.3. Building increasingly true propositions by the dichotomic method. The exact solution is the limit of the sequence of approximate solutions.**

of  $f(b)$  or that of  $f(x_1)$ . Suppose the former is the case. Try  $x_3 = (x_1 + x_2)/2$ , compute  $f(x_3)$  and proceed as before. In this way a sequence is built each term of which equals the average of the last two. Either one of the members of the sequence solves the problem or the sequence approaches the exact solution, i.e. the solution is the limit of the sequence. In the former case an exact solution is obtained, in the latter approximate solutions to any desired degree of accuracy are obtained. Notice that the concept of *partial truth* is involved in iterative procedures. We shall meet this concept again, in Secs. 10.4 and 15.2.

Our third example of a quasi-universal special method of science is *random sampling*, i.e. the extraction of a small subset from an original set or population (which may be infinite) in such a way that the selection does not depend on the properties of the individuals, but is blind to them and consequently unbiased. Random sampling is what we are supposed to do when we try a free sample of some merchandise or when we control the quality of a manufactured good without testing all the items. Random sampling is used also when a hypothesis is subjected to the test of experience: we check the hypothesis against a small number of data relevant to it and chosen without bias from a potential infinity of data.

Tree questioning, iterative procedures and random sampling are as many specializations of the *method of successive approximations*, which is characteristic, though not exclusively, of science. In pure logic there is no place for this method because exact solutions (or exact proofs of the absence of solutions) are sought. But in factual science and in large areas of numerical mathematics *approximate solutions* are all we can get, whence the method of successive approximations is indispensable.

The great interest of the method of successive approximations for the theory of knowledge (epistemology) is that it constitutes a clear reminder of the following points. First, scientific research proceeds *gradually*, and indeed in such a way that even the right insights that may be hit upon by chance from time to time are the outcome of previous research and are eventually subjected to correction. Second, scientific research yields, at least in relation with the world of facts, *partial truths* rather than complete and accordingly final truths. Third, the scientific method, in contrast with the haphazard groping of common sense and of uncontrolled speculation, is *self-correcting*: it can recognize mistakes and can attempt to obtain higher-order approximations, i.e. truer answers.

Other tactics of science are less universal: they must be discussed with reference to specific scientific problems and theories. Thus, the X-rays technique for the identification of chemical compounds requires the application of wave optics to the diffraction of waves by crystal lattices: such a theory alone allows us to interpret the observed rings in the X-rays diagrams, which would otherwise be meaningless signs, since the rings bear no resemblance to the atomic configurations about which they convey information.

In general, the special methods of science are somehow *grounded* in scientific theories, which are in turn tested by such techniques. This is true even of such an elementary technique as weighing with a two pan balance: it presupposes statics and, particular, the law of the lever. Scientific techniques and instruments are never consecrated by success alone: they are designed and justified with the help of theories. The possibility of theoretically justifying whatever special method is employed in science renders it neatly different from the various pseudosciences, which employ groundless procedures, such as divination by looking at a lamb's liver or at ink blots, or by listening to the recounting of dreams.

The design and justification of the special techniques of science belongs to the special sciences. Although every scientific technique raises philosophical problems regarding inference, such problems must be discussed in the context of the respective disciplines. Unfortunately these questions are as a rule either neglected or treated without philosophical competence, as a result of which the very nature of scientific techniques and of the results they yield are widely misunderstood. For example, if the question of the theoretical validation of the empirical techniques of science were in a more mature state everyone would realize that empirical information is not weighed in a theoretical vacuum: every piece of evidence must be judged in the light of the theory employed in the design and implementation of the technique used to gather that information. Just as no factual theory stands by itself, so no datum constitutes an evidence for or against a theory unless it is gathered and interpreted with the help of some scientific theory. In particular, no alleged information obtained through extrascientific means (e.g., mediumnism) can count as evidence against scientific theories or in favor of nonscientific theories. There is no test of science independent of science. This does not entail that the results of science are above criticism, but that only the internal criticism of

science is legitimate. A moral for philosophical critics of science: First bow, then strike.

Let us now explore some consequences of the thesis that science is methodologically one despite the plurality of its objects and associated techniques.

### **Problems**

1.3.1. Point out the differences between the techniques and the general methodology of a given scientific discipline. See P. Lazarsfeld and M. Rosenberg, Eds., *The Language of Social Research* (Glencoe, Ill.: The Free Press, 1955), pp. 9—10.

1.3.2. Comment on and illustrate the fourteen search principles proposed by E. Bright Wilson, *An Introduction to Scientific Research* (New York: McGraw-Hill, 1952), pp. 140ff.

1.3.3. Does biology need special methods of its own in addition to those of physics and chemistry? If so, why?

1.3.4. Examine the steps in a typical pharmacological sequence, as described by C. D. Leake, "The Scientific Status of Pharmacology", *Science*, **134**, 2069 (1961).

1.3.5. Geology has always employed physical *concepts* ("deformation", "pressure", "transport", "heat", "melting", "solidification", etc.). But the use of physical *theories* (mechanics, hydrodynamics, thermodynamics, etc.) came only late, and the application of physical *methods* was not tried until our century. In particular, experimental geology (the simulation of geological processes in the laboratory) is a new-born. Use this example, and if possible others as well, to illustrate and expand the thesis that a discipline acquires only gradually a scientific status, and usually does so by adopting some of the ideas and special methods of a mature contiguous science.

1.3.6. In what does the comparative method consist, in which sciences is it used, and why? *Alternate Problem*: Examine the iterative methods and discuss their relevance to the theory of knowledge. See, e.g., E. Whittaker and G. Robinson, *The Calculus of Observations*, 4th ed. (London and Glasgow: Blackie & Son, 1944), Secs. 42–45.

1.3.7. F. Bacon thought he had invented routine procedures for conducting scientific research: *Novum Organum*, (1620), repr. In *The Philosophical Works of F. B.*, Ed. By J. M. Robertson (London: Routledge, 1905), Aphorism LXI, p. 270: “the course I propose for the discovery of sciences is such as leaves but little to the acuteness and strength of wits, but places all wits and understandings nearly on a level”. What did Bacon have in mind: the scientific method or a set of data gathering and comparison techniques?

1.3.8. Examine the claim that psychology cannot employ the objective methods of science because the subject (the investigator) and the object (the subject of research) are one and the same (or because the object of investigation is a part of the cognitive subject).

1.3.9. The layman’s study of a subject’s personality involves placing himself in the subject’s shoes, the better to understand his behavior. This procedure has been called the *method of sympathetic understanding* (empathy, *Verstehen*) and was advocated by W. Dilthey and R. G. Collingwood as the proper method of psychology and history. Examine this claim. See T. Abel, “The Operation Called ‘Verstehen’ ”, *American Journal of Sociology*, 54, 211 (1948), W. H. Walsh, *An Introduction to Philosophy of History* (London: Hutchinson, 1958), esp. P. 58, and M. Bunge, *Intuition and Science* (Englewood Cliffs, N. J.: Prenticehall, Inc., 1962), pp. 10—12.

1.3.10. In the course of the history of philosophy the following precepts concerning the philosopher’s use of science have been advanced. (i) Philosophy can find no use for either the methods or the results of science; (ii) philosophy can use some results of science but none of its methods; (iii) philosophy can use the general method of science rather than its results; (iv) philosophy can use both the method and the results of science. Expound your own opinion and argue in favor of it. *Alternate Problem*: From a logical point of view all possible scientific questions and their answers are “there” as just as many actual infinities. Examine the view that the method and the techniques of science constitute an operator converting questions into answers. (Symbolically,  $M: Q \rightarrow A$ .)

### 1.4. Branches of Science

By contrasting the general method of science to the special methods of the particular sciences we have learned this. First, the scientific method is a way of handling intellectual problems—not things, instruments, or men; consequently it can be employed in all fields on knowledge. Second, the nature of the subject matter dictates the possible special methods of the corresponding subject or field of research: object (problem system) and technique go hand in hand. The diversity of the sciences is apparent as long as their objects and techniques are focused on; they vanish as soon as the underlying general method is disclosed.

The first and most remarkable difference among the various sciences is the one between the *formal sciences* and the *factual sciences*, i.e. between those dealing with ideas and those dealing with facts. Logic and mathematics are formal sciences: they refer to nothing in reality and therefore cannot use our transactions with reality (i.e., experience) in order to validate their formulas. Physics and psychology are among the factual sciences: they refer to facts supposed to happen in the world and accordingly have to resort to experience in order to test their formulas.

Thus, the formula “ $x$  is blue” “ $B(x)$ ” short, is true of certain things: i.e., it becomes a definite true proposition if the variable  $x$  is assigned as a value the name of something actually blue, like the Aegean sea; and it is false of most other things, i.e. it becomes a false proposition for most other values of the object variable  $x$ . On the other hand, “ $x$  is blue and  $x$  is not blue”, or “ $Bx \ \& \ \neg Bx$ ” for short, is false for every value of  $x$ , i.e. in all circumstances. Consequently its negate, “It is not so that  $x$  is blue and  $x$  is not blue” is true and its truth is independent of fact; in particular, it does not depend on experience (the realm of fact in which man takes part). In short, “ $Bx$ ” is the skeleton or form of a simple factual idea (if we stick to the interpretation of the predicate ‘ $B$ ’ as designating the property of blueness). On the other hand “ $\neg[Bx \ \& \ \neg Bx]$ ” (read ‘it is not so that  $x$  is  $B$  and  $x$  is not  $B$ ’) is the structure of a formal idea, in this case a logical truth: its truth value does not depend on the particular values that  $x$  may take on; moreover, it is independent of the interpretation we may wish to attach to the sign ‘ $B$ ’.

Logic is concerned, among other things, with the structure of both factual and formal ideas; but whereas in the former case logic is insuf-

ficient to find out truth values, in the latter case logic and/or mathematics are all we need to validate or invalidate any such pure ideas. In short, formal science is *self-sufficient* as regards both content and method of proof, whereas factual science depends on fact for content or meaning, and on experiential fact for validation. This explains why complete formal truth is attainable whereas factual truth is so elusive.

The form of ideas may be said to constitute the proper subject of formal science. An equivalent way of characterizing formal science is to say that it is concerned with *analytic formulas*, i.e. formulas that can be validated by rational analysis alone. Consider, for example, the statement that, if  $A$  and  $B$  are sets, then if  $A$  is (properly) included in  $B$ , then  $B$  is not included in  $A$ . The truth of this statement does not depend on the kind of set and is not established by studying sets of real objects: the formula belongs to the theory of abstract (non-descript) sets: it is purely formal and, consequently, universal—i.e. applicable whenever there is any talk of sets, kinds, or species, whether they be of numbers or of plants. There are a number of kinds of analytic formulas. For our immediate concern the most important are those which are true (or false) by virtue of their logical form, and those which are true (or false) on the strength of the meanings of the symbols occurring in them. The former set—syntactical analyticity—is exemplified by “If  $x$ ,  $y$  and  $z$  are numbers, then: if  $x=y$  then  $x+z=y+z$ ”. The second—semantical analyticity—is instanced by “Synthetic formulas are all those and only those formulas which are not analytic”. Formal science contains only analytic formulas, whereas factual science contains, in addition, *synthetic formulas*, i.e. formulas that cannot be validated by reason alone.

The neat dichotomy between formal and factual science should not blind us to the fact that conceptual knowledge of all kinds (as distinct from habits, skills, and other kinds of nonconceptual knowledge) consists of ideas: logic is a set of ideas and so is theoretical physics. All ideas, however concrete their reference may be, have some definite form or other. Thus, the form of “ $x$  is blue” is the same as that of “ $x$  is prime”, i.e., a subject-predicate schema: “ $P(x)$ ”. Likewise, “ $x$  is lovelier than  $y$ ” and “ $x$  is larger than  $y$ ” involve a binary predicate: both are schemas of the form “ $L(x, y)$ ” or, more specifically, “ $x > y$ ”. Moreover any given formula, no matter what its content may be, can be transformed into a logically equivalent formula: thus, the simple statement  $p$  may be converted without either gain or loss into  $\neg\neg p$  (double

negation),  $p \ \& \ t$ , and  $p \ /- \ t$ , where ‘ $t$ ’ stands for any tautology (*logical identity*).

Logical form is independent of content. Thus, a propositional variable  $p$  can be interpreted in infinitely many ways. And a logical identity (tautology), such as  $\neg(p \ \& \ \neg p)$ , has no content at all: it holds under all circumstances. Hence logic cannot say anything about the world. On the other hand, we cannot say anything reasonable about the world unless we abide by logic, not only because the latter rules argument, but also because content depends upon logical form. Indeed, the interpretation of a formula, far from being arbitrary, is constrained by the structure of the formula. For instance, ‘ $x < y$ ’ may be interpreted as “ $x$  lies lower than  $y$ ”, but not as “ $x$  lies low” or as “ $x$  lies between  $y$  and  $z$ ”. In sum, logic goes its own way but it provides ready-made frameworks for thinking about anything. The same holds for mathematics.

Since every formula has some logical form or other—and is on occasion nothing but a logical form—we must expect to find fibers of formal science everywhere in the body of science, even if such fibers are not apparent. What rigidity the body of knowledge may have is due to the logical and mathematical structures embedded in it rather than to the facts it deals with or the evidence by means of which its truth claims are weighed. For, after all, the scientific knowledge of facts is always partial, indirect, uncertain and corrigible, whereas forms are our own make and we are free to freeze them. In short, what hardness is to be found in science lies in its formal structure: data and hypotheses are soft, i.e. corrigible.

It does not follow that objective *facts* are soft, i.e. changeable at will: for better or for worse most cannot. It does follow that factual science presupposes and contains certain formal theories which it does not question and cannot subject to doubt because facts are irrelevant to pure ideas. (Nor does it follow that formal theories are incorrigible: they are perfected without pause in their own formal contexts—only, not as a result of attempts made to better match facts and accordingly not with the same special methods of factual science.) In short logically, though not psychologically, factual science *presupposes* formal science. (We shall dwell on this in Secs. 5.9 and 15.6.)

Within formal science various orderings can be tried; our subject being factual science we shall not touch that question. As to factual science we shall adopt the ordering displayed in the diagram below. The diagram seems methodologically sound, in the sense that it sug-

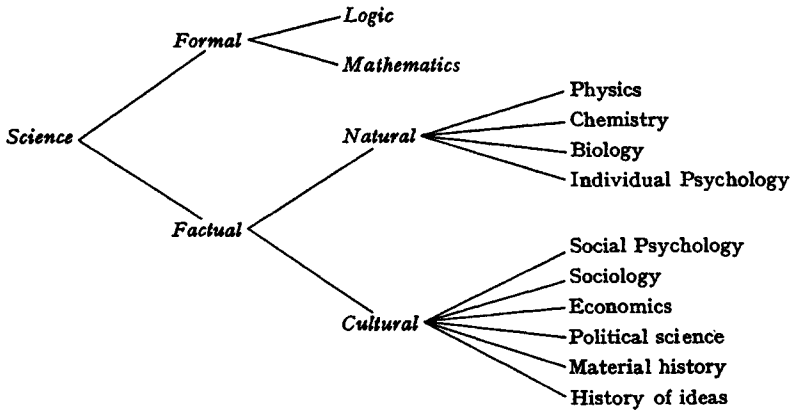


Fig. 1.4. A classification of the sciences. The reader is invited to rearrange the items and fill in some of the gaps.

gests what disciplines any given science presupposes. Yet alternative orderings are possible and boundaries between contiguous disciplines are hazy and of little practical avail. Moreover, it would be foolish to place much emphasis on the problem of classifying the sciences, once a favorite pastime of philosophers and now a subject for science administrators and librarians. A more interesting subject awaits us: the aim of research.

### Problems

1.4.1. Give two examples each of factual ideas and formal ideas. Show, furthermore, that they are indeed factual and formal respectively.

1.4.2. Many statements in factual science can be rigorously proved by deduction from premises (e.g., axioms of a physical theory). Does it follow that they have no factual content?

1.4.3. If a formula is a priori, i.e. independent of experience, then it is analytic, i.e. its validation is a purely logical affair. Does the converse hold, i.e. is every analytic formula a priori? Or is it possible to have analytic a posteriori formulas, i.e. formulas that can be derived by purely logical means on the strength of previous assumptions yet cannot be validated, as to truth value, apart from experience? See M.

Bunge, *The Myth of Simplicity* (Englewood Cliffs, N. J.: Prentice-Hall Inc., 1963), Ch. 2.

1.4.4. Many mathematical theories have been built largely in response to needs of daily life or of factual science, both pure and applied. Does this prove that mathematics deals with facts? And does it prove that mathematics is tested by being applied?

1.4.5. Archimedes and other mathematicians have employed mechanical devices for proving mathematical theorems. Does this show that mathematics can be pursued as a factual science, or that the aluded proofs were not mathematical proofs at all but rather heuristic procedures?

1.4.6. If logic and mathematics are not concerned with reality, why are they applicable? Hint: examine whether formal science is applied to reality or rather to our ideas concerning reality.

1.4.7. Certain formulas, such as "If  $p$ , then: if  $q$  then  $p$ " (i.e.,  $p \rightarrow (q \rightarrow p)$ ) and "For every  $x$ , either  $x$  is  $P$  or  $x$  is not  $P$ " (i.e.  $(x) [P(x) \vee \neg P(x)]$ ) are *universally* true: the former holds for all values assigned to the propositional variables  $p$  and  $q$ , and the latter for all values of the individual variable  $x$  and the predicate variable  $P$ . From this it has been concluded that logic holds for the most general traits of all objects, whence it would be a kind of general ontology or even "*Une physique de l'objet quelconque*" (F. Gonseth). Hint: begin by establishing whether logic is really concerned with objects of any kind or rather with ideas of any kind.

1.4.8. The label *empirical science* is more frequent than *factual science* in English speaking countries. Why? And are they mutually incompatible designations, or do they point to different aspects of science: to its object (the world of facts) and to the way it validates its truth claims (experience)?

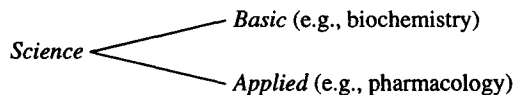
1.4.9. Analyze the relations between any two contiguous branches of science—e.g., climatology and geophysics, geology and physics, zoology and palaeontology, anthropology and archaeology, history and sociology, economics and sociology.

1.4.10. Improve on the classification of the sciences offered in the text. Make sure you use a definite classing criterion. Hint: do not try to include all sciences, because some new science is surely being born while you are wrestling with the problem. *Alternate Problem:* Granting that the classification of the sciences is a somewhat stale problem, does it follow that the boundaries among the sciences are altogether artificial and arbitrary, or do they correspond to objective differences in subject matter and special method? And does the classification of the sciences have any relevance to *ontology*, the discipline dealing with basic categories such as object, space, time, and change?

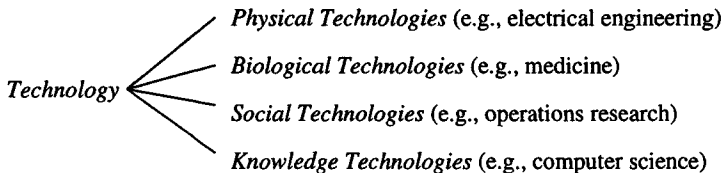
### 1.5. Goal and Scope of Science

Methods are means devised to attain certain ends. To what ends are the scientific method and the various techniques of science employed? Primarily, to increase our knowledge (intrinsic or cognitive goal); derivatively, to increase our welfare and power (extrinsic or utilitarian goals). If the aim is strictly cognitive, *basic science* results; if the aim is utilitarian in the long run, *applied science* obtains; and if the aim is utilitarian in the short run, *technology* results. But all three employ the same method, and the findings of either can be used by the other two. However, there is an important moral difference between these fields: whereas basic science is harmless, applied science and technology can be harmful.

As regards goals we have, then, the following partition:



The main branches of contemporary technology are:



Many people deny this tripartition of grounded knowledge of fact into basic, applied and technological, arguing that all research is ultimately directed at meeting needs or wants. This opinion overlooks the

difference in aims: knowledge in one case, utility in the others. It is also at a loss to account for the differences in outlook and motivation between the explorer who aims to find a new pattern, and the researcher or tinkerer who is after a new thing or process of possible practical utility. At other times this difference is granted, but it is claimed that technology and applied science generate basic science rather than the other way round. But there must be knowledge before it can be applied.

What is true is that action—industry, government, education, etc.—often *poses problems* that can be solved by pure science alone. And if such problems are worked out in the free and disinterested spirit of pure science, the solutions to such problems may eventually be applied to practical ends. In short, practice is a source—alongside with sheer intellectual curiosity—of scientific problems. But giving birth is not rearing. A whole cycle must be performed before anything comes out from practice: Practice→Scientific Problem→Scientific Research→Rational Action. This was most the frequent pattern until about mid-nineteenth century, when physics gave birth to electrical engineering: from then on technology proper—rather than prescientific craftsmanship—became firmly established. Since then, intellectual curiosity has been the source of most, and certainly of all important, scientific problems; technology has often followed in the wake of pure research, with a decreasing time lag between the two. If the external goals of science are exaggerated curiosity and freedom of research—freedom to doubt received ideas and try new ones, even if they do not look socially useful—are stamped on. The immediate result is the languishing of pure science, which ultimately leads to technological stagnation. The most practical policy is to abstain from making practical demands on pure research.

The primary target of scientific research is, then, the *advancement of knowledge*. This is the case even with applied research, such as the investigation of the effect of drugs on pathological conditions; only, in such cases not just knowledge but useful knowledge is sought. Now, there is research for the sake of knowledge, but there is no such thing as knowledge in itself: knowledge is always *of* something—e.g., of the ageing of stars, or of men. The central goal of research in pure factual science is, by definition, to improve our knowledge of the world of facts; that of applied scientific research, to improve the control of man over facts.

Does that mean that scientific research aims at *mapping facts*, at writing as it were a huge cosmography containing the description of every event in nature and culture? Clearly not. First, because an exhaustive description of even our little finger would be practically impossible given the number of its constituents and the variety of events that occur within it during one second; and even if it were possible it would be uninteresting. Second, because no description of a real system can be reasonably complete unless it employs the laws of the system, since laws are what constitute the essence of whatever exists: a sheer description of appearances will miss the essential traits of the system. But once the laws are known little interest remains for a detailed description. Third, because we are interested not only in actuals but also in possibles—the seeds of the future—and again laws alone can give us a knowledge of possibilities. Fourth, because no description can assist us either in explaining what happens or in predicting what may happen: scientific explanation and prediction are based on law statements which in turn interlace in theories. The understanding of the world, in short, is achieved with the help of theories, not of catalogues. Consequently, the exhaustive mapping of every single bit of reality—or even of every item of human experience—is not sour grapes: it is no grapes at all.

What factual science seeks is to map the *patterns* (laws) of the various domains of fact. The conceptual reconstruction of an objective pattern is a scientific law (such as the law of inertia); a system of such law statements is a scientific theory (such as Newton's theory of motion). Rather than a cosmography, then, factual science is a cosmology: a conceptual reconstruction of the objective patterns of events, both actual and possible, whereby their understanding and forecast—hence their technological control—is made possible.

When scientific techniques are applied to data gathering without finding general patterns, embryonic science—*protoscience*—is produced. And when the goal of mature science is pursued but its method and techniques are not employed, nonscientific *speculation* is at stake, whether in the form of philosophy of nature or of traditional metaphysics (the ontology which is neither inspired nor controlled by science). Nonscientific speculation thrives on the backwardness of science proper: thus, philosophical psychology and philosophical anthropology are strong wherever the corresponding scientific disciplines are still in a protoscientific stage—which is not surprising, as they are

both easier and more interesting than the aimless collection of isolated items of information. In short, there is no science proper unless the scientific method is applied to the attainment of the goal of science: the building of theoretical images of reality, and essentially of its web of laws. Scientific research is, in short, the search for pattern.

(The terms 'world' and 'reality' are avoided by some philosophers on the ground that they denote metaphysical concepts: they claim that all there is to know is our own experience, and consequently the sole legitimate goal of science is to account for the sum total of human experience. This view—radical empiricism—does not account for the very existence of most sciences, namely those dealing with empirically inaccessible objects such as the atoms inside our skulls. Science attempts to explain facts of any kind, including those comparatively few in which man gets involved—experiential facts. As a matter of fact experience is not the sole or even the main object of research, hence not the sole *referent* of scientific theories: experience, if scientific, is an indispensable *test* of those theories but does not provide the content or meaning of all of them. Moreover, in order to explain human experience—the object of the sciences of man—we need some knowledge of the natural world of which we are a part: and this world, mostly unseen and untouched, is gradually being mapped by testable theories that go beyond what can be experienced.)

Science, then, tends to build *conceptual mappings of the patterns of facts*—i.e., factual theories. But mythology too offers models of the world, both to understand and to better bear it. Why should we prefer scientific theories to mythological speculations? One is tempted to reply: because scientific theories are true reconstructions of reality. But a glimpse at the endless convulsions of science, in which most theories are caught in some error or other and just a few of them are pronounced unbelievably true, yet not quite, should convince us that scientific research does not attain complete truth. What right do we have, then, to believe that science is better off than mythology—especially if science, too, invents concepts, such as "field", "neutrino", and "natural selection", which can be associated with no sensory experience?

Must we conclude that mythology and science supply just different but equally legitimate mappings of reality? Clearly not: science does not claim to be true, hence final, incorrigible, and certain as mythology does. What science claims is (i) to be *truer* than any nonscientific model of the world, (ii) to be able to *test* such a truth claim, (iii) to be

able to *discover its own shortcomings*, and (iv) to be able to *correct its own shortcomings*, i.e. to build more and more adequate partial mappings of the patterns of the world. No extrascientific speculation is as modest and yields as much.

What enables science to achieve its goal—the building of progressively truer partial reconstructions of reality—is its method. By contrast the nonscientific speculations about reality (i) do not usually ask proper questions, but rather problems with false or untestable presuppositions, such as “How and when was the universe created?”; (ii) they do not propose hypotheses and procedures both grounded and checkable but offer groundless and usually untestable theses as well as uncontrollable (inscrutable) means for finding out their truth (e.g., revelation); (iii) they do not design objective tests of their theses and of their alleged sources of knowledge but resort to some authority; (iv) they accordingly have no occasion to contrast conjectures and procedures with fresh empirical results: they remain content with finding illustrations of their conceptions for persuasion purposes rather than for the sake of test—as shown by the eagerness with which they explain every negative evidence away; (v) they give rise to no new problems—their whole point being to put an end to inquiry by providing a ready made set of answers to every possible or permitted question.

Science, on the other hand, yields problematic but improvable conceptual reconstructions of reality. Actually it does not provide a single model of reality as a whole but a *set of partial models*—as many as theories dealing with different aspects of reality, such a variety depending not only on the richness of reality but also on the assortment and depth of our own conceptual outfit. Research does not start with such synthetic views of chunks of reality but arrives at them through *rational and empirical analysis*.

The first step in analysis, whether scientific or not, is the discrimination of components at some level—e.g., the distinction of organs, or of functions, in an organism. In a second stage the relations among these components are found—and this already provides a first picture of the whole, i.e., the synoptic conceptual picture that had been sought. Once such a model of the system (set of interrelated items) is on hand it can be used as a tool for a deeper analysis, the outcome of which is hoped to be a more adequate synthesis. Proceeding the other way around, i.e. starting with grandiose synthetic views instead of working in a piecemeal, analytic way, is characteristically nonscientific.

Scientific research, then, does not end up with a single final and complete truth: it does not even seek a single world-embracing formula. The outcome of research is a set of more or less true, as well as partially interconnected statements (formulas) concerning different aspects of reality. In this sense, science is pluralistic. In another sense it is monistic: it attacks all fields of knowledge with a single method and a single goal. The unity of science does not reside in a single all-embracing theory, nor even in a unified all-purpose language, but in its singleness of approach.

The process of reconstructing the world with ideas, and of testing every partial reconstruction, is endless—notwithstanding the groundless hopes that the definitive theory is just around the corner. Research does not cease to discover holes in its mapping of the world. Hence, science cannot have an ultimate goal, such as building a complete and flawless cosmology. The goal of science is rather the *ceaseless perfecting* of its chief products (theories) and means (techniques), as well as the subjection of more and more territories to its sway.

Are there *limits* to this expansion of the object of science? That is, are there problems of knowledge that cannot be attacked with the method and the goal of science? The unavoidable temporary limitations determined by our ignorance are not in question; nor are extrinsic limitations meant, such as those imposed by ideological, political, or economic power. What is being asked is whether there are any objects of knowledge inherently recalcitrant to the scientific approach. An optimist would think that, since the history of science shows an increasing domain of facts covered by science, we must believe that this expansion will never stop—unless we manage to blow ourselves up. Yet no past experience and no historical trend, however suggestive, is demonstrative: problems might come up, for all we know, which could prove impermeable to the scientific approach.

The preceding conclusion need not lead us to pessimism with regard to the scope of the scientific approach: between pessimism and optimism there is place for realism. A realistic appraisal would seem to be as follows. Firstly, we can hope that every problem of knowledge will eventually be shown to be either partially solvable or unsolvable by the means (special methods) and with the data available to science at any given moment. Secondly, no method more powerful than the method of science has been found, and every successful effort in such a search has resulted in perfecting the scientific method; in

particular, the attempts to grasp reality directly, without working (e.g., by perception, empathy, or pure speculation), have all failed and, moreover, we can explain why they were bound to fail: namely, because most facts are beyond experience and must therefore be hypothesized. Thirdly, the scientific method and the special techniques by which it is implemented are not final: they have evolved from more rudimentary ancestors and they will have to be improved if we want to obtain better results. Fourthly, since what is peculiar to science is not a definite object (or set of problems) but rather an approach (method and goal), anything is turned into a scientific subject, i.e. into an object of scientific inquiry, if treated with the method of science in pursuit of the goal of science—even if such a treatment is unsuccessful. In short, we cannot and do not wish to warrant the success of the scientific approach to problems of knowledge of any kind: science is not a panacea: we are just making the more modest claim that the scientific approach is the best available.

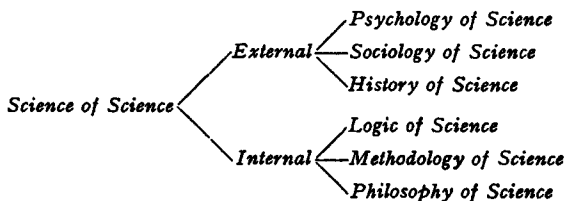
There is one object though—one might be tempted to rejoin—that factual science does not study: namely, science itself. Yet clearly the study of science can be approached scientifically and is so done on occasion: we have, in fact, a number of immature sciences of science. If science is viewed as a peculiar activity of individuals and teams, the psychology of science can emerge; this discipline will study, among other things, the cognitive drive, the psychological processes of hypotheses generation, mental rigidity among scientists, etc. Viewing science in its social context can lead to the sociology of science, i.e. the study of the social factors that prompt and those which inhibit research, the role of science in the planning and control of human action, and so on. And if science is studied as an aspect of cultural evolution, the history of science emerges, i.e. the study of the origins and development of a line of research, of the changes of scientific outlook, and so forth. The above are *external* approaches to science, in the sense that they do not analyze and criticize either the method or the outcome of research but take them for granted. Moreover, the psychology, the sociology and the history of science are factual (empirical) sciences of science: they handle large masses of empirical data.

The *internal* approach to science has, since its inception, been a philosophical subject. It is philosophers—and occasionally scientists on holidays—who have studied the general pattern of scientific research, the logic of scientific discourse, and the philosophical implica-

tions of method and outcome. This internal study of science bears on scientific knowledge apart from its psychological origin, cultural setting and historical evolution, whereas the external approach is concerned with the activities of the men involved in the production, consumption, waste, and corruption of science: the external sciences of science are as many branches of the sciences of culture. The internal study of science on the other hand, steps above its object, in the semantical sense that it is a discourse on a discourse. Just as a statement about a statement is called a metastatement, so the internal study of science may be called *metascience*, itself part of the theory of knowledge (*epistemology*).

Metascience may be divided into three parts: the *logic* (syntax and semantics) of science, concerned with problems such as the structure of scientific theories and the empirical import, if any, of scientific concepts; the *methodology* of science, dealing with the general method of science and the techniques by which it is implemented, such as, e.g. randomization; and the *philosophy* of science, studying the logical epistemological, and ontological commitments and upshots, if any, of scientific research. These problem domains have some roots in the past but they have only recently been approached scientifically. Moreover these fields are unequally advanced: whereas the formal logic of science particularly the syntax of theories, is an exact science, the methodology and the philosophy of science are still limited, in the main, to describing and analyzing science: only occasionally they produce theories proper, such as the theory of the probability of hypotheses, but then such theories usually apply to oversimplified models of science rather than to real science. Metascience, in short, is chiefly a *protoscience* rather than a fully grown science: it adopts a scientific approach but has so far produced few scientific results.

Anyway, in addition to science *tout court* we have the science of science:



In conclusion, however limited the outcome of the scientific approach may be, no *inherent* limitations to it have been shown to exist

and moreover, it is only from within science that such limitations can be correctly appraised: all of nature and all of culture, including science itself, can be made to fall under the domain of science. There certainly are subjects that have so far not been approached scientifically—for instance, love—either because no one has as yet realized their existence or because they have not attracted the curiosity of investigators or finally, because of external circumstances such as prejudice—e.g., the tenet that certain human experiences cannot be approached scientifically but must remain private. Such tenets have in their favor not only the weight of tradition but also a mistaken conception of science: most often, its identification with physics. These prejudices are among the last bastions of obscurantism; they are rapidly crumbling down: we are having scientific studies of aesthetic experience and even of the subtle manipulations of men's minds by means of stale ideologies, such as those which discourage the scientific study of man.

The successes of the scientific approach, as well as its independence with regard to subject matter, account for the expansive power of science, which now occupies territories previously occupied by the humanities—e.g., anthropology and psychology—and is continually exploring new territories. The same factors account also for the increasing importance of science in modern culture. Since the Renaissance the centre of culture has steadily shifted from religion, art, and the classical humanities to science—formal and factual, pure and applied. It is not only that the intellectual results of science and its applications to good and bad ends are being acknowledged by even the least cultured painter: an even more important and welcome change consists in the spread of a scientific *attitude* towards problems of knowledge and towards problems whose correct solution requires some knowledge. This is not to say that science is gradually absorbing all of human experience: that we shall end by loving and hating scientifically just as we can cure and kill scientifically. Except scientific research itself, human experiences are not scientific, not even if they take advantage of scientific knowledge: what can be and should be scientific is the study of any such experience.

Important changes in outlook and behavior, both individual and collective, can be expected from a widespread diffusion of the scientific attitude—not however from a popularization of just some results of scientific research. The universal adoption of a scientific attitude might render us wiser: it would make us more cautious in receiving

information, in keeping beliefs and in making forecasts; it would render us more stringent in testing our opinions and more tolerant to other people's opinions; it would make us more eager to freely inquire into new possibilities and readier to get rid of consecrated myths; it would enhance our trust in experience guided by reason and our confidence in reason checked by experience; it would stimulate us to plan and control action better, to select aims and to search for norms of conduct consistent with such ends and with available knowledge rather than with habit and authority; it would foster the love of truth, the willingness to acknowledge error, the thrust to perfection and the understanding of the inevitable imperfection; it would give us an ever young world-view founded on tested theories instead of a die hard untested tradition; and it would encourage us to hold a realistic view of human life: a well-poised rather than either an optimistic or a pessimistic view. These may seem remote or even improbable effects, and at any rate scientists could never, by themselves, bring them about: a scientific attitude demands a scientific training, which is desirable and possible only in a scientifically programmed society. But this much may be granted: that the growth of the relative importance of science in the body of culture has already born some such fruits in a limited scale, and that the program is worth being tried, especially in view of the limited success of alternative programs.

To conclude: the scientific approach has no known inherent limitations; it is in a process of rapid expansion and is yielding increasingly true partial pictures of the world outside and inside man—not to speak of the tools for its control. (Should anyone hold that the scientific approach does have inherent limitations we would ask him to sustain his claim—by conducting a scientific investigation of the problem.) By virtue of its spiritual power and its material fruits science has come to occupy the center of modern culture—which is not to say the culture of our days. In fact, it would be foolish to forget that, alongside higher culture, folk culture still lingers. And pseudoscience occupies in contemporary urban folk culture a position similar to the one held by science in higher culture. It should prove both instructive and amusing to take a look at what is often smuggled for science although it lacks both the method and the goal of science. To this subject—folk science—we now turn.

## Problems

1.5.1. Draw a distinction between the goals of science and those of individual scientists—which may include the obtainment of fame, power and riches. Explain why individuals with purely egoistic goals can make distinguished contributions to pure (disinterested) science.

1.5.2. Can we conclude, from the objectivity of scientific research that it is impersonal? If not, i.e. if research does involve the whole person even when performed by teams, does it follow that it cannot attain objective truth—that the objectivity of science is therefore mythical, as has been held? See Problem 1.1.2 and M. Polanyi, *Personal Knowledge* (Chicago: University of Chicago Press, 1959).

1.5.3. Management, advertisement, warfare, and other activities can be conducted either empirically (in the traditional way) or scientifically, i.e. with the assistance of experts with scientific knowledge and with a scientific attitude. Are scientific management, advertisement and warfare sciences? If so, why? If not, what do they lack?

1.5.4. Is scientific knowledge a means or an end? Begin by completing this question: a means and an end are terms of a triadic relation involving also a subject. *Alternate Problem:* Means and ends come in pairs. Change the goal and you may have to change the means. Apply this to the proposal of investigating theological problems with the scientific method.

1.5.5. Expand and illustrate the thesis that science is self-corrective i.e. that it is criticized and improved from within. *Alternate Problem:* Does the self-corrective character of science render philosophical criticism invalid and/ or ineffective?

1.5.6. Describe and exemplify scientific analysis of the two kinds: *factual* (e.g., chemical) and *conceptual* or theoretical analysis (e.g., the analysis of forces into imaginary components along coordinate axes).

1.5.7. In what senses is science analytic: logically, methodologically, or ontologically? (*Logical analyticity:* the property of a statement of being determinable as true or false with the sole help of an

analysis of its logical structure or of the meanings of its terms. *Methodological analyticity*: the property of a procedure of decomposing an object either in fact or in thought, instead of leaving it as a block; such an analysis can be into parts, properties, and relations. *Ontological or metaphysical analyticity*: the doctrine that the world is either an aggregate or a system of smaller units.)

1.5.8. Expand the thesis that a scientific conceptual synthesis is not independent of analysis, but rather an outcome of analysis. *Alternate Problem*: Is history a science or a protoscience?

1.5.9. Examine the following theses concerning the unity of science. (i) The unity of science resides in its object: reality. (ii) The unity of science resides in its objective, namely recounting the history of what there is. (iii) The unity of science consists in having or in striving for a single language—be it a sense-data language (sensationalism), an observation language (empiricism), or the language of mathematics (Pythagoreanism). (iv) The unity of science consists in the ultimate reduction of all factual science to physics (physicalism). (v) The unity of science resides in its singleness of approach (method and goals). *Alternate Problem*: Discuss the following conflicting proposals concerning the goal of factual science. (i) The aim of science is the complete adaptation of our thought to our experiences (physicist E. Mach). (ii) The aim of science is the creation of a world-view completely independent of the investigator (physicist M. Planck). *Alternate Problem*: Comment on the “Declaration of Interdependence in Science”, *Science*, **111**, 500 (1950), in which the unity of method and goal of all the sciences are stated.

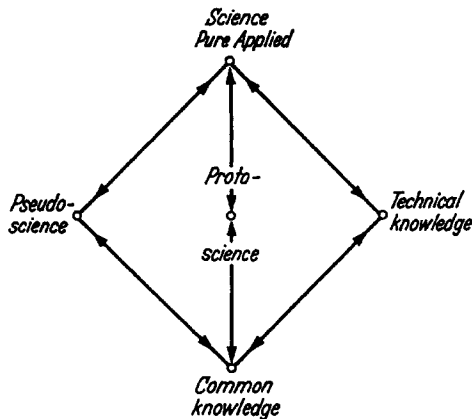
1.5.10. Try to explain why philosophical anthropology, philosophical psychology, political philosophy and the philosophy of education are still taught alongside the corresponding sciences (pure or applied).

## 1.6. Pseudoscience

Ordinary knowledge can develop in either of the following three directions. (i) *Technical knowledge*: the specialized but nonscientific knowledge that characterizes the arts and crafts. (ii) *Protoscience* or embryonic science, as exemplified by careful but aimless observation

and experiment. (iii) *Pseudoscience*: a body of beliefs and practices whose practitioners wish, naively or maliciously, pass for science although it is alien to the approach, the techniques, and the fund of knowledge of science. Still influential pseudosciences are dowsing, psychical research and psychoanalysis.

Science is not unrelated to technical knowledge, protoscience, and pseudoscience. In the first place, science makes use of the artisanal skills, which are in turn often enriched by scientific knowledge: In the second place, science makes use of some of the raw data gathered by protoscience—though most of it are useless because insignificant. In the third place, occasionally a science has grown from a pseudoscience, and sometimes a scientific theory has been stiffened into dogma to a point where it has ceased to correct itself and has become a pseudoscience. In short, many are the flow lines between science and its neighbors:



What is wrong with pseudoscience? Certainly not just that it is basically false, since anyway all our factual theories are at best partially true. What is wrong with pseudoscience is, first, that it refuses to *ground* its doctrines and could not do it because pseudoscience makes a total break with our scientific heritage—which is not the case of scientific revolutions, all of which are partial since every new idea has to be gauged by means of others that are not questioned in the given context. Second, pseudoscience refuses to *test* its doctrines by experiment proper; moreover, it is largely untestable because it tends to interpret all data in such a way that its theses are confirmed no matter what happens: the

pseudoscientist, like the fisherman, exaggerates his catch and neglects his failures or excuses them. Third, pseudoscience lacks a *self-correction mechanism*: it cannot learn from either fresh empirical information (which it swallows without digesting it), new scientific discoveries (which it despises), or criticism (which it rejects indignantly). It can make no progress because it manages to interpret every failure as confirmation and every criticism as an attack. Differences of opinion among its sectarians, when such deviations arise at all, lead to endless sect splitting rather than to progress. Fourth, the primary aim of pseudoscience is not to set up, test, and correct systems of hypotheses (theories) mapping reality, but to influence things and men: it has, like magic and like technology, a primarily *practical aim* rather than a cognitive one but, unlike magic, it presents itself as science and, unlike technology, it does not enjoy the backing of science.

Our first example of a pseudoscience will be dowsing or, more generally, *rhabdomancy*. The thesis of rhabdomancy is that certain particularly sensitive subjects can unconsciously and directly feel underground inhomogeneities, such as ore mines and oil basins. The technique of rhabdomancy is to use a hazel-twigg or a pendulum as an indicator of such a feeling. Summarily, the pattern would be this: Geological Accident → Unconscious Reception → Involuntary Bodily Motions → Pendulum Oscillations → Perception of Oscillations. Some rhabdomants claim that the first link in this chain may also be a tumor or a car ailment.

What can be wrong with rhabdomancy? First, both the thesis and the technique of rhabdomancy are not *grounded* on the bulk of scientific knowledge, according to which a direct action of physical bodies upon mental states is impossible: both a physical agent and its action on a biological mechanism are needed, for the simple reason that mental functions are proper of highly developed nervous systems, which are in turn physical systems. On the other hand, the standard geological prospecting techniques (e.g., with the help of artificially produced seismic waves) are based on well-known physical laws: the mechanism of their operation is known and this is why they are regarded as reliable. Second, the thesis of rhabdomancy is *untestable* or nearly so for either or both of the following reasons: (a) it involves neither a definite mechanism nor a definite law, so that it is difficult to ascertain what can be argued about and what experiments could conceivably refute the thesis; (b) if the dowser makes a correct guess of, say, an

underground water vein, the thesis is pronounced confirmed; should he fail to correctly signal water he might defend his belief either by saying that there is water, only deeper than the drilling can reach, or by humbly acknowledging that he made a mistake: he took for indicators what were just signs of fatigue, or of excitement. No geologist can ever achieve such a hundred per cent degree of confirmation.

Notice that experience is irrelevant to the refutation of rhabdomancy. First, because this belief is empirically untestable. Second, because a dowser with a descriptive knowledge of the terrain can beat a geologist equipped with scientific instruments and laws but with no equivalent knowledge of the locality. Consequently rhabdomancy must either not be discussed or disposed of by metascientific argument: by showing that its thesis and its technique fail to be grounded and testable—two requisites of scientific ideas and procedures.

Our second example will be *parapsychology* or psychical research, the modern names for spiritualism, mediumnism, cartomancy, and other archaic beliefs and practices. This doctrine holds the existence of certain phenomena, such as telepathy (thought transmission), clairvoyance (seeing at a distance), precognition (future seeing), and telekinesis (mental causation of physical phenomena). These alleged facts are ascribed by parapsychology to extrasensory perception (*ESP*) and other supranormal abilities which it does not profess to explain. Parapsychology is somewhat elusive not only because it deals with nonphysical entities (such as ghosts) and events (such as telepathy) but also because it makes no detailed, hence no definitely testable assertions about either action mechanisms or regularities—but this makes it all the more suspicious to the critical metascientist. Let us spell out this complaint.

Firstly, parapsychologists do not state and treat their theses *as hypotheses*, i.e. as corrigible assumptions concerning unperceived events: by calling the alleged anomalies cases of extrasensory perception the parapsychologist commits himself a priori to a definite assumption which he will henceforth try to illustrate rather than substantiate. Secondly, the theses of psychical research are *loosely stated* and have *little content*: they are just assertions about the existence of certain rare events with no intimation about the possible mechanism for the production, propagation and reception of psychical messages. Of course, no physical mechanism is or could be accepted by parapsychology, since it would automatically place the whole field within the reach of

physics and psychology: explanations in terms of subliminal cues or in terms of special new waves miss the whole point of parapsychology. The sole “interpretation” of the alleged anomalies that a parapsychologist can admit is that they are nonphysical and nonnormal: as soon as he attempts to be more specific he risks being refuted.

Thirdly, the vague theses of parapsychology are *nonnaturalistic* and *ungrounded*. More than this: they collide head-on with scientific knowledge. The latter, in fact, suggests the following generalizations: (i) no event lacks a physical basis, (ii) the mind is not a substance, however subtle, that can abandon the body, propagate over space and act on matter: ‘mind’ is a name for a complex system of functions or states of the nervous system; (iii) no effect preexists its cause and, in particular, no message can be received before it has been sent—as required by precognition. The inconsistency of *ESP* with science voids it of empirical support, because empirical information alone is no evidence at all: for a datum to become an evidence in favor or against a scientific hypothesis it must be interpreted in the light of some set of theories. Since parapsychology lacks a theory altogether it must accept the interpretations proposed by normal science; but *ESP* impugns the competence of the latter to handle the alleged anomalies it deals with, hence it cannot accept any data, not even those it collects itself. In short, *ESP* can marshal no evidence in its own favor.

Fourthly, the observations and experiments conducted by parapsychologists have been shown to be *methodologically invalid* a number of times: (i) many of them have been exposed as frauds; (ii) they are not repeatable, at least in the presence of unbelievers, and there is considerable disagreement among psychical researchers concerning the “facts”; (iii) parapsychologists tend to reject contrary evidence: this they do, e.g., by selecting lucky runs and stopping as soon as randomness reappears; (iv) they often misapply statistics, for example when they apply it to nonrandom samples (selected subsequences of trials) as if they were strictly random, much in the same way as vitalists refute materialism by showing how small the probability is that an organism will emerge spontaneously from the “random” encounter of a myriad of atoms.

Fifthly, even though the theses of parapsychology are separately testable—though barely so—parapsychologists tend to combine them in such a way as to make *the whole set insensitive to test*, hence immune to criticism on the strength of experience: if a set of guessings

is consistently about chance the subject will be said to be tired, or to resist belief, or even to have lost his paranormal ability—which is unrelated to other abilities, so that it can be manifested by above-chance performances alone, never by a personality analysis, let alone by a neurophysiological investigation; if the subject does not read the right card or message but the next one in a sequence, he is said to exhibit the phenomenon of forward displacement, which is in turn interpreted as a clear case of precognition; if he fails to move the die or to blow the trumpet at a distance, again a momentary inhibition or even a final loss of ability can be resorted to. In this way the gang of parapsychological theses is rendered unassailable and, by the same token, the testing techniques of science become pointless in their regard: conspiracy defeats checking.

Sixthly, parapsychology is guilty of not having produced, in 5,000 years of existence, *a single empirical regularity*, let alone a law statement embodied in a theory. It has produced neither certified facts nor laws: it is not even an untested but promising young theory: it is not a theory at all, as the few theses of the doctrine are elusive and they gather for purposes of mutual defence against criticism rather than for the logical derivation of testable consequences. In other words, psychological research has not attained the goal of science—and has never aimed at it.

Our last example of a pseudoscience will be *psychoanalysis*—not to be confused with either psychology or psychiatry (the technology associated with psychology). Psychoanalysis claims to be both a theory and a therapeutical technique. As a theory it would be acceptable if shown to be true enough; as a technique, if shown to be effective enough. But in order to sustain either the claim to truth or the claim to efficiency a body of ideas and practices must subject itself to the canons of grown up pure and applied science—at least if it wishes to pass for science. Psychoanalysis fails to pass the science tests.

Firstly, the theses of psychoanalysis are *alien to, and often inconsistent with, psychology, biology, and anthropology*. For instance, the whole doctrine is alien to learning theory, the most advanced chapter of psychology. The hypothesis of an unconscious racial memory has no foot in genetics; the assertion that aggressiveness is instinctive and universal contradicts ethology and anthropology; and the hypothesis that every man harbors an Oedipus complex is contradicted by anthropological findings. If these were secondary points of the doctrine it

would not be grave: they are important ones and, what is more, psychoanalysis cannot resort to science in order to get spare parts for its worn out doctrine, because it presents itself as an independent rival science.

Secondly, some psychoanalytic hypotheses are *untestable*: for example, those of infantile sexuality, of the existence of disembodied entities within the self (the id, the ego, the superego), and of sleep as representing a return to the maternal womb.

Thirdly, those theses of psychoanalysis that are testable have been illustrated but never *tested* by psychoanalysts with the help of the standard testing techniques; in particular, statistics plays no role whatsoever in psychoanalysis. And when they have been tested by psychologists they have failed. Examples: (i) the conjecture that every dream is a wish fulfilment has been tested by asking subjects with objectively known urges, such as thirst, to report their dreams: there is a very low correlation between urges and dreams. (ii) According to the catharsis hypothesis exposure to films showing brutal behavior should result in a discharge of aggressiveness: experiment has shown the opposite result (R. H. Walters et al., 1962). (iii) No significant correlation between early feeding habits and toilet training, on the one hand, and personality traits on the other, has been found in follow-up studies (W. H. Sewall, 1952 and M. A. Straus, 1957). (iv) When control groups have been formed to gauge the influence of psychoanalytic therapy on neuroticism no favorable influence was found, the percentage of cures being sometimes below the percentage of spontaneous remissions (H. H. W. Miles et al., 1955; H. J. Eysenck, 1952; E. E. Levitt, 1957); on the other hand, the reconditioning technique is successful in most cases, on top of which it is backed up by learning theory (J. Wolpe, 1958).

Fourthly, although some psychoanalytic conjectures are individually testable and have occasionally been tested, *as a gang they are untestable*. For example, if the analysis of a dream's content does not show it to be the imaginary fulfilment of a wish, the psychoanalyst will argue that this only proves the subject has strongly repressed his wish, which so remains beyond control; similarly, if a man fails to exhibit the Oedipus complex he is said to have repressed it, perhaps for fear of castration. In this way the various members of the gang protect themselves mutually and the doctrine as a whole remains unassailable by experience.