THE SPHERE OF SCIENCE

A STUDY OF THE NATURE AND METHOD OF SCIENTIFIC INVESTIGATION

BY

FRANK SARGENT HOFFMAN, PH.D.

PROFESSOR OF PHILOSOPHY IN UNION COLLEGE
AUTHOR OF "THE SPHERE OF THE STATE," ETC.

G. P. PUTNAM'S SONS
NEW YORK & LONDON
The Knickerbocker Press
1898

The Knickerbocker Press, New York

To the Memory of

JULIUS H. SEELYE, D.D., LL.D.

President of Amherst College

from 1876–1890

PREFACE

THE primary object of this book is to point out with clearness what it is that constitutes a science, and to set forth with some detail what are the grounds upon which every science rests and what are the principles and rules that must be followed in order to construct one.

It is maintained from the first chapter to the last that every department of knowledge is capable of scientific treatment and must be so treated before any great advance can be made towards a consistent and rational conception of the universe. Marvellous progress in some directions has without doubt been made during the last fifty years, owing to the rapid development of the physical sciences; but a lofty and symmetrical civilization will not be realized until all the other sciences are exalted to their true place in the general system.

The chief need of our time in all departments of thought is not so much more facts as a more rational treatment of the facts already at hand. Nearly all the sciences are now undergoing a radical reconstruction; but "The New Astronomy," "The New Chemistry," "The New Political Economy," "The New Psychology," and "The New Theology" are not so much the products of new facts as of a more thoroughgoing and scientific way of looking at the old ones.

This book is the outcome of a series of lectures recently given to my classes in Union College to supplement their work in Formal Logic. It is hoped that the work is adapted to the actual needs of every thoughtful student, whatever profession he may have in mind as a life-work.

Technical and unusual expressions have intentionally been avoided as far as it was possible to do so. This has been done with the clear conviction that unless philosophical discussions can be carried on in the language of the average educated adult, they will fail of their true mission.

Whether the present writer has successfully adhered to this conviction must, of course, be left to the decision of others. At any rate he invites criticism upon this point as well as upon the subject-matter of the book from every quarter, but he will especially welcome the criticism of those who have done the work the honor of subjecting it to the tests of the classroom.

F. S. H.

UNION COLLEGE, *June, 1898.*

CONTENTS.

THE SPHERE OF SCIENCE

THE SPHERE OF SCIENCE

CHAPTER I

THE TRUE CONCEPTION AND AIMS OF SCIENCE

THE violent controversies that have been waged during the last half-century over the nature and aims of science have chiefly been due to careless and inexact definitions. Most of them could easily have been avoided by paying a little more attention to logic and the dictionary in the use of terms.

In a comparatively recent work of nearly four hundred pages on *The Conflict between Religion and Science*, the author nowhere attempts a precise statement of the things in conflict, nor of the grounds of the controversy. Near the close of the book he refers to religion as a "quiescent immobile faith," and in another earlier passage he gives us a glimpse of his conception of science by the remark that "it relies on a practical interrogation of nature." Such a vague and careless way of dealing with the terms involved causes the whole discussion to degenerate very largely into a mere war of words. It deprives the book of half its value. For, instead of entertaining or instructing the reader, the principal effect of it is to perplex and mystify him.

It is no exaggeration to assert that the first requisite of a careful and accurate treatment of any subject is a clear and rational definition of the terms to be employed. And no writer has presented more concisely the chief characteristics of such a definition than Archbishop Thomson. "A definition," he says in his *Outlines of Thought*, "must recount the essential attributes of the thing defined; the definition must not contain the name of the thing defined; a definition must be precisely adequate to the species defined; a definition must not be expressed in obscure or figurative or ambiguous language; a definition must not be negative where it can be affirmative." To define words as signs by which an orator expresses his thoughts, life as the sum of the vital functions, God as a circle whose centre is everywhere and whose circumference is nowhere, is to do violence to one or all of these requirements.

Yet so frequently are these precepts set at defiance by the learned and the unlearned alike, that a constant appeal to their binding authority is an absolute necessity to any clearness or precision of thought. Dr. Johnson's definition of network as "anything decussated or reticulated with interstices between the intersections" is a case in point.

To the rules given by Archbishop Thomson concerning definitions, one or two others may well be added. (1) A definition should not employ terms in a forced or unusual meaning. Those who violate this precept stand in danger of misleading themselves as well as others. (2) A definition should not beg the question by reading out of court every dispute that may have arisen concerning the nature of the thing defined. This precept is set aside when one defines science in such a way as to exclude everything but physics. Thus one could easily eliminate at the outset all inquiry as to whether psychology or rhetoric may not be placed in that category. (3) A definition should not coin new terms when those in use entirely suffice for the purpose. There cannot be an easy and rapid progress of thought where old and familiar things are referred to in unusual relations or described, as it were, in an unknown tongue.

With these general precautions before us we are prepared to betake ourselves more specifically to the task in hand, and directly to face the inquiry, What is it that constitutes a science? What is the only rational and consistent conception of its nature and aims?

Science, in its primary sense, coming as it does from the word *scio*, I know, means, of course, any kind of knowledge. But by common consent there is always made in our day a great distinction between scientific knowledge and unscientific. It is not meant by this, however, that the one kind of knowledge is true and the other false. The unscientific knowledge that grass grows, that iron is hard, that man perceives and thinks, is just as real as the scientific knowledge of the same facts. When an untutored savage looks up at the starry heavens, all he sees is a countless number of gleaming points of light scattered through the firmament. To a Newton the same thing is a vast system of worlds unceasingly whirling through space with inconceivable velocity, yet never deviating by a hair's breadth from their predetermined course. In spite of all this difference in their knowledge, both have some knowledge, and both have genuine knowledge, though the latter alone is worthy of being called by the name of science.

This distinction between scientific and unscientific knowledge is well expressed in German by the terms

Kenntniss and *Erkenntniss*. *Kenntniss* is plain, spontaneous, every-day knowledge, knowledge of anything merely as it seems; *Erkenntniss* is thoughtful, reflective, systematized knowledge, knowledge *an und für sich*.

While it is true, in a sense at least, as Herbert Spencer says, that science is simply the higher development of common knowledge, those who assert that science is knowledge and knowledge is science add nothing to our understanding of the universe. They spend their time and strength in beating the air. Knowledge, it must be allowed, is the common possession of the race. No individual can arrogate it to himself, nor can it be lassoed and held captive within the pale of any sect or school.

As another expresses it: "The physicist might as well think to confine the atmosphere within the receiver of his air-pump, the chemist to compress the rivers into his retort, as to monopolize the term knowledge by the limitations of his own particular science." The same thing might also be said of the psychologist and the philosopher. They none of them have exclusive possession of knowledge. In truth, they differ from the rest of mankind not so much in what they know as in the character of their knowledge, not so much in the material of their knowledge as in the way they use that material.

Yet it cannot be too strongly emphasized that the foundation of all science is facts. It matters not whether they be material facts or immaterial facts, whether they be obtained by external observation or internal observation, there can be no science without facts. But before the facts can be used in the formation of a science they must first of all be critically examined. Their exact nature and limits must be carefully determined. If they cannot be clearly separated from all other facts, the first step cannot be taken towards the formation of a science. In other words, if they are so vague and obscure that they cannot be accurately defined, they must be left outside the realm of scientific knowledge.

But given an exact knowledge of the facts, something more is necessary in order to make a science. The facts known must also be capable of verification. A series of individual experiences that could not be repeated by another would have no place in the construction of a science. And a person who was incapable of experimenting upon the facts presented to him, and of thoroughly testing their validity for himself, would have no claim to be called a scientist. It is for this reason that laboratories have come to be in our day an indispensable aid to science. There, all old facts can be reexamined under the most favorable conditions, and all alleged new facts subjected with the least waste of time and labor to the most critical tests. Most of the knowledge that the average man possesses is of little value for the purposes of science, for the simple reason that it is of such a character that it cannot be re-examined. No one can lay hold of it in such a way as to experiment upon it and re-observe it, and thus bring it within the realm of the critical experiences of mankind. This is largely true of the experiences of the artist, the physician, the orator, and even of the divine. The marvellous influence they often exert over others is due to no conscious arrangement of facts that they themselves understand, or can impart to others. Being almost wholly personal and indefinable, it cannot be critically examined and thus be made to conform to the demands of a science.

Furthermore, scientific knowledge must at the same time be classified knowledge. It is not enough that the facts have been carefully ascertained and thoroughly verified. There is no science unless the facts have also been arranged into classes.

The ultimate ground of all classification is likeness. As Jevons puts it, "Science arises from the discovery of identity amid diversity." We would never know that there were any differences between things unless we had first observed some general likeness. There is no way of investigating anything that is absolutely *sui generis*, and no way of using such a thing even if we could investigate it. If in any collection of facts there were no observable likenesses, no classification of those facts would be possible, and hence no science. Before we can have scientific knowledge of anything we must know it as a member of a class. Some at least of the facts to which it is similar must be known and must be thought of as in some real connection with it. No science is formed out of any given set of facts until the like facts are put in their respective groups. Any fact that cannot be put into some class with other facts cannot belong to a science.

Finally, in order to have a science, the facts that have been fully ascertained, thoroughly verified, and carefully arranged into classes, must be put together into a system. Nothing short of this will give a science. Nothing short of this will change unscientific knowledge into scientific. It is this "intuition of unity," as Plato calls it, that first impels the mind to form a science. And no man is properly called a scientist who does not have before his mind the formation of a system out of the facts he studies as truly as the ascertainment of the reality of those facts.

With these observations before us we are prepared to form our definition of science. We see that the difference between scientific knowledge and unscientific is not one of reality, but of method. The facts are the same in both cases, but the one takes them just as they first appear, the other subjects them to a critical examination and logically organizes them into a system.

This is true regardless of the nature of the facts. But no mere accumulation of recorded observations or experiences can make a science. Nor can a purely abstract theory be regarded as a science, however closely fitted together may be its facts. Even in pure mathematics, the x, y, z's of algebra, as well as the lines and angles of geometry, must be posited by the mind as concrete realities before any attempt can be made logically to arrange them into a system. Only actual or idealized facts can be taken up by the thinking power of man and woven into the woof of a science, that is, be carefully adjusted to one another and put together into a rational system.

Science, therefore, may be properly defined as logically arranged and systematized knowledge, or more fully, that kind of knowledge which consists of facts carefully ascertained, accurately verified, and logically put together into a system. Any department of inquiry where a number of like facts can be collected and systematized may be made into a science.

This conception of science conforms to all the requirements of a clear and rational definition, and does away with the illogical and useless controversy that is still being carried on so vigorously in many quarters concerning the nature and aims of science. For it helps us to see with clearness, how arbitrary and unscientific, not to say irrational, it is for any thinker to take the position so strenuously insisted upon by Professor Ernest Haeckel in his so-called *History of Creation*, that science has to do only with the facts of "sensuous experience." The avowed object of his work is, to be sure, to destroy all ground for the conception of a personal Creator, but he at once oversteps the bounds of reason and logic by thus arbitrarily limiting the facts to be discussed. Science has to do with all the facts of human experience, not simply with those of some particular class.

Comte and his followers go to an equally false extreme in their use of the term science. For they also limit it entirely to the phenomena of matter, openly and avowedly maintaining that no knowledge of any kind has a real existence that is not attained through the observation of the senses.

For students of the physical sciences arrogantly to monopolize the whole field of knowledge and style themselves the only scientists is, to say the least, an unworthy artifice. And, besides, it logically involves the entire abandonment of the most important scientific questions that are now attracting the attention of the public, and being most earnestly discussed by the great scientific associations in all parts of the world.

The facts in the universe that are open to human investigation are of two kinds—mental facts, which are the most certain of all facts, and material facts. And as many sciences are possible in both of these realms as there are possible combinations of like facts. A new science may come into being, whenever a new set of facts is discovered or a larger number of likenesses among the old facts is pointed out. In this way an old science may be entirely obliterated by having each separate group of its facts made into a separate science.

By keeping in mind the true character of science, that it has to do merely with the accurate apprehension and logical arrangement of facts, we are helped to see the distinction between an art and a science. A science teaches us to know, an art to do. Science gives us principles, while an art gives us rules. In art, truth is a means to an end; in science, it is an end in itself. Historically, art has often preceded science. But no art can reach a high degree of perfection unless it is grounded on a science, unless the truths that the art involves are kept more or less definitely before the mind to guide the hand and balance the judgment.

A high authority has divided the arts into the industrial, the æsthetical, and the ethical. To the industrial arts belong manufacturing, agriculture, engineering, navigation, and the like. Though often called practical sciences, they are usually pursued merely for a livelihood and not for the increase of pure knowledge. They can be cultivated, and were for centuries, without much, if any, reference to the chemical and mechanical sciences upon which they rest.

The æsthetical arts—architecture, sculpture, painting, music, and poetry—were also carried to a high pitch of excellence before any special attention was given to the physical and mental sciences to which they are related and upon which they are based.

Among the ethical arts might be put the so-called learned professions—law, medicine, and divinity. They simply apply knowledge rather than accumulate it. They, therefore, are not to be confounded with the sciences properly so called.

A clear distinction should also be made between science and literature. For literature is the vehicle and ornament of science rather than its ground and source. The languages and literatures of the different nations of the earth do, of course, contain a vast amount of scientific information. But from our present standpoint they are to be viewed apart from their content. And as such they are simply the instruments and appliances of science. They do not originate facts or scientifically arrange and systematize them, but they preserve and transmit them and thus perform for science an indispensable service.

In a certain sense, science is also to be distinguished from philosophy. The term philosophy has had a great variety of meanings in the course of history. Many centuries elapsed before it was restricted to any definite sphere. Among the early Greeks it meant any kind of knowledge and any effort to secure it. The Stoics made it include even grammar and music. Other writers confounded it with mythology and theosophy. The Neo-Platonists called Orpheus the first philosopher, Cicero defined philosophy as "the science of things divine and human and of the causes in which they are contained." Descartes calls it "the science of things evidently deduced from first principles," while Leibnitz speaks of it as "the science of sufficient reasons." The vaguest definition of all is that of Hegel, who calls it "the identity of identity and non-identity." The trouble with all these definitions is that they are either one-sided and partial, or else include far more than should be included within the sphere of the study to be defined. Philosophy has to do with facts just as truly as any other science. But it does not take the facts until after they have been generalized by the other sciences. It is, therefore, properly defined as the science of the sciences. It is distinguished from the other sciences as the general is distinguished from the special. It does not attend to the details of botany, physics, chemistry, psychology, and the like, or the elaborate deductions of mathematics, logic, and ethics, but it takes up the general truths which they each establish, or upon which they rest, and unifies them into one general system.

Science always requires for its completion the unifying process of philosophy, and philosophy also demands the scientific basis of experience. The real distinction between the two spheres of knowledge lies chiefly in the proportion in which the two factors of speculation and experience, which are common to both, are intermingled. Zeller, in his introduction to the *Philosophy of the Greeks*, well sums up the distinction between philosophy and science as follows: "Every other science has in view the explanation of some one particular domain, whereas philosophy has its eye upon the totality of existence as a whole, strives to comprehend the particular in its relation to the whole and to the laws of the whole, and thus to establish the coherence of all knowledge."

Some of the relations of science to faith and religion may here also be briefly noted. It is the opinion of many that science has nothing to do with faith. "Where faith commences," says Haeckel, "science ends. Both these arts of the human mind must be strictly kept apart from each other. Faith has its origin in poetic imagination; knowledge, on the other hand, originates in the reasoning intelligence of man." The faith that Haeckel here refers to is the ideas of religion, which he elsewhere describes as ideas which are proclaimed as the "revelations of the Creator and then believed in by the dependent multitude." He ignores entirely the fact that every true religion is based upon objective realities as truly as any science; that a knowledge of facts is its groundwork, quite independent of the question whether or not it is accompanied by an alleged revelation.

Tyndall equally errs in his famous Belfast address when he called upon men of science to regard the religions of the world as "mischievous, if permitted to intrude on the region of knowledge, . . . but capable of being guided to noble issues in the region of emotion," which he considered to be their only and their appropriate sphere.

Faith considered as a mental act is exercised in the formation of every science. So far from faith commencing where science ends, as another puts it, "there could no more be science without faith than there could be extension without space." Gravitation, motion, force, atom, ether, and the like are the veritable products of faith, and in no sense matters of absolute knowledge. Perhaps no science is more dependent upon the "poetic imagination," than the great field-marshal of the sciences itself—mathematics. And Förster says that "astronomy ventures itself upon the approval of mankind through the practical realization of its theories of motion, though it knows absolutely nothing concerning the first impulse of motion, and is utterly ignorant of the inner essence of the so-called powers with which it works so boldly and so successfully."

From this conception of science as carefully ascertained facts logically arranged into a system, we see that science is a purely human construction, and must partake of all the imperfections of our finite human powers. Strictly speaking, there is no botany, or chemistry, or physics in nature, no psychology in man, no theology in revelation. All these sciences are simply the results of man's attempts to observe and classify the facts connected with these departments of investigation. And the results of to-day may be materially changed to-morrow. Chemistry in our day is a very different science from what it was before the time of Dalton, and yet it was just as truly a science then as it is now. Huyghens did much to perfect the science of optics, but he did not by any means bring it into being. Great contributions were made to theology by Calvin, but the science existed centuries at least before his day.

It is not at all essential to the true conception of science that it be complete or free from error. For a department of knowledge is called a science with reference to the intellectual process pursued in it, not with reference to its own inherent perfection. The astronomy of the ancient Greeks was as truly scientific as our own, though, of course, we now see that the Copernican conception of the heavenly bodies is much nearer to the truth.

If perfection were an essential attribute of science, then we should have no science. For there is no perfect science in this world or anything else that has that attribute. Either the facts required are not all at hand, or some error may exist in the way they have been treated. This would be true even if the facts were divinely imparted. For there would be no infallible way of recording the facts or of interpreting them after they were recorded. In no sphere of knowledge can we rightfully say that all the facts have been fully ascertained. We know a great deal more about many spheres of knowledge than our ancestors, but we are still in every science far from the entire truth.

" Now we see through a glass darkly," well describes the condition of every science.

The progressive character of science is essential to any adequate conception of its past history and future prospects. Even the truths of Scripture have been gradually revealed, and theology, which is so largely based upon these truths, is, like every other science, ever open to change and improvement.

In the time of Francis Bacon, only a few departments of knowledge were cultivated, and these were pursued with very little of the truly scientific spirit. By his *Novum Organum* he directed human investigation into new channels and toward the accomplishment of more rational ends. Within the last three centuries almost every science has undergone a revolution. It is the opinion of many that the sum-total of scientific knowledge has been increased more during the nineteenth century than during all the previous centuries put together. At all events, the nineteenth century is preeminently the age of science, and it is an age of the greatest progress for that reason. For the more scientific our knowledge becomes in any sphere of investigation, the more easily and the more completely can it be applied to the advancement and elevation of the race.

Down to the seventeenth century, tradition and authority were taken as the chief sources of opinion rather than carefully observed facts. Almost every preceding school of thought, whatever the subject investigated, was largely dependent upon the systems and authorities of the past. Even Aristotle is continually referring to the doctrines of " the ancients," and Plato puts all of his choicest thoughts in the mouth of his great master, Socrates. Later, for a long interval during the Middle Ages, all questions were solved by immediate reference to the edicts of the Church. Thomas Aquinas and the Schoolmen professed to have brought one science at least, the science of theology, to a state of perfection on that basis.

Then came a startling conjunction of events that revolutionized the world of thought as well as the world of action. "The revival of letters, the invention of printing, the Reformation in religion, the discovery of America and the passage round the Cape of Good Hope, and the rapid development of the power of the municipalities and the burgher class, were all crowded together, so to speak, into one epoch about the close of the fifteenth century." This led to such an outburst of mental activity, such a collision of opinions, that the foundations of the old dogmas began to totter and a new era for science soon appeared.

Yet the sixteenth century was a century of great scholars rather than of great thinkers. The physical sciences, to be sure, made some progress during this century, as that field had hitherto been almost wholly neglected. Students were left to cultivate it comparatively at their option, the persecution of Galileo, which was largely provoked by his own dogmatic temper, being almost the only exception. The leaders of the age gave their energy chiefly to hunting out and collating old manuscripts. They contented themselves with annotating and expounding the new sources of authority that they had rediscovered among the Greeks. Not until the time of Descartes and his contemporaries did the modern scientific age really reach a full dawn.

The thinkers of the seventeenth century broke away entirely from the past. They arrogantly regarded the ancient views as obsolete and attempted to reconstruct every department of knowledge. "They accepted nothing upon authority; they borrowed not a stick or a stone from those who had gone before them." Descartes built up his whole system on the proposition, *cogito, ergo sum*. Hobbes went so far as to assert: "If I had read as many books as other men I would have been as ignorant as they are." In spite, however, of these extreme views, the men of the seventeenth century reconstructed the sciences of their day and laid the foundations for many new ones. Descartes and Leibnitz made over mathematics and philosophy. Pascal reformed geometry, Kepler and Newton soon revolutionized astronomy, and nearly all the physical sciences then began their triumphal march of progress that has made them the marvel and glory of the modern world.

And yet no science has reached the limit of its development. The progress of the future may be as wonderful to coming generations as anything in the past or present. Many fields of research still abound in prejudiced inquiries, rash generalizations, crude conjectures, and subtle conceits. Bacon's "idols of the den" still pursue their petty rounds in their own shadowy dungeons, and his "idols of the forum" are still current in the vague and meaningless phrases so often employed even by the masters of thought. What Renan said about the metaphysics and theology of his day may be true of almost every science,—that the time may come when it will be to those yet to be discovered as "the cosmos of Anaximines is to the cosmos of La Place and Humboldt."

The progressive character of all science is, however, no reflection upon its reality or value. It would be alike the denial of reason and common sense to maintain that the great changes in astronomical systems have proved the untruthfulness and worthlessness of astronomy. Not only do the truths and facts of the old system for the most part persist in the new, but without them there would never have been any advance to the new.

In all human knowledge there is a nucleus of certainty surrounded by a great zone of probability. The changes that take place in the latter are usually changes in our interpretation of facts rather than in the facts themselves. Such changes will always be possible so long as man remains finite. But through all larger inferences and new interpretations the great mass of knowledge abides. The steps are almost always towards the enlargement of knowledge and not towards its decay and annihilation. The ocean remains the same even though the waves are continually rising and falling upon its surface.

In those very sciences where the call for a reconstruction is the loudest and most persistent, the chief need is not so much more facts as a new arrangement and classification of the facts already at hand. Wherever theories and conclusions that should have been accepted provisionally, awaiting further investigation, have come to be regarded as scientific verities, the questioning of their validity and value need involve no reflection upon the reality of the facts. The data of the new geology, the new psychology, the new political science, and the new theology do not necessarily vary much from the data of the old. The facts that are common in all these reconstructions are far more numerous and important than those that are different. Furthermore, it rarely happens that the changes required in our scientific beliefs by these readjustments do not materially clarify and enlarge our conceptions of the universe.

The chief end of all human effort after scientific knowledge is not the mere exercise of our faculties, but the possession and use of truth. The great impelling motive to the formation and enlargement of science is not primarily intellectual enjoyment, but the attainment and application of the truth. Lessing utterly failed to express the true scientific spirit in his famous saying that "if God held in his right hand all truth, and in his left hand the single, always urgent, impulse to search after truth, with the condition that I be always and forever in error, and should say to me, Choose, I should humbly turn to his left hand and say: Father, give me this; the pure truth is for thee alone." No genuine thinker in any sphere can content himself with making his own amusement the goal of his endeavors. There is something vastly higher in the life of a true student of science than the mere enjoyment of intellectual activity. Only as the truth is sought after for what it is in itself, and what it can do for the ennobling of human life, is there any dignity or worth in scientific investigation and research.

It is no disparagement to the scholar if, as the necessary result of a life of devotion to some particular field of labor, he becomes less proficient than others in practical affairs. "But if," as Dr. Samuel Harris so wisely declares, "study is prosecuted with only a speculative interest, there is a weakness of the man and not merely a necessary professional limitation; for his development is abnormal, his culture is sickly, and his knowledge awry."

Every genuine lover of science will irrevocably commit himself to the proposition that the highest mission of man is to know and love the truth. And he will boldly proclaim to all his fellows: "The more patiently and persistently you observe, the more carefully you experiment, the more logically you arrange and systematize,—in other words, the more scientific you make your knowledge,—the more quickly will ignorance and superstition vanish, and the earth be prepared for the reign of righteousness and peace."

CHAPTER II

WHAT SCIENCE TAKES FOR GRANTED

WITH the conception of science already presented as a system of accurately ascertained and logically classified facts for our starting-point, we next need to treat of the prerequisites of science. By this expression we mean those truths that must be consciously before the mind or assumed to be there before we can intelligently begin the formation of a science.

For, as Porter very properly maintains, " to science of any kind certain axioms or fundamental principles are necessary prerequisites. Whether these principles are original and self-evident, or whether they are derived from experience, reasoning, or association, they must be assumed and asserted in order to any scientific deduction or enforcement."

Mivart, in *The Helpful Science*, expresses essentially the same thought when he says: " Physical science can tell us the truth about many things, but can tell us nothing about the truth itself. It can afford us good reason for believing various facts, but not the grounds on which we should believe such reasons. It is essentially superficial, and not fundamental."

While it is the work of the scientist to search for truth, yet all truths are not capable of scientific classification. Some are antecedent to such classification, and furnish the ground upon which it must proceed. The greatest thinkers from the earliest times have recognized this fact, and none more fully than the ancient Greeks.

Aristotle presents his views upon this point as follows: "Since there is nothing more certain than science except intuition: and since principles are better known to us than the deductions from them; and since all science is connected by reasoning, we cannot have science respecting principles. Considering this, then, and that the beginning of demonstration cannot be demonstration, nor the beginning of science, science; and since, as we have said, there is no other kind of truth, intuition must be the beginning of science."

It is not necessary for our present purpose that we should discuss at length the origin of these "principles" referred to by Aristotle, or accurately enumerate them and point out their mutual relations. We shall have accomplished our purpose if we succeed in establishing the existence of a few of the more important, and in showing that if they are clearly apprehended by the mind at the outset, progress in science will be immeasurably quickened thereby.

The first and most evident prerequisite to the formation of a science is the existence of the scientist. In other words, a knowledge of one's own existence is the foundation and starting-point of all scientific knowledge.

The chief reason why a brute cannot form a science is because he does not have this knowledge. The most striking fact about him is that he does not reflect. He cannot hold his ideas up before himself and subject them to a critical examination. Until he can do this he cannot generalize or take the first step in the formation of a science. Possessed of a nervous organism, he experiences sensations, and oftentimes they are far more vivid and intense than those of man. The eagle, for example, can see more distant objects. A dolphin can hear more delicate sounds. Many other animals have a more highly developed sense of touch and smell. Some brutes can also remember their sensations and associate them together more distinctly and accurately than man. But no mere brute can ever separate himself from his sensations as a man can do and hold them up before himself for contemplation.

Furthermore, no brute can put like things together into a class—that is, form a general notion. Hence he has no language in the proper sense of that term. For language is the expression, or embodiment, of thought, and thought proper begins with the formation of general notions. It is for this reason that a brute cannot make or use a dictionary. For a dictionary is chiefly a collection of general terms. No others need to be defined or are capable of being so treated.

In common with all sentient beings a brute possesses consciousness, although it is difficult to tell exactly what consciousness is. It is a state or condition that is known only by being experienced, and is experienced by every being that has any kind of knowledge whatsoever. But no science can be formed without self-consciousness. A being must be able to distinguish himself from his experiences before he can use any of his own experiences or the experiences of others as data for a science.

It matters not from our present standpoint what may be our theories concerning the origin and nature of the conscious self. Whether we say, with Spinoza, that "the mind does not know itself except in so far as it perceives the ideas of the affections of the body," or with Kant that the ego is "a simple representation which in itself is totally void of contents," or with Hegel that the I "is the vacuum or receptacle for anything and everything; for which everything is, and which stores up everything for itself"; or even with John Stuart Mill that the mind is "a series, succession, or flow" of experiences "aware of itself." Nevertheless there comes a time in the development of every human being when he comes to himself, when, as the Germans say, "one clears himself up to himself."

This is the most important epoch in the experience of any human being. It at once separates him from all the rest of the animal creation. Before this time in his experience arrives, he manifests only the attributes of a brute, but when this stage in his development is reached, he finds himself endowed with the powers of a person, capable, in a way at least, of comprehending the universe. For the first time in his career he possesses the chief prerequisite of science—a knowledge of his own existence. Without this knowledge, he must forever remain in the condition of the brute, incapable of objectifying his ideas, and thus incapable of taking the first step towards the formation of a science.

Moreover, this knowledge of himself, which is the starting-point of all the endeavors of man after science, is not his own exclusive possession. He must allow the same kind of knowledge to all his fellows. Otherwise he could not communicate the results of his investigations to others or receive any aid from their observation and research. The words for I and he, me and him, are the most important in any language. Let the knowledge upon which this distinction rests be lost or beclouded, and we have either the drivelling idiot or the raving maniac. It is possible for a person to deny the reality of this knowledge, but in so doing he asserts the existence of the one who denies. In short, he commits intellectual suicide. As another expresses it, "all you can do for such a person is to give him a decent burial and pass on."

The next thing that every scientist must presuppose is the existence and validity of the laws of thought. At the very beginning of his investigations he must acknowledge their authority and power. Everything that collides with them he must reject, and everything that accords with their demands he must not call in question.

In order to avoid all misunderstanding on this point, we need to explain with some detail what is meant by the expression "laws of thought."

For both of the principal terms in the expression have been used with a great variety of meanings in the course of history. Descartes employs the word thought to designate "all that in us of which we are immediately conscious." "All the operations of the will," he says, "of the imagination and senses, are thoughts." He answers the question, What is a thing which thinks? by asserting: "It is a thing which doubts, understands, conceives, affirms, desires, wills, and does not will, which imagines also and feels." Locke takes a very broad view of the word when he says, "Though thinking be supposed ever so much the proper action of the soul, yet it is not necessary to suppose that it should be always thinking, always in action." Others employ the term to comprehend all our cognitive powers. But even this is a much more extended use of the term than it properly has in the phrase we have under consideration.

For thinking is not a synonym for knowing. It is possible for a person to have a great deal of knowledge and at the same time very few thoughts. Any act of the intellect is an act of knowledge. We know when we experience sensations, when we recall past experiences, when we associate ideas together, when we imagine, and the like, as truly as when we think. A thought is a species of knowledge. We think when we generalize what we have already acquired,—in more technical language, when we form concepts and put concepts together to form judgments and then bring judgments into such a relation to one another as to form a conclusion. To think is to reason, or to elaborate our past acquisitions. It always requires an act of comparison. Merely having an idea in consciousness does not necessarily imply that any logical process is going on. It is only when the mind is consciously expressing some relation between two or more objects that we have a thought.

A satisfactory view of the matter is taken by Sir William Hamilton when he says: "All thought is a comparison, a recognition of similarity or difference; a conjunction or disjunction; in other words, a synthesis or analysis of its objects. In conception, that is, in the formation of concepts (general notions), it compares, disjoins, or conjoins attributes; in an act of judgment, it compares, disjoins, or conjoins concepts; in reasoning, it compares, disjoins, or conjoins judgments. In each step of this process there is one essential element; to think, to compare, to conjoin or disjoin, it is necessary to recognize one thing through or under another; and therefore in defining thought proper, we may either define it as an act of comparison, or as a recognition of one notion as in or under another. It is in performing this act of thinking a thing under a general notion, that we are said to understand or comprehend it." It is therefore to an act of the understanding or logical power as distinguished from the other mental powers that we refer when we are speaking of the laws of thought.

The term law is perhaps as loosely used in popular language as the term thought. It has so wide and varied an application that it is difficult to give it a comprehensive definition. It is derived from an Anglo-Saxon verb meaning "to lay down," and thus its primary signification was, as Austin defines it, "a rule laid down for the guidance of an intelligent being by an intelligent being having power over him."

The broader view of law is given by Montesquieu. In the introduction to his *Spirit of Laws* he says: "Laws in their most extended signification are the necessary relations arising from the nature of things; and, in this sense, all beings have their laws, the Deity has his laws, the material world has its laws, superior intelligences have their laws, the beasts have their laws, and man has his laws."

A careful distinction should always be made between a law and a cause. It is true of causes that they exert force of some sort and may counteract or interfere with one another; but laws do not possess any power and do not accomplish any results. They are never efficient agents. They are, to be sure, closely related to energy or power, but in themselves they are impotent. They only tell us the way in which a cause acts or ought to act. A cause, on the other hand, cannot be thought of except in relation to an effect, and as the source or origin of that effect. A law is always some prescribed mode of action.

When we are talking about physical law, or the laws of nature, we always refer to some observed way or mode that physical energy has of conducting itself. It is the business of physical science to find out what these laws are, and state them with all possible accuracy. As no human being or collection of beings can ever observe all the ways of nature under all circumstances and conditions, these laws can never be regarded as anything more than approximate truths.

Civil law is a mode of action prescribed by the government for the guidance of its subjects. As the persons who make the statutes are fallible, and as the condition of the people may constantly change, such laws may require frequent alteration and some of them may even be set aside altogether.

But the laws of thought are not of this character. They are universal and unchangeable. Everybody who thinks at all must think in accordance with them if he thinks correctly. They are those self-evident truths that must be recognized as prior to all reasoning and thus to all science.

These laws of thought are commonly stated as four in number: the law of Identity, the law of Contradiction, the law of Excluded Middle, and the law of Sufficient Reason.

The law of identity is expressed by the affirmation that a thing is identical with itself. A is A. Whatever is, is. The proposition that animals are animals is an example of absolute identity, while the statement that animals are living beings is a case of relative identity.

The law of contradiction means that a thing cannot be affirmed to be what it is not. A thing cannot both be and not be. Dogs cannot both be animals and not be animals.

The law of excluded middle is that a thing must either be or not be. Of two contradictory propositions, one only can be true. If the proposition that dogs are animals is true, then the proposition that dogs are not animals is false.

The law of sufficient reason was first propounded by Leibnitz. It is that for every conclusion there must be an adequate ground. It does not have to do with the identity or non-identity of objects, but is fundamental in determining their connection. We must never affirm or infer the existence of any relation between things without a sufficient reason or ground for so doing.

Now all these laws exist before the formation of any science. They are not discovered by the study of any science. The moment one begins to form a science, he assumes their validity; and so long as he continues to carry on his investigations in a scientific manner, he proceeds on the basis of their truthfulness.

Furthermore, every scientist must recognize the fact at the very outset that the universe of which he is himself a part is rationally constructed. In other words, every scientific investigator sets himself to work on the assumption not only that he is himself so made that he can recognize and apply the laws of thought in his study of the universe, but also that the universe is itself so constructed as to be capable of rational comprehension.

If he did not take it for granted that his mind was rationally constructed and could, under the guidance of the laws of thought, detect fallacies in his own mental processes and the processes of others, he would never undertake the formation of a science. Nor would he undertake it if he did not assume that the universe is capable of being understood by the application of those laws. Otherwise all motive for scientific study would be wanting. The very idea of making the attempt to comprehend things scientifically would never enter the mind. Every human being would be as listless and indifferent to the nobler aspects of the universe about him as the brute.

It is by no means our purpose to attempt to describe all the *a priori* truths that the scientist assumes regarding the structure of the universe. Nor shall we undertake to show that those we do present are by their very nature ultimate and original. Even if some of them were capable of being resolved into others or were all of them reducible to one, it would in no wise affect the position that the reality and binding force of these truths must be recognized as preliminary to all science.

In the first place, all the objects that any science can deal with are related together as substances and attributes. It is only through the properties or attributes of things that we can get acquainted with their existence. But when we know attributes, we must know them as the attributes of something. They have no existence apart from the substances or beings that they manifest. The words attribute, quality, property, have no meaning by themselves. Every substance is something that manifests attributes, and every attribute or property is a mode of manifestation of a substance. Everything a scientist can study is a substance with its conjoined attributes.

In the second place, every science presupposes the fact that the universe is so constituted that every beginning or change of existence in it has a cause; no effect can be thought of apart from a cause. The only meaning the word effect can have is that which is produced by a cause, and the only meaning that the word cause can have is that which produces an effect. It may be difficult in a given case to tell what the cause of the known effect is, or it may have a multitude of causes, but it must have at least one. Every object that can be scientifically considered must be regarded as either an effect or a cause.

Every scientist also presupposes that the universe he studies exists in space and time. It is impossible to think of a single event taking place or a succession of events transpiring without time. The knowledge of a period necessitates and implies the knowledge of time as past, present, and future. Being the condition of all sequence, it is the condition of all activity, mental or physical.

In the same way it is impossible to think of motion without space. A knowledge of bodies occupying a place implies a knowledge of space as of the three dimensions—length, breadth, and thickness. It is the primary condition of the existence of bodies and of movement from place to place.

All arithmetical and geometrical computations depend upon the existence of space and time, and could not be made without them. It is for this reason that mathematics has such a prominent place in every scheme of modern science. Its processes are made the model of all scientific investigation. No physical forces could be measured without mathematics, and all such expressions as the law of gravitation, the laws of falling bodies, of chemical affinity, of heat, light, electricity, and the like, would have no meaning if they could not be formulated in the terms of mathematics, which in all its ramifications is simply different forms or aspects of space and time.

Every scientist still further assumes that the universe is regulated and controlled by design, that all the objects and powers in the universe are adapted to certain ends. The thought of design in the ongoings of nature is not artificially produced by us. It is a conviction that spontaneously arises whenever we begin to subject the objects of nature to a critical examination.

The intelligence that the study of the universe reveals cannot be a blind intelligence. Such an expression is a contradiction in terms. The moment the mind begins to see the order that reigns in nature it must assert that this order exists for some intelligible end, and when we think of nature as a whole we cannot help regarding it as made up of interacting powers and activities constituting one complete system. No sane man can think of the separate forces of the universe as fashioned to subvert and destroy its unity, but to sustain and promote it.

"Naturalists," says Professor Fisher, "whatever be their theory as to final causes, cannot describe plants and animals without constantly using language which implies an intention as revealed in their structure. The 'provisions' of nature, the 'purpose of an organ,' the possession of a part 'in order that' something may be done or averted,—such phraseology is not only common, it is almost unavoidable."

Lord Kelvin, whom many regard as the greatest living master of natural science, closed his inaugural address as President of the British Association for the Advancement of Science with these words: "Overpoweringly strong proofs of intelligent and benevolent design lie around us. And if ever perplexities, whether metaphysical or scientific, turn us away from them for a time, they come back upon us with irresistible force, showing to us through nature the influence of a free will, and teaching us that all living things depend on one everlasting Creator and Ruler."

Finally every scientist presupposes that the universe is so constructed as to be consistent with itself. This is what the phrase uniformity of nature means when properly interpreted. It does not imply that the future will always resemble the past. Even the sun will not always rise every twenty-four hours forever, nor has it always done so in the past. No two leaves or faces have been exactly alike or ever will be. Nature, so far from being uniform in this sense, presents an infinite variety of products. But in all this variety it is always true that like causes have produced and will always produce like effects. In more exact terms, the same complexus of causes must always and everywhere produce the same effect. If the circumstances and substances are the same, the same effects will result from the same causes. This truth concerning nature is assumed by every scientific investigator. He implicitly rests in the assurance that, whatever be the changes in the actual succession of events, the same sequence of effects will invariably follow wherever and whenever the same complexus of causes has an opportunity to act.

Besides the three fundamental truths already described,—his own existence, the existence and validity of the laws of thought, and the rational structure of the universe,—every scientist must still further take for granted that the universe is the product of mind and not of blind chance. The reign of law in the cosmos that every science assumes necessitates an intelligible principle of co-ordination, and an intelligible principle of co-ordination cannot be anything else than a product of intelligence. The reason why the scientist regards the cosmos as comprehensible by thought is because it is the product of thought. In assuming law as the clew to guide him through the labyrinth of phenomena, he assumes the existence of a power that ordains the law, and as all law implies a preconceived plan of action, the power that ordains the law must be a rational power. If we found caprice and confusion everywhere, we should be obliged to abandon our innate conviction of the existence of a rational Creator of the universe. For no one learns by experience how to believe, but how to disbelieve. Chaos and confusion show only the absence of mind, but order and system reveal its controlling presence.

This is what the late Professor Green of Oxford meant, in part at least, when he insisted that the cosmos is a spiritual cosmos, implying and revealing an eternal consciousness. The knowledge that every human being has of self is the primary fact of all his knowledge. And the moment he attempts to explain this self as self-conscious, self-reflecting, self-objectifying, self-distinguishing from the cosmos of which it is a part, he is compelled to regard the universe to which he is related as one organically connected whole, as the product and manifestation of an eternal and universal mind.

In another way Le Conte has well brought out and emphasized this prerequisite of science in his work on *Evolution and its Relation to Religious Thought.* In justifying Agassiz for rejecting the doctrine of evolution as it was presented in his day with all its atheistic implications, he writes as follows: "Will some one say the genuine truth-seeker follows where she seems to lead whatever be the consequences? Yes, whatever be the consequences to oneself, to one's opinions, prejudices, theories, philosophies, but not to still more certain truth. Now to Agassiz, as to all genuine thinkers, the existence of God, like our own existence, is more certain than any scientific theory, than anything can possibly be made by proof. From his standpoint, therefore, he was right in rejecting evolution as conflicting with still more certain truth. The mistake that he made was in imagining that there was any such conflict at all."

This leads us to the next assumption of science, namely, that the human mind is, in some respects at least, a reflex of the divine. It was no mere play of fancy, but a spontaneous and rational conviction that led Kepler, as the three great laws for which he had been laboring unceasingly for years first dawned upon his mind, to exclaim: "O God! I think thy thoughts after thee!" When our greatest thinkers assert that all scientific arrangement and classification is simply an attempt to interpret the thoughts of the Creator, they have in mind this assumption of all science that the human mind by discovery can acquaint itself in some degree with the divine mind in creation. The fact that so many of the elements and powers and laws of the universe have already been brought to light, shows that the human intellect is so akin to the divine that it can read, to some extent at least, in the things that are made, the plans and purposes of the Infinite.

"The most sagacious questioner of nature," says an eminent philosopher, "is the man who takes the wisest views of her indication by appropriate signs of her economy in the use of given forces, of her adaptation to the ends of harmony, beauty, and perhaps of beneficence. He is the wisest interpreter of nature, who through nature has entered most intimately into the thoughts of God."

Another prerequisite to an intelligent pursuit of science is the recognition of the fact that the primary data of science are not furnished by science itself, but by the mind's own intuitive powers. Before science can classify and systematize, it must have material upon which to work. All this material in its elemental form is obtained by the mind without reasoning, or any act of thought, but by an immediate beholding. All sensations are results in consciousness that are immediately apprehended by the mind without any other mental acts. The objects of the external world that we come to know through these sensations furnish the material for the physical scientist. And the immediate knowledge that the mind has of itself, and its acts and states, furnishes the elemental subject-matter of other departments of science.

While it is true that thought can create new combinations of the realities already immediately known, it cannot put into its creations any new elements not so known. Thought enlarges our knowledge by making it more definite, distinct, and orderly. It also assists to the discovery of new properties and laws by inducing from known effects or deducing from known causes. It invents instruments to aid the senses, and guides and stimulates our intuitive powers. It greatly extends our knowledge by the formation of general notions and language. From the ideas of space and time it develops the whole of mathematics in all its manifold forms, measuring not only the action of molecules, but even the orbits of planets and suns. Yet notwithstanding its marvellous transforming and elaborating power, Dr. Samuel Harris is right in affirming that "reflection or thought gives no elemental object of knowledge. The objects about which we can think are all first given in intuition." With this truth we need also constantly to associate the fact that "beings, their qualities, differences, and relations, are not known from the logical concepts of thought; the logical concepts are formed from the knowledge of beings."

Finally, every student of science starts out with the presupposition that the realm of science is coincident with the realm of reflective thought. All the powers of the mind are commonly considered under three general heads: the Intellect, or the mind regarded as capable of knowing; the Susceptibility, or the mind regarded as capable of feeling and emotion; and the Will, or the mind regarded as capable of volition and choice.

It is clear that science has to do only with the first of these powers. But even then a further analysis is necessary in order accurately to determine the field of science. The intellectual powers may be subdivided with sufficient exactness for our present purpose into those for acquiring material about which to think, those for reproducing the material acquired, and those for elaborating this material into the different forms of thought.

In acquiring the materials of knowledge we are said to do it by sense-perception, which is the mind's power for gaining a knowledge of the objects of the material world through the medium of the senses; by simple intuition, which is the power of the mind for immediately beholding its own acts and states; and by rational intuition, which is the mind immediately beholding universal and necessary truth.

We have already emphasized the fact that the acquisition of material is one of the prerequisites of science, not its own proper field of investigation. But the material acquired would be of little use to us if it could not be retained. And even if it were retained it would still be of slight value if it could not be reproduced and recognized. This power of memory, like the power of original acquisition, is also one of the prerequisites to science. "Without it," says another, "observation and experiment can ascertain no fact, reasoning can reach no conclusion, experience can accumulate no knowledge; for knowledge of this moment would vanish irrecoverably in the next."

Still, acquiring, retaining, reproducing, and recognizing objects of knowledge is not science. They are acts of mind that precede science. Science begins when the mind takes these objects and attempts to put them together into a system in obedience to the laws of thought. Before reflection lays hold of these objects that memory brings up to view, they repose, as it were, in consciousness as so much indeterminate matter. Then the mind turns itself back upon these objects and accurately examines them. It takes the material already presented and discerns more definitely what it is. It does not thereby create any new realities or relations, but simply notes with greater exactness those at hand. This is the first act in the formation of a science as well as the first act of reflective thought.

The next thing done by the mind is rightly called an act of differentiation. This is an act of reflection in which the mind discriminates the object it has carefully apprehended from other objects in the nebulous mass of simple representation. This element of differentiation or discrimination is so conspicuous in every act of thought that some writers, such as Hamilton and Ulrici, speak of it as the only element. It is as prominent in the formation of a science as the act of definite and distinct apprehension, and just as indispensable to its successful pursuit.

The final act in a complete process of thought is an act of integration. By this act the mind puts the objects that have been accurately apprehended and discriminated into their real relations as a whole. It integrates or unifies them. Unless this is done the process of reflection is incomplete and partial. No result is arrived at that can be expressed in a definite proposition. So it is in science. All the classes that are formed out of the objects taken into consideration must be put together into a system before we can have a science. Without this act of integration all our efforts fall short of the realization of a science. Thought fails of fruition because it has not been carried to its required limit. Whatever acts of the mind are not concerned with this process of accurate examination, discrimination, and integration, are not acts of thought, and therefore are not within the sphere of science. All error in thinking or reasoning arises from the failure adequately to discern the exact character and condition of the objects given, or from confounding them with some other objects from which they differ, or from placing them together in false relations. In the same manner, errors are made in the construction of a science. And just as thought may pass beyond the primary data given in acquisition, and in accordance with the laws of thought infer the existence and nature of new but similar realities, so science may induce the existence and nature of new causes or deduce the reality of new effects.

The truth that we have attempted to illustrate and enforce in the foregoing enumeration of some of the more important presuppositions of science is well brought out by Alexander Winchell. In an able article in the *North American Review* (vol. 130) on "The Metaphysics of Science" he summarizes the matter as follows: "All the fundamental conceptions of science—self, substance, cause, force, life, order, law, purpose, relation, unity, identity, continuity, evolution, natural selection, species, genus, order, class—are purely metaphysical concepts or ideas."

When we attempt to arrange the facts of matter or mind into a system, these ideas are assumed at the very outset. They alone render possible an intelligent interpretation of the universe and enable us with some degree of exactness to show how the different parts of the cosmos are built up into a consistent and coherent whole.

In urging attention to these ideas, it has not been our purpose to call in question in any way the authority and value of scientific knowledge, but merely to emphasize and make clear and vivid the fact that the authority of science is not in itself. All its laws and generalizations derive their validity from the ulterior truths which they assume and upon which they rest.

CHAPTER III

THE SCIENTIFIC METHOD

IT is probably the chief merit of the logical writings of John Stuart Mill that he pointed out with great clearness the entire insufficiency of the Baconian conception of the method of science. For Bacon, while doing a great service in turning the minds of men away from mere notions to the observation of concrete realities in their bearing upon the needs of practical life, advocated what might well be called the bookkeeping method for the study of science. He protested with the greatest vigor against "anticipating" nature, and would in point of fact confine all scientific investigation essentially to the summing up of actually observed facts.

For two centuries Bacon's *Novum Organum* completely displaced the so-called *Organum* of Aristotle, which was universally supposed to be entirely unequal to the demands of modern research. It must be admitted, however, that Mill fully vindicated his position that Bacon's conception of the scientific method is radically defective, and that science has not proceeded and does not proceed according to his view.

In fact we are now coming to see that the revolt against Aristotle has been carried to an unjustifiable extreme and that the true position is much nearer than many have supposed to that of the ancient Stagirite.

The two great methods of science in our day, as in

Aristotle's, are known as the inductive method and the deductive method. The former is often called the method of discovery, the latter the method of instruction, inasmuch as the one has especially to do with the acquisition of knowledge and the other is chiefly employed in imparting to others the knowledge acquired. But the two methods are not wholly independent of each other. In reality they are frequently blended or employed alternately in the pursuit of science. It is no exaggeration to say that all the more important and extensive investigations of science rely as much upon the one as upon the other. No so-called inductive science can make much progress unless it is capable of constant deductive application. "However useful may be empirical knowledge," says Jevons, "it is yet of slight importance compared with the well-connected and perfectly explained body of knowledge which constitutes an advanced and deductive science. It is in fact in proportion as a science becomes deductive, and enables us to grasp more and more apparently unconnected facts under the same law, that it becomes perfect."

The true form of all reasoning is the syllogism with its major and minor premises and conclusion. It may not always be necessary to express an argument in the form of a syllogism, but it must always be thrown into this form when scientific accuracy is required. Principal Campbell, in his *Philosophy of Rhetoric*, takes exception to this position and holds that the syllogism is only one of the possible forms of reasoning, there being others which in many cases, he thinks, are greatly to be preferred to it. His error consists in confounding reasoning with the association of ideas and with other mental processes to which it is allied, and also in assuming that the failure to state a premise in words is equivalent to its non-existence.

Equally faulty is the statement of Mill, who claims that the syllogism is no form of reasoning at all. "It must be granted," he says, "that in every syllogism, considered as an argument to prove the conclusion, there is a *petitio principii*." His criticism is not that the conclusion must be contained in the premises, for that everybody admits, but that the conclusion must be known to be true before the major premise can be established, and inasmuch as it is not so known, it must be begged in the major at the very outset. He fails to observe that the minor premise in a true syllogism is a new truth not known to the one forming the major. Hence by putting the two premises together the arguer gets some addition to his knowledge which has the same degree of certainty about it and no more than the general statements have that are used for his premises.

To illustrate. The information comes to me that all on board the *City of Paris* went to the bottom. Afterwards I learn that John Smith was on board the *City of Paris*. I do not in any way beg the question when by using these two statements as the premises of a syllogism I draw the conclusion that John Smith went to the bottom.

Mill is in further error in holding that all reasoning consists in arguing from the known to the wholly unknown. In deduction we may reason from the known to the partially known as truly as from the known to the unknown. We argue to the known when the conclusion is an actually known fact, but not seen in all its relations to general principles, until those relations are definitely pointed out; and to the unknown, when the conclusion, though implied in the premises, is not realized by the reasoner or the hearer until fully enunciated. The major premise of a deductive syllogism may be a universal principle, like an axiom of mathematics, or a generalization from concrete facts, but in either case the way of reasoning about it is the type of all true reasoning. The variety of forms the syllogism may assume are fully elaborated in any good text-book on formal logic. It is sufficient for our purpose to have pointed out its fundamental character and to call attention to the fact that it plays an essential part in the formation of a science.

The other process employed in the pursuit of science, in some respects in contrast with this deductive process, is, as we have already intimated, induction, or the process of passing from particular facts to general. But, as we shall see later, the process is never independent of deduction, and as a matter of fact is not a wholly distinct mode of inference.

The term induction is used by writers on the subject in at least three different senses. This accounts for the fact that while there is little or no disagreement among thinkers about the nature and place of deduction there is often a great deal of controversy over the sphere and proper function of induction.

In the first place, induction may be used to designate the old Socratic method of attaining definitions. This consists simply in enumerating all the particulars of a class. It is what we now call a perfect induction and, although it is in the form of reasoning, it is not reasoning at all. The following illustration will make this apparent. Sunday has twenty-four hours, Monday has twenty-four hours, and so do Tuesday, Wednesday, Thursday, Friday, and Saturday. But Sunday, Monday, Tuesday, Wednesday, Thursday, Friday, and

Saturday are all the days of the week. Therefore all the days of the week have twenty-four hours. Here the phrase "all the days of the week" is merely a device to avoid repeating each of the days. No new thought is expressed by the so-called conclusion. If it means all the days of the week taken together have twenty-four hours, it is evidently not true. Nothing is inferred here, and consequently there is no reasoning whatever. All we have done is to solve a simple problem in addition and to state the result.

Of course this process in many ways is of great value in science as well as in common life. For without it we could never make a comprehensive statement on any subject, but would always be obliged to enumerate every particular. After examining, for example, all the books in the Astor Library, and finding them printed on paper, we should be unable to say, "All the books in the Astor Library are printed on paper," but would always have to take the time to mention each individual book whenever we wished to acquaint another with that fact. Nevertheless, it is not a reasoning process and should have no place when we are considering what there is besides deduction that has to do with such a process.

The second meaning given to induction is any process of adding to our knowledge. It was Bacon's chief objection to the Aristotelian logic that its premises were all taken for granted. It could never, in his opinion, in any way increase our knowledge. He therefore asked the question, How do we obtain our knowledge and how do we progress in it? The answer to the question he called induction, and as contrasted with the old method the term took on the meaning of any process that adds anything to what we already know at any given time. But this view of induction is too broad, just as the first view is too narrow. It includes every other mode of acquiring knowledge as well as inference, while the first view excludes reasoning altogether.

The third and more rational definition of induction is ~~the~~ process of thought by which we pass from particulars to generals, or from effects to their causes. It is only in this sense that it can in any way be brought in contrast with deduction as one of the essential methods employed in the pursuit of science.

The chief preliminary step to this inductive process is of course the acquisition of the particulars. This is done by the two processes of observation and experiment. While they form no part of induction properly so called, we need to point out with clearness the manner in which they condition inductive inference. Observation means to note, to watch for, and is simply another name for perception and introspection. It furnishes the mind with all its primary facts. Observation is of two kinds, spontaneous and voluntary. The latter requires an act of attention and is of much more value than the former to the progress of science.

The old astronomy was chiefly the product of observation. By simply observing the motions of the sun, the moon, and the planets among the fixed stars, many of the laws of those bodies were gradually brought to sight. The geologist, the zoölogist, and the botanist are chiefly observers when they examine the rocks, the animals, and the plants as they are met with in the ordinary conditions of nature, without attempting to vary or change those conditions. The value and amount of one's knowledge depend chiefly upon the accuracy of one's observations. And a good observer will discover far more data for scientific use than one who is not.

Still no positive rules can be given for making a good observer. It is an art which can be acquired only by practice and training. The early study of language and mathematics, as well as the natural sciences, is one of the chief ways of disciplining this power. A caution of much value urged by Mill on this subject is to discriminate accurately between what we really do observe and what we only infer from the facts observed. Jevons in reiterating and illustrating the importance of this caution adds: "It is not too much to say that nine tenths of what we seem to see and hear is inferred, not really felt."

In regard to all our knowledge through the senses it is well to bear in mind that we know with certainty only that we experience sensations and that there is a cause for the sensations. The endeavor to find out what the cause is, is always a matter of inference. For example, when a person affirms that he hears a child's voice, all he really hears is a sound. That the sound is a voice and that the voice is the voice of a child are not perceptions but inferences.

Experiment is observation plus altered conditions. When astronomers began to climb mountains, go up in balloons, and the like, they began to experiment. It is not, like observation, preliminary to all induction, but a great help in varying and multiplying observations and thus artificially increasing the data for inductive inference. As another well expresses it: "In observation we *find* our instance in nature; in experiments we *make* it by an artificial arrangement of circumstances. When, as in astronomy, we endeavor to ascertain causes by simply watching their effects, we *observe;* when, as in our laboratories, we interfere arbitrarily with the causes or circumstances of a phenomenon, we are said to *experiment.*"

No reliance should be put upon the statement of a careless or impatient observer. Nor is anything more important in observation and experiment than freedom from prejudice. Because "men mark when they hit and never mark when they miss," as Bacon puts it, it has come about that there are far more false facts in the world than false theories. It is no exaggeration to say, with Sir William Hamilton, that "facts, observation, induction, have been the watchwords of those who have dealt most exclusively in fiction." The saying is as ancient as Demosthenes that what we wish, that we believe; what we expect, that we find. He who does not keep himself free from prejudice can almost always find facts to support any opinion he may choose to advocate, however far removed it may be from the actual truth.

The first great step in induction proper is the forming of the hypothesis. This may briefly be defined as a supposition. It is a guess, or conjecture, as to what the general fact is which includes the given particular facts, or what the cause is which has brought about the given effect. The term is sometimes contrasted with the term theory as though the two were necessarily distinct, an hypothesis being regarded as a mere possibility, while a theory is called a verified hypothesis. But this view is largely an arbitrary one, as the terms are often used interchangeably. Professor Hyslop, in his *Elements of Logic*, has well elaborated this point. "We speak indifferently," he says, "of the 'Darwinian hypothesis' and the 'Darwinian theory,' the 'nebular hypothesis' and the 'nebular theory.' Also we say 'undulatory theory,' of light and sound, but never 'hypothesis,' although the conception is precisely that of a conjecture, or supposition, awaiting satisfactory verification."

Allowing that the term theory has a broader meaning than the term hypothesis when it is applied to a number of related ideas brought together to represent a system of truths, he continues: "But their actual interchangeability in many crucial and important instances, and the fact that they both represent an inductive process having indistinguishable degrees of probability, are sufficiently cogent arguments for making them identical in all essential features, and so using one of them for describing the whole process incident to the attainment of new conceptions which require verification."

What, then, is the process that the mind goes through in forming its hypothesis? How did Newton proceed in solving the motions of the solar system, or Sir Humphrey Davy in the discovery of potassium? In other words, what are the grounds of any successful invention or conjecture?

Some might reply to this question that the ability to read the secrets of nature is purely a gift of nature. To describe or analyze its methods is quite beyond our powers. While this is in part a true position, still there are certain conditions which, if conformed to, will materially help to develop the skill and tact that are requisite to success in this very important phase of the inductive process.

In the first place, special attention should be given to the facts already known. They alone can suggest the unknown. It would be folly for any man to expect to make a new discovery in a realm of facts to which he had given little or no attention and with the peculiarities of which he had put forth no endeavor to make himself especially familiar. A botanist cannot hope to advance the science of psychology, or a chemist the science of geometry. Newton made himself thoroughly familiar with the known facts of the celestial universe long before he was in a position to anticipate the theory of universal gravitation, and Davy had all the chemical knowledge of his day clearly in mind before he surmised that he could bring one of the most brilliant of metals out of such ungainly stuff as common potash. Always and everywhere it is from an accurate acquainttance with the known that we rise to a knowledge of the unknown.

Another condition of the successful formation of hypotheses is special attention to the relations of facts. For the purposes of science these relations are all important. The great discoveries in every department of science are usually due to the apprehension of some relations heretofore overlooked. Men differ greatly in the facility with which they can lay hold of these relations ; one sees similarities and dissimilarities where another sees none at all. While largely a matter of original aptitudes, ability in this direction is also capable of large cultivation. It is often most rapidly developed where the emergencies of the case require the most energetic exertion of one's powers. The adage that necessity is the mother of invention is based upon this fact.

A third condition of a successful hypothesis is a special insight into the peculiar methods employed in any given sphere of scientific inquiry. The devotee of any special science must thoroughly familiarize himself with the ways of nature that are most characteristic of that science. He must learn by daily experience what are nature's favorite methods in his chosen field of study. The physicist, the biologist, and the psychologist will anticipate the correct interpretation of the unknown in their respective spheres, other things being equal, only in proportion as they are familiar not alone with the objects and relations, but also with the methods that most intimately concern their special fields of research.

The hypothesis when once formed is always the product of the constructive imagination. All previous acts are simply by way of gathering material for the imagination to rearrange and recombine into a new creation. In a certain sense the mind takes a leap into the dark. It literally passes *per saltum* from the realm of the known into the realm of the unknown. From all the material that the memory places at its command it makes a guess, or conjecture, as to what will best meet all the exigencies of the situation.

A seemingly trivial event may sometimes arouse the imagination into activity and be the occasion for a great discovery. The Marquis of Worcester, it is said, incidentally observing the rise and fall of the cover of a tea-kettle, began a course of speculations which resulted in giving to the world our present knowledge of the nature and uses of steam. But it was his previous knowledge of science and intimate personal acquaintance with all the special facts connected with the operations of the agent in question that alone enabled him to conjecture the real significance of an every-day phenomenon which had been known for centuries.

The only way by which we can finally decide which of all the various suppositions suggested by the imagination is the true one, is by the process of verification which will be described later. Nevertheless, there are certain approximate rules which should be observed by every one engaged in scientific study for determining at the outset the respective degree of probability of the several different hypotheses that may be suggested by a given set of facts. In some cases the circumstances give so great a degree of probability to some one hypothesis that even a verification is scarcely necessary. But usually the situation is not so clear, and any injunctions that will help to a wise decision should be duly appreciated.

Some of these are the following :

1. No hypothesis should be regarded as probable that is inconsistent with the laws of nature and of mind already established. A supposition in physical science should not be entertained that is irreconcilable with the simple laws of motion, with the conservation of energy, or with the fundamental laws of light and sound. For these are doctrines already verified beyond reasonable doubt, and must be set aside before we can rationally entertain their contradictories. So with the primary facts of consciousness and the laws of thought.

Almost any hypothesis not inconsistent with these fundamental truths may under some circumstances be taken into consideration. The very limits of conceivability, so to speak, may be transcended, if it will lead to an explanation of the facts. The undulatory theory of light requires us to assert that empty space is everywhere filled with "something immensely more solid and elastic than steel," which unceasingly exerts a pressure of over sixteen billion pounds to every square inch, and also that we are constantly passing through this something without experiencing the slightest perceptible resistance. Yet it is one of the most indispensable and most probable theories of modern physical science.

2. No hypothesis should be accepted as probably a true one that leaves out of consideration any of the facts. Jevons makes conformity with observed facts the sole and sufficient test of a true hypothesis. It is rather one of the tests than the sole and sufficient one. For it sometimes happens that several hypotheses equally account for the given facts, and some other data must be taken into consideration in order to decide between them. Yet a single absolute conflict between a fact and an hypothesis destroys the hypothesis at the outset. Here the old saying, *falsa in uno, falsa in omnibus*, has a literal application. This is not the same as asserting that a theory must be freed from all apparent inconsistencies before it can be entertained. For some of the grandest and most firmly established generalizations of science are beset with them. Nevertheless, one experiment of the finger-post, one *experimentum crucis*, is fatal to the most plausible hypothesis. There was nothing inherently absurd or inconceivable about Descartes's theory of vortices, but the one fact that comets, "the most flimsy of bodies," pass on their way through them in elliptical orbits was enough to explode it. The entire insufficiency of the corpuscular or Newtonian theory of light was established by the simple fact that light moves more slowly in a dense refracting medium than in a rarer one, although the theory at the time it was promulgated seemed to explain all the other observed facts. The Ptolemaic theory of the heavens, based on the notion that the sun moves round the earth, had to give way when Galileo, in 1610, through his extemporized telescope, beheld

phases in Venus and afterwards observed like phenomena in Mercury. Ever since Pascal had his barometer carried to the top of Puy-de-Dome, which is perhaps the first *experimentum crucis* on record, the most elaborate hypotheses have been at once set aside because of conflict with a single observed fact.

3. No hypothesis should be entertained that will not allow of sure and ready deduction. If no conclusions could be formed from an hypothesis it could never be verified, and an hypothesis that could not be verified would be of no use whatever. For it is of value only as it explains observed facts. Even if we could imagine an hypothesis wholly out of accord with known facts, it would be an idle and fruitless waste of mental energy to do so. The whole inductive process would be brought to a standstill after the first step if no inference could be made from an hypothesis.

The only reason for making the hypothesis at all is that we may pass on to the completion of our inference and obtain some practical results, and if an assumed hypothesis did not have sufficient likeness to already ascertained truths to admit of a comparison with them, no advance whatever would be made in our knowledge.

Jevons has well illustrated this truth by reference to the hypothesis of the so-called ether. "If this ether," he says, "were wholly different from anything else known to us, we should in vain try to reason about it. We must apply to it at least the laws of motion, that is, we must so far liken it to matter ; and as, when applying those laws to the elastic medium, air, we are able to infer the phenomena of sound, so by arguing in a similar manner concerning ether, we are able to infer the existence of light phenomena corresponding to what do occur. All that we do is to take an elastic substance, increase its elasticity immensely, and denude it of gravity and some other properties of matter, but we must retain sufficient likeness to matter to allow of deductive calculations."

Of hypotheses in general, we may say that all attempts to establish a new hypothesis are to be abandoned, if hypotheses already in existence equally well explain all the facts. We have no right whatever to introduce a new hypothesis unless we have some facts that are new and unaccounted for, or unless the known effects are only in part explained by existing causes.

Nor should we claim for a new hypothesis more than the facts will bear. For example, protection is often appealed to as the cause of industrial prosperity, and the matter is discussed as though it was the sole cause. While it may under some conditions be a cause, it is illogical to claim without further investigation that other causes may not be equally potent to that end. Or again, if a country that has adopted free trade becomes rich and prosperous, we have no right to assert, *a priori*, so to speak, that the prosperity was due solely to such a policy. It might have prospered in spite of free trade.

Then, too, in our endeavor to find an hypothesis to explain our facts we should be careful not to undervalue the facts or ignore their true character. As Victor Cousin somewhere remarks, in trying to explain facts we should be careful not to explain the facts away. It is wiser by far to keep an old hypothesis than to adopt a new one at such a sacrifice.

Yet it is as true in regard to hypotheses as it is in many other similar matters, that a poor hypothesis is better than none at all. The reason why the alchemists added so little to our knowledge, though laboring indefatigably for centuries, was that they had no theory by which to work. Their discoveries were of the haphazard sort, unconnected with any rational plan or purpose. Unless we have some theory to guide our experiments, a great many important details are likely to be passed over unnoticed. The astronomer Bessel regretted exceedingly that he had no distinct hypothesis regarding the constitution of comets when he made his observations of Halley's comet in 1808. Even if the hypothesis be confuted, the confutation will involve the accumulation of much valuable material for future use.

The next step in the inductive process after the selection of the probable hypothesis is the deduction of consequences. This involves, when the act is fully analyzed, the creation of a deductive syllogism with the selected hypothesis as the major premise and finding what the conclusion would be if the chosen hypothesis were regarded as an established truth.

The nature of this deductive process has already been explained and does not need to be dwelt upon here. A single and very simple illustration of its application in this inductive act of passing from particulars to generals will suffice. Supposing that one had observed that every dog, A, B, C, D, etc., he met delighted to bark, and had imagined the hypothesis that every dog delights to bark. In determining the consequences of such a position he would form a deductive argument as follows: All dogs delight to bark. The dog A belongs to the class of dogs; therefore, the dog A delights to bark. As complete a deduction of consequences as the conditions would allow would require as many syllogisms as there were particular facts at the outset.

We pass next to the third step in the inductive process, namely, the comparison of the conclusions or consequences arrived at by assuming the hypothesis to be true, with all the facts attainable that have to do with the matter under investigation. When Newton, with whose name the true scientific method, the method of hypotheses, has come to be especially associated, first conjectured his law of universal gravitation, he saw that if the hypothesis were actually true the moon must fall toward the earth just as rapidly as a stone would fall under the same circumstances. But, according to the best information then attainable, it fell much slower. Newton's love of verification was so great that, owing to this supposed fact, he "laid aside at that time any further thoughts of this matter."

It was not till some fourteen years later, having obtained more exact data as to the distance of the moon, which enabled him to correct the discrepancy, that he again took up the subject. But this was to him only the beginning of a long course of deductive calculations, each ending with its appropriate verification.

A more detailed exposition of the different ways of verifying inductive inferences may properly be made, under the following heads: observation, experiment, the inductive canons, and prediction.

When observation is used in verification, it is of course under different conditions than when used in acquisition. After an hypothesis has once been made, observation helps to determine whether or not the expectation has been realized. If I have argued from observations in one locality that certain diseases come from the use of putrid water, I am greatly confirmed in my belief if I observe that the same diseases exist in other localities under the same conditions. If the conditions under which the hypothesis was first made are simple and isolated, a very few observations may raise the probability of an hypothesis to the highest attainable proof.

Experiment in verification, like experiment in acquisition, is only a modified form of observation. But it is far more important in verification than observation can be. For it often involves the reproduction of phenomena under conditions that only occasionally exist in nature, or else at times and places where they cannot be successfully examined. Sir David Brewster's well-known experiment to show that the colors seen upon mother-of-pearl are not caused by the nature of the substance, but by the form of the surface, is an excellent example of verification by this method. He took impressions of the mother-of-pearl in wax and found that, although the substance was entirely different, the colors were exactly the same. It was also found that any material with similar grooves upon its surface would also show these iridescent colors, thus raising the proof of the conjecture almost to a certainty.

Inasmuch as experiment frequently enables us to eliminate conditions unfavorable to the occurrence of a phenomenon, it is often employed where simple observation could have no application at all. It is largely for this reason that it is so widely used in all the sciences, but especially in those where artificial conditions are almost absolutely essential to any progress.

Whatever may be said about the five so-called canons of induction laid down by Mill as furnishing the grounds of the hypothesis, they can certainly be used as a means for its verification. They act in the latter capacity when they show that the recurrence of the phenomenon under the conditions assumed in each of these respective methods coincides with what the hypothesis requires.

The first of these is called the method of agreement. It may be briefly expressed by saying that the sole invariable antecedent of any fact or event is probably its cause. Suppose after a few observations with reference to certain particular cases I had formed the conjecture that typhoid fever was due to the presence in the system of certain kinds of bacteria. If I should examine a great many other cases under many other conditions and in many other localities, and always find the same kind of germs present, it would be a case of verification by this method.

The second canon is called the method of difference. The antecedent that is invariably present when a given phenomenon is present, and always absent when it is absent, other conditions remaining unchanged, is probably its cause. An example of this method would be to verify the suggestion that friction is one of the causes of heat by noting that two sticks when rubbed together become heated and when not rubbed together do not become heated. The hypothesis might be still further verified by subjecting two pieces of iron or two cakes of ice to the same treatment and observing that they exhibit the same phenomena.

These two methods, of agreement and difference, as Mill has pointed out, are methods of elimination. "The Method of Agreement stands on the ground that whatever can be eliminated is not connected with the phenomenon by any law. The Method of Difference has for its foundation that whatever cannot be eliminated is connected with the phenomenon by a law."

The third canon is the joint method of agreement and difference. This method is chiefly a double employment of the method of agreement and a comparison of the results thus obtained. In this way it is assimilated with the method of difference. In attempting to verify the position that crystalline structure is one of the causes of the double refraction of light, we can easily produce the phenomenon by experimenting on any one of a number of substances known to possess that property. But if we take a piece of Iceland spar, for example, and endeavor to find out whether its crystalline structure is the property upon which this phenomenon depends, we cannot proceed by the method of difference. For no other known substance sufficiently resembles Iceland spar to make the comparison. We have to proceed, therefore, by the method of agreement. Taking all the known substances that doubly refract light, we find they are crystalline. And notwithstanding the fact that the reverse is not true, we are justified in holding that crystalline structure is one of the causes of the phenomenon in question.

The fourth of these canons is that of residues, which is another way of applying the method of difference. "It is by this process, in fact," says Sir John Herschel, "that science, in its present advanced state, is chiefly promoted. Most of the phenomena which nature presents are very complicated; and when the effects of all known causes are estimated with exactness, and subducted, the residual facts are constantly appearing in the form of phenomena altogether new, and leading to the most important conclusions." Astronomers verify their doctrine of the precession of the equinoxes by the method of residues as well as the aberration and mutation of the fixed stars. Catastrophists in geology support their hypothesis by alleging that after the effects of all causes now in existence are accounted for, a large number of residual facts remain that can be explained only on that basis. The existence and character of many of the new elements in chemistry have been proved in the same way.

The fifth and last canon is called by Mill the method of concomitant variations. This is in reality the method of difference applied under conditions where the variations of one phenomenon are constant and simultaneous with the variations in another. One of the ways of verifying the hypothesis that air is the cause of the transmission of sound, would be to strike a bell with a very little air in the receiver of the air-pump instead of striking it in a complete vacuum. We should then hear a very faint sound, which would increase or decrease every time we increased or decreased the density of the air. The cases of verification by this method are exceedingly numerous. One of the most remarkable is that which confirms the existence of a connection between the aurora borealis, magnetic storms, and spots on the sun. The magnetic storms that affect the compass needle, and the electric currents the telegraph wires, come to their worst every eleven years. The brilliance of the northern or southern lights reaches its maximum at the same time. The dark spots on the sun, which are gigantic storms on its surface, also increase in size and number at the same period. All these facts thus fully verify the hypothesis of a connection, though the mode of the connection is quite unknown.

Mill presents these five methods as canons of induction in the sense that they are the methods of discovery, but Dr. Whewell takes exception to this view in his *Philosophy of Discovery*, and affirms that " they take for granted the very thing which is most difficult to discover, the reduction of the phenomena to formulæ such as are here presented to us." Other eminent writers have also opposed their usefulness from the standpoint of discovery. We are here, however, insisting on their value solely from the standpoint of verification or proof. Very few oppose them from this point of view. Even Mill closes his discussion of the subject by saying: "But even if they were not methods of discovery, it would not be the less true that they are the sole methods of proof; and in that character, even the results of deduction are amenable to them."

Another extremely helpful mode of confirming the hypotheses of science is prediction. Auguste Comte goes so far as to affirm that "prevision is the test of true theory." It is rather one of the tests and that one which is most likely to attract general attention. The history of science from the earliest times is full of striking instances of the application of this test. Herodotus tells us that Thales, the Father of Philosophy, so successfully predicted an eclipse of the sun that he was able to bring to a peaceful and happy issue a violent battle between the Medes and Lydians that was raging at the time.

In a similar way, Columbus is said to have overawed the islanders of Jamaica who had refused to supply food for his men when in great need. His threat to deprive them of the moon's light was treated at first with indifference; but when the eclipse actually commenced, the barbarians vied with each other in the production of the necessary supplies.

Halley vindicated his theory concerning comets by predicting the return of the great comet of 1682 about the end of 1758 or beginning of 1759. It was actually detected on the night of Christmas day, 1758. On the basis of similar theories, Herschel was able to write of the planet Neptune some years before its discovery:

"We see it as Columbus saw America from the shores of Spain. Its movements have been felt trembling along the far-reaching line of our analysis with a certainty not far inferior to ocular demonstration."

Nowhere has prediction done more for a science than in the case of the undulatory and corpuscular theories of light. The former theory led to the discovery of many optical laws, the most difficult to detect and the most complex; the latter to almost none at all. "Even Newton," says Jevons, "could get no aid from his corpuscular theory in the invention of new experiments, and to his followers who embraced that theory we owe little or nothing in the science of light."

The place of prediction in all the sciences is perhaps not overstated by Dr. Joule when, in describing the remarkable mathematical investigations of his friend Professor James Thompson into the thermo-elastic qualities of metals and his other similar researches, he said: "To him especially do we owe the important advance which has been recently made to a new era in the history of science, when the famous philosophical system of Bacon will be to a great extent superseded, and when, instead of arriving at discovery by induction from experiment, we shall obtain our largest accessions of new facts by reasoning deductively from fundamental principles."

In concluding this brief outline of the scientific method, we should not fail duly to emphasize as one of its most important features what Dr. Francis E. Abbot calls the "consensus of the competent." After a new scientific law or theory has been discovered and verified by and for the individual thinker, an appeal should be taken to the experience and judgment of those whose opinions are entitled to respect to verify it for mankind. The most cautious and painstaking man of science may err in his observations and in his reasonings about those observations. Hence it is that the complete verification of any new hypothesis requires the co-operative action of many minds. Not until the new law or theory has received the final approval of those who have the ability and knowledge necessary to understand it should it be regarded as an established truth.

The appeal to the consensus of the competent lifts the scientific method up out of the realm of mere individualism into the realm of universal human knowledge, and, at the same time, emphasizes the important truth that intellectual co-operation, in the widest sense of that term, is essential to the elevation of any set of facts into the august position of a science.

CHAPTER IV

CERTAINTY AND PROBABILITY IN SCIENCE

IT is essential to any right understanding of the nature and sphere of science that we carefully discriminate between what is certain in our knowledge of the universe from what is probable.

Fleming, in briefly commenting upon these two realms of knowledge, says: "It should be observed that probability and certainty are two states of mind, and not two modes of reality. Probability has more or less of doubt, and admits of degrees; certainty excludes doubt, and admits neither of increase nor diminution."

When we can affirm without any room for contradiction the existence or non-existence of any being or phenomenon, the truth or falsity of any proposition, we are justified in saying that we have certain knowledge of it; anything short of this ought always to be called probable knowledge. The etymology of the two words certain and probable may help to make the distinction clear. Certain comes from *certus*, which means sure, unquestionable, not to be denied or doubted. Probable comes from *probabilis*, meaning provable, and hence includes everything which has to do with evidence or proof.

One of the criteria of certainty is self-evidence. A thing to be certain to me must reveal itself in its own light. If it requires any evidence to make it plainer, I have no right to call my knowledge of it certain.

The knowledge I have of my own existence is for this reason certain, but my knowledge of the character of Mary Queen of Scots is quite the opposite. Another criterion of certainty is the impossibility of believing the contrary. If I feel a pain, my knowledge of the fact is such that no amount of evidence could make me believe the opposite. In the same way, no one by the presentation of evidence could make me doubt that whatever is, is. For the proposition is not one where evidence can be applied.

A third criterion is the uselessness of all attempts to disprove it. Not being established by argument, it cannot be overthrown by argument. Things that are equal to the same thing are equal to each other, every effect must have a cause, are propositions that are certain to the mind that apprehends them, though they are by their very nature wholly incapable of proof. They are more certain, so to speak, than anything can possibly be made by proof.

A fourth test of certain knowledge might perhaps be added to those already given, namely, self-consistency. No two certainties ever collide. Our inferences from them may lead to conflict, but that is due to a misuse of the certainties and not to the certainties themselves.

Applying these criteria to the whole realm of human knowledge, it is not difficult to see that the nucleus of certainty in it is exceedingly small and the zone of probability exceedingly large.

At this point in our discussion we need also to note the distinction to be made between certain knowledge and belief. I certainly know a thing to be true when I have an immediate and complete knowledge of it. I believe a thing to be true when I fall short, however little, of such knowledge. That is to say, belief is simply imperfect knowledge. It is any kind of knowledge, in any sphere, that fails in any respect of being absolute. Inasmuch as it is knowledge based on testimony or proof, it is synonymous with probable knowledge and admits of doubt or degrees. Such a proposition as "all men must die" is a matter of belief or probability. For no one has observed but a few men in the past, and it is beyond our human powers to assert that all men in the future will go through that experience. We simply believe the proposition to be true in just the same way, and no other, as we might believe in a material heaven, or a mountain of gold, or the real existence of a centaur.

The nucleus of certainty includes only the facts and principles of direct intuition and the immediate inferences derived therefrom, while all other facts and all generalizations from facts lie within the zone of the probable. Only those sciences that are based on intuitively known truths, such as pure mathematics and logic, start with certain knowledge. But the moment we make any application of the axioms and rules of logic or mathematics to our concrete experience, we pass over into all the uncertainties of that experience, where our theoretic conditions never meet their full realization, and where the probability of our conclusions must ever vary with the probability of our premises.

All the lines and angles and circles of geometry, for example, are ideal objects. They are never met with in our actual experience. Hence all our arguments about the size and form of material bodies can lead only to approximate or probable results. The laws of deductive logic, however unquestioned they may be in themselves, when applied to the materials of our actual experience, can never relieve our conclusions of all the possible inaccuracies of that experience and give us perfect knowledge.

This is seen also in ethics viewed as a deductive science. Granting that the ground principle of this science is the intuitive truth that every rational creature ought to act rationally, when we attempt to decide what is rational under the ever varying conditions of life we can come to only a fallible conclusion. We must judge according to the probabilities in the case and abide by the consequences.

The diversity of opinions among men as to moral judgments is well accounted for by Epictetus when he says: "The same general principles are common to all men. . . . Where, then, arise the disputes? In adapting these principles to particular cases."

It is a curious fact that what has come to be commonly spoken of as "positive science" has, in reality, little if anything to do with positive knowledge, but is confined by its very nature to just the opposite sphere of thought. If we would only lay aside our unscientific prejudices and examine the matter with some care, we could not help acknowledging that the realm of the inductive sciences is the realm of probability only, and that all their generalizations, so far from being absolute truths, rest in the last resort upon the same logical basis as the guesses we make about the weather or in playing at a game of chance, never transcending in any case the limits of the probable.

Huxley, in his life of Hume, characterizes the grandest inductions known to us as "those generalizations of our present experience that we are pleased to call the laws of nature." Jevons puts it even more strongly when he declares in his *Principles of Science:* "I am convinced that it is impossible to expound the methods of induction in a sound manner without resting them upon the theory of probability. Perfect knowledge alone can give certainty, and in nature perfect knowledge would be infinite knowledge, which is clearly beyond our capacities."

The fundamental principle of the theory of probability that Jevons here refers to is, treat equals equally. It is well stated by Prof. T. W. Wright, in his work on *Adjustment of Observations*, as follows: "The probability of the occurrence of an event is represented by the fraction whose denominator is the number of possible occurrences, all of which are supposed to be independent of one another and equally likely to happen, whose numerator is the number of these occurrences favorable to the event in question. . . . If an event may happen in c ways and fail in d ways, all equally likely to happen, the probability of its happening is $\frac{c}{c+d}$ and of its failing $\frac{d}{c+d}$, certainty being represented by unity."

On the basis of this theory of probability, we try to measure the "quantity of our knowledge," or the degree of belief we should give to matters of which in the nature of the case we cannot have certain knowledge. As La Place says, the theory "is good sense reduced to calculation."

That probability is the basis upon which all inductions rest will best be shown by a few illustrations. Take, for example, the doctrine of the correlation of force. This induction assumes that in all the experiments that have been made with any given force the experimenters have always been able to change that force into some other kind of force; and on the basis of that assumption the conjecture is made that all kinds of force, those known to us and those unknown, can be changed into other kinds.

The law of gravitation is also an induction of the same sort. A few particles of matter have been examined and found to attract one another directly as the mass and inversely as the square of the distance. All other particles are assumed to be exactly like those examined, and we assert of all particles what we really know only of a few.

A good illustration of a more familiar class of inductions is the proposition, "Fire burns." From the alleged fact that this particular fire burned, and that particular fire burned, the conjecture is made that all fires are like those examined and will burn.

Now, of these and all similar generalizations we have no certain knowledge. All we know about them is that they are highly probable,—so probable under existing circumstances and with our present knowledge that it would be irrational not to accept them as true and not to act on the basis of their truthfulness.

That all inductions belong to the sphere of the probable clearly reveals itself when we examine the process of thought we go through in forming inductions. This has already been done in our discussion of the scientific method, and all we need here to do is to recall a few of its chief features.

Of course the first thing for us to do is to get our facts. For no one can do any thinking without first of all getting something to think about. And we must have more than one thing to think about before we can begin the process of forming an induction. Furthermore, the two or more things we have to think about must be like things. There would be no generalizing on any subject if objects were not similar. Then we must discover some way in which these like things may be bound together into one rational whole.

As a simple illustration of this process, let us take the observed fact that this magnet A attracts these particles of iron, and put it alongside of another observed fact that another magnet B also attracts other particles of iron. Suppose we have a half-dozen such facts. No collection of observed facts can ever give us a perfect generalization in any science. If we had observed a million magnets, we could never say on the basis of our observation and experiment that all magnets attract iron.

What we actually do is to take a leap in the dark. We plunge into the sea of the unknown. We make a guess that what is true of the magnets A, B, C, etc., that we have examined, is true also of all others. Then by an act of the imagination we combine what is known by observation and experiment with what we guess, and form the proposition: All magnets attract iron. This we make the major premise of a syllogism, and taking "This object A is a magnet" for the minor premise, and forming as many syllogisms as we have objects, we get for our conclusions the observed facts with which we started. We have thus completed our process of forming our induction and have done all we can do toward establishing its truthfulness.

We might, to be sure, examine a greater number of magnets, but only an infinite being can ever be sure he has examined them all, and so long as we remain finite our induction will remain simply a guess, or conjecture, with that degree of probability in its favor that comes from its binding together into one bundle all of the actually observed facts and from its harmonizing with other guesses already made on similar matters.

The example we have taken is typical of all inductions in physical science, and the process is one and the same for all. Both the nature of the induction itself and the process of forming it make it abundantly evident that the study of physical science can never give us any generalization that is more than probable, and that if we are ever to find any knowledge that is strictly positive, we must look for it elsewhere than in this kind of science.

But not only are all the generalizations of physical science probable only ; the same is true also of all its facts. When I say, I see the lamp, or hear the ticking of the clock, I can never be positively certain that I actually do either. For every assertion that I make concerning the nature of the objects external to me is an induction, and as all inductions are probable, these must be also. A little attention to the process of knowing through the senses will make this evident.

All I am positively certain of in the case of the lamp is that I experience a sensation of sight and that something external to me has aroused me to this experience. From all the data that I can gather on the subject I infer that the lamp is that "something." My inference may be wholly wrong. I never can be more than probably certain that I am right about it. If I learn that the judgments of others under the same circumstances coincide with my judgment, the probabilities that I am right increase. If they do not coincide, the probabilities diminish.

That is to say, every act of knowing through the senses gives us some probable knowledge of the external object said to be known. We know positively that we experience a sensation. We know positively that we who experience the sensation exist and that there is some cause of the sensation; but precisely what that cause is is an inference—an induction,—and we never can know positively that we have given a right answer to the question. Even though we could call in the aid of a hundred senses in addition to those we already possess, the possibility of error in judgment would not be removed thereby. Our knowledge would still remain probable, and could never become anything else except on the basis of our minds becoming infinite. Our senses never deceive us. The knowledge they may give us is good as far as it goes, although it never can be exhaustive knowledge. But our inferences from what the senses give us are always fallible, and can never go beyond the sphere of the probable.

Even the experiments of the laboratory, made with the most accurate instruments and under the most favorable conditions, are unable to give us absolutely certain results. There is always a possibility of a mistake being made in performing the experiment, and if we could be positively certain that no mistakes had been made in the given case, we could never be positively certain that any other case would be exactly like this case. Hence the result attained in any one experiment, or series of experiments, is only probably applicable to others that seem to be similar. Our inference transcends our data, if we treat it as more than probable.

Positively certain knowledge, as we have seen, is never a matter of proof or inference. It is always immediate, direct, intuitive. No amount of evidence can make a person disbelieve what he has positively known. No amount of evidence could ever persuade Professor Nicolai of Berlin, or Dr. Cogswell of New York, that they did not experience the sensations of sight and sound when they reported interviews with persons that they were afterwards convinced were never present. No one could have persuaded the witnesses in the London witchcraft trials that they did not experience the sensations of sight when they testified, it is said, to seeing the defendants taken up bodily to the roofs of dwellings by an invisible power and borne off in mid-air to places one and two miles distant.

The facts of physical science have none of the characteristics of positive knowledge. They are always mediate (obtained through the medium of the senses), indirect, and inferential. Our knowledge of them can never be more than probable, and the degree of confidence we should have in them ought ever to vary with the degree of their probability.

Of course there is nothing probable in nature itself. The probability is wholly in our minds. Nature is constructed on rational principles, and all that takes place in nature takes place according to those principles. All her operations are predetermined from the beginning. There is no such thing as chance in the universe. The Infinite Mind knows with absolute certainty the course of the lightning, the path of every falling leaf, and the exact position of every grain of sand and drop of water. But while there is nothing capricious about the ongoings of nature or any uncertainty about her facts, there is always a deficiency in our knowledge of those facts. To say of anything in nature that I am positively certain of its existence and qualities because I have seen it with mine own eyes and handled it with mine own hands, is to assume infallible powers and to let imagination take the place of scientific knowledge.

When we speak about our knowledge of a thing, we are talking about our mental condition with reference to that thing, and when we say that all our knowledge of physical science rests on the theory of probability, we do not mean to say that the theory measures what our belief is, but what it ought to be. Different people may vary greatly in their beliefs about the same event and at the same time. Some may never consciously think in accordance with the theory, and others may habitually hold to beliefs that are exactly opposite to what they would be if formed on the theory. But this does not collide with the statement that all the actual knowledge we possess on the subject is grounded on this theory.

Let us look at the matter for a moment from another standpoint and see how the view taken above is confirmed by the teachings of history. We think it easy to show that the great thinkers in physical science have proceeded on this theory and that the value of their discoveries to the world has been determined by the strictness with which they have adhered to it.

The Ptolemaic system of astronomy was accepted as the true system till Copernicus pointed out the probabilities against it and showed that another view of the matter far more consistently accounted for all the facts. He himself describes for us his mode of thought. After speaking of his study of the ancients on the subject, he continues: "Then I began to meditate concerning the motion of the earth, and though it appeared an absurd opinion, yet since I knew that in previous times others had been allowed the privilege of feigning what circles they chose in order to explain the phenomena, I conceived that I also might take the liberty of trying whether, on the supposition of the earth's motion, it was possible to find better explanations than the ancient ones of the revolutions of the celestial orbs."

It cannot be doubted but that Copernicus would have heartily endorsed what has recently been said of his theory by a careful thinker: "Though this is perhaps of all sciences the best attested by observation, yet the Copernican theory of the earth's motion cannot be asserted as the absolute truth of knowledge, but only as the highest attainable probability hitherto offered to faith. The theory accounts for so many phenomena, it is confirmed by such a multitude of observations, and reduces the unsolved difficulties to such a minimum, that there remains no reasonable ground of doubt that the earth revolves upon its axis and moves round the sun."

La Place, the great apostle of the theory of probability, avowedly constructed the nebular hypothesis upon the theory and amassed a multitude of facts in its favor, though the objections urged by Lockyer and others in our day,—that it does not adequately account for comets and the light they emit in such a rare cold fluid, that no nebula is actually known to revolve on an axis or to emit heat, that heat radiating from a centre would tend to form a current causing the cooler external surface to fall toward the centre, not away from it,—these and like considerations have diminished, perhaps, the probabilities of its truthfulness, at least in its original form.

It is said that Kepler tried nineteen or twenty different hypotheses, and worked for years in testing them, before he came to the one that gives us his three laws. Rejecting one after another according as he found the balance of probabilities for or against it, he came at last upon the one that seemed to him to account for all the then known facts.

Sir Isaac Newton, taking the results attained by

Kepler and observing the fact that the power of gravity does not sensibly diminish either at the tops of the loftiest buildings or on the summits of the highest mountains, at once began to argue that it probably extended much higher. "Why not as high as the moon?" said he to himself; "and, if so, her motion may be influenced by it; perhaps she is retained in her orbit thereby." This "if so" and "perhaps" led to the discovery of the law which made him famous, though the law is to-day in some quarters being seriously called in question.

Perhaps no man in modern times has done more for the progress of physical science than Charles Darwin, and where do we find a more perfect example of the application of the theory of probabilities than in the argument for *The Descent of Man* and *The Origin of Species?* Would not the thinker in physical science who should attempt in our day to proceed on any other theory fail at once to command the respect and confidence of his fellows?

What we have found to be true of the sciences already referred to is equally true of all the inductive sciences, but is most strikingly manifested perhaps in the science of theology. As in all other departments of knowledge, all theological generalizations are matters of high or low degree of probability, to be accepted or rejected as the balance of probability is for or against them. In other words, the degree of confidence we are justified in having in such generalizations is determined by the degree of their probable truthfulness.

Great thinkers, from Thales and Plato and Moses, in almost every age of the world and almost every clime, have had their theologies, and many of them have been of extraordinary merit. But even Paul himself could never have been more than probably certain that his explanation was the true one. Of the three great systems of theology presented in the New Testament, some prefer that of Paul, some find the Petrine theology more to their liking, while others adhere to that of John. Who can tell which is the absolutely true one, or whether any one is wholly true, or whether they are not all equally distant from the absolute truth? Who can give us more than a probable answer to these questions?

The Apostles' Creed contains perhaps the sum and substance of all three, but no assertion in it transcends the realm of the probable. A brief examination of the creed itself will make this apparent. It begins with the statement: "I believe in God, the Father Almighty, Maker of heaven and earth." Now the existence of the Absolute back of nature and all finite being, like one's own existence, is a matter of positive certainty, but any assertion concerning the nature of that Absolute, since it is an induction from probable facts, can never be more than probable. When we say, therefore, with the creed, that God is the Father Almighty, Maker of heaven and earth, we are asserting something about the nature of the Supreme Being of which no man can be more than probably certain. The degree of confidence we are justified in having in this statement depends on the degree of its probable truthfulness.

Take, again, the statement of the creed concerning the nature and mission of Jesus: "And in Jesus Christ his only Son our Lord; who was conceived by the Holy Ghost, born of the Virgin Mary; suffered under Pontius Pilate, was crucified, dead, and buried; he descended into hell; the third day he rose from the dead; he ascended into heaven, and sitteth on the right hand of God the Father Almighty; from thence he shall come to judge the quick and the dead."

Whether there ever existed on the earth such a person as Jesus, and what he experienced, are purely matters of historical evidence. And as everything that is a matter of evidence is a matter of probability, this must be also. We can never be absolutely certain that those who wrote his history were really acquainted with the facts of his life, or have honestly represented them, or that their testimony, after being once recorded, has not been so frequently and radically altered as to give us to-day, in some respects, an erroneous conception of the truth. Even if we regard the record as it stands as veritable history, the doctrine of the actual divinity of Jesus, that he was in reality Son of God as well as Son of man, is an induction from certain alleged facts, and can, therefore, never be established beyond all possible doubt.

The creed closes with the affirmation: "I believe in the Holy Ghost; the Holy Catholic Church; the communion of saints; the forgiveness of sins; the resurrection of the body; and the life everlasting."

The writer of this passage, from the data that he had before him, simply drew the conclusion that the arguments in favor of these propositions were far stronger than those against them, and accordingly he was ready to say concerning them, as he does say in the statement itself, "I believe"—not, "I am absolutely certain of their truthfulness."

But it makes no difference to the matter in hand from what source he obtained his information. We will grant, for the sake of the argument, that he got it from the Scriptures. But even if we allow that every word in Scripture came directly from the lips of the Almighty, no man could ever be more than probably certain that he correctly heard the words when they were uttered, or correctly wrote them down, or correctly understood them after they were written, either by themselves or in their mutual relations. There is always room for possible doubt concerning any of these assertions; and all that the profoundest thinker can do for them is to establish their probable truthfulness.

What we have said concerning the so-called Apostles' Creed applies with equal force and validity to every creed in Christendom and to every system of theology ever published, however elaborately constructed or however dogmatically expressed. The most certain of their generalizations are probable and probable only, and those who teach them are never justified in urging their acceptance upon others on any other ground. The only theology that has any basis for its existence is an inductive theology; and just as "all inductions in physical science are only probable," so they are in theological science also.

It is perhaps the strongest argument in favor of the view taken above of the element of probability in science that it is abundantly confirmed by the conduct of men in all the affairs of life, from those that seem to be most trivial and insignificant up to those attended by the most momentous results. Buckminster puts it none too strongly when he says: "The whole life of man is a perpetual comparison of evidence and a balancing of probabilities." And Archbishop Butler voices the same sentiment when he affirms that "probability is the very guide of life."

In fact, there is exceedingly little that we know or do in any sphere that is not based on the theory of probability. We eat bread on the probabilities that it will nourish us; we drink water on the probabilities that it will quench our thirst; we seek the shade in summer on the probabilities that it will cool us; we build a fire in winter on the probabilities that it will keep us warm; we buy shoes on the probabilities that we can wear them; we build a house on the probabilities that we can use it for a dwelling; we start on a journey on the probabilities that we can reach our destination; we take medicine when we are sick on the probabilities that it will help us; we go to school on the probabilities that there is something to learn; we read our Bibles on the probabilities that they tell us the truth; we rely on our friends on the probabilities that they will not betray us; we confide in our parents on the probabilities that our well-being is also their own chief concern; and we trust in God on the probabilities that "he is both so wise that he cannot be mistaken, and also so honest that he cannot deceive."

The conclusion of the whole matter is this, that it is never necessary, in fact, that it is never possible, to do more for any doctrine in any department of inquiry than to show that the balance of probabilities is in its favor. When we have shown that, we have made the doctrine worthy of credence, we are entirely justified in accepting it as a truth and adopting it as a rule of conduct.

He who says of any generalization in any sphere of thought that he will not accept it as true until he is absolutely certain of it, literally does not know enough to eat when he is hungry, or to drink when he is thirsty. The conduct of an ordinary idiot would put him to the blush. As John Locke so tersely puts it: "He that will not stir until he infallibly knows that the business he goes about will succeed, will have but little else to do but to sit still and perish."

Every man, because he is a man, is endowed with powers for forming judgments, and he is placed in this world to develop and apply those powers to all the objects with which he comes in contact. In every sphere of investigation he should begin with doubt, and the student will make the most rapid progress who has acquired the art of doubting well. But doubt is simply a means to an end, not an end in itself. We begin with doubt in order that we may not end with it. To continue to doubt after the material for forming a judgment is before the mind, is a sign of weakness. The man who does it commits a crime against his own intellect and deserves neither recognition nor respect.

The only claim that any science has for a hearing is its reasonableness. If this can be shown we are bound to accept it and act upon its teachings until we see good reason for setting them aside. But the only way to establish this reasonableness scientifically is to carefully weigh the arguments for every doctrine, accepting or rejecting each assertion according as the balance of probabilities is for or against it. It is only as we thoroughly "test all things" that we can ever learn how to "hold fast to that which is good."

Prof. William Rice, the distinguished New England geologist, very fittingly closes one of the most important chapters in his recent excellent work on *Twenty-five Years of Scientific Progress* with these words: "From the clear recognition of the extremely narrow limits within which certitude is attainable, we may learn the rationality and the wisdom of acting upon beliefs which are merely probable, and acting with an earnestness proportionate to the importance of the interests involved. We may learn to walk by faith more steadily by perceiving that in this universe in which we live only he who is willing to walk by faith can walk at all."

CHAPTER V

THE USE OF THE IMAGINATION IN SCIENCE

TO such an extent does imagination enter into the daily life of man and permeate all his thinking, that Sir William Hamilton in his famous *Lectures on Metaphysics* closes a learned analysis of the nature and functions of this power with this statement: "The happiness and misery of every individual of mankind depend almost exclusively on the particular character of his habitual associations, and the relative kind and intensity of his imagination. It is much less what we actually are, and what we actually possess, than what we imagine ourselves to be and have, that is decisive of our existence and fortune. . . . The present is the only time in which we never actually live; we live either in the future or in the past; so long as we have a future to anticipate, we contemn the present; and when we can no longer look forward to a future, we revert and spend our existence in the past."

Washington Irving, writing in *The Sketch-Book* from a somewhat different point of view, says of this same power: "It is the divine attribute of the imagination that it is irrepressible, unconfinable; that when the real world is shut out, it can create a world for itself, and with a necromantic power can conjure up glorious shapes and forms, and brilliant visions to make solitude populous and irradiate the gloom of the dungeon."

It is hardly necessary to remind the reader of Shakespeare's famous lines on the imagination in *A Midsummer Night's Dream:*

> "The lunatic, the lover, and the poet
> Are of imagination all compact,
> . . . .
> And, as imagination bodies forth
> The forms of things unknown, the poet's pen
> Turns them to shapes, and gives to airy nothing
> A local habitation and a name."

With these varied aspects of the imagination before us, we are prepared to raise the question, What can such a power have to do with science? If science consists of facts carefully ascertained, thoroughly verified, and logically arranged into a system, what place can there be in it for the exercise of so unique a faculty? The answer to this question may at least be suggested by an extract or two from Professor Tyndall's famous lecture on "The Scientific Use of the Imagination," published not long ago, in part, in his *Fragments of Science*.

"There are tories," he says, "even in science who regard imagination as a faculty to be feared and avoided rather than employed. They had observed its action in weak vessels, and were unduly impressed by its disasters. But they might with equal justice point to exploded boilers as an argument against the use of steam. Bounded and conditioned by co-operant Reason, imagination becomes the mightiest instrument of the physical discoverer."

"Newton's passage from a falling apple to a falling moon was, at the outset, a leap of the imagination. When William Thomson tries to place the ultimate particles of matter between his compass-points, and to apply to them a scale of millimetres, he is powerfully aided by this faculty, and in much that has been recently said about protoplasm and life, we have the outgoings of the imagination guided and controlled by the known analogies of science. In fact, without this power, our knowledge of nature would be a mere tabulation of co-existences and sequences. We should still believe in the succession of day and night, of summer and winter; but the soul of force would be dislodged from our universe; causal relations would disappear, and with them that science which is now binding the parts of nature to an organic whole."

Among the many concrete illustrations that he gives of the use of the imagination in science, he has much to say about Sir John Herschel's conjectures regarding the density and weight of comets. "Now suppose," he says, "the whole of this stuff [the comet in question being 100,000,000 miles in length and 50,000 miles in diameter] to be swept together and suitably compressed, what do you suppose its volume would be? Sir John Herschel would probably tell you that the whole mass might be carted away at a single effort by one of your dray-horses. In fact, I do not know that he would require more than a small fraction of a horse-power to remove the cometary dust.

"After this you will hardly regard as monstrous a notion I have sometimes entertained concerning the quantity of matter in our sky. . . . I have sometimes thought that a lady's portmanteau would contain it all. I have thought that even a gentleman's portmanteau—possibly his snuff-box—might take it in. And whether the actual sky be capable of this amount of condensation or not, I entertain no doubt that a sky quite as vast as ours, and as good in appearance, could be formed from a quantity of matter which might be held in the hollow of the hand."

But Professor Tyndall's discussion of the uses of the imagination in science is hardly a satisfactory one. A more logical and concise presentation of the subject requires that we determine with greater exactness what the sphere and functions of the imagination really are. There is no better way of doing this than to contrast the imagination with some of the other mental powers from which it is to be distinguished, but with which it is closely allied. A great amount of intellectual confusion will easily be avoided thereby.

And naturally the first power to attract our attention in this contrast will be perception. For every thoughtful person must allow that all our knowledge begins with experience and with our experience of the external world. In other words, that our senses furnish us with our first materials of thought. We have no good reason for doubting the proposition that if our bodily powers were dormant our minds would be also. Now in this act of gaining a knowledge of things through the senses imagination plays a most important part.

When I affirm that I see an apple, all that is actually present is a few sensations—possibly only those connected with sight. The rest of the perception is supplied by the mind. All the other sensations, such as those of touch, taste, smell, and the like, that might have been experienced through other senses, are brought in by the imagination and made a part of the object perceived. That is to say, in every act of knowing anything through the senses the mind idealizes the object known. And it is this idealized object that is reproduced by memory when the mind wishes to put any of its past acquisitions to future use.

In the next place, imagination is not to be confounded with intuition. It is not one of the powers for acquiring the primary materials about which we think. Intuition is such a power, and from the point of view of acquisition the most important power with which any being can be endowed. But the function of the imagination is to create ideals. The material for the ideals must come to it from other sources. No blind man can ever imagine what it is to see, and no deaf man can ever picture to himself what it is to hear. Nor can we imagine a disembodied spirit or a rational creature endowed with mental powers wholly different from any that we ourselves possess. Yet we can divide and combine the parts of the material things with which we are acquainted into any number of new existences, and can connect a spirit with almost any kind or form of matter from a grain of sand up to the most distant planet or star.

In the third place, imagination is not memory. There could be no exercise of the imagination without memory, but memory might act without the exercise of imagination. Memory is the mind's power for reproducing past experiences. It has to reknow the past experience and relocalize it in the place and time of the original experience. Imagination takes these past experiences furnished by the memory and puts them together into new forms. While memory is thus clearly indispensable to imagination, it leads to great inaccuracy and confusion of thought to hold that memory is simply one of its modes or manifestations.

Nor is imagination to be confused with fancy. Both, to be sure, are related in the same way to memory. For both have past experiences for the material upon which they work. But fancy takes these experiences and lets them combine themselves, as it were, into all sorts of grotesque and haphazard relations. Imagination, on the other hand, endeavors to put them together so as to express some rational plan or purpose.

When Dugald Stewart describes fancy as "imagination at a lower point of excitement—not dealing with passion, or creating character," he takes an extremely unsatisfactory view of both powers. For it is by no means an essential feature of imagination that it should have to do with passion. Nor does it create character alone. Its function is to create ideals, and to create them for a reasonable end and in accordance with the laws of nature and thought. The fancy, on the other hand, does not manifest any conscious rational purpose. It is especially active in dreams and reveries, and largely predominates in the daily life of the child and the savage.

Wordsworth's attempt to set forth the distinction between these two powers, though full of suggestion, is almost equally a failure. "Fancy," he says, "is given to quicken and beguile the temporary part of our nature, imagination to incite and support the eternal." But the real distinction is one that concerns the way of using the material that each has at its disposal rather than the part of our nature affected thereby. If Hume had properly noted the true distinction between imagination and fancy he never would have expressed the sentiment that "nothing is more dangerous to reason than the flights of imagination, and nothing has been the occasion of more mistakes among philosophers. Men of bright fancies may, in this respect, be compared to those angels whom the Scriptures represent as covering their eyes with their wings." He is here really writing of fancy only, and should have used the word throughout the passage. Then the sentiment would undoubtedly have been a rational one. But if imagination proper is meant, nothing could be farther removed from the actual truth. If we would only observe the distinction made in almost all foreign languages between these two powers, we should have little trouble. No German, for example, ever confounds *Einbildungskraft* with *Phantasie*.

Furthermore, imagination is to be carefully distinguished from the mind's power for forming logical conceptions and judgments. Imagination has to do with concrete objects, conception with objects of thought. The things we imagine are always individual, as some particular man or tree, while the things we logically conceive are abstract and general, as man or tree. Products of the imagination may, to some extent at least, be represented by some definite object outside the mind that imagines them, but a conception has no such existence. The judgment that man is an animal is a union of two conceptions, both of which are logical abstractions only and are not to be regarded as concrete realities.

The philosopher Reid, using conception in the broadest sense as equivalent to thought proper, very fittingly concludes his elaboration of the difference between logical conceptions and products of the imagination as follows: "I can conceive a thing that is impossible, but I cannot distinctly imagine a thing that is impossible. I can conceive a proposition or a demonstration, but I cannot imagine either. I can conceive understanding and will, virtue and vice, and other attributes of mind, but I cannot imagine them. In like manner, I can distinctly conceive universals, but I cannot imagine them."

Notwithstanding the necessity and importance of this distinction to all clear thinking, Herbert Spencer ignores it. For he asserts explicitly that "to think a thing as possible is the same as to imagine it." The error injuriously affects his whole system of philosophy and obliges him to posit ability to be imagined as the criterion of all knowledge, and thus to limit knowledge to one only of the great spheres of human investigation and research.

Enough has now been said concerning the relation of imagination to some of the other mental powers for us to see that while it must always depend on memory for its resources, it does not use its material capriciously, but combines it together for the expression of some reasonable end or purpose; that although it is excluded from the sphere of abstract thinking, technically so called, it may extend its activity over the whole universe of known concrete existences and put them into any rational relation or form.

It is for this reason that the imagination is the dominant factor in human progress in every department of inquiry or thought. The master minds in all ages and in all spheres have ever been men of great imaginative powers. This is no less true of Plato, Aristotle, and Kant; of Faraday, Newton, and Charles Darwin, than of Homer and Shakespeare, Mozart and Beethoven, Raphael and Michael Angelo.

It matters not whether it be in mental science or physical science, literature or art, no man has ever been prominent as a leader and inspirer of his race who did not possess in an unusual degree the ability to take the material of past experience and create out of it new forms and adapt it to new uses.

Right here is the chief distinction between genius and talent. Genius implies a high and peculiar gift for new combinations and discoveries. Talent involves a special aptitude for specific employments, or for carrying out certain proposed plans or ends. Genius requires first of all a highly developed imagination, and oftentimes seems to attain its ends as if by magic. Talent depends more upon training and the perfect control of all one's powers. Hence we speak of a genius for art or science and a talent for business or politics. Men of talent exist in almost every land and age, while whole centuries have elapsed without the appearance of a single man of genius. In the realm of science men of talent are, so to speak, hewers of wood and drawers of water. They incessantly bring into the storehouse treasures new and old. But only a genius can rightly estimate the value of these treasures and show mankind how to devote them to the attainment of high and noble ends.

Applying now some of the distinctions made above to the pursuit of science, it is not difficult to see, in the first place, that there is no room in science for men of fancy. While the indulgence of the power may be allowable under some conditions as a pastime, no reliance can be placed upon its products. Its existence and operations may almost be called the bane of science.

In the second place, we see that important as perception and memory are for acquiring and treasuring up the materials of science, no structure can actually be formed out of this material unless the imagination first comes in and supplies the framework. Hence it is that only men of strong imaginations have ever been masters in science. For only such men have been able to furnish the rational hypotheses that are essential to its formation at the outset and its continuous advancement after it is once formed. The world has always had multitudes of men who could fill notebooks with innumerable scientific facts and arrange endless tables of statistics, but it is not by such work alone or chiefly that we rise to great discoveries. Men of highly developed powers of observation and good memories abound in every land. Nor are persons of great deductive ability for reasoning out in detail the results of some previous discovery few in numbers or difficult to find. These all have their place, to be sure, and often nobly fulfil their mission, but it is only when some creative genius appears that the great strides are made in science.

"Advances in knowledge," says Whewell, in his *Philosophy of the Inductive Sciences*, "are not commonly made without the previous exercise of some boldness and licence in guessing. The discovery of new truths requires, undoubtedly, minds careful and scrupulous in examining what is suggested; but it requires, no less, such as are quick and fertile in suggesting. What is invention except the talent of rapidly calling before us the many possibilities and selecting the appropriate one? It is true that when we have rejected all the inadmissible suppositions they are often quickly forgotten, and few think it necessary to dwell on these discarded hypotheses, and on the process by which they were condemned. But all who discover truth must have reasoned upon many errors to obtain each truth; every accepted doctrine must have been one chosen out of many candidates."

The truthfulness of this view is abundantly confirmed by the whole course of science, but nowhere do better illustrations of it occur than at its very outset.

Physical science as well as mental had its origin among the inventive and acute intellects of the Greeks. The other nations of their time had practically no theories and did not feel the need of any. But the Grecian mind from the earliest times manifested a strong desire to find out the causes of things. An interesting confirmation of this statement is found in the different theories concerning the overflow of the Nile that Herodotus describes in his histories as current among his contemporaries. "Some of the Greeks," he says, "who wish to be considered great philosophers have propounded three ways of accounting for these floods." He then proceeds to a critical examination of these "ways," and concludes with the advocacy of a way of his own. We have here, in all probability, one of the first recorded attempts at the formation of a science.

The Greeks were the first great discoverers of the race because they were far more highly endowed than any other people with great imaginative powers. What they saw excited these powers and urged them to conjecture, to reason about things, and try to explain their nature and cause.

The true theory on the subject of acoustics was guessed, though somewhat vaguely of course, by these early investigators, at least as far back as the time of Aristotle. In his treatise *On Sound and Hearing* he says: "Sound takes place when bodies strike the air, not by the air having a form impressed upon it, as some think, but by its being moved in a corresponding manner. . . . For when the breath falls upon and strikes the air which is next it, the air is carried forwards with an impetus, and that which is contiguous to the first is carried onwards; so that the same voice spreads every way as far as the motion of the air takes place."

And in another treatise describing the origin of an echo, he says: "An echo takes place when the air, being as one body in consequence of the vessel which bounds it, and being prevented from being thrust forwards, is reflected back like a ball." It only required that these conjectures should be distinctly verified and traced to mechanical principles to form a genuine science. Hence the work of modern students of this science has been more largely the solving of suggested problems than the discovery of original causes and laws.

The first sound knowledge on the subject of mechanics was contributed by Archimedes in a work still extant; and so fully did he elaborate his notions concerning the lever that the science remained absolutely stationary for nearly two thousand years. "No single step," says Whewell, "was made in addition to the propositions established by Archimedes, till the time of Galileo and Stevinus." He also laid the foundations of hydrostatics and solved its principal problem. His hypothesis concerning fluidity, which he states at the beginning of his *Treatise on Floating Bodies*, furnishes the groundwork for the whole science of hydrostatics in its most modern form.

Euclid was the first to conjecture the true law concerning the reflection of light. In his *Treatise on Optics* he argues in favor of the doctrine that all light is carried in straight lines as follows: "The greatest proof of this is shadows, and the bright spots which are produced by light coming through windows and cracks, and which could not be except the rays of the sun were carried in straight lines. So in fires, the shadows are greater than the bodies if the fire be small, but less than the bodies if the fire be greater."

His supposition that the rays passed from the eye to the object in vision instead of the reverse is not to be wondered at. For all the mathematical conclusions are the same whichever proposition is assumed to be the true one.

The story that Pythagoras accidentally discovered the groundwork of the science of harmonics while passing near a blacksmith's shop and listening to the sound of the hammers as they struck the anvil, may be entirely a philosophical fable, but his hypothesis that the notes of strings have a definite relation to the forces which stretch them is still a fundamental idea in the theory of musical chords and discords.

While it is quite uncertain whether, as some assert, Anaximander, a pupil of Thales, taught that the earth was round and suspended in mid-heavens, yet in the time of Aristotle many had surmised the doctrine. In his *De Cœlo* Aristotle expressly asserts: "As to the figure of the earth, it must necessarily be spherical." And after arguing at length in support of the proposition he concludes: "Wherefore we may judge that those persons who connect the region in the neighborhood of the pillars of Hercules with that towards India, and who assert that in this way the sea is one, do not assert things very improbable." In another passage he argues the matter still further and adds: "The mathematicians, who try to calculate the measure of the circumference, make it amount to 400,000 stadia; whence we collect that the earth is not only spherical, but is not large compared with the magnitude of the other stars."

But it was in their theory of epicycles and eccentrics that the Greeks made an epoch in the history of astronomy. The other unimaginative nations of their day were content to refer the motions of the planets to cycles of time ; and this was enough to enable them to determine with considerable accuracy their re-occurrence. But the inventive Greeks felt themselves compelled to form an hypothesis that would account for all the complex movements of the heavenly bodies. Venus, for example, was observed to move generally west to east. But at certain intervals she retrograded a little, and for a short time remained stationary. Then she turned again and started on her direct course westward. The Greeks pictured this operation to themselves by putting Venus in the rim of a wheel turned edgewise, the centre of which was turning round in the heavens from west to east, while the wheel itself was revolving round its own centre. This would give to the planet somewhat the same motion that a torch would have if a person should run with it turning himself round. A mechanism of this sort was imagined for each planet, and to each of these wheels was given the name epicycle.

Afterwards the hypothesis of eccentrics was added to account for the apparently irregular motions of the heavenly bodies, and the hypothesis thus modified was so fully elaborated by Hipparchus and was so abundantly confirmed by all the known facts of that day that Ptolemy did little more than develop and extend it in his *Almagest*. Even Copernicus adopted it without essential modification. "We must confess," he says, "that the celestial motions are circular, or compounded of several circles ; since their inequalities observe a fixed law and recur in value at certain intervals, which could not be, except they were circular ; for a circle alone can make that which has been, recur again." It may fairly be maintained that the Hipparchian theory has never been entirely set aside. In its essential features it has been taken up and incorporated into every succeeding system, and still constitutes one of the most important parts of our modern astronomical knowledge.

The two theories concerning the nature of matter devised by the ancient Greeks have continued to attract the attention of thinkers to the present day. The one theory holds that matter is infinitely divisible. However small may be the parts into which you divide any portion of it, it is still to be regarded as capable of further division, and so on without limit.

The other theory maintains that matter is only finitely divisible, that a point may be reached in the division when it will be impossible to proceed farther. The ultimate particle thus obtained is to be thought of as being a real unity, and not being composed of parts it is called an atom.

The chemical atomic theory elaborated by Dalton is closely allied to this theory. If the doctrine of the identity of chemical and physical atoms be allowed, the similarity of the two theories is very striking.

If we should pass from the physical to the mental and moral sciences we would find that the Greeks were there also marvellously prolific in original theories and ideas. Aristotle was not only the father of logic, but also of empirical psychology and the science of rights. And as to philosophy, it will always remain essentially a Grecian product.

But enough of their work has been pointed out to show that they were the first great originators of science, and that the part imagination played in their products had chiefly to do with making them so pre-eminent. Their skill in conjecturing new theories and explanations was the one characteristic that more than any other distinguished them from the other nations of antiquity before and after them. All the unimaginative Romans could do was to copy them. In fact, the Romans always acknowledged their inferiority to their teachers, for they possessed but little of the Grecian inventive and systematizing spirit.

What Whewell says of the Arabian astronomy is largely true of all science after the time Greece reached its climax: "During the interval of thirteen hundred and fifty years (from Ptolemy, A.D. 150, to Copernicus, A.D. 1500) the principal cultivators of astronomy were Arabians, who adopted this science from the Greeks whom they conquered, and from whom the conquerors of Western Europe again received back their treasure, when the love of science and the capacity for it had been awakened in their minds. In the intervening time the precious deposit had undergone little change. The Arab astronomer had been the scrupulous but unprofitable servant, who kept his talent without apparent danger of loss, but also without prospect of increase."

The long and barren period which intervened between the scientific activity of ancient Greece and that of modern Europe has well been called the Stationary Period of science. During this period discovery came to a standstill chiefly because the creative power was forced into the background. The leaders of the day depended almost exclusively upon memory and the deductions they could make from what it furnished. They, therefore, contented themselves with reproducing and re-expounding the doctrines of those who had gone before them. This naturally led to an extreme unwillingness to entertain new opinions or to tolerate any form of dissent. By merely repeating the terms of science and accepting its doctrines purely as a matter of tradition and not of individual conviction, they soon lost their power to apprehend its truths with any clearness or vigor. And consequently, when they undertook to expound the knowledge that the great discoverers before them had brought to light they almost invariably distorted it if they did not lose sight of it altogether. It should always be borne in mind that a mere collection of opinions is relatively of little importance to the progress of science. For, as has been well said by another, "a multiplication of statements of what has been said in no degree teaches us what is. Such accumulations of individual notions, however vast and varied, do not make up one distinct idea. On the contrary, the habit of dwelling upon the verbal expressions of the views of other persons and of being content with such an apprehension of doctrines as a transient notice can give us, is fatal to firm and clear thought."

This stationary period in science was the period of abstracts, epitomes, natural histories, and biographies. Commentators and critics took the place of original investigators, and scholars abounded instead of great discoverers and men of science. It is the function of the commentator to develop, not to create. He does not search for new truth, nor does he attempt to render a productive service. His end is accomplished if he elucidates the obscurities and technicalities of his author and supplies the missing steps in his reasoning. Hence it very naturally happens that he soon comes to overestimate the value and importance of his calling, and to undervalue other forms of mental activity and other fields of thought.

The learned men of this stationary period were almost wholly of this sort. They did not use an author as a stepping-stone to higher things, but often confined themselves for indefinite periods to the study and exposition of some small fragment of his works. The temper of the times is illustrated with but slight exaggeration in the somewhat famous peroration of Sir Henry Savile at the close of his extended course of lectures at Oxford on Euclid: "By the grace of God, gentlemen hearers, I have performed my promise; I have redeemed my pledge. I have explained, according to my ability, the definitions, postulates, axioms, and first eight propositions of the Elements of Euclid. Here, sinking under the weight of years, I lay down my art and my instruments."

This stationary age was also an age when fancy crept into the existing sciences and began its destructive work. Most men ceased to search after intelligent and rational causes for their experiences and were content to refer them to the magician's art. Astronomy largely degenerated during this period into astrology, chemistry into alchemy, and philosophy became at times almost wholly a theosophical study.

But it would be an error to suppose that the thousand years that followed the decline of the Roman Empire were an entire blank in the progress of science. Law and theology were assiduously cultivated during this period, and thus the minds of men were prepared for a more rapid and continuous advance in the other sciences when the time came to resume their pursuit. The fine arts in particular were carried to the highest stage of excellence. Painting, especially in the fourteenth and fifteenth centuries, seems to have reached its climax. The extraordinary development of the imagination required in order to attain these ends made it immensely easier to progress swiftly and surely in science when men of genius came to devote their energies exclusively to its cultivation and advancement. It is no accident that a high development of the inductive sciences has always been preceded and accompanied by a high development of the fine arts.

The first science to recover from the general stagnation and barrenness of the middle ages was astronomy. For it gave the easiest and fullest play to the awakened imaginative powers and was by nature the least affected by the dogmatism and servility of that period. In addition, it had already during the previous centuries brought together a great mass of ascertained facts. For always and everywhere, it need hardly be remarked, rational hypotheses and conjectures are impossible except on the basis of a multitude of observed and verifiable facts.

Copernicus is the great master of this period of astronomical progress, and few if any better examples of the quality in a scientist of which we are here treating can anywhere be found. He was not, however, the first to announce the heliocentric doctrine for which he has become so famous. Some affirm that Pythagoras taught it. Archimedes expressly asserts that it was held by Aristarchus, one of his contemporaries. "Aristarchus of Samos," he says, "makes this supposition, —that the fixed stars and the sun remain at rest, and that the earth revolves round the sun in a circle." Aristotle shows his knowledge of the existence of such a doctrine by his arguments against it. But if we apply to Copernicus the maxim that "he only discovers who proves," that is, who can verify his hypotheses by observed facts, there can be no question but that he first brought the heliocentric notion to light as a profound and consistent truth and made it an essential part of astronomical knowledge.

We have in the work of Copernicus in establishing this notion one of the best examples of the complete scientific method and the place of imagination in it to be found in all literature.

The first thing he did was to gather together all the known facts of his day that in any way had a bearing on the subject. Then, as he tells us in his preface addressed to the Pope, he searched through all the works of philosophers to determine if any had held conceptions concerning the motions of the world different from those taught in the schools of mathematics. With this material before him, he set himself definitely to the task of forming new and more rational conjectures than the ancient ones concerning its nature and significance.

It was in this power of forming rational conjectures based on facts, and that can be vindicated by an appeal to facts, that he excelled all his contemporaries. Others, in all probability, possessed as thorough a knowledge of the facts and could deduce the results of a given supposition with as much accuracy and acuteness. None, however, possessed to an equal degree the faculty to divine the true significance of the facts and bind them all together in one harmonious whole. But what Copernicus did for the facts of his day was not done, and is rarely, if ever, done, at the first trial. The speculative or imaginative powers when they once begin to work with vigor, although they are the source of all true theories, are continually overshooting the mark, and producing many false ones.

They acquaint us with the true relations of things by constantly conjecturing relations that have no real existence as well as those that have, and obliging us to make the elimination. If all the thoughts of the master minds in science were recorded so that we could read them as we can those of Copernicus and Kepler, we would doubtless find that all real discoveries have been mixed up with many baseless ones, and that many days, if not years, of patient and arduous thought have been spent in going through the process of making the separation.

"To try wrong guesses," says another, "is apparently the only way to hit upon right ones. The character of the true philosopher is not that he never conjectures hazardously, but that his conjectures are clearly conceived and brought into rigid contact with facts. He sees and compares distinctly the ideas and the things—the relations of his notions to each other and to phenomena. Under these conditions it is not only excusable but necessary for him to snatch at every semblance of general rule; to try all promising forms of simplicity and symmetry."

After Copernicus, by much meditation and repeated failures, had finally attained a supposition that so fully accounted for all the then known facts that by it "the several orbs and the whole system are so connected in order and magnitude that no one part can be transposed without disturbing the rest and introducing confusion into the whole universe," he could well conclude the preface to his great work *De Revolutionibus*, containing his final results, with the remark: "All of which things, though they be difficult and almost inconceivable, and against the opinion of the majority, yet in the sequel, by God's favor, we will make as clear as the sun, at least to those who are not ignorant of mathematics."

Equally important illustrations of the supremacy of the imagination in the pursuit of science can be found in Kepler's account of his experiences in the discovery of his three great laws.

His account is especially remarkable for the candor and copiousness with which it tells of the time and labor expended in refuting bad conjectures as well as in confirming good ones. "If Christopher Columbus," he says, "if Magellan, if the Portuguese, when they narrate their wanderings, are not only excused, but if we do not wish these passages omitted, and should lose much pleasure if they were, let no one blame me for doing the same."

He worked for years refuting one conjecture after another before he finally came to the doctrine that the orbits of the planets are elliptical. And so with each of his other two laws. When one set of hypotheses became untenable, he at once betook himself, as he expressed it, to sending "into the field a reserve of new physical reasonings on the rout and dispersion of the veterans."

Although in one sense Huyghens may well be called the discoverer of the undulatory theory of light, Young and Fresnel undoubtedly deserve the credit of presenting it to the world as a well-attested scientific truth. For they first established the true theory concerning the fringes of shadows and showed that the hypothesis that accounted for double refraction also sufficed for the polarization of light. Both of these positions had to be established before the undulatory theory could be put upon a solid basis.

In his papers *On Double Refraction* Fresnel, describing his method, says: "Long before I had conceived this theory, I had convinced myself, by a pure contemplation of the facts, that it was not possible to discover the true explanation of double refraction without explaining at the same time the phenomena of polarization, which always goes along with it ; and accordingly it was after having found what mode of vibration constitutes polarization, that I caught sight of the mechanical causes of double refraction."

Young several years previously wrote in a similar vein about his investigations of optical fringes. "In making," he says in his report to the Royal Society, "some experiments on the fringes of colors accompanying shadows, I have found so simple and so demonstrative a proof of the general law of interference of two portions of light, which I have already endeavored to establish, that I think it right to lay before the Royal Society a short statement of the facts which appear to me to be thus decisive." Fresnel gives it as a reason why Young anticipated him in the publication of some of his discoveries, that Young was "more bold in his conjectures and less confiding in the views of geometers."

If space allowed, these historical illustrations might be indefinitely increased. Enough have been given, however, to show how indispensable imagination is to the formation and progress of the so-called inductive sciences, and we only need to add a few examples from the deductive sciences in order fully to accomplish our purpose.

And we select the science of mathematics as being by common consent the most exact of all sciences and at the same time furnishing us with the greatest number of happy illustrations of our theme. It is an interesting and instructive fact of history that the Greeks from the earliest times made much of this science.

They seem to have assumed at the outset that a science of every part of the universe was possible, and speedily to have adopted the notion that such a science must put all its conclusions into the form of mathematics. This idea is especially conspicuous in Plato's *Republic* and *Timæus.* "Probably no succeeding step in the discovery of the laws of nature," says another, speaking of this characteristic of the Greeks, "was of so much importance as the full adoption of this pervading conviction, that there must be mathematical laws of nature, and that it is the business of philosophy to discover these laws. This conviction continues throughout all the succeeding ages of the history of science to be the animating and supporting principle of scientific investigation and discovery."

Now it is in no respect an overstatement of the case to affirm that every line and angle, every circle and sphere, and indeed every other figure employed by the geometer, is a product of the imagination and never an observed fact. When we affirm that the diameter of a circle is to its circumference as 1 to 3.14159, even if we carry the decimal out to its seven hundred and eighth place, as was done by Shanks, we are still talking about imaginary products.

It was chiefly for the reason that geometry gives such a scope for the exercise of the scientific imagination that the Greeks took so keenly to the study. Plato early saw with clearness that the pursuit of the study is one of the most effective means for the development of this power. Hence he had inscribed over the entrance to his academy at Athens: "Let no one ignorant of mathematics enter here."

Arithmetic, on the other hand, although encumbered, to be sure, in ancient times with a vicious notation, was little cultivated by the Greeks, as it gives much less play to the higher scientific powers. Even in our day it often happens for the same reason that the great mathematicians pay it little regard. In fact, unusual proficiency in arithmetical calculations is not a prime essential to great success in mathematical studies. Many arithmetical computations can be made most quickly and most surely by a machine, but the work of a discoverer in mathematics can never be carried on in that manner.

If, as Jevons says, "all the figures really treated in Euclid's Elements are imaginary," and if all the a, b, c's and x, y, z's of algebra are also of the same character, what must be said of the elaborate constructions built up on the foundations of these two sciences? What of Vieta's discoveries in the use of symbols and the analytical algebraical geometry invented by Descartes which so vastly extended the domain of mathematical science? What is the differential and integral calculus but an invention of this marvellous creative power?

When Sylvester says that "the mathematician has to train and inure himself to a habit of internal and impersonal reflection and elaboration of abstract thought," he means that it is in the world of imaginary forms and formulas that he finds his certainties. A more eloquent refutation of the charge that devotion to mathematics does not tend to cultivate the imaginative powers it would be difficult to find than his address as President of the Mathematical Section of the British Association published not many years ago.

It is as great a mistake to maintain that a high development of the imagination is not essential to progress in mathematical studies as to hold with Ruskin and others that science and poetry are antagonistic pursuits;

as though the poet saw more deeply and more truly into nature than the man of science, instead of looking at different aspects of the same great truths. Those who make these errors wofully misunderstand what science really is and have a very meagre conception of its range and power.

It is well said by Dr. Carpenter that " it cannot be questioned by any one who carefully considers the subject under the light of adequate knowledge, that the creative imagination is exercised in at least as high a degree in science as it is in art or in poetry. Even in the strictest of sciences—mathematics—it can easily be shown that no really great advance, such as the invention of fluxions by Newton and of differential calculus by Leibnitz, can be made without the exercise of the imagination."

As it is hardly necessary to dwell at length upon the importance of carefully cultivating this power on the part of every student of science, we may fittingly conclude our present inquiries with the following statement of results: All the laws of nature and all the generalizations arrived at in every other science are nothing more nor less than verified products of the imagination, the same power that forms all our ideals in poetry, literature, art, and religion ; and so long as the human mind remains what it is and obtains its knowledge chiefly by investigation and research, we have every reason to affirm that all future generalizations will be of the same sort.

As a necessary corollary to this position we need to add that the very utmost we have a right to demand of any new truth presented for our acceptance is that it harmonize with all previously attained truths and explain all the known facts.

CHAPTER VI

ANALOGY AS AN AID TO SCIENCE

"IN almost every department of human knowledge," says Blakey in his *Essay on Logic*, "analogical reasonings are employed to a great extent, and are found to be of great value." And Jevons in his *Principles of Science* does not hesitate to affirm: "There can be no doubt that discovery is most frequently accomplished by following up hints received from analogy."

Our estimate of the truthfulness of these assertions will depend, as all must admit, upon our conception of the nature and place of analogy in the various processes of thought. To attempt to answer the inquiry by an appeal to history would be to impose upon ourselves by no means an easy task. For there is no word, as Mill remarks, that has been used more loosely or in a greater variety of senses than analogy.

The term was originally devised by the ancient Greeks to denote an equality of ratios. When, for example, they wished to express the proportion three is to nine as seven to twenty-one, they did it by saying the ratio of three to nine is analogous to the ratio of seven to twenty-one. This use of the word analogy, even in mathematics, is now practically obsolete, surviving only in a few such phrases as Napier's analogies, four important formulas in spherical trigonometry.

The schoolmen applied the word to any similarity of relations. They tell us, for example, that there is an analogy between intellect and sight, for the reason that the intellect is related to the mind as sight is to the body. Archbishop Whately adopted this view of analogy and called Mandeville's argument against popular education—that " if the horse knew enough he would soon throw his rider "—a typical analogy, because it can be expressed by the proportion as the horse is to its rider so are the people to their rulers.

In our day, however, analogy has come to mean any sort or degree of resemblance that enables us to assume of one thing what we already know of another. In other terms, it has to do with any degree of agreement or likeness between things that furnishes a ground upon which to infer a further degree of likeness. The matter is well stated by Davis in his recent *Elements of Inductive Logic* as follows: " It is now usual and better to extend the meaning of analogy to any resemblance, not merely of relation, but of things, and classes of things, that justifies an inference to further resemblance."

In accordance with this view the term analogical evidence may be used to designate any argument from any sort of similarity that falls short of an actual induction. For this reason Mill reduces all analogical reasoning to the formula: " Two things resemble each other in one or more respects: a certain proposition is true of the one; therefore it is true of the other." But, as he himself points out, we have here no sure way of discriminating analogy from induction. We must, therefore, in the case of an induction show by a due number of instances that there is an invariable conjunction between the properties possessed by the known objects and the property assumed to be possessed by the object in question.

In arguing by analogy no such conjunction is known to exist. For example, if I should argue that a stone thrown into the air will fall to the ground after a single observation of the fact in the case of an apple, it would be an argument from analogy. But the inference, if made after a number of such observations had established the position that all bodies thrown into the air will fall to the ground, would be based upon an induction.

In general we may say that the chief difference between an argument by analogy and an induction is that in the former we argue from one of the objects of a class to another of that class ; whereas in the latter we reason from several objects of a class to the whole class. From this we are not to suppose, however, that an argument by analogy is a case of immediate inference from one particular to another ; every complete analogical argument is a weak induction followed by a deduction. The weakness of the induction is what makes all analogical evidence uncertain proof.

The conclusion when attained by analogy is always particular, but when arrived at by induction it is always general. The evidence upon which an analogy is based is always indirect and collateral. For the fact that two qualities co-exist in a given object does not give us any direct testimony that they co-exist in a second object. In an induction, on the other hand, the evidence is direct ; for the quality that we affirm of the class we have already ascertained to be true of many individuals of the class. Every induction begins with analogy. We can never examine all the members of a class. A few only do we come to know through direct observation or experiment. The others we assume on the evidence of analogy to be like those observed, and then proceed to our generalization.

That analogy always precedes induction proper is not only shown by an analysis of the process itself, but it is fully confirmed by an appeal to experience. It is the predominant mode of argument in all primitive and immature forms of thought. The customs and beliefs of savages show beyond question that they were formed on this basis. We have it on good authority that when a Zulu wants to soften the heart of a man from whom he wishes to buy some oxen he chews a bit of hard wood to accomplish it. A Malay, we are told, eats tiger to acquire the cunning of that animal, and Indians, it is said, often stab the figure of the one whose days they wish to shorten.

The superstitions and folk-lore of all nations, civilized and uncivilized, consist chiefly of more or less distinct analogies. To dream of gloom, we are told, indicates imprisonment; of pineapples, anxieties and troubles; of onions, the betrayal of secrets. The notions that many people have about witches and such numbers as three, seven, and thirteen, are further illustrations of this mode of inference. It is because of this primitive habit of mind that the grotesque performances and fanciful remedies of the medicine-man have been held in all savage lands in so high esteem. Of course, it was argued, snails, because of their resemblance in form to the external ear, must be used as a cure for ear-aches, fevers must be treated by red remedies, and liver complaints by yellow.

Divinations of all kinds rest on some assumed analogical fitness. And the use that has been made of such notions, even by some of the most civilized nations of antiquity, shows how natural it is for the mind to treat its experiences in this manner. Sidgwick, in his work on *Fallacies*, dwells at length upon the connection of analogy with the formation and use of proverbs. "It is the slackness," he says, "with which any 'striking' analogy will commonly pass muster that leads at all times to the use so freely made of proverbs. To assume that some case comes under some well-known proverb, without a shadow of evidence to show that it does so beyond what may be gathered from the crudest superficial inspection, is still in many quarters a favorite practice. Hence, as a rule, the earliest recorded crystallization of wisdom has usually been a collection of proverbs or of fables or allegories,—which latter are only a less generalized form of the same expedient,—and to some extent the process appears to be still going on."

The ancient astrology was perhaps the first attempt of man to form a science, and it was almost wholly a collection of analogies. Because of some supposed resemblance each planet was given the name of some particular deity, and the person who was born when a certain planet presented some particular phase had ascribed to him the character of that deity. In a similar way the constellations came to have the names of certain animals. And persons born when they were prominent had the characteristics of those animals. If one came into the world under the sign of the lion he would be by nature full of courage, but if under the crab he would have a hard time in life.

This tendency to reason by analogy is especially prominent in the doings and sayings of children. A study of their experiences as well as those of undeveloped adults abundantly confirms the remark of

Dugald Stewart that "the tendency of our nature is to confide in analogy; we spontaneously reason in accordance with it."

In all the lower planes of existence all inference is by analogy, and it is only by slow and painful effort that we pass up to that stage of development where we find ourselves able to establish some at least of the doctrines of science upon broader grounds.

This historical phase of the subject has been dwelt upon at length in order to emphasize the thought that while many of the analogies of the undeveloped mind are plainly fallacious, they ought not on that account to be ignored or held in slight esteem. For they all have a most important bearing upon the progress of science. They furnish the necessary stepping-stones to higher things. Without them science could not be, with them it may be.

Some writers on the subject of analogy make much of a distinction between reasoning by analogy and reasoning by example, yet little room for such a distinction actually exists. The expression reasoning by example may be used in two different senses. If we mean by the phrase giving an illustration of a proposition already established in order to make it clearer, it does not seem to be any kind of inference at all. It is only an endeavor to make the statement a little easier of comprehension by making it particular.

Suppose I say to a little child: "All birds have wings; look at the wings of your canary." I am not inferring by the example, but only illustrating. If, however, I should say: "Just look at the wings on your canary. Your poll-parrot must also have wings," I should be reasoning from example. But this would differ in no respect from reasoning from analogy.

Hence, so far as progress in science is concerned, the view of Sidgwick is the correct one, that reasoning from analogy is one of the subdivisions of reasoning by example, the other being induction proper when several examples are taken as the basis of the inference instead of one.

Because the evidence upon which an analogy rests is indirect and collateral, as has been observed above, argument by analogy is closely related to what is commonly called proof by circumstantial evidence. If the term circumstantial evidence were taken in its literal sense and made to include every kind of evidence founded upon observed facts, that is, circumstances having to do with the matter under investigation, there would be little difference between these two kinds of proof. Not only do we proceed in this way in forming our opinions about every-day affairs, and in forecasting the future, but the geologist bases his theories on what he can gather from the testimony of the rocks, and the physicist founds his generalizations and laws upon similar data.

It is an arbitrary, but not uncommon, limitation of the term circumstantial evidence to restrict it solely to criminal law and make it apply only to those cases where a crime is traced home to its perpetrator by means of the evidence that the criminal himself has left behind him, the testimony of eye-witnesses not being obtainable, and the circumstances taken separately having little evidential value.

But this restriction does not destroy the analogical character of the argument in the case. The analogy under such conditions may be a slight one and always remain merely an analogy, or it may rise to the dignity and value of a well attested induction.

None of the facts open to human investigation stand isolated and alone. They constitute a web of circumstances inseparably interwoven with each other. The connection between them, however, we can never infallibly trace. The utmost we can do is to attain a very high degree of probability that we have discovered the connection in any given case.

But this is no more true in matters of criminal jurisprudence than in the investigation of any other set of facts. A few things we come to know by seeing or hearing them ourselves, but the great mass of our knowledge comes to us through the only other source left open to our choice, namely, circumstantial evidence. And the ground of its cogency is the same as that for all analogical or inductive inference—conformity to, or agreement with, our experience and the general experience of mankind. A high authority on circumstantial evidence expresses it thus: "The whole value and use of this kind of evidence depend upon the twofold condition of all facts whatever being very closely bound together, and upon our having in our own past lives some limited experience of the actual order in which they come."

The relation of analogy to the formation and development of language, the vehicle of science, should not be overlooked. Whenever the names of visible and tangible things are given to those that are invisible and mental, it is done because of some real or assumed analogy between them. We have no other words with which to denote the objects and attributes of mind except those that are derived by analogy from those of matter. When we speak, for example, of a person as dull of comprehension, obscure in his statements, wandering in his thoughts, wrong in his conduct, or the opposite, we are using adjectives that are formed by analogy from our experiences with the external, sensible world. The same thing is true of many of the other elements of speech. In fact, as is well said by Jevons, "The whole structure of language and the whole utility of signs, marks, symbols, pictures, and representations of various kinds rest upon analogy." Without it there would be no way to describe our notions or to register our thoughts.

An analogy, however, should not be confounded with a metaphor. The ground of a metaphor lies in the fact that it is an imaginary resemblance, not a real one. When the Psalmist exclaims, "He that sitteth in the heavens shall laugh, the Lord shall have them in derision"; "O God, incline thine ear unto me and hear my speech"; "The eye of the Lord is upon them that fear him"; he does not mean to imply that God actually has eyes, or ears, or organs of speech. The similitude is only a fancied one, not one founded on fact. In an analogy, a correspondence in the very nature of things is always affirmed or implied.

When we turn our attention to the history of the different sciences and undertake to trace out the way in which they have actually developed, we find analogy everywhere present. Even the mathematical sciences furnish us with some of the most striking and important evidences of its use. It was not until Descartes and others had seen and developed the analogy between algebra and geometry and had established the proposition that every equation may be represented by a curve or figure in space, that Newton's *Principia* was rendered possible. Jevons unhesitatingly affirms that the discovery of this analogy is the chief source of the progress made in mathematical methods during the last three centuries. La Place, he thinks, confirms this opinion when he asserts: "So long as algebra and geometry have been separate their progress was slow and their employment limited; but since these two sciences have been united, they have lent each other mutual strength and have marched together with a rapid step toward perfection."

The differential calculus, mathematicians tell us, is mainly due to geometrical analogy. For in trying to treat the tangent of a circle algebraically they had to deal with infinitely small quantities.

Equally important service has been rendered by analogy to the mechanical sciences, and some are of opinion that the chief advances in modern logic have come from the discovery of its analogy to the science of mathematics.

Of the physical sciences, none, perhaps, affords more numerous or interesting illustrations of the successful use of analogy than the science of chemistry. At the beginning of the present century the so-called earths and alkalies, such as magnesia, lime, and potash, were universally regarded as elementary substances. But Lavoisier, the founder of modern chemistry, had already shown that some things resembling the earths, such as iron-rust and the like, could be resolved into two substances, a metal and a newly discovered gas called oxygen. Then analogy stepped in and suggested that all the earths and alkalies could be thus resolved. The means were not at hand, however, at that time, to test the matter.

But as soon as Galvani and Volta had made the discoveries for which they are famous, and water had been separated into its elements by means of the voltaic current, Sir Humphry Davy applied the new force to the alkalies and the analogy became an established fact.

These experiments of Davy and others again, in their turn, became the basis of a further analogy that all amorphous powders resembling alumina and magnesia, and possessing similar chemical properties, are metallic oxides. So that when a few years ago several new earths were brought to light they were immediately accepted by chemists as metalliferous, although few of the metals that they are supposed to contain have yet been isolated. It is no exaggeration to say with a high authority that "the science of chemistry as now developed rests almost entirely upon a careful and extensive comparison of the properties of substances bringing deep-lying analogies to light. When any new substance is encountered, the chemist is guided in his treatment of it by the analogies which it seems to present with previously known substances."

The history of physics is also strikingly full of discoveries to which analogy has been the principal guide. Perhaps the most famous of these was Newton's guess that diamonds are combustible. He had observed the fact that certain oils and resins, which are highly refractive, are combustible. He put alongside of this the known fact that the diamond is highly refractive, and the added fact that it, as he said, "probably is an unctuous substance coagulated," and conjectured that it was also combustible. The guess was afterwards verified by Lavoisier, who actually burned a diamond in oxygen, converting it all into carbonic acid.

Another most instructive instance of guidance by analogy to important results in physics is given in Sir John Herschel's well known description of the way in which he was led to anticipate some of Faraday's most important discoveries in electro-magnetism. Having observed the screw-like form that presents itself in the case of electrical helices, certain quartz crystals, and the rotation of the plane of polarization of light, "I reasoned thus," he tells us: "Here are three phenomena agreeing in a very strange peculiarity. Probably this peculiarity is a connecting link, physically speaking, among them."

On the basis of what he knew about these crystals and about light, he inferred by analogy that any transparent material, such as glass, if subjected to a similar magnetic strain would show the same effect of rotating the plane of polarization which these quartzes exhibit; and further, that a powerful electro-magnet would develop such a strain. Herschel never verified the suggestion, but Faraday did and made the great discovery that magnetic strain has a marked influence upon polarized light.

The power of analogy to assist discovery is in no case more finely illustrated than by the history of the undulatory theory of light in its application to the problems of modern physics. The progress of science among the Greeks was immensely impeded by the notion that all motion involves the transition of the particles moved from place to place. It was not until about the time of Newton that the more rational view began to dawn upon the minds of investigators that the motion is rhythmical, the matter remaining comparatively fixed while the energy passes on from wave to wave. This position was first brought out in connection with the study of optics. After it had been established by the study of the eclipses of Jupiter's satellites that light travels about two hundred thousand miles per second, it was clearly seen that either matter or energy must be transferred at that rate from any object before it can be rendered visible.

Newton adopted the first of these views, namely, that material particles are thus transmitted. But if one of these particles weighed but the millionth of a pound, it would impinge upon the eye with ten times the momentum and six million times the penetrating power of a rifle-ball. Furthermore, if this corpuscular theory were true, millions upon millions of these particles would enter the eye at once from every part of the surface of the visible object.

These difficulties suggested the need of another theory. And, on the basis of the analogy of sound in air and of waves in water, Huyghens assumed that there was a highly elastic fluid pervading all space called ether, and that light consisted in the propagation of waves in this fluid. This analogy was afterwards verified by Foucault, who showed that light travels much slower in water than in air, just as the theory requires. When the undulatory theory had been established in the case of light by this *experimentum crucis*, it was soon applied by analogy to heat, and later Maxwell applied it to magnetism and electricity.

Franklin's brilliant discovery of the identity of lightning and electricity is another illustration of the usefulness of analogy to physics. He had the electrical machine and the Leyden jar, and was thoroughly familiar with the phenomena that could be produced by them,—especially the sparks of light and the report coming from the contact of bodies oppositely electrified. With the common phenomena of lightning he was equally familiar. While he was meditating on these facts, the conjecture came to him that perhaps two things having so many attributes in common might have all in common and be identical. The decisive experiment of making a small quantity of lightning, so to speak, run along an isolated kite-string, emit a spark, and charge a Leyden jar, established the truthfulness of his conjecture beyond question.

Our inference that the laws of motion that are known to be true of stars and planets are also true of molecules and atoms is largely an inference by analogy. For no necessity exists that the laws of the macrocosmos revealed by the telescope should be exactly the same as those of the microcosmos of which the microscope gives us now and then an occasional glimpse.

Because astronomy has to do with such distant bodies and because the means for studying these bodies and the means for observing them are so restricted, analogy has had and must continue to have in this department a very large place.

The controversy between the Copernican and Ptolemaic systems that was carried on for so many years with such bitterness was finally settled on the suggestion of an analogy. Galileo's discovery with his extemporized telescope of the four satellites of Jupiter furnished the data. Astronomers and thinkers of all classes were at once contented with the inference that what they could see taking place on a small scale was probably true of the whole solar system. Even Francis Bacon, who had previously opposed the Copernican view, regarded the analogy as valid.

Observations on these moons of Jupiter also greatly strengthened by analogy the position of La Place that the perturbations of the planetary system tend to neutralize each other. For the oscillations in the case of these satellites, as they extended over a definite period, were carefully studied, and it was argued that what was true of this system in this respect will be true of all.

The opinion that has been so commonly held by astronomers for many generations, that the stars are suns attended by a planetary system like our own, is founded on the analogy that because stars manifest some of the qualities of our sun they probably possess all. In essentially the same way we argue about the moon, and boldly assert from certain likenesses in its appearance to our globe that it has high mountains and deep valleys, fathomless seas and elevated plateaus, but no air or water.

No subject in astronomy of a purely analogical character has perhaps been discussed with such persistence from generation to generation as the question, Are other planets besides the earth inhabited? Jevons gives an interesting summary of the views of Huyghens and La Place on the matter, and then supplements them with some remarks of his own. Huyghens argued that as we infer by analogy from the dissected body of a dog to that of a pig or other animal of the same general form, expecting to find the heart, the stomach, the lungs, and other internal organs in corresponding positions; so from the similarity of the planets in many known respects we should infer their likeness in respect to organic life. The inhabitants of other planets, he thought, while differing in power of intellect from ourselves, had the same kind of knowledge.

La Place maintained that analogy justifies us in holding that the rays of the sun which bring to birth plants and animals on the surface of the earth have the same effect elsewhere; that matter which so teems with life here cannot be wholly unfruitful on so great a globe as Jupiter; and that, although it is doubtless true that man with his present organism could not live upon the other planets, no limit should be put upon the number of possible forms or bodies for finite spirits.

Jevons goes on to argue that because many metals exist capable of forming organic compounds which as yet are not so employed, it is possible that creatures might be formed at different temperatures "of different yet analogous compounds" to those now in use. From the facts in our present possession the analogical evidence on the matter is, it is urged, far stronger for Mars than for any other planet. For it is nearly equidistant from the sun, has about the same density, a similar distribution of seas and continents, nearly equal humidity and temperature, and essentially the same length of the seasons with about the same changes from light to darkness as occur in our own day.

Good illustrations of the use of analogy in another sphere are afforded by the way we reason from what we know about animals to ourselves and from what we know about ourselves to animals. Alexander Bain dwells at length upon this class of analogies as especially typical of all. A quadruped resembles a human being in many known points of structure and function; therefore, it is argued, it resembles him in many others. The function of the saliva and of the gastric juice is observed to be of a certain character in dogs and horses, and the inference is made that it is the same in man. Cats and rabbits are drugged, or dissected alive perhaps, in order that we may find out more about the structure and functions of man. The ancient anatomists, who were prevented by their superstitions from dissecting human bodies, obtained most of their knowledge of man's structure in this manner.

A great portion of what we know about the mental states of the lower animals is obtained by analogy. We hold many of them at least to be consciously intelligent, because they possess organs of sense like our own and a similar nervous system culminating in a brain of similar form and functions.

Sydney Smith gives us in his *Sketches of Moral Philosophy* an excellent example of the application of analogy to the question as to whether dispositions are hereditary. "The analogy of animals," he says, "is in favor of the transmissibility of mind. Some ill-tempered horses constantly breed ill-tempered colts; and the foal has never seen the sire,—therefore in this there can be no imitation. If the eggs of a wild duck are hatched under a tame duck, the young brood will be much wilder than any common brood of poultry; if they are kept all their lives in a farmyard, and treated kindly and fed well, their eggs hatched under another bird produce a much tamer race."

Hartley made the first attempt to solve the mystery of nerve action and he based his vibratory theory on the analogy of sound. Present theories on the subject are founded chiefly on the analogy of electricity. Much is made by Bain of analogy in determining the relations of the mind to the body and he carries it even into the region of motives in their bearing upon the will.

In legal matters analogy occupies a most important place. Cases open to contention are those that do not fall with any clearness within the provisions of any existing statute and therefore must be argued on the analogies involved. "It is," as Paley well says in his *Political Philosophy*, "by the urging of different analogies that the contentions of the bar are carried on; and it is in the comparison, adjustment, and reconciliation of them with one another, that the sagacity and wisdom of the court are seen and exercised."

Paley's analogy of the watch, elaborated in his *Natural Theology*, to prove the existence of a designer in the universe, is a matter of common knowledge, and similar analogies have had a powerful influence in the development of that science.

But beyond all question the most elaborate attempt to support a system of religious doctrines by an appeal to analogy was made by Bishop Butler in his famous work entitled *The Analogy of Religion, Natural and Revealed, to the Constitution and Course of Nature.* The primary object of this work was to meet the objection of the Deists of his day to all revealed religion. He does it by showing that the difficulties in revealed religion are similar to those in nature. If the latter do not prevent our maintaining that nature is of divine origin, the former should not have an opposite effect in the case of Christianity. There is no attempt made to establish by direct evidence the divine origin of the Christian religion, but only indirectly to confirm its proofs. As Butler himself expressed it: "Those who believe will here find the scheme of Christianity cleared of objections, and the evidence of it in a peculiar manner strengthened; those who do not believe will at least be shown the absurdity of all attempts to prove Christianity false; the plain, undoubted credibility of it; and, I hope, a good deal more."

Archbishop Whately's unique and interesting pamphlet on *Historic Doubts Relative to Napoleon Bonaparte* is a work of the same sort, and was written to serve a similar purpose. If arguments were applied to the life of Napoleon, Archbishop Whately argues, similar to those used to destroy the evidence for the truthfulness of the Scriptures, it could easily be shown to be the elaboration of a myth. Professor Drummond's brilliant work on *Natural Law in the Spiritual World* is confessedly based on analogies. And while it may not have fully established its ultimate position, it certainly has had no small influence in quickening theologic thought and in answering many modern objections. All these works admirably illustrate what might be called the negative use of analogy in the progress of science. For while its principal function is undoubtedly to suggest new lines of research, its service in refuting objections may often be no less helpful to a continuous and permanent advance.

The perils of analogy need of course to be kept constantly before the mind of the investigator, and should not in any way be underestimated or overlooked. For analogy is quite as capable of gross abuse as of legitimate use. Perhaps the fallacy of false analogy is the most common of all unsound modes of inference. "It is so much less trouble," as Sidgwick observes, "to see that two things bear a 'striking resemblance' than to discriminate accurately how far the resemblance really goes, and the point wherein they differ." The error in all false analogies is in failing to recognize the essential differences between the things compared. Liability to this error exists in every argument from analogy. It is for this reason that we can never depend upon it for conclusive proof. In many of the instances where it has been most helpful in suggesting new truths further application of it would have led to error. If Newton had argued about several other minerals that refract light, such as greenockite and octohedrite, as he did about the diamond he would have made a great mistake. After Lord Rosse, with his powerful reflector, had resolved many of the distant star groups into their elements, it was argued by analogy that all the nebulæ are groups of stars. But the spectroscope has established the fact that many of them are simply masses of luminous vapor, though in the process of condensation.

The ancients held that because the circle is a perfect figure all the heavenly bodies must move in circular orbits and with uniformity. "For no one," as the Pythagoreans used to say, "would tolerate such anomaly [as irregularity] in the movements of a man who was decent and orderly." Kepler maintained for quite similar reasons that there could be only six planets, while Huyghens, on equally fallacious grounds, put the limit at twelve.

Paley maintained that animals are so similar to men that they have essentially the same rights and duties as men. For this reason he argued that they should not be killed for food or domesticated. The favorite argument for an absolute monarchy often is: A paternal government works well for the family, therefore it will work well in the state, ignoring the two striking differences in affection and superior wisdom, and basing the entire opinion almost wholly on the one likeness of irresponsibility.

Of the same sort is the notion that because individuals grow old and perish, so must nations; as though the changes in man that naturally lead to decay were typical of the changes that affect a nation's history.

These examples of the misapplication of analogy in no wise detract from its usefulness to the scientific investigator, but only caution him to be on his guard against employing it in a random or haphazard manner and against claiming for it more than the facts will bear. Like all other good things it is open to abuse, but those who use it the most are just the ones least likely to abuse it. "We always find," says another, "that those are the greatest slaves to metaphorical language who have but one set of metaphors." So it is in regard to the use of analogy. Minds that are so barren of ideas that only a few analogies between the objects they contemplate ever present themselves for consideration will greatly overestimate the value of those few. But minds that are ever teeming with possible likenesses will be most on their guard against accepting those that experience has taught them to hold in light regard. Such minds will be the quickest to discern the incongruity and worthlessness of an unreal analogy, and the first to cast it aside.

While acknowledging fully the position taken in the *Encyclopædia Britannica* that, "whether in science or the affairs of life, the abuse of the process, or what is technically called False Analogy, is one of the most besetting snares set for the human mind," we still maintain that it is entirely reasonable to hold with Mill that "there is no analogy, however faint, which may not be of the utmost value in suggesting experiments or observations that may lead to more positive conclusions"; and that "where the resemblance is very great, the ascertained difference very small, and our knowledge of the subject-matter tolerably extensive, the argument from analogy may approach in strength very near to a valid induction."

When the actual history of science is duly considered and we reflect upon the prominent part that analogical arguments have had in its development, it seems but a slight exaggeration to assert with Professor Cooke, of Harvard, in his recent work on the *Credentials of Science*, that "there can be no question that the suggestions of analogy have led to more discoveries in science than all other influences combined."

CHAPTER VII

THE LIMITATIONS OF SCIENCE

"IN the writings of some recent philosophers," says Jevons, in his *Principles of Science*, "especially of Auguste Comte and in some degree of John Stuart Mill, there is an erroneous and hurtful tendency to represent our knowledge as assuming an approximately complete character. At least these and many other writers fail to impress upon their readers a truth that cannot be too constantly borne in mind, namely, that the utmost successes which our scientific method can accomplish will not enable us to comprehend more than an infinitesimal fraction of what there doubtless is to comprehend."

It is by no means uncommon for students of the different sciences to speak as though the material that they have already examined and systematized was so large a fraction of the sum total that any new data could have but slight if any effect upon their general results. We have every reason to suppose, however, that what we know is but a drop of water in the great ocean of the unknown. In whatever direction we turn our investigations we always find a host of new and unexplained facts putting in their appearance just the moment we begin to think that we have succeeded in some degree at least in reducing to a system those already at hand.

No science can of course exceed its data. We have always first to ask, What is? And to this inquiry it is never possible to give more than an imperfect and partial answer. The vastness and complexity of the universe and the inherent weakness of our powers will forever constitute an insuperable barrier to anything like a full and adequate knowledge of even that class of objects that has come most definitely within the range of our observation.

It may be accepted as a satisfactory scientific hypothesis that if we had a perfect knowledge of the universe as it now is, we should have thereby a perfect knowledge of what it has been and of what it will be. That the present is the outcome of the past and the cause of what is to be, is the basis of all scientific inference. But we do not and cannot have anything like a perfect knowledge of what is, and must rest content to remain at almost an infinite distance from such a goal. A little careful reflection upon our actual situation will abundantly justify this view of the matter, and enable us to estimate what we do know at its true worth.

Astronomers tell us that this earth, on the surface of which we now find ourselves, is but a mere speck in the vast universe of worlds, being only a small part of a solar system that is itself but one among a countless myriad of systems occupying infinite space. All that any human being is ever permitted to come in contact with of this boundless ocean of material existences is comparatively so insignificant that the comparison of it to a particle of dust in a beam of sunlight on our planet probably falls far short of giving us any adequate conception of the actual fact.

Such being our relative position in this vast universe, how presumptuous it is in us to assert anything of a universal character concerning it as more than a reasonable conjecture or a happy surmise.

When we come to look into our origin as portrayed to us by the biological authorities of our day, we find abundant reason for caution against expecting too much of our inherently limited powers. Man's pedigree is now traced back, we are told, to infusoria and rhizopods. Out of the lowest forms of animal existences by gradual development through innumerable ascending orders he is said to have come to what he is at present.

If this view of man's origin be correct, it is not to be wondered at, as Professor Huxley remarks in his *Man's Place in Nature*, after describing somewhat at length the close relationship that exists between men and monkeys, that, "brought face to face with these blurred copies of himself, the least thoughtful of men is conscious of a certain shock, due, perhaps, not so much to disgust at the aspect of what looks like an insulting caricature, as to the awakening of a sudden and profound mistrust of time-honored theories and strongly rooted prejudices regarding his own position in nature, and his relations to the underworld of life."

Whether or not this conception of the biology of to-day concerning the pedigree of the scientist be fully adequate to all the facts is immaterial to our present purpose. Enough of it is established truth to make him beware not to transcend the limitations of his origin and history in his assertions about the constitution of the universe.

But the need of caution in this respect is perhaps most strikingly manifest when we take into consideration the inherent imperfection of our powers.

In the first place the most capable and most gifted of mortals is limited in his knowledge to the so-called five senses and to the short period of threescore years and ten. Nowhere, perhaps, is this limitation more vividly depicted than in one of the philosophical romances of Voltaire, quoted at length by Sir William Hamilton.

Micromegas, an inhabitant of the dog-star Sirius, is represented as starting out on a tour of the universe in order to inform himself more accurately than could otherwise be done of the character and attainments of its occupants. On arriving at the planet Saturn he inquires of the president of the Academy of Sciences there, "How many senses have the men on your globe?" The academician replies: "We have seventy-two senses, and we are every day complaining of the smallness of the number. Our imagination goes far beyond our wants. What are seventy-two senses! and how pitiful a boundary, even for beings of such limited perceptions, to be cooped up within our ring and our five moons!"

The Sirian visitor tells him that on his globe the inhabitants have nearly one thousand senses, yet they are even more conscious of their limitations than he has found the inhabitants of Saturn to be. "And pray," he continues, "how long may you Saturnians live with your few senses?" "Alas," replies the Saturnian, "we live only five hundred great revolutions of the sun [about fifteen thousand years]. You will see that this is to die almost the moment of one's birth. Our existence is a point, our duration an instant, our globe an atom." Micromegas says that the Sirians live seven hundred times longer, but are always complaining of the shortness of life and their inability on that account even to begin to pick up a little knowledge.

The conversation then turns upon the properties of matter. The Saturnian says that in his planet the essential properties of matter, without which his globe could not exist at all, are three hundred. To which Micromegas replies: "That small number may be sufficient for the views which the Creator must have had with respect to your narrow habitation. Your globe is small and its inhabitants are so too. In all this Providence has suited you most happily to each other."

The moral of this romance is evident. We of the insignificant planet Earth, with our insignificant number of senses, in some cases reduced almost to one, as in the cases of Laura Bridgman and Helen Kellar, ought not to be too presumptuous in talking about how Nature acts and does not act, considering the very slight opportunity we have of making her acquaintance.

But we are not only limited by the small number of our senses, but by their imperfection both in range and power. Sir John Lubbock, in his work on *Ants, Bees, and Wasps*, remarks: "It is, I think, generally assumed not only that the world really exists as we see it, but that it appears to other animals pretty much as it does to us. A little consideration is, however, sufficient to show that this is very far from being certain or even probable." By careful and elaborate investigations he has shown that the sense organs in brutes have a different range and power than the corresponding organs in man. His experiments on ants, for example, make it evident that they cannot hear the sounds that we call extremely loud and do hear sounds produced by vibrations so rapid as to be inaudible to us.

All sounds occasioned by vibrations below a certain degree of rapidity per second we cannot respond to, and the same thing is true of all vibrations above a certain degree of rapidity per second. Most of the objects of nature with which we have to do are perceived by us through the eye, but all the objects in the universe that vibrate more than a certain number of times per second, or less than a certain number per second, are to us entirely invisible. Similar facts are true of all the other senses. The number of objects on our own planet that we have any means of getting acquainted with must be extremely small in comparison with the number whose mode of existence transcends our powers. The microscope and the telescope may extend a trifle our range of vision, but still the number of unknown objects even on our globe must be out of all conceivable proportion to the known.

Then, too, we must remember that the organs we possess are not only few in number, but they perform their task in a very imperfect manner. The normal eye and the normal ear exist in the imagination only, not in fact. Professor Helmholtz, one of the very highest authorities on the subject we have, tells us in his Innspruck address: "I need not call to mind the startling and unexpected results of ophthalmometry and optical research, which have proved the eye to be a by no means more perfect instrument of research than those constructed by human hands, but on the contrary to exhibit, in addition to the faults inseparable from any dioptric instrument, others that in an artificial instrument we should severely condemn."

Expert students of the ear bear witness to defects in that organ of a very grave character, and very few persons, if any, have anything like a normal sense of touch or smell. And yet it is out of the material that these defective and constantly varying senses give us that we build up our notions of the ongoings of nature and dignify them with the name of laws.

In trying to apprehend the facts of mind we meet with still greater difficulties. True it is that mental facts are the most certain of all facts. We may question whether the eye or the ear guide us aright, but we cannot question the fact that we experience the sensations of sight and of sound. We may doubt whether an alleged external object is a reality or a phantasm, but we cannot doubt that we doubt. Yet it is also true that many of the facts of psychology are in the gravest dispute. The reasons for this condition of affairs are manifold.

In the first place, mental facts are far more variable than material ones. Most of the facts of the material world are so permanent in their character that we can observe them repeatedly and at our leisure until every aspect has been carefully and minutely examined. With mental facts it is quite otherwise. The moment we begin to examine them they cease to be. Then, too, the sum total of mental energy at our disposal at any given time is a limited quantity. The portion employed in producing the state or condition we wish to examine takes just so much away from the degree of attention with which we can examine it after it is produced. The more keenly we attend to material objects the more vivid and distinct do they become, but with mental phenomena it is quite the opposite. "The objects of consciousness are dissipated before the concentrated gaze which would master their secrets."

Any number of investigators can study the same material object and compare and re-compare their observations, but a mental state or condition is open to a single observer only and to him but for an instant. Even when an agreement is made by several observers to attend to the same mental fact, it may not be successfully carried out because they cannot be sure that they are examining the same fact. No student of psychical facts can profit much by the observations of others, at least to any such extent as a student of the world of matter. To be really sure of his position he must experience the state or condition himself.

Every psychical fact, in order to be critically studied, must first be set up over against the mind as an object of contemplation. The mind must tear itself away from it, so to speak, and hold it up before itself, but as at the same time its own object. In short, the mind must be at once the observed and the observer—a task that from its very nature must be limited to the few individuals in any community who have the highly developed powers that its accomplishment requires. It is at best an artificial act. For the sole purpose of performing it is merely to see what sort of an act it is, without any other impelling motive.

"We perceive, remember, and imagine," says Porter, "we hope and fear, choose and reject, naturally and readily enough, when the objects arouse and excite us; but to perceive and re-perceive, to hope and fear again and again, simply that we may know more exactly how it seems or what it is to perform or experience these states, are, at best, forced and unnatural efforts."

But supposing that just the opposite from what we are here maintaining were true, and it were both possible and easy to gain an accurate and complete knowledge of the facts of the universe of which we form so insignificant a part, we should no sooner begin to arrange and classify them than we would suddenly discover that the whole matter of classification is a very uncertain one and that there may be as many different ways of doing it as there are different plans and purposes to be served thereby.

Kepler went too far when he exclaimed, "O God! I think thy thoughts after thee," if he meant thereby that his generalizations were absolutely certain truths. And Agassiz fell into the same error in his famous *Essay on Classification*, by holding that the groups of a natural classification are "instituted by the Divine Intelligence as the categories of his mode of thinking," at least if he meant to affirm that any human being can unfold that mode. "From the standpoint of pure science," says Professor Rice, "the dictum of Agassiz appears utterly irrelevant. The Creator has certainly not seen fit to reveal what characters he regards as of the greatest taxonomic importance; and the judgment which any individual naturalist may form as to the relative importance of the various likenesses and unlikenesses which exist between different animals, will be entirely independent of his theological opinions."

Agassiz's great mistake was in insisting that his division of the animal kingdom into vertebrata, articulata, mollusca, and radiata was *the* classification instead of *a* classification. He seems to have thrown out the protozoa from his classification chiefly for the reason that there were only four types in the animal kingdom and could be neither more nor less. Whatever could not find a place in his divinely ordained fourfold classification must be explained as conglomerates that were either larval forms of higher animals, or purely vegetable, or so little understood as to make it impossible to tell to which one of the four subdivisions they actually belonged.

Another of Agassiz's false notions regarding classification was that no part or organ in an animal belonging to one sub-kingdom could be homologous with any part or organ in an animal belonging to any other sub-kingdom. But the researches in embryology carried on by Kowalevsky soon showed the error in this doctrine and made it evident that the possibility of a genetic transition across the boundaries of these sub-kingdoms cannot be left out of the question.

Twenty-five years ago zoölogical classifications were often based on physiological characteristics, and even such superficial ones as habits and modes of life. Birds were classified as perchers, walkers, and swimmers, and a great gap was made between them and reptiles because of their different locomotive powers. All vertebrates were divided into cold-blooded and warm-blooded. Spiders and scorpions were put with insects, and lamper-eels with fishes. Now it is clearly recognized that morphological characteristics must have the first place in all natural-history classifications. All other methods fail to keep abreast with advancing knowledge. The same thing is true in the case of plants. The old physiological method of classification is giving way to the morphological in the systematic botany of to-day as less artificial and as better adapted to our present scientific purposes.

The entire history of classification furnishes abundant proof that we can never expect to attain a perfect and final system in any science, but must take the one, and rest content with it, that best tabulates our present knowledge and least impedes our future progress.

Prof. G. F. Wright, of Oberlin, in an excellent paper on the "Uncertainties of Science," well summarizes this whole matter as follows: "The classification of plants and animals expresses, not facts, but the judgment of individual botanists and zoölogists as to the relative importance of certain features of resemblance and diversity. So that, whether we shall call a class of plants or animals a variety, a species, or a genus, depends not only on the meaning we give those words, but upon our estimate of the permanence and importance of the peculiarities marking the class. This uncertainty about the limitation of species does not decrease with the increase of knowledge. It is just those who know most of botany and zoölogy who have the deepest sense of their own ignorance as to the precise relationship of one plant or animal with another."

The limitations that beset the path of the scientific investigator nowhere more impressively present themselves than when we come to examine the fundamental terms used in science and raise the question as to what they really signify. Professor Tait is speaking strictly as a scientist when he asserts that "gravitation, force, monad, ether, and the like are names upon which we hang our faith."

In spite of all that has been written on the subject, the origin and nature of the so-called ether is still, for the most part, shrouded in impenetrable gloom. Pretty much all we know about it is that it undulates. When Young and Fresnel made known to us that light is simply the motions of an incandescent object conveyed to our eyes by undulations, we were obliged to assert that there must be something between our eyes and the object that undulates; and when Clerke Maxwell showed that light and the electric impulse move approximately at the same rate through space, it was thought necessary to assume that the undulations that convey them are undulations of one and the same medium.

All the fluids that we know anything about transmit the impulses they receive by waves which undulate backward and forward in the path of their advance, but ether undulates athwart this path. Lord Kelvin has shown, however, that this might be true without violating the laws of mathematics of a fluid in a special state of equilibrium and of infinite extent. Consequently we are taught that ether is in this special state of equilibrium, and is of infinite extent, that is, that it pervades all space whether occupied by any kind of matter or by no matter at all. But all we actually know about it is that it is an inscrutable something that undulates, and undulates in a very peculiar manner, and it is not easy to see how our knowledge of it can ever be much more complete than it is at present.

The existence of atoms is a primary conception of science, but our knowledge of their origin and nature is still extremely limited and likely to remain so. What we accept about them must be taken chiefly on faith. This is as true to-day as it was centuries ago, in spite of all the intellectual energy that has been expended upon the subject by many careful thinkers during the interim. All the sciences of our time that have to do with atoms are built up on this faith. Professor Cooke, of Harvard, in the introduction to his *New Chemistry*, does not hesitate to affirm that "if we would become imbued with the spirit of the new philosophy of chemistry, we must begin by believing in molecules."

Between sixty-five and seventy of these so-called elements have been brought to light. Many of them differ from each other in almost every conceivable particular,—in weight, in melting-point, in conductivity, in cohesive power, and law of combination. They seem to be related together about as the particles of sand on the shore of the sea. When Dalton made the great discovery that the atoms of these elements have a special weight of their own and always combine in fixed proportions, the theory was advanced that perhaps they can all be reduced to a common origin. An atom of hydrogen was assumed as the basis and its weight was taken as the unit of molecular weight. Sir William Thomson (now Lord Kelvin) estimated this atom to weigh approximately 0.000,000,000,000,000,000,000,-109,312, or 109,312 octillionths of a gramme. But the most elaborate analyses, conducted by the most expert experimenters, have failed to reveal any foundation for the theory from the standpoint of ascertainable facts.

Later came the spectrum analysis, which was expected to throw great light upon the nature and origin of atoms. Kirchhoff and Lockyer in particular have done much to increase our knowledge by the use they have made of this means of gathering information about the universe. We have found out that the elements that exist in the stars and our sun are for the most part the same as those here on the earth. But the surprising fact is that the sun contains no oxygen or nitrogen, although the former makes up by far the larger part of our solids and liquids, and the latter the chief part of our atmosphere. Yet how can this be if the nebular hypothesis be true, and our earth was once an essential part of the sun that in the fulness of time was merely thrown off into space to revolve upon its own axis?

Another interesting fact that the spectroscope has revealed to us is that the lines of the spectrum produced by any atom or combination of atoms never encroaches upon the spectrum produced by its neighbor, and that when any kind of atoms causes the ether to undulate the undulations proceed at a rate peculiar to that particular kind. Spectrum analysis, however, has not done what was expected of it. It still leaves the nature of atoms, their marvellous differences, and the origin of those differences as great a mystery as ever.

Much was looked for also from the ingenious and laborious researches of Mendeléeff. He did succeed in showing that the elements may be put into families resembling each other in some such particulars as weight, heat, volume, and the like, but his periodic law has not solved the enigma of their parentage or method of genesis.

The real situation regarding the whole matter is well summarized by the Marquis of Salisbury in his inaugural address as president of the British Association for the Advancement of Science, delivered at the Oxford meeting in 1894:

"The upshot is," he says, "that all these successive triumphs of research, Dalton's, Kirchhoff's, Mendeléeff's, greatly as they have added to our store of knowledge, have gone but little way to solve the problem which the elementary atoms have for centuries presented to mankind. What the atom of each element is, whether it is a movement, or a thing, or a vortex, or a point having inertia, whether there is any limit to its divisibility, and, if so, how that limit is imposed, whether the long list of elements is final, or whether any of them have any common origin,—all these questions remain surrounded by a darkness as profound as ever. The dream which lured the alchemists to their tedious labors, and which may be said to have called chemistry into being, has assuredly not been realized, but it has not yet been refuted. The boundary of our knowledge in this direction remains where it was many centuries ago."

Great strides have been made in recent years in the science of biology. Its triumphs have been extraordinary, and its successes in the future are not unlikely in many ways to surpass those of the past. Yet it gives us little hope of ever being able to unravel the great mystery of the origin and nature of life in our day or at the time of its first appearance on our globe. Theories in abundance have, of course, been propounded on the subject from which we are invited to take our choice. There is the chemical theory represented by Sylvius in the seventeenth century, the mechanical theory current in the time of Harvey, the discoverer of the circulation of the blood, the dynamic theory elaborated by Stahl, the irritation theory of the French physiologists, the evolution theory, and so on.

Herbert Spencer defines life as "the continuous adjustment of internal relations to external relations," which really is equal to saying, "Life is what it is." Others define it as "the sum of functions which resist death." Aristotle's definition is "that which gives form to an organism." This is a description of life rather than a definition. For it is one of those things that, by its very nature, cannot be defined. Some say that because chemists have produced by imitation many of the compounds which are found in nature only in organic bodies, there is no such thing as vital force. Yet this does not explain the origin of the organism itself or how it is made to run on through its appointed course. Darwin, in his *Origin of Species*, has traced the history of animal organisms from the jellyfish on the primeval beach down to man as we find him to-day.

But as this transition was effected by means of variations so minute that the whole known history of man does not suffice for a single one of them either in plant or animal, hundreds of millions of years must have been necessary to make the transfer. Just here comes in the objection of the physicists that such a period cannot possibly be allowed. Lord Kelvin has demonstrated beyond all reasonable doubt that, taking into consideration the rate at which the earth is now cooling, no organic life could have existed upon its surface one hundred millions of years ago. The alleged jellyfish would have been dissipated into steam the moment of its birth.

Professor Tait goes much further and boldly asserts that the claims of biologists and geologists on this point are in irreconcilable conflict with the demands of physics. "A limit of something like ten million years is all that can be allowed them," he declares. "But I dare say," he continues, "many of you are acquainted with the speculations of Lyell and others, especially of Darwin, who tell us that even for a comparatively brief portion of recent geological history three hundred million years will not suffice. We say, so much the worse for geology as interpreted at present by its chief authorities."

In spite of this objection to the doctrine of natural selection and the survival of the fittest, as furnishing an adequate and complete explanation of how the present forms of life came to be upon our planet, Weismann persists in accepting the Darwinian hypothesis as entirely satisfactory, giving as his reason that "it is the only possible one we can conceive." "We must assume natural selection," he adds, "to be the principle of the explanation of the metamorphoses, because all other apparent principles fail us, and it is inconceivable that there could yet be another capable of explaining the adaptation of organisms without assuming the help of a principle of design." But are we to accept an alleged explanation of anything as complete and final simply because other alleged explanations fail to satisfy? Is it not far better logic to suspend judgment until we can obtain some further light upon the matter?

There may be little ground, perhaps, for doubting the fact of the evolution of higher organisms from lower. But this does not necessitate the adoption of this man's or that man's theory as to how the evolution has come about. One might even claim with Haeckel that the crystal is the probable ancestor of all the flora and fauna on our planet, and still hold that no one has produced, or is likely to produce, a satisfactory explanation of the process by which this result has been arrived at.

Every careful thinker holds fast to the doctrine that all that is has developed out of that which has been. *Ex nihilo nihil fit* is fundamental to all sound thinking. To deny it would be to break up the whole continuity of our thought. But, notwithstanding, may it not transcend all our powers to explain the inscrutable mystery of our present existence and mark out in detail how we came into being? Certainly science of to-day, whatever may be said of the distant future, must content itself with the endeavor to discover how life acts, leaving the question as to how it originated and how it perpetuates itself in the region of the unknown. It is contrary to the true scientific spirit to advocate theories about matters of which we are profoundly ignorant. It is far better and wiser frankly to acknowledge our limitations when we come to them than to keep on dogmatizing to the end whatever happens.

Ever since Sir Isaac Newton first announced in his *Principia*, given to the public in the summer of 1687, the great law that "every particle of matter in the universe attracts every other particle with a force directly proportioned to the mass of the attracting particles, and inversely to the square of the distance between them," most of the great mathematicians of the world have been devoting their energies to the computation of its effects. But nobody knows to-day any better than Sir Isaac Newton knew, or Adam knew, or anybody else knows who has observed a falling apple what gravity is, or can state with absolute certainty its law of operation.

As Prof. Simon Newcomb reminds us, Newton was not the first discoverer of gravitation. The fact that bodies in general tend to fall toward the earth has been known to all people in all times, even from their very infancy. Nor could he have posited his law without the help furnished him by the researches of Galileo, Huyghens, and Hooke on terrestrial gravitation, as well as the results of the labors of Kepler, which he had formulated into his three great laws. None of these laws of Kepler are, however, more than approximately correct, and the most that can be said of Newton's law is that from all the evidence at hand it seems to be universally true that every particle of matter attracts every other particle directly as the mass and inversely as the square of the distance. Still the law has often been called in question. Faraday, in particular, was strenuously opposed to it. "This idea of gravity," he says, "appears to me to ignore entirely the principles of conservation of force, and by the terms of its definition, ' varying inversely as the square of the distance,' to be in direct opposition to it."

But Newton himself did not claim any knowledge of what gravity is, although he had such a decided opinion about the way it operates. In a letter to a friend he says: "You sometimes speak of gravity as essential and inherent to matter. Pray, do not ascribe that notion to me, for the cause of gravity I do not pretend to know."

It is not too much to say that no one to-day has any more knowledge on this point than was possessed by Newton. We cannot correlate gravity with anything else. Heating a body does not diminish its gravity, or cooling increase it. It cannot be made to disappear into any other form of force. What may be done with it in the future is more than we can say, but at present science is dumb before this mysterious power.

No word in science is more frequently upon our lips than the term force. But when we come to examine with any care into its meaning we very soon reach a limit beyond which we cannot go and attribute to the term any real significance. The authors of *The Unseen Universe* go so far as to say: "We have as yet absolutely no proof that force proper has objective existence. In all probability there is no such thing as force, any more than there is such a thing as sound and light, which are mere names for physical impressions produced upon special senses by the energy of undulatory motions of certain media."

Whether this is a correct opinion or not will probably for some time to come remain an unsettled question. At all events we are entirely justified in saying that the ultimate nature ot force is wholly beyond the present powers of experimental science. Any investigation of force based on experience will affirm nothing of its nature, but will wisely confine itself to the effects that are said to be due to it.

We can, of course, measure force and talk of statical and dynamical force, or force producing actual motion and force held in check by opposing forces. We can formulate our laws of motion and hold them in the highest regard as among the most certain generalizations of which we have any knowledge. Yet from the very nature of the case itself, and from the limitations of our powers, we must ever be ready to say with Professor Pickering, of Harvard: "Nothing is known of force except as a cause producing, or tending to produce, motion or change of motion in matter." Anything more than this transcends at least the present boundaries of science.

It is not necessary to proceed further or enter into greater detail in order to make clear and vivid the many limitations that beset all attempts to arrange and classify human knowledge in accordance with the demands of science. It has not been our purpose to disparage in any way the extraordinary advances that have been made in the past in reducing our knowledge of the universe to scientific form or to throw any doubt upon the validity of that knowledge. But we do mean to emphasize the fact that all scientific knowledge, while it is good so far as it goes, is far from being exhaustive knowledge and is surrounded by limitations that every serious mind is bound to take into due consideration.

Much is being said at present in many quarters about the bankruptcy of science, as though it had utterly failed to keep its obligations and had gone to pieces in its attempts to accomplish what it had no ability to perform. But, as President Gilman remarks, that depends upon what we mean by science and upon what we expect of it. It will go into bankruptcy if it strives to take the place of art or literature or religion. But if it does not profess to do what there is no possibility of its doing, and keeps to its sphere of carefully ascertaining the facts and making out of them a system of consistent truths, there never has been any danger of its ending in bankruptcy, and there never will be.

We must, however, keep constantly in mind that science does not deal with absolute certainties. The best it can do is to displace the uncertain by the more certain. As a noted scientist himself expresses it: "It is the province of science to overcome in part, but only in part, the limitations of our ignorance."

CHAPTER VIII

SOME RECENT ADVANCES IN THE PHYSICAL SCIENCES

AN eminent New England geologist closed a recent address at New Haven before a distinguished company of his fellow-workers with these words: "We make no prophecies. As scientific men we know too well the fallibility of all processes, and the uncertainty of all results, of human thought to suppose ourselves to be the custodians of absolute truth on any subject. Our creed revisions come not once in three hundred years, but every day. We have no belief to-day on any subject which we are not ready to abandon to-morrow."

It is in the spirit of this frank and candid utterance that all the great investigators of our day are carrying on their ceaseless labors. And it is because of this spirit that such wonderful advances have been made in recent years in almost every department of human knowledge.

Astronomy, the first of all the sciences to assume any definite form, although it was completely revolutionized by the laborious and profound investigations of Copernicus, Kepler, Galileo, and Sir Isaac Newton, is still in the van of progress and is likely to be for some time to come. A little attention to the recent marvellous developments of that science as set forth by its recognized exponents will make this evident.

The old astronomy confined itself to the ascertainment of the positions and motions of the heavenly bodies. It determined accurately the place of the stars in the heavens and arranged them in carefully prepared catalogues for future use. It studied the motions of the planets and measured their satellites. It computed the orbits of comets and investigated the laws of motion as they are revealed in the whole solar system. On the basis of this ancient and mediæval astronomy, carried to great perfection by the mathematical geniuses of the time, the successes of modern practical astronomy have been built up. Any well instructed navigator of to-day, with the proper instruments and tables, can tell within a hundred yards where he is (in latitude and longitude), if the weather is clear enough for him to see the stars, even though he were set down in mid-ocean, and had no knowledge at all of how he arrived there.

Yet this astronomy is only a small part, and, in many respects, the least interesting part, of the astronomy of to-day. Physical astronomy, or, more properly speaking, astrophysics, which the discovery of the spectroscope has brought into being, and photography has done much to perfect, is now absorbing the attention of investigators. It deals with the physical composition of the heavenly bodies and shows us in what respects they are like our earth.

Before the discovery of spectral analysis, it was not possible to draw the line between nebulæ and clusters of stars. Many objects that looked like nebulæ when seen through small telescopes were resolved into clusters of stars when viewed through large ones. No one could tell whether all nebulæ were not star-clusters. For they might all be either so small or so distant that no telescope could help to a decision. But when the spectroscope was applied to such of these nebulæ as could produce a visible spectrum it was found that many of them were simply masses of hydrogen or nitrogen or some other incandescent gas and not solid bodies at all. Of the two great nebulæ of Orion and Andromeda clearly visible to the naked eye in our northern sky, Orion is now known to be a true nebulæ. But Andromeda is a solid or liquid body probably consisting of an enormous agglomeration of stars, though so distant as to be out of the range of present telescopic power.

Our sun is now ascertained to be but one, and probably an inferior one, of the fifty million stars now separately visible through telescopes of the greatest magnifying power. Each one of these stars is probably the centre of a solar system like our own. The fact that with one possible exception no planets have been discovered in connection with a star is no objection to this view, because if they did exist they are so distant that they would be entirely invisible to us even with our most powerful telescopes.

Yet it is not the vastness or complexity of the stellar universe that chiefly concerns the new astronomy, but the physical constitution of the bodies that have always been known to exist there. Herschel's theory that our sun is a dark, cool body surrounded by a stratum of luminous clouds floating in air is wholly set aside by the modern doctrine of the conservation of energy and our present views of heat and light. On the contrary, astronomers now hold that the photosphere—the shining surface of the sun—is a cloud-like mass of matter floating in a fluid, all of which is heated to an extremely high temperature. Depressions in this matter give us what we call the spots on the sun. Astronomers are also generally agreed that the interior of the sun is chiefly composed of materials similar to those found on the crust of the earth.

The chromosphere, or the red light above the photosphere, whose existence and nature were first detected by Lockyer's spectroscope, reveals to us still greater wonders. "It is agitated by storms of fire," says Prof. Simon Newcomb, "the fury of which exceeds anything ever pictured by the wildest imagination of the poet. The velocity of the wind sometimes rises to one hundred miles per second, and the masses of fiery vapor many times the size of our earth shoot up to the height of twenty thousand, fifty thousand, or even eighty thousand miles." Outside of the chromosphere has lately been discovered the still more wonderful solar corona, which can be studied only during total eclipses of the sun. So far its spectrum consists chiefly of a single green line unlike that of any known terrestrial substance.

Why the sun, which has for millions of years, perhaps, been radiating into space as great floods of light and heat as at present, did not cool off thousands of years ago and why it does not now grow cooler is a fact receiving the attention of the astronomers of our day as never before, though no wholly satisfactory explanation seems yet at hand. Many incline to the contraction theory. It is estimated that the present supply of heat and light may be kept up for a million of years yet in this way before the sun will be condensed into a solid or liquid involving our whole system in darkness and death.

There is no instance on record, we are told, of a known sun or star disappearing from the heavens or of a really new one coming into view. Many of the stars vary extraordinarily in brilliancy, owing, probably, to great changes in position and internal condition or to a temporary eclipse. Dr. Vogel, of the observatory at Potsdam, has recently shown in the case of the star Argol that the revolution of some dark object like a planet temporarily comes in between the star and the earth and intercepts, in part at least, its light. The latest authorities also tell us that "there is, in fact, no certain evidence that the stellar universe is held together by any bond of attraction whatever, as our solar system is. Mädler's view that Alcyone is the central sun of the universe is a piece of groundless speculation, which has never received the assent of astronomers qualified to judge."

What is true of the stellar universe is also true of comets. The old astronomers were content to describe their orbits and size and times of reappearance. Some to-day busy themselves with this phase of the subject. For example, it has recently been definitely ascertained by elaborate mathematical calculations that the great comet of 1858, after flying off fifteen billion miles into space, will return again about the year 3820. But the chief interest of the new astronomy is in the physical properties of comets and what the spectroscope reveals concerning their composition. While the mystery concerning them in some respects increases with more knowledge, it is now being generally maintained that the tail of a comet is not a permanent part of its structure, but consists of very fine particles of matter driven off from it by some unknown repulsive power in the sun as it approaches that body. If so, all comets will eventually be dissipated into space and cease to be.

If the term geology were used in as wide a sense as we are accustomed to use the term astronomy, it would include all that relates to the origin and nature of the phenomena of the earth, both organic and inorganic; and the word is sometimes so employed. But the narrower and more usual sense is to confine it to the rocky bed of the earth and the changes that have taken place in it. The ancients had little interest in the earth's structure, as they were acquainted with only a small portion of it and the changes in it were not so striking as to excite special attention. In fact, geology, as we now know it, is a comparatively recent science. Genesis was about the only geology we had until long after the Protestant Reformation. When marine fossils were discovered high up on the Alps, indicating that these mountains were once under the sea, the chief use made of the fact was to confirm the story of the extent of the Noachian deluge, although Voltaire is said to have argued from it that some pilgrims on their way home from the Holy Land stopped there to eat their scallops, and very naturally did not take the shells away with them.

Geology did not make its influence felt in the world to any marked degree until some of its more ardent devotees began to demand far more time for their theories than the expounders of Genesis were inclined to give them. For the many physical and biological changes that must have taken place on the earth in order to make possible the deposition of the fossil-bearing strata thousands of feet thick, found at so many places on its surface, must have required millions of years. But even at this period in history geology had hardly advanced beyond its infancy. "The geologists of the closing years of the last century and the first third of the present century," says Professor Rice in an extremely satisfactory chapter on Genesis and Geology, in his work already referred to, "were all catastrophists. They knew no mode of transition from the physical and biological conditions of one geological period to those of another, except by gigantic cataclysms or convulsions of nature, exterminating all living creatures, and leaving the field clear for a new creation."

Quite the opposite opinion now prevails. Rarely if ever has the change in fauna and flora been complete in passing from one stratum to another. Whenever it seems to be complete the probable explanation now offered is not a sudden and universal extermination of the old life and the creation of new, but simply a case where examples of a gradual transition failed to be recorded.

The geology of our day, according to its acknowledged exponents, makes a clear distinction between the geology of the crust of the earth and that of the nucleus. The former is by far the more definite and well grounded, but the latter, although investigated by different methods, is now receiving unusual attention and giving rise to many problems of uncommon interest. If the nucleus consists of the same kind of material as the crust, which is by no means certain, the pressure at the centre coming from the overlying mass would be fairly estimated at about ninety thousand tons to the square inch. But we must also remember that wherever the earth's crust is penetrated by borings or by shafts of mines there is a regular and gradual rise in the temperature equal to one degree Fahrenheit for every fifty-five feet of descent after the first hundred. The testing of the water in artesian wells reveals the same fact. It is also known that hot or boiling natural springs rise through deep and large fissures. The molten rocks emitted by volcanoes show that they come from depths where the heat is so intense that they are retained there in a state of fusion. From these and other facts it is argued that the solid crust of the earth is not more than twenty-five miles in thickness, the heat at that depth being more than sufficient to fuse any known substance.

On the other hand, it is contended that if the nucleus of the earth were in a liquid state an eruption of molten rock once begun would go on indefinitely, the greater density of the solid outer crust allowing no cessation. But all volcanoes, as is well known, are intermittent. It is also urged that if the nucleus were liquid it would respond to the tidal influence like the ocean and create conditions on the surface quite different from those that now exist. It seems to be now generally admitted that while great advances have been made on the subject in recent years the question as to the composition, temperature, density, and physical condition of the nucleus of the earth still presents a problem so complex that its solution is impossible until our knowledge of the general properties of matter has increased far beyond what it is at present.

The geology of the crust, or the lithosphere, as it is called, offers us much surer ground. From almost every standpoint this division of geology has greatly developed in recent years. Only a few generations ago some of its most important departments were just emerging into being. Werner, who died in 1817, by the study of the varied mineral deposits of the Erzgebirge laid the foundations of mineralogy, although his so-called Neptunian theory of the origin of all mineral substances in their present form from the action of water is now regarded as only a partial truth. The beginning of modern dynamical geology was made by

Hutton through his patient and exhaustive study of the Scotch Highlands. And William Smith (d. 1839), who is commonly regarded as the father of English geology, by his careful investigations of the English series of rock formations, was the first to put stratigraphical geology upon a satisfactory basis.

Paleontological geology is as recent as Cuvier. Twenty-five years ago the gaps that separated the groups of fossil organisms from one another seemed almost impassable. Most of the leading paleontologists of the time were anti-evolutionists for that reason. The absence of connecting links caused even Darwin to remark that "this, perhaps, is the most serious and obvious objection which can be urged against my theory." It is too much to say that these gaps have already been bridged, but immense strides towards it have been made in the last few years, the credit for which is due in no small measure to the marvellous discoveries in the western part of the United States made by such American experts as Marsh and Cope, Powell and Gilbert, Osborne and Scott.

Even as late as 1863, when Lyell published his famous *Antiquity of Man*, the time of the appearance of human beings upon the earth was a leading question of the hour. But, as a well-known authority expresses it, "the man who doubts to-day the co-existence of man with the mammoth and the cave bear is not an antagonist to be argued with, but an ignoramus to be sent to school; and certainly no scientist at present would dream of limiting the age of man to anything like the six thousand years of tradition."

The age of the earth itself has always been a matter much discussed, and never more so perhaps than at present. Estimates based on geologic data vary from twenty million years to as many billion. When the cooling of the earth is taken as the standard the limit is put at from twenty million years to four hundred million.

On the subject of mountains and volcanoes geologists still greatly differ, although the matter has recently been carefully studied. The most generally accepted theory for mountain uplifts is the contraction theory. The temperature of the rigid crust is supposed to be approximately uniform, but that of the earth's nucleus to be constantly diminishing by dissipation. The adjustment of the one to the other is assumed to be the cause why some portions of the earth's surface are elevated far above the general level and others depressed far below it.

Turning now to biology it is probable that no naturalist would deny the statement that the whole character of the science within the last thirty or thirty-five years has been radically altered. Before Darwin's *Origin of Species*, published in 1859, began to dominate scientific thought, biology was almost wholly a mere description of species; now it is chiefly a dynamic science. In fact, it is being generally admitted that the reaction against systematic botany and zoölogy has gone too far.

That Darwin's theory of natural selection has been by far the most important contribution to the explanation of the evolution of organisms there can be no question. It is based on the well-known principles of heredity and variation supplemented by the familiar fact that all organic beings tend to multiply in a geometric series. But, as has been observed, natural selection is sometimes progressive and sometimes conservative. When the environment is stationary and the species fitted to it, natural selection will tend to keep the species stationary. But when climatic or other changes alter the environment natural selection will tend to perpetuate those individuals of the species that vary with the changes and to destroy those that most closely adhere to the ancestral type.

The paleontological facts most remarkably confirm what this theory would lead us to expect. Yet as an eminent defender of the theory puts it, "that natural selection is a complete explanation of the process of organic evolution cannot reasonably be claimed. Indeed, the claim was never made by Darwin himself. But that it is by far the most important contribution to the explanation of that process which has thus far been made is certain." It is evident, however, that before we can have anything like a complete explanation of the evolution of organisms we must have an explanation of the principles of heredity and variation. For it is only through individual variation that any occasion can arise for the origination of new species. But all the ingenious speculations that have been devised thus far to account for these principles have confessedly failed to add very much to our knowledge.

Twenty-five years ago spontaneous generation was a burning question and no one dreamed of the marvellous developments that were to result in the creation of the new science of bacteriology.

The doctrine that living organisms may originate out of inorganic matter without parent organisms to produce them has been maintained in every age of scientific history. Lucretius held that reptiles might be developed directly out of the mud or slime of rivers. "Down to the seventeenth century," says Professor Billings, "the belief that living things may originate without eggs or germs or living parents from which to proceed may be said to have been universal in Europe." It was even maintained on scriptural grounds. The fact that Samson found a lot of bees in the carcass of a dead lion was regarded as sufficient proof of it. Those who denied it were accused of impiety as calling in question an article of religious faith.

The first person to show the falsity of the doctrine was an Italian philosopher by the name of Francis Redi. He confined some pieces of fresh meat in some jars that were covered with gauze only and then left them in the sun to putrefy. The putrefaction went on as usual, but no maggots appeared in connection with it, although they did appear on the gauze, being generated by the flies that gathered there. From this experiment Redi generalized the doctrine: *omne vivum ex vivo.* No living thing comes into existence without getting its life from something previously living.

This new doctrine of biogenesis did not, however, meet with general acceptance. It was stoutly denied by Needham, in the middle of the eighteenth century, who experimented on some infusions that he made and sealed up in flasks after boiling them a long time so as to kill, as he thought, all possible organic germs. He found that living organisms appeared in the flasks after several days just as they did in infusions freely exposed. Spallanzani, however, performed the same experiments, taking more care to exclude the outer air, and no animalcules were found.

Still the controversy went on unabated. Early in the nineteenth century the celebrated Lamarck took up the matter and vigorously espoused the cause of spontaneous generation, and he found many followers. Schultze and Schwann, however, by repeating the experiments of Spallanzani under the most careful conditions and with the most satisfactory results, again brought the doctrine of biogenesis to the front in triumph.

A great struggle over the matter broke out again about three decades ago, led on the side of spontaneous generation by Pouchet, and on the side of biogenesis by Pasteur. Bastian advocated the views of Pouchet in England, and Wyman did the same in the United States.

Pasteur showed that infusions hermetically sealed while boiling showed no traces of organic life after indefinitely long periods of time, while the same infusions exposed to the open air very soon abounded in animalcules. He also repeated in a way the experiment of Redi with the gauze-covered jar. He found that even a plug of cotton put into the neck of a flask filled with boiling infusion would prevent the development of organic life the same as when the flask was sealed. Others claimed that they had performed similar experiments with opposite results, bacteria appearing not only after the infusion had been boiled and hermetically sealed, but even when the boiling had been kept up after the sealing for many hours.

Authorities tell us that the methods of bacteriological research in vogue in our laboratories since 1878 show clearly enough that the old methods would not insure the killing of all spores. An infusion containing the hay bacillus, for example, would not succumb to their treatment. No one doubts to-day, however, that the views of Pasteur are correct. "It may now be considered as definitely settled," says a high authority, "that there is no evidence that spontaneous generation can occur in the earth under existing circumstances."

The vast amount of time and labor put upon this controversy was not, however, spent in vain. On the contrary, a large quantity of material was accumulated for future use.

The germ theory of disease is one of its products. The great majority of bacteria are directly beneficial to all forms of life. In fact they are essential to its existence on the earth. It is through the ceaseless activity of these minute cells or chains of cells that the carbonic acid, ammonia, and water are formed out of the complicated tissues of dead plants and animals that are essential to the growth and development of all the more highly organized members of the vegetable kingdom.

These bacteria that obtain their nutrition from dead organic matter and are so beneficial to mankind in furnishing the food stuffs for the support of its life, are called saprophytic bacteria, in contradistinction from the parasitic bacteria that exist at the expense of other living organisms, producing changes in their tissues which usually result in disease, and often in death.

Living bacteria are almost omnipresent. They are found in the water, the soil, the air, and the intestinal canal of all animals, though not in their tissues if in a healthy state. Usually many species of bacteria exist in the same body, and much attention has been given to devising methods by which they may be separated into like groups for careful study.

It is by these methods that it has recently been established that bacteria in great multitudes exist in all open water-courses over the entire earth. Water bacteria, however, are saprophytic, and instead of possessing the property of inducing disease, they turn the complex nitrogenous matter in the water into simpler forms, so that it can be taken up as food by higher organic forms or changed into innocent inorganic salts.

In the same way bacteria are found to affect the soil. In connection with other organisms they purify sewage as it filtrates through the soil. The great saltpetre beds of Chili and Peru are largely the product of these microscopic creatures working upon large masses of nitrogenous wastes. The employment of bacteria in the industries is likely to become a very important one. For example, the flavor of certain cheeses that are highly prized is due to the activity of a peculiar species of bacteria, and many of the organic acids are produced by them.

But bacteriology is chiefly valued, perhaps, for the light it throws on the origin of disease. It is now established beyond reasonable doubt that many diseases formerly regarded as incurable can now be treated successfully from the standpoint of the bacteria by which they are caused. The first disease that was shown to be due to these microscopic organisms was anthrax, or malignant pustule, a disease so common among Russian sheep and cattle as to be called the Siberian plague.

The bacteria that cause consumption have been carefully studied. Infection from them can occur through the air-passages, the alimentary tract, or through wounds of the skin. The bacillus of tuberculosis, it is found, grows very slowly, if at all, at a temperature lower than that of the human body. Most animals, as well as man, are susceptible to the action of this organism, although white mice, rats, and dogs seem to be exempt.

Diphtheria has also been shown to have its peculiar bacillus. It is about the size of the tubercle bacillus, but very irregular in its form, which may be curved, straight, or spindling, while the tubercle bacillus is always rod-shaped. It is found in the false membranes of the pharynx in patients suffering from the disease, not often in the internal organs, even in case of death. Diphtheritic bacteria, like those of tetanus or lockjaw, stay in the throat; but the poisons they secrete there are taken up by the blood and disseminated over the body.

It is generally admitted that pneumonia has its bacillus, which is the chief factor in the production of that disease, and Sternberg estimates that it is found in the saliva of about twenty per cent. of all healthy persons, waiting for favorable conditions to develop.

The bacilli of erysipelas, typhoid fever, and Asiatic cholera are now clearly recognized by physicians, and their treatment of these diseases is in accordance with this knowledge.

Almost every particle of dust in the air is now known to be covered with bacteria. They are, however, for the most part, saprophytes whose mission it is to purify the air, and not the death-dealing parasites so much to be feared. Disease-producing bacteria are not found in the open air, but are sometimes discovered in closed apartments occupied by persons or animals suffering from infectious diseases.

"The results of studies upon the *modus operandi* of infections," says Dr. Abbott, "lead us to believe that bacteria invade and destroy the vitality of tissues in which they are located, principally by the production of poisonous products that are of an albuminous nature. These products are the weapons, so to speak, of the invading foe, and the result of the contest depends mainly upon the power of the tissues to resist the action of these agents."

These great discoveries in bacteriology, for which our age is famous, have been accompanied by equally important advances in many other kindred sciences, such as physiology, pathology, and therapeutics—upon the basis of which modern surgery has achieved its marvellous triumph. Portions of the skin may now be taken from one part of the body to supply defects in another. Nerves may be sewed or spliced so as to restore lost functions, and intractable neuralgia is often cured by nerve stretching or excision. The largest blood-vessels may be tied to prevent death by hemorrhage, and ligations of the large arteries are now made with impunity that a few years ago were not supposed to be within the realm of the possible.

Diseased joints are made strong and healthy by scraping out the diseased tissue or cutting out the offending articulation. Hip disease, in its milder forms at least, is no longer called incurable. Knock-knees and bow-legs are straightened, and club-feet are made shapely and serviceable. Dislocated bones are drilled into and joined together with silver wire and held in place by screws buried beneath the overgrowing tissues. The skull is opened with impunity to check intracranial hemorrhage, to evacuate abscesses, and remove tumors, whose exact location the recent study of cerebral localization has made it possible to determine.

The advances in abdominal surgery in our day seem almost incredible. "Hardly any organ of the abdominal cavity," says Professor Ashhurst, "but is subjected to exploration, and, in cases otherwise incurable, to complete or partial extirpation. The surgeon cuts into a kidney, removes stones from its interior, stitches it into its proper place when it is dislocated, and when hopelessly disorganized, removes it entirely from the body. The spleen is excised, as is the pancreas; wounds of the liver are sewed up or plugged to prevent hemorrhage; stones are removed from the gall-bladder, or the latter is itself removed, or, if occlusion of the duct prevents the natural escape of bile into the intestine, an artificial passage is established into a neighboring portion of the bowel. Wounds of the stomach and bowel are closed by suture, malignant tumors of these organs are boldly cut away, and the continuity of the alimentary canal is established, sometimes after the removal of many inches, or even several feet, of intestine."

Dr. Carl Schlatter, of Zurich, Switzerland, has recently succeeded in removing the entire stomach, and, by joining the œsophagus directly to the intestine, producing all the apparatus necessary for the digestion and assimilation of food, the patient nine days after the operation eating milk, eggs, meat, gruel, and tea, the same as before.

The *Medical Record* (New York, December 25, 1897), speaking editorially of this experiment of Dr. Schlatter, and allowing that he had proven that a human being can live and be reasonably active for months at a time without any stomach whatever, says: "We are now brought face to face with a very curious demonstration, which destroys the validity of many preconceived opinions, and in a great measure nullifies the results of many previous experiments. . . . He [Dr. Schlatter] has opened the first chapter in a new history of surgical triumphs."

Another science, the recent changes in which have greatly contributed to the progress of mankind, is chemistry. The earliest chemical work recorded was that done by the alchemists, and for fifteen hundred years they labored assiduously to show how the baser metals, such as lead, copper, and mercury, could be converted into gold. They did not succeed in their mission, but the material they accumulated laid the foundations of our present conception of chemical elements. About seventy of these substances which cannot be decomposed by us into simpler substances are now known to exist. All but eight or ten of them are, however, extremely rare.

The first object of chemistry is to determine what elements enter into the composition of things. This is called qualitative analysis. The second object is to determine in what proportion by weight these elements are present. This is quantitative analysis. A third object is to show how many things that occur in nature can be made by synthesis in chemical laboratories, and also how many things that do not occur in nature, but are useful to the progress of man. It was under the spell of this view of the science that Paracelsus, the father of iatro-chemistry, was led to declare that "the true object of chemistry is not to make gold, but to prepare medicines."

It would be impossible to measure the effect upon civilization of the comparatively recent discoveries made by chemists of the aniline dyes, of artificial ways of making sulphuric acid, Turkey red, saccharin, antipyrine, sulphonal, chloral, and nitroglycerin. But there is another side of chemistry that is now receiving much attention, namely, the nature of chemical action itself. The chemist of to-day wishes to study not only chemical elements and chemical compounds, but to observe the process of chemical action and get an insight into the nature of the act. This physical or general chemistry, of which thermo-chemistry is a special branch, is greatly attracting original investigators at present. "It is clear," says Professor Remsen, "that the chemist's task is not done when he has determined the composition of substances. He must go further and determine the constitution, and further still and strive to learn what the chemical reactions are that give rise to the compounds he deals with. He must investigate everything that is likely to help him in this effort to discover what takes place when substances act upon one another chemically. His field is boundless, and new visions are appearing to him at every advance."

Equally hopeful is the outlook of the modern electrician, although the last thirty years have witnessed the development of submarine telegraphy, the invention of the telephone, and the marvellous triumphs of electric lights and electric motors.

From this brief survey of some of the more striking advances in the physical sciences of our day we see the marvellous results of a genuine scientific study of the phenomena in question. More careful observation and experiment have been accompanied by more accurate examination of the facts attained. And out of a more careful examination of the facts have arisen far more rational hypotheses in explanation of the facts. Investigators have learned by actual experience how to throw aside quickly a false theory and to apply at once the proper scientific tests to every new one. Thus the material is rapidly being accumulated for a rational and satisfactory conception of the universe.

CHAPTER IX

THE OLD AND THE NEW PSYCHOLOGY

THE earliest philosophers, because they made no distinction between mind and matter, regarded the soul as simply a moving force. Thales ascribed a soul to magnets, and declared that the whole world is full of souls. Anaximenes thought the soul was made out of air, Heraclitus derived it from fire, and Empedocles found it in the blood which streams through the living body. Some of the Pythagoreans taught that the motes seen in a beam of sunlight are souls, and consequently that their number is infinite. All these thinkers derived their notion of the soul from what they considered to be the fundamental element in the universe.

Plato was the first person among the Greeks to separate the soul from the body and treat it as distinct from matter. He ascribed to it power to move itself and to move the things about it. It was also able to know and to will. He was impelled to this position by his doctrine of ideas. The existence of these ideas and their relation to the world could not be accounted for except on the basis that the soul partook in some degree of their changeless essence. It therefore has two natures: the rational, by means of which it is related to the world of ideas; and the irrational, which binds it to the world of sense. The former, though now ensnared in the body, existed before the body existed, and does not perish when it disintegrates.

Aristotle's conception of the soul was largely affected by his doctrine of form and matter. The soul is the form of the body, the cause of its motion and changes. Still he maintained that the facts of the psychical life are capable of independent treatment. It is for this reason that his work *On the Soul* is the first attempt at a scientific psychology, though his division of souls into those of plants, of animals, and of men, never gained general acceptance, and many of the topics discussed in the work are now regarded as wholly irrelevant.

The Stoics and Epicureans looked upon the soul as a fiery breath. The former thought it was a part of the world-soul and that it would ultimately be absorbed by it at the universal conflagration ; while the latter regarded it as mechanically connected with the body, and to perish with it. The triple division of man into body, soul, and spirit was maintained by the Alexandrians, though the boundaries between these divisions were by no means firmly settled. Augustine, in his search for the universal ground of certainty as the starting-point of philosophical knowledge, maintained that the soul was a unit, its different activities revealing different aspects of the one being, which by its own self-consciousness knows its own existence as the surest of all truths.

Descartes, though sometimes called the founder of modern psychology, was searching rather for an ultimate rational truth upon which he could ground a sure system of philosophy, and he found it in his famous maxim : " Cogito, ergo sum." He made the essence of matter to be extension and of mind to be thought,—

the two substances having nothing in common. The soul and the body are essentially opposed to each other, and can be held together by force only at one point. This point is the so-called pineal gland situated at the meeting-place of the two hemispheres of the brain. This, he said, is the seat of the mind where all thoughts have their origin. The whole brain, in his opinion, could not be the organ of the mind, for its twofold structure would cause the soul to perceive two objects instead of one.

This mechanical view of psychology was also taken by Spinoza, who carried the Cartesian doctrines to their logical consequences.

According to Leibnitz the whole universe consists of an indefinite number of supersensual entities which he called monads. Every monad is a soul, and reflects in itself, as in a mirror, all the rest of the universe. The lowest monads that constitute the realm of inorganic nature reflect it obscurely, but monads of the highest rank, such as the developed human soul, reflect it with clearness. Starting with this notion of the soul he holds that while the soul has no connection with the body, as no monad can be affected by any other monad, they work together in perfect harmony. Their relation is like that of two clocks so exquisitely constructed that they strike in absolute unison, though the mechanism of the one has no connection whatever with the mechanism of the other.

The Lockian philosophy starts out with a polemic against what is called the doctrine of innate ideas,—a doctrine, as Locke represents it, falsely ascribed to Descartes and others. In opposition to the view that the mind comes into possession of certain ideas coetaneously with birth, Locke maintained that the soul is to be regarded as a blank tablet, a piece of white paper, deriving all its ideas from experience only. Out of this notion he elaborates his views concerning the mind's operations and powers. All our ideas, he says, are either simple or complex. All simple ideas are obtained by the use of the bodily senses and by noting the activities of the soul that arise on the exercise of those senses. All complex ideas are formed by associating together simple ideas into various groups or combinations.

Condillac took essentially the same philosophic standpoint as Locke, and constructed in many respects a similar psychology. He derived all knowledge from sensation, omitting what Locke called the inner sense or reflection. He likens man to a statue with a perfect internal organization whose powers are gradually awakened one after another by impressions upon his senses. All his knowledge and motives are received from without. He is a perfect brute, and brutes are imperfect men.

Hartley, who first popularized the associational view of psychology, and also Priestley, came essentially to the same position. Abandoning the difference between psychical and physical processes, they made nerve physiology account for them both.

La Mettrie carried this notion so far as to declare that matter alone is. Mind is nothing else than refined matter.

Hume's views in psychology were also closely connected with the philosophy of Locke. He spent his strength chiefly in criticising the doctrine of causation, which he claimed to be, in accordance with the Lockian system, nothing but the habit or custom of regarding things as conjoined. All there is, therefore, at the basis of either mind or matter is our custom of conjoining their attributes. Mind is simply a bundle of perceptions, and the bundle goes to pieces with the cutting of the cord that holds it together.

Berkeley's philosophical opinions led him to take the position that so far as material substances are concerned they exist only as compounds of sensations. But he did not apply this doctrine to the mind itself. On the contrary, minds are the only existences. We get all our sensations from God. For only a spirit superior to ourselves, he holds, can affect our spirits.

The Scottish philosophers were opposed to sensualism in all its forms. The idealism of Berkeley, the scepticism of Hume, and the materialism of Hartley and others being all equally repugnant to them, they set to work to find a more satisfactory conception of the universe, and they found it in psychology. The whole task of philosophy consists, according to them, in a thorough investigation of man and his mental capacities. In this investigation we discover, they tell us, those original truths which, as self-evident and universal, furnish the supreme rule of all philosophical knowledge.

Then came the critical psychology of Kant, which is chiefly a deduction from his philosophical position, that we have a knowledge of phenomena only, and can never know things in themselves. From this point of view, the human mind can have no power to know itself as an immaterial simple entity, as a thinking being endowed with the attributes of a person.

Herbart's primary philosophical idea was that everything in the universe is a combination of simple, unchangeable metaphysical substances called reals. All the changes that occur in the qualities of things are merely changes in the relation of these reals. The soul as a real, like all other reals, is constantly struggling for its own self-preservation against the disturbances of other reals, and this gives rise to all the phenomena of our mental life. The relation of equilibrium that results from this struggle can be calculated according to the rules of mathematics. From such metaphysical notions as these Herbart elaborated his psychological system.

Herbert Spencer explains the universe by the theory of evolution and makes the laws of evolution common to both mind and matter. Accordingly he treats psychology as a subdivision of biology, and from that standpoint determines what are our mental processes and powers.

From these illustrations taken from the history of psychology, it is clear that down at least to the opening of the nineteenth century, psychology was almost universally treated as a deductive science. It was so closely connected with philosophy that the accepted postulates in philosophy determined beforehand what the views were to be concerning the nature and functions of the soul. But early in the nineteenth century a powerful reaction set in against this mode of treating the subject. In fact, the century has well been characterized by Windelband as chiefly a "controversy over the soul." The result has been that psychology has broken loose from philosophy and set itself up as an independent science. Influenced largely by the progress and methods of the physical sciences, thinkers have come to see that the facts of mind and the facts of matter are to be treated by essentially the same method, and that the chief function of philosophy is to explain these facts after they have been ascertained, and not to determine beforehand what they must be.

The new psychology, therefore, as distinguished from the old, is chiefly a change of method,—a difference in the way of attaining and classifying the facts, not of necessity a radical difference in the facts themselves that go to make up the science. It does not seek to answer inquiries regarding the origin of the mind or to tell the time it first enters the body. As little does it concern itself with the question whether it can exist without a body or in another body. Nor does it attempt to determine what will be its state or condition in another sphere of existence. Important as these problems are, none of them have to do with psychology proper. The business of the new psychology is to ascertain the facts as best it may concerning the mind in its present connection with the body, and carefully arrange them into a system.

Nor does it need to affirm what the mind is in order to fulfil its mission, any more than the physicist must tell us what matter is before he sets out to study its phenomena.

"Whether mental facts find their ultimate basis in an independent mental substance or in the brain, the facts remain the same," is Baldwin's way of stating this truth. Modern psychology is so far a "psychology without a soul" that it makes no assertion about the absolute nature of the mind, leaving that to be determined by a higher science.

Professor Ladd defines the psychology of to-day as having to do with "the description and explanation of states of consciousness as such." Professor James accepts this definition, and takes the phrase, "states of consciousness," to mean "such things as sensations, desires, emotions, cognitions, reasonings, decisions, volitions, and the like." To explain these states is, of course, to give their causes and conditions as well as their immediate consequences, so far as these can be ascertained.

While the method of modern psychology is the same as that of any other science, the study of the subject has its peculiar difficulties.

In the first place, the facts to be observed are subjective facts. They have to do with our inner selves and are to be discerned by looking within, not through the medium of the senses. The facts cannot be accepted on any preconceived notion of what they should be or on the authority of others. Unless they come clearly within the range of our conscious experience, we have no right to introduce them as a part of our science. This introspective way of attaining the facts is not easily acquired. It is not until a high degree of development has been reached that either the leisure or the disposition shows itself to attend to one's subjective states. The historical fact, therefore, is not to be wondered at that many centuries elapsed before even the Greeks, the most intellectual people the world has ever seen, were able to comprehend the so-called maxim of Socrates, Know thyself, and then only in the most vague and imperfect manner.

The objects of the material world are constantly and vividly before us from the first moment of our conscious existence, and the habit is soon acquired of attending to the impressions they make upon our senses with ease and pleasure. They are also, for the most part, of such a permanent character that we can examine and re-examine them at our leisure until every feature has been carefully ascertained. Furthermore, they are the objects that most intensely excite our interest and allure us on because of some immediate use we intend to make of them or some past enjoyment we expect to repeat in connection with them.

With the facts of consciousness the case is far different. They are constantly coming and going. The effort to attend to them is at the outset at least a difficult and disagreeable one. It cannot be continued for any length of time without exhaustion. The mind's power is limited, and in endeavoring to re-create its past experiences for the sake of examining them, it takes away just so much from the energy with which it can attend to them. The mind cannot separate its experiences from itself as easily as it does material objects. The constrained effort necessary to objectify one's mental states or conditions so as to study them scientifically is what Locke refers to when he remarks that "the understanding, like the eye, while it makes us see and perceive all other things, takes no notice of itself; and it requires art and pains to set it at a distance, and make it its own object."

Porter, in treating of this difficulty of reproducing our mental states in order that we may know more exactly what it is to experience them, goes so far as to say: "Nothing but the deepest convictions of the dignity and value of the results, in the acquisition of intellectual discipline and the advancement of psychological science, can impel to the earnest undertaking of such efforts, and the patient prosecution of them to a successful issue."

Another difficulty that meets the student of psychology at the very outset is the ambiguity of language. Language is the embodiment of thought. We speak because we think. But inasmuch as the first and most imperative needs in the struggle for existence are those of the body, the first things we think about are material objects. The mass of mankind rarely think about anything else than what they can see or hear or touch. The study of comparative philology abundantly confirms the position that all words were originally applied to objects of sense. "All roots," says Max Müller, "that is, all the material elements of language, are expressive of sensuous impressions and of sensuous impressions only."

Because of this fact, whenever the student of psychology wishes to describe a mental state or condition, he must first of all give a new meaning to the words he uses. To invent new terms would be inexpedient, if not impossible. For the terms invented would have no significance to others, and probably not to the one inventing them. In this process of giving new meanings to words to designate new thoughts, great room is offered for uncertainty and misunderstanding. It is not too much to say that most controversies over psychical matters arise from this source. As is well said by Hickok: "It may be doubted whether men would ever dispute upon any point in psychology if they perfectly understood one another."

But perhaps the most serious difficulty connected with the study of psychology is the great variety and complexity of the subject-matter itself.

It is comparatively easy to gain an adequate conception of a machine. Its law and purpose are imposed upon it from without, and when they are once discovered, the details of its construction are easily mastered. With a plant it is quite otherwise. It grows and develops from within. The mysterious phenomenon of life here manifests itself and begins its endless series of wonders. The brute with all his added capacities still further complicates the problems open to our investigation. But incalculably more than any one or all of these does the human mind, with all its marvellous capabilities, challenge the comprehension of our powers. To ignore any one of its faculties or unduly exalt any one of them would lead to a faulty psychology ; and to place them in wrong relations to each other might vitiate the entire system.

But supposing all these obstacles had been successfully overcome and all the single facts were definitely before us, we might still greatly err in our attempts at their proper classification. As many systems can be made out of any set of facts as there are possible combinations of those facts. Because the facts of psychology are so varied and complex, their correct classification is all the more difficult. Few minds in any community have the patience, even if they have the ability, to survey the whole field and see to it that each fact is put in its right relation to every other fact, and that all the facts taken together form one harmonious whole.

The hindrances to rapid progress in mental science enumerated above are real hindrances, and they are not to be ignored or underestimated. But they are not to be looked upon as insuperable. They by no means justify our going to the extreme of some recent critics, and declaring that psychology, for these reasons, is unworthy of being called a science. Professor Jowett, in an essay on the "Nature and Limits of Psychology," inserted in the third edition of his translation of the *Platonic Dialogues*, declares that "psychology is necessarily a fragment, and is not and cannot be a connected system." "It is only an hypothesis or outline, which may be filled up in many ways—according to the fancy of individual thinkers. The basis of it is a precarious one." "It may be compared to an irregular building, run up hastily and not likely to last, because its foundations are weak, and in many places rest only on the surface of the ground."

Professor James, writing in a similar vein, sums up his views on this point as follows: "A string of raw facts; a little gossip and wrangle about opinions; a little classification and generalization on a mere descriptive level; a strong prejudice that we have states of mind, and that our brains condition them; but not a single law, in the sense physics shows us laws, not a single proposition from which consequences can causally be deduced."

The former of these critics confuses psychology with metaphysics and theories concerning the ground of ethics and religion; and the latter, while a great name in this study, does not by any means voice the opinion of the great mass of the competent on this point.

It must be allowed, however, that much of the criticism against psychology as an established science would have considerable force if internal observation were the only source of information regarding its facts. Without calling in question the ultimate authority of consciousness, errors in interpreting its data may easily arise. For in adult life when the power of reflection has developed far enough to enable the investigator to take up this study, the facts of consciousness no longer present themselves in their original purity, but are attended with a mass of derived material which greatly obscures the vision. As Mill has well said: "Hardly has consciousness spoken when its testimony is buried under a mountain of acquired notions."

This confusion is inevitable from the mere fact that there is a course of development in our experience from first beginnings. Moreover, when the intellectual powers have matured enough to make inner observation possible, the time has passed for consciousness to throw any light on the rise and growth of our mental powers. And as any process or fact is best explained by ascertaining its origin, we make a great mistake in regarding the mature and developed consciousness as necessarily the ultimate and final form of our mental life.

We ought rather to look without and seek to discover what other facts there are that may help us in the construction of our science. "If it is impossible," says Baldwin, "with the positivist to deny the utility of inner observation, it is almost equally dangerous to depend upon it exclusively. Failure to resort unceasingly and repeatedly to external observation at every stage of our study leads to the most chimerical subjective systems and the most one-sided views of life."

To depend upon inner observation alone would be to make every man his own psychologist. It would lead to psychologies, but not to psychology, and would deprive the science of its universal character. Those mental states, for example, that are due to individual differences in temperament, taste, and talent, must be duly eliminated as well as those arising from peculiarities of environment, race connection, and systems of education. Like every other true scientist, the student of psychology must be constantly changing the conditions of his inquiries, and ever alert to discover in the products of other minds whatever may help him to separate the true from the false in his own experience and substitute the permanent and abiding for the fleeting and temporal.

In other words, only as external observation confirms and corrects the direct observation of consciousness can its material be made of such a character as to furnish the basis of a genuine and universal science.

This external observation naturally extends itself in four directions. The first of these is the sphere of race psychology, to the development of which so much has been done in recent years by Maine and Lazarus and Steinthal. This investigates the facts of mind as it shows itself in its products. It examines the languages, customs, laws, and institutions of mankind not only as they are in our own day, but as they have developed throughout all the periods of history. Mythologies, traditions, biographies, and books of travel it carefully studies. The present condition and manner of life of the savage and degenerate races it is concerned with no less than with the sciences and arts of the most cultivated and refined. The museums and art galleries, as well as the general statistics regarding the progress of civilization that are now being zealously collected by the advanced nations of the earth, are of great value to psychology. For they show what ideas and convictions can and do come within the experience of the conscious self.

Another great source of material for our science is animal psychology, and no subject has recently been pursued with more enthusiasm and profit. It is the opinion of many that this study is likely to throw as much light upon human psychology as animal or comparative anatomy has thrown upon human physiology. Many intellectual states reach a higher degree of intensity and under less complex conditions in animals than in man. Many of them have more highly developed sense organs and by experimenting upon these in a great variety of ways their action in man may be brought more vividly to view. All the mental processes of the brute creation, from the lowest to the highest, are being carefully investigated. And in the works of such students of animal intelligence as Lubbock, Romanes, Wundt, and C. Lloyd Morgan, we have contributions of the greatest value to mental science.

Infant psychology is also a great aid to psychology proper. For it enables us to go back to the beginnings of our experience and trace out the development of our powers.

At the outset, the human child is perhaps the most ignorant and defenceless of all animals. It is absolutely dependent upon others for the continuance of its existence. Its instinctive or automatic adaptation to its environment is less perfect and varied than in other animals. But as it has to learn almost everything from the beginning, the unfolding of its mental powers in conjunction with those of the body offers a fruitful field of observation not elsewhere to be found. In the very first years of its existence it learns how to lisp intelligently its own name and to know the meaning of the pronoun *I*, a feat that no other animal can perform, even at the climax of its powers.

Of course there is need of caution against placing too high a value upon observations of this sort. Max Müller goes so far as to affirm: "Nothing is more common among psychologists than to imagine that they can study the earliest processes in the formation of the human mind by watching the awakened mental powers of a child. The illustrations taken from the nursery are not perhaps quite so fanciful as those collected from menageries, but they have often done more mischief, because they sound so much more plausible." This view of the matter may have had some basis in the past, but the work of such observers as Preyer, Sully, Baldwin, and G. Stanley Hall is not open to such a charge.

Another source of light upon the normal operations of the mind is its forms of activity when in a pathological state or condition. This is sometimes called abnormal psychology, or psychiatry, and has to do with all cases of variation from the normal and healthy activities of the conscious self. It investigates such phenomena as dreams, somnambulism, hypnotism, aphasia, hallucination, idiocy, insanity, and the like. By eliminating what is known to be due to physical causes we get a much clearer view of what is due to mental. Investigation in this direction has already established beyond reasonable doubt that mental diseases are occasioned by bodily diseases or imperfections, and are not to be attributed to an occult or supernatural influence. The study of these phenomena is now being prosecuted with unusual vigor in all civilized lands. *The Society for Psychical Research*, headed by such men as Balfour, Sidgwick, Meyers, and Lodge in England, and by James, Langley, and Hodgson in America, is carrying on the work with great energy and effectiveness. Data for large additions to our psychological knowledge have already been acquired from this source.

But besides the means already described of internal and external observation for gathering his material, the modern psychologist makes much use of experiment.

The object of experiment in psychology, as Wundt expresses it, is to enable us to get results concerning the origin, composition, and temporal succession of psychical occurrences. This is done by artificially varying the conditions so as to separate the physical from the mental causes in any complicated internal effect. Simple observation in any science cannot go below the surface of things, and must always rest content with a mere description of the facts.

But no science can have much value or progress very far that cannot also explain its facts, and explanation is possible only when complex groups of facts can be carefully separated into their elements, and individual causes can be discovered for individual effects.

In psychology no single mental phenomenon ever shows itself alone. It is always accompanied by a multitude of other activities. The greatest care, therefore, should be taken to isolate it in every possible way, if it is to be known in anything like its real character and original purity.

As in the case of observation, psychological experiment may be considered as of two kinds, internal and external. That is, we may experiment upon the mind directly or upon the body. The former, however, is very limited in its range, at least when we apply it to ourselves. For the mental exertion required to be both the experimenter and the object experimented upon is usually too severe for the most satisfactory results. Still actors make it their constant study. Success in their calling depends chiefly upon the accuracy and vividness with which they can discern and reproduce the mental states of the characters they endeavor to represent.

The chief advantage of this kind of experiment is seen when we consider how easily and constantly we can employ it upon others. Whenever we try to influence their thoughts and feelings or arouse their wills by any other means than physical force we are experimenting upon them in this way. This can be done even in sleep, and the degree to which it can be carried is perhaps the most striking feature of the hypnotic state.

But the most efficient way of experimenting upon the facts of consciousness is indirectly through the body. The relation of the mind to the sense-organs and muscular system is so intimate that by experiments upon them much may be learned of the composition and relation of sensations, of the nature of attention, and of the time occupied by the various operations of the mind. This is known as psychophysics. It makes use of the physical processes of life for the sake of investigating psychical states. Some of the great names in this study are Weber, Fechner, and Wundt. Psychological laboratories have been established in many institutions of learning for the advancement of this department of knowledge, especially in this country, where the subject has awakened unusual interest. That it has been and will continue to be of great value to psychology proper is freely admitted, but as there is at present much danger of overestimating its importance, a few of its limitations need to be pointed out.

In the first place, it cannot account for the mind's higher processes and powers. "How, for example," exclaims Professor Ladd, "should one test with laboratory methods and apparatus the higher and more complex feelings and choices, the thoughts about duty and God, and the elaborate plans we form for to-morrow or for our entire lives?" Even Ribot admits in his introduction to *German Psychology of To-day* that experimental research is useless for ascertaining the nature of these phenomena.

In the second place, many of its actual results are only tentative. Natural differences in the subjects, defects in the instruments employed, and the abnormal excitement likely to attend any experiment, all have their influence. But the chief limitation of all is the fact that its results are necessarily subordinate to those of introspection. This point is well elaborated by Baldwin when he says that the attempt of physiological psychology "to usurp the place of consciousness is suicidal and absurd. And this for two reasons. First, observation through consciousness is direct and immediate; external experiment is indirect and mediated through the nervous system. Second, external experiment assumes direct observation in arriving at its results; for, if the organic as cause gives the mental as effect, this effect can only be estimated from within, through observation."

Valuable as external observation and experiment are in furnishing indispensable correctives to the internal observation of our mental processes and powers, we must never allow objective psychology to dominate over subjective psychology. For whatever we may think we discover of mental life outside of ourselves can never be really ours until it has been reproduced by analogy in our own consciousness. "It must be borne in mind," says Höffding in discussing this subject, "that in the last resort objective psychology always rests on an inference by analogy, subjective psychology alone sees the phenomena themselves face to face." In spite of the many changes and additions that modern psychology has made in the method and subject-matter of this science, it is a most significant fact that it has not subverted or contradicted any of the established principles of the old.

After the facts have been ascertained by the processes already described, we proceed in psychology as in any other science and form hypotheses as to how the facts are to be explained. It is admitted that many of the laws thus attained are as yet general descriptions only and far from being on a satisfactory basis. This is due to the extraordinary variety and complexity of the facts, not to errors in the method of forming the science.

The most effective way to gain a vivid apprehension of the sphere of psychology is to compare it with the other sciences to which it is closely allied but from which it is to be kept clearly distinct.

Its relation to biology needs, first of all, to be pointed out. Comte, Herbert Spencer, and similar thinkers make psychology a subdivision of biology. There is no objection to this position if we take biology to include everything that has any connection with life whatever. But it may be regarded as having to do with the phenomena of physical life only. As such it precedes and prepares the way for psychology, but does not contain within itself its peculiar facts.

Psychology is also related to anthropology. This latter study, as we here contemplate it, describes man as he appears to the common observer wherever found over the surface of the earth, an animal among other animals, but yet possessing many powers that raise him immeasurably above the brute. It assumes the human species is one and has in many respects a common human experience. It treats of the differences that are seen to exist among the various members of the species in sex, race, temperament, and the like. The effects of sleep upon the body it also studies, and the reactions that are constantly taking place between the mind and the body. It does not experiment, and thus it does not possess the full prerogatives of a science. Yet more directly than biology, perhaps, it furnishes psychology with some of its most important data.

More essential than either of the sciences already mentioned to the progress of psychology is physiology. Some hold that thought is merely a function of the brain and that, as physiology is the science of the function of all the bodily organs, psychology must be only one of its chapters. But as has been well said, the fullest knowledge of the brain would not lead us to suspect the existence of such a thing as thought if we did not know it already in consciousness. The facts of physiology are known through the senses. They are modifications of matter and can be measured; but the facts of mind are subjective, and are inwardly discerned. The two sciences while distinct are, however, not independent of each other. It is highly probable that all mental acts have a physical basis, and that all diseases of the mind are to be traced to diseases of the body.

Pedagogics, as the science of education, is little else than applied psychology. It is the office of the teacher to impart information to those committed to his charge and to develop and discipline their powers. His success depends chiefly on his answer to such inquiries as: What truths are at first most naturally received as the foundation of others? What is the effect of illustration and repetition upon the ease and permanency with which ideas are apprehended and retained? What are the best methods of correcting aberrations of the intellect, chastening the feelings, and inspiring the will? It is plain that the only intelligent way of dealing with these matters is by starting with an accurate and comprehensive knowledge of the mind's processes and powers. The only hope of a sound pedagogical system is a sound psychology.

But in saying this, we do not mean the so-called experimental psychology. We fully agree with Professor Münsterberg, director of the Harvard psychological laboratory, when he says in a recent paper on "The Dangers from Experimental Psychology (*The Atlantic Monthly*, February, 1898): "No laboratory and no experiment can ever measure a psychical fact, and all hope for pedagogics on the basis of a mathematically exact psychology is and will be a perfect illusion. . . . This rush toward experimental psychology [referring to Dr. Scripture's recent book on *The New Psychology*] is an absurdity. Our laboratory work cannot teach you anything which is of direct use to you in your work as teachers; and if you are not good teachers, it may even do you harm. . . .

"You may collect thousands of experimental results with the chronoscope and the kymograph, but you will not find anything in our laboratories which you could translate directly into a pedagogical prescription. The figures deceive you. There is no measure of psychical facts, and therefore no psychology which is antagonistic or in any contrast with the psychology of introspection."

Among all the sciences psychology stands in closest relation to ethics. Ethics has to do not so much with what is as with what ought to be. It is the science of human duty. But we cannot tell what a man ought to be and mark out a course for him to pursue until we have determined what he is and what it is possible for him to accomplish. We must first determine what power he has for forming a standard of conduct and of applying it after it is formed before we can decide what rules or maxims he ought to follow.

In the same way we see how much psychology has to do with political science. No government can justly prescribe regulations beyond the capacity of its subjects to understand them or their power to carry them into execution. Political science assumes that man is a political being and made for existence in a state—an assumption that psychology alone is competent to vindicate.

Æsthetics, or the science of the beautiful, can have no place among the sciences except as it is based on the science of the human mind. Man must be shown to have the power to apprehend the beautiful and express it in works of art, if criticism is to have any meaning or furnish any motives to the embodiment of higher ideals.

Furthermore, the question whether there can be any such thing as theology is primarily a psychological question. If man is not endowed with power to know of the existence of God and to ascertain in some degree the nature of that existence, theology is as fictitious as a dream.

But besides the sciences already alluded to, psychology has a most important relation to logic and metaphysics. Logic is the science of method. It inquires into all the special ways of investigating the universe and attempts to trace them back to certain fundamental ways immediately arising from the very nature of human consciousness. In this attempt to lay down the general principles of human knowledge and prescribe its limits, it is evident that no valuable results can be attained that are not founded upon a deep insight into the mind's actual processes and powers.

Metaphysics, properly regarded, is an inquiry into the ultimate nature and constitution of being. Its mission is to investigate all the original conceptions and ultimate relations that lie at the foundation of all the sciences. But this cannot be done until psychology has shown that man in all the processes he performs necessarily originates and applies these conceptions. While psychology in and for itself is not a part of metaphysics, it is introductory to it inasmuch as it furnishes the primary truths out of which the mind is to construct its theory of the universe.

From this contrast with other spheres of knowledge, the place of psychology in the circle of the sciences is brought more definitely to view. As the science of the facts of consciousness it sustains some kind of relation to every other science, though an especially close one to all those which in any way have to do directly with man. For it stands, as Höffding remarks, " at a point where natural science and mental science intersect, where the one passes over into the other. In its principle is the central point round which the currents circle from either side, since all knowledge—being based upon human nature and organization—becomes directly or indirectly knowledge of mankind."

In view of this fact it is fitting that special attention should here be called to some of the benefits to be derived from the study in addition to those arising from its relation to the sciences as shown above.

In the first place, it conduces more than any other study to the development of our mental powers. The chief end of man being self-realization, he fulfils his mission by bringing himself to the highest possible perfection. In this way he also contributes as much as in him lies to the perfection of the universe. To understand ourselves is the first requisite for the cultivation and expansion of our powers.

Moreover, it is the only way in which we can be helped by the instruction of others. Unless we develop ourselves so as to think the thoughts of others after them, all their endeavors to assist us will be of no avail. There is, strictly speaking, no such thing as the impartation of ideas. Every individual must create them for himself. If the ability to do this is wanting in any mind, the ideas will not exist. "Books and instructors," says another, "essays, poetry, and the drama, cannot describe or teach that which is not confirmed by the researches of the learner within his own spirit."

No one ignorant of his powers can learn how to strengthen and invigorate them. How to cultivate a defective memory, how to enliven and expand a weak imagination, what are the best means for making strong and vigorous the reasoning powers, are questions which cannot be answered except by an appeal to this science. The same thing is also true regarding the feelings and the will.

In the second place, this study furnishes us with the one instrumentality for gaining a knowledge of human nature. We understand others only by first understanding ourselves. Ability to read others is acquired in no other way than by a subtle analysis of our own mental states and operations. We judge by the conduct and language of others that they have thoughts similar to our thoughts. It is on the basis of the assumption that the same considerations that influence us will influence others, that we proceed in all our plans and purposes concerning those with whom we come in contact.

Again, the study of psychology helps more than any other study to the production and correct appreciation of literature. The master minds in literature in any age have always been those that sounded most profoundly the depths of the human spirit. They may not have been trained in the technicalities of the science, but they studied deeply the mind's processes and powers. Other things being equal, those who can most fully enjoy the literary productions of others and most fairly estimate them at their true value are those who have been most carefully educated in psychological studies. No one but a careful student of himself can thoroughly appreciate such works as the *Antigone* of Sophocles, Shakespeare's *Hamlet*, or George Eliot's *Adam Bede*.

But one of the most important benefits in our day arising from the study of psychology comes from its counteracting the evil results of a too exclusive devotion to material pursuits. Psychology is not a Brodwissenschaft, a bread-and-butter science. The mass of men are so situated that they must devote the most of their energies to the needs of the body. But even when they have the leisure for other interests physical facts absorb their attention and physical rewards lure them on. The result is, that they form abnormal views of life and do not put things in their true relations. The student who is exclusively devoted to physical science cannot help losing the ability to apprehend and appreciate other truths.

Of this fact Darwin is a most conspicuous example. Writing of himself in 1876, he says: "Up to the age of thirty or beyond it, poetry of many kinds, such as the works of Milton, Gray, Byron, Wordsworth, Coleridge, and Shelley, gave me great pleasure, and even as a schoolboy I took intense delight in Shakespeare, especially in the historical plays. I have also said that formerly pictures gave me considerable, and music very great, delight. But now for many years I cannot endure to read a line of poetry.

I have tried lately to read Shakespeare and found it so intolerably dull that it nauseated me. I have also almost lost my taste for pictures and music. . . . My mind seems to have become a kind of machine for grinding general laws out of large collections of facts, but why this should have caused the atrophy of that part of the brain alone, on which the higher tastes depend, I cannot conceive."

Keeping one's thoughts exclusively fixed on material things, logically and inevitably leads to materialistic views of the universe, to the denial of moral responsibility, and the existence of a personal God. By giving mental facts their due place in the system, we avoid these errors and prevent ourselves from being carried away by one-sided and erroneous conceptions of the truth. The most important matters that concern us in this world are not material, but intellectual and moral. Whenever these are called in question, the final resort is to the science of the human mind, beyond which there can be no appeal.

In the light of this fact, we are abundantly justified in not only declaring with Pope that "the proper study of mankind is man," but in reiterating with vigor the favorite aphorism of Sir William Hamilton, that "on earth there is nothing great but man; in man there is nothing great but mind."

CHAPTER X

MODERN SCIENTIFIC ETHICS

THE question as to what is the chief end of man, what is his *summum bonum*, is one that is not raised in the infancy of any race or individual. And even when it is raised, little attention is at first paid to the further inquiry: Is there any rational way by which this end can be attained? A comparatively high degree of reflective power must be developed before such questions as these will receive any serious consideration.

Moral codes, however, of some sort come to exist very early among every people. But such codes are always at the outset chiefly an unconscious growth. Certain habits or customary ways of acting spontaneously arise, and these speedily become crystallized into a system which is handed down by tradition from generation to generation. It is not long before the system comes to be regarded as of divine origin. Its authority is unquestioned; its binding force none would dare to gainsay. Such, for example, were the early codes of the Greeks and Romans. Such are still the codes of all the unprogressive races of our day.

But with an advancing people the case is far different. As soon as the receptive stage of its childhood is past and the aggressive activity of early manhood has extended somewhat the range of its experiences, the more intelligent and alert of its number begin to make inquiry into the origin and inherent rightfulness of these traditional requirements. They no longer accept them on their face. Questions as to the why and how of things are persistently raised and will not be set aside without an answer.

This is the beginning of criticism which is the beginning of science—a fact as true of ethics as of any other study. Indeed it is only when criticism lays hold of the moral codes of the unthinking past that ethics begins to emerge into a science. But the first result of criticism in every sphere of thought is always a period of perplexity and unrest. It is so because it is a period of intellectual ferment. Fears naturally arise that the very foundations are being undermined, that our most sacred institutions are being put in jeopardy. The discovery is soon made, however, that the choice is not between open revolution on the one hand and tradition on the other, or between pure anarchy and blind faith. The sober second thought comes in and what is valuable in the old is not cast aside as worthless, but the endeavor is made to incorporate it with the new and to bring the two together into one harmonious system.

It is the business, therefore, of modern ethics to find out first of all what is permanent in the customs and institutions of the past and make it the nucleus of a progressive and consistent science. Muirhead in discussing the mission of ethics in our day well says: "It shirks no difficulty which the spirit of scepticism suggests. It ignores no claim which tradition puts forward. But it goes its own way, regardless of both, with a deeper doubt than scepticism, because it doubts the conclusions of scepticism, and a deeper faith than traditionalism, because it believes in the reason which traditions embody, and which is the source of what power they still possess."

According to Windelband, the honor of first propounding a scientific principle for ethics belongs to Heraclitus; but, as he made little or no use of the principle, it seems truer to history to ascribe the actual origin of the science to the age of the sophists. For it was in their time that such great changes took place in the political, industrial, and intellectual life of the people as to produce a radical and wide-spread dissatisfaction with the older forms of thought. Criticism became everywhere rampant. It laid violent hands upon all existing customs and institutions. The traditional views of the time were repudiated as wholly inadequate. But out of all this confusion and turmoil came the material for the first attempt at a rational conception of the universe and the place that man was intended to take in it. Only by this upheaval were the great advances in ethical science that immediately followed this period rendered possible.

Before taking up for examination the leading conceptions of a few of the great ethical systems that have appeared in history, it is necessary to determine with greater precision what we mean by ethics. Ethics, as the word itself clearly implies, has prominently to do with character, and may be vaguely described as the science of human conduct. Yet to define it with much greater exactness and have the definition meet with general approval, is not an easy task. The reason of this, in large measure, is the fact that there are two radically different ways of viewing the subject. According to the one, ethics is regarded as dealing simply with human conduct as it actually is, and its sole mission is to formulate general maxims from the experience of the past. According to the other, the primary and chief concern of ethics is to show what human conduct ought to be, not what it is. It begins by laying down a supreme end of action and then sets forth in orderly arrangement the rules and maxims that must be followed in order to attain that end. The former way of viewing ethics makes it an empirical science, such as botany or physics, while the latter treats it as a normative or deductive science similar to logic or mathematics. It is certainly possible to treat human conduct purely as a natural science by confining the investigation to past occurrences. In this way its phenomena would be put upon the same plane as the phenomena of light and electricity. Free will would be regarded as a delusion or left out of consideration altogether. The entire aim of such a science would be to formulate general laws of action from past observations and then deduce from them what will take place when the conditions are repeated.

This is essentially the view of Herbert Spencer. "I conclude to be the business of moral science," he says, in his *Data of Ethics*, "to deduce from the laws and conditions of existence what kinds of actions necessarily tend to produce happiness and what kinds tend to produce unhappiness. Having done this, its deductions are to be recognized as laws of conduct, and are to be conformed to, irrespective of a direct estimation of happiness or misery."

But this is to take a very narrow and one-sided view of the subject we have under consideration. By doing it we arbitrarily shut out from investigation the very problems that have almost universally been regarded and are now regarded as the chief subject-matter of the science. For ethics has to do primarily and chiefly with moral character, and there can be no such character where there is no power of choice. Character is the result of choice. A being that has not made a choice has no character. By regarding ethics as a natural or purely empirical science, we leave no room for choice and thus no room for character. We drop out the subject we propose to investigate and, while using the same terms, smuggle in some other study.

Granting, then, that the element of free will must be taken into due consideration in all discussions concerning human conduct, it follows that what ought to be, rather than what is or will be, must constitute the principal field of ethics.

Nor can it treat primarily of concrete facts. For otherwise there would be no way of meeting the objection urged by vigorous thinkers, that "if the will is free the whole conception of a science of ethics falls to the ground; there is a variable and incalculable element in character and conduct that vitiates all its results."

The science of ethics, properly regarded, does not attempt to predict what the facts of human conduct will be, and then try to arrange these facts into a system. That were indeed a hopeless task. But it is concerned with the rules and maxims that a free being ought to follow; or, expressed in other terms, with our judgments as to what the facts of human conduct ought to be and must be in order to be right.

Ethics, therefore, is properly called moral philosophy. For it is inseparably connected with philosophy and finds in philosophy its rational ground. What human beings ought to do is ultimately determined by their place in the system of things as a whole, and our conception of what that system is will vitally affect our views of the aim and scope of ethics. For ethics must think of man as a member of a cosmos, as related to a material and social environment, and as consciously a part of it.

While it is true of every fact that it cannot be fully understood until its relation to every other fact and the world as a whole is clearly pointed out, the world as a whole cannot be treated by any single science. So far as this is done at all, it is the work of philosophy. Each particular science gathers up the facts that pertain to its sphere of investigation and unifies them, while philosophy seeks to put all ascertained facts into one rational system. It might be said in a sense that the physical sciences are largely independent of philosophy, but it cannot be true of ethics. Our conclusions as to what the world in general is and what man's place is in it, will always be a vital matter to ethics. Every system of ethics that has ever appeared in history has been determined by the philosophical views of its originator, and such will continue to be the case for all the future.

"The history of every period of human activity," says Porter, "attests the fact that the psychology and metaphysics of individuals and generations of men have, in fact, modified and determined their views of moral science. The ethics have followed the philosophy and psychology by a natural and necessary sequence, more or less rapidly at times, but invariably with a logical and inevitable sequence."

Only the view that the world is rationally constructed and is working out rational ends—is the product of mind—can ever place the science on a secure basis. As Professor Dewey so truthfully asserts: "A spiritual interpretation of reality can alone found a truly scientific ethics" (*Andover Review*, June, 1887).

Starting, then, from the position that ethics is a teleological science having to do with a final end, and not an empirical science seeking merely an efficient cause, the next important question we have to consider is, What is this ultimate end, and what is the fundamental law or principle from which are to be deduced the various rules to be followed in the attainment of this end?

Almost as many conceptions of the ultimate end of human conduct have appeared in the course of history as there are different philosophies. Yet there is no better way of putting ourselves in a position to appreciate adequately the present status of ethics and its future prospects than to examine briefly some of the most important of these conceptions. For they embody in the most available form the results of the labor of many generations and even centuries of thinkers on this subject. No attempt will be made, however, to observe an exact historic order.

1. One of the most natural and common answers to this inquiry after the chief end of life is embodied in the injunction: "Live for present happiness; make your own enjoyment the goal of your activities." This is one of the principal forms of the hedonistic conception of ethics, and is well represented in its higher aspects by the ancient Greek Epicurus. He differed from Aristippus, one of his contemporaries, who held that the pleasure of the moment was to be taken as the end of all human endeavor, by maintaining that such a system of pleasures should be adopted as took in the whole of life. The adage, "Eat, drink, and be merry; for to-morrow we die," is falsely ascribed to him. For he especially refrained from excessive indulgence in bodily pleasures, and often boasted that with a little

barley bread and water he could rival Zeus in happiness. The fear of death he claimed to be the most foolish of all fears, "For while we live, death is not, and when death is, we are not."

There was one thing about this view of Epicurus that made it popular, and that was its apparent simplicity. Nothing could be plainer, it would seem at first thought, than to say that the chief end of life is pleasure. Every one thinks he knows what pleasure is and very few persons have any dissatisfaction with this view of the matter. But when we come to look at it a little more thoughtfully we see that it is beset with insuperable difficulties.

In the first place, there is the curious fact that pleasure can never be obtained by seeking it. No man has ever yet attained pleasure by setting himself deliberately in quest of it. The more strenuously we struggle after it, the more completely does it elude our grasp. Only when we are absorbed in something else and have no thought of its presence, do we actually have it in our possession.

Again, if pleasure were the end of life, we should have no way of distinguishing the noble from the ignoble. For pleasure has only one characteristic, intensity. It is always a matter of more or less. To make any distinctions between pleasures as lower and higher is to abandon the hedonistic standpoint. There is no basis for it except in an appeal to another standard. That pleasures are to be regarded as simply more or less is openly accepted by most of the writers of modern times who have adopted the hedonistic point of view. Bentham expressly says: "Quantity being the same, one kind of pleasure is as good as another."

It is only fair to say that, in spite of these objections, the happiness theory has been the prevailing feature of modern English philosophy, and many think it is so to-day. Hobbes advocated it in the sixteenth century, and it is the philosophy of James Mill, of John Stuart Mill, and of Herbert Spencer. However widely they may differ on other subjects, they all agree that pleasure in some form is man's highest good. They do not, of course, apply the principle in the same way. Hobbes maintained that the end could be attained only by complete submission to the authority of the state. The natural condition of man, he asserts, is war. It is only as he comes under the care and guidance of the state that he has any respite from war and an opportunity to pursue happiness. When the state has legislated, the subject is bound to unquestioned obedience. The will of the sovereign is his absolute guide in his relations to his fellows, to nature, and to God. The preservation of the public welfare would be impossible if any individual were allowed to question the authority of the government. No man is justified in attempting to inquire into the ground of its decrees or in criticising them by setting them in contrast with any other assumed standard.

In every such conception of the ultimate ground of conduct, all distinction between legality and morality is obliterated. The fundamental difference between the intention and the overt act is ignored, and the ruler is assumed to have almost omniscient powers. Such a theory, if carried out, would lead to despotism, stagnation, and moral death.

2. A somewhat different answer to our present inquiry from the one presented above, yet closely allied to it, was given by Paley. He contended that while happiness in its most general sense was the *summum*

bonum, it was not present earthly happiness that men should strive after, but future eternal happiness. In all our action we should think only of the rewards of eternity. Present gratification should be as lightly regarded as possible, and the supreme motive in all our activities should be the endless happiness of heaven. All of the objections that have been urged against the happiness theory in general apply of course equally well to this theory, but it is open to the further charge of unduly minimizing the importance of the present life, a position which a sound philosophy would not tolerate.

The ultimate rule for the carrying out of such an end as is here proposed would most appropriately be the one advanced by Descartes and Dymond,—the revealed will of God. Whatever God wills, they claimed, is ultimate simply because he wills it. His creative power extends to principles as well as to natural existences. He alone can make and unmake truth. The supreme duty of man is to acquaint himself with this will and then implicitly to follow it. In this way only can he prepare himself for the bliss of heaven.

We have already called attention to the fact that such a conception as this of the ultimate rule of conduct is found in the primitive stages of every nation's development. It is probably the prevalent notion of the basis of morality among the people at large in all civilized lands. It is also the earliest idea of moral conduct that comes to us as individuals. As Muirhead remarks: "Each of us at his first introduction into the world, finds himself in the presence of a law which he is conscious he did not make, and which seems to require of him an unconditional obedience."

But when we reach the stage of reflective analysis we cannot help asking the question, What is the origin of these mandates? Why and to what extent are they to be regarded as of binding force? For we at once see that will is not the ultimate thing in the universe, not even in God. A thing is not true because God wills it, but he wills it because it is true. The Scriptures in particular constantly represent him as appealing to reason as the ground of his requirements. "Shall not the Judge of all the earth do right?" "Are not all my ways equal?" A system of ethics founded on this rule as its ultimate principle could only be satisfactory to man in an undeveloped state. It would have to give way to another as progress was made in civilization and philosophical insight.

3. John Stuart Mill, although brought up in the hedonistic school, recoiled from accepting in full such an ethical theory as either of those criticised above, and proposed a modification. He insisted that a distinction should be made in the quality of pleasures. "It is better to be a human being dissatisfied," he exclaimed, "than a pig satisfied; better to be a Socrates dissatisfied than a fool satisfied." While the highest good of life is pleasure, it is not my pleasure or your pleasure, or the pleasure of any other individual, but the pleasure of all mankind,—as Mill himself expresses it, the pleasure "of all social beings."

This utilitarian theory is a great advance on its hedonistic predecessors, and some claim for it that it is equivalent even to the Golden Rule of Jesus. It certainly has had a great influence in modern political philosophy. In the form of "the greatest happiness of the greatest number," each individual counting only for one, it has done much to advance the general good. But as a theory of the *summum bonum*, and the ultimate rule by which it is to be reached, it does not meet any of the objections we have urged against the hedonistic view in general, although it is perhaps a little less selfish than either of the two phases of that theory already examined. Logically considered, it is just as indefensible. If it is irrational for me to make my own pleasure the goal of my endeavors, it is just as irrational to make that goal the pleasure of others. Happiness, from its very nature, can never be had for the seeking. It is not and cannot be made the primary thing in the universe.

4. In marked contrast with the conceptions of the chief end of life thus far considered stands the theory of self-sacrifice. Instead of pleasure for pleasure's sake, the supreme end is asserted to be duty for duty's sake. It is one of the forms of the intuitional theory and is sometimes called the altruistic conception of the ultimate good. According to this view, no account at all is to be taken of the consequences of our acts. The end of man is unconditional obedience to the call of duty. Pleasure is ruled out altogether. In so far as it comes into consideration, just so far is the act deprived of all its virtue. The doctrine was carried to great extremes by the ancient Cynics, who maintained, in opposition to the Epicureans referred to above, that all pleasure is evil and that the complete absence of desire is the only true good. The Stoics took a more rational view of the matter and held that the highest good is not passivity but activity. The man who stands up and confronts the world is realizing his chief end. The ultimate rule of the Stoics was, "Live according to nature." This meant, in reality, live according to reason. For they held that nature is rationally constructed and that it is only by the use of

reason that we can discern the harmony of the universe and keep ourselves in accord with it.

Another phase of this intuitive doctrine is the notion, urged by Shaftesbury and others, that every human being is endowed with a so-called "inner sense" that tells him infallibly what he ought to do and what he ought to refrain from doing.

This sense perceives, according to this view, what is right and what is wrong, as the eye perceives color and the ear sound. It is implanted in the soul by the Creator, and makes itself felt as an inward revelation, and is thus the source of all morality. Absolute and unquestioning obedience to its behests is the one supreme concern of man.

Closely allied to this view is Kant's famous categorical imperative, "So act that the law of thy will shall be valid for all rational creatures." The human mind, according to his view, in its rational endowment has the power directly to behold universal and necessary principles. Among these is the ultimate principle of morality. Being immediately apprehended by the reason, it needs and admits of no explanation, but must be accepted as the imperative law of all moral action. Reverence for this law is the sole test of character, and obedience to its mandates is man's chief concern.

While these intuitional theories have the common excellence of regarding morality as something internal and spiritual, they all have the common defect of confounding the end of life with the law by which it is to be attained. Clear thinking requires a careful distinction to be made between these two elements of a scientific ethics. Schleiermacher has shown beyond all doubt that the three essential ideas of every moral system are the good, duty, and virtue, and in this order. The very idea of duty implies a law to be followed. But the existence of a law to be followed just as truly implies an end to be attained by obedience to that law. We might allow that the ultimate moral law is immediately beheld and is absolutely binding on all rational creatures and still hold that the ultimate end was not discovered in that manner.

The different examples given above of the way ethics has been treated in the course of history are sufficient to illustrate and confirm the position that moral science properly begins with some philosophical conception or ideal of man's ultimate end and that the different systems vary according to the conception that is taken of that end. The first business of the ethical scientist, therefore, is to search for a true conception of this end if he would construct upon it a valid science. It is a most significant fact that Aristotle, the first great writer on the subject, in his work now called the *Nicomachean Ethics*, proceeded on this basis. After reviewing what he considered to be the defective conceptions of his day, he concludes by advocating mental activity, the highest development and use of the powers of the mind, as the chief good of human life. This is, he claims, not only the *summum bonum* of man, but of God. For they both are rational beings, and the rule to live and act " according to right reason " is common to both alike and leads in each case to the highest blessedness.

In spite of all that has since been thought and written on the subject, Aristotle's position remains to-day essentially unassailable. The wisest modern thinkers agree with him that self-realization, the highest development of all our powers in harmonious adjustment with each other and with the constitution of the universe, is the ultimate goal of human endeavor.

This of course assumes that man is something more than a mere animal. As Professor Green maintains in his *Prolegomena to Ethics*, which many regard as "probably the most considerable contribution to ethical science that has been made in England during the present century," the essential element in man is the rational or spiritual principle. Because of this fact, the chief significance of the moral life consists in bringing out and making more and more explicit our rational selves. Shakespeare's familiar line, "This above all—to thine own self be true," well expresses the same great truth.

But the rational self is by no means an isolated or independent self. For every individual belongs to a social system and his supreme end cannot be attained apart from that system. Indeed it may truly be said that his own perfection involves the perfection of the social organism of which he is an inseparable part.

However much evolutionary ethics may err in making pleasure the ultimate thing in the universe, it has done a great service in pointing out the falsity of the atomic theory of human nature and substituting for it the organic. All that man is at the start comes to him as an inheritance from those who have gone before him, and whatever he attains in life depends fundamentally upon his social environment. Dr. James Ward puts it none too strongly in the much-quoted passage: "We might as well regard the members of our own body as animals as suppose man is man apart from humanity."

Egoism, which is complete devotion to one's own individual ends, would be a most unsuccessful way of securing those ends. And altruism, or entire devotion to the ends of others, would equally fail of securing their highest good. Herbert Spencer and Leslie Stephen among others rightly dwell at length on the self-destructive character of both these theories of the moral life. The truth is, we cannot realize the ideal self without at the same time realizing the highest good of others. All true self-realization on the part of the individual necessarily involves the self-realization of the whole. "In a realization of this sort," as Mackenzie well expresses it, "the mere wishes and whims of the private self have been sacrificed, and we seek to develop ourselves in the same spirit and for the same ends as those in which and for which we seek to develop others. When we live in such a spirit as this, the opposition between egoism and altruism ceases. We seek neither our own good simply nor the good of others simply, but the good both of ourselves and of others as members of a whole."

Kidd and Huxley are in error when they maintain that the struggle for self is necessarily antagonistic to the struggle for others. "Goodness or virtue," says Huxley, "involves a course of conduct which in all respects is opposed to that which leads to success in the cosmic struggle for existence." Drummond, in his *Ascent of Man*, takes a more rational view, and holds that self-sacrifice is from the beginning an essential part of progress, reproduction among plants and animals being in some degree at least expressive of it.

Professor George Harris has shown with marked ability and success in his recent work on *Moral Evolution*, that love of self is as truly an essential feature of the moral law as love of others ; in fact, that the one is impossible without the other. "Unless," he says, "one does make the most of himself, he is incompetent for good to others." "Self-sacrifice is not self-abasement; self-obliteration, self-debasement. One may, for the sake of another, sacrifice outward things—goods, time, pleasures, comforts, reputation. He may sacrifice possessions and enjoyments which in themselves are legitimate and so may practise self-denial. But he may not sacrifice character, the goods of the soul—truth, honor, purity, nobleness."

In all true sacrifice of ourselves for others, we simply sacrifice our lower selves to our higher. We lose our lesser life in order that we may find it again in a larger and nobler. No one ever saw these truths with greater clearness than Jesus of Nazareth, or put them together in more harmonious relations. In fact, it would be difficult, if not impossible, to frame a more exact or satisfactory expression of the supreme end of human existence than is found in the injunction: "Be ye therefore perfect as your Father in heaven is perfect."

With self-realization, or the perfection of all our powers as the ultimate goal of a valid ethics, our next inquiry will be, What is the ultimate rule from which the subordinate rules or maxims may be deduced for the attainment of this goal? There is no other way of answering this inquiry in a satisfactory manner than by the clear recognition of the fact that every man is a person and endowed with all the powers of a person. In fact, ethics deals alone with persons, not at all with things. Things cannot be good or virtuous.

Unless human beings possess reason and free will there can be no ought, and thus no ethics, in any proper sense of the term. What such beings ought to do must be primarily determined by what they can do. If they have no power to discern an ultimate rule of conduct, then they can have no obligation to follow it.

But the fact that every man is a person gives him that power. A new-born infant is not a person, and can have no ethics. Only when a being has developed far enough to be a person has he any moral obligations. But on becoming a person he has the light of reason for his guide. Being in possession of reason, he knows by an immediate beholding that he ought always to follow reason. In other words, what is true to reason he intuitively sees is a law to his will, and he unhesitatingly demands that all other creatures like himself shall recognize the same obligation and adopt the same law as the ultimate norm or standard of all their conduct. Essentially the same view of the matter is expressed by Hegel when he says: "The Law of Right is therefore—Be a Person: respect others as Persons."

With self-realization as the supreme end and obedience to reason as the supreme law, it is the business of the ethical scientist to show, as best he may, what specific maxims of conduct such an end and such a law, under the present conditions and limitations of humanity, require. This, of course, is no easy task; and, on the face of it, it is evident that ethics can never be made an exact science of closely co-ordinated facts. The best that can be done is to lay down certain general lines of procedure which each individual thinker must be left to apply to his own conduct and incorporate, as far as he may be able, into the customs and institutions of his times.

But what place is there in such a system for conscience, which has always been regarded as inseparably connected with every moral act? Allowing that this connection is a real one, what part does conscience have in the matter? Is conscience an infallible guide? Can it be educated and developed in the same way as many of our other powers? The answer to these questions depends on what is meant by conscience. Few terms in moral science have been used in so many different senses.

If we define it as the reason intuitively discerning the ultimate moral law, it is infallible and incapable of development except in the sense that previous experiences must furnish the fitting occasion for its exercise. But if we regard it as capable of telling us what the law requires us to do in individual cases, it is simply one of our judging powers, and is as liable to err as the judgment in general, being from its very nature ever susceptible to cultivation and improvement.

Most of the controversies that have arisen over the authority of conscience have been due to the confounding of opinion with conscience, claiming for opinion all the binding power of conscience or denying to conscience any greater authority than belongs to opinion. All confusion of thought on the subject is avoided by giving to the term conscience the first of the meanings mentioned above and holding with Kant that "an erring conscience is a chimera."

The supremacy of conscience is not found in the nature of the faculty itself, but in the truth it discovers. Its recognition of the supreme moral law is not a moral act but an intellectual one. It furnishes the condition which is essential to a moral act. The truth it discerns bears the same relation to right willing that the laws of thought have to right thinking. It is conscience in this sense that Calderwood has in mind when he says: "Conscience is a faculty which, from its very nature, cannot be educated. Education, either in the sense of instruction or training, is impossible. As well propose to teach the eye how and what to see, and the ear how and what to hear, as to teach Reason how to perceive the self-evident, and what truths are of this nature."

But accepting this view of conscience as the one most in harmony with a sound psychology, and granting that no rational creature can attain his supreme end of self-realization except by action in conformity to the demands of conscience, why is there so great a diversity of opinion among mankind as to what conscience actually requires? In other terms, why do men differ so much in what they approve or disapprove in their own conduct or the conduct of others? No better answer can be given to this question than we find in the oft-quoted passage from Epictetus: "The same general principles are common to all men. . . . Where, then, arise the disputes? In adapting these principles to particular cases."

In our efforts to apply the rule in the concrete, we have no infallible guide. No two persons may have before them the same data regarding the given case, and different conclusions may be arrived at even though the material is the same. But the very fact that people can often point out errors in the ethical opinions of others shows there is a common standard to which they all appeal. The Spartans are said to have approved of theft; but they did so only when it was so shrewdly done as to escape detection, the purpose being to make men skilful in deceit in times of war. We have no evidence that either they or any other people have ever approved of the act of taking from another what is clearly his own. We all commend good-will to others and a spirit of general helpfulness, but whether I ought to help this beggar is quite another matter.

Then, too, men yield to wrong impulses and afterwards seek to excuse their conduct. It is easy to think a thing is right to do, if we strongly desire to do it. The reasoning powers are greatly affected by the reactions of the will either to stimulate or to deaden their activity. The attention may be almost wholly averted from certain lines of argument or fastened exclusively upon certain others. A criminal rarely acknowledges that he deserves to be punished. Furthermore, the feelings may be perverted as well as the intellect. For they cluster around false opinions and customs as truly as around true ones. If a person has learned to approve a certain course of action, he will suffer remorse for not following it, even though the course be a bad one, just as he will experience the feeling of self-approbation for refraining from a course he has come to disapprove of, although it be a good one. Many a Hindu mother has suffered untold anguish for not having thrown her child into the Ganges, and many a thug or professional assassin has rehearsed his successes to his confrères with genuine pride and self-congratulation. When these and similar facts concerning human nature are duly considered, the wonder is that the diversity in moral judgments is not far greater than it is, rather than less.

In addition to what has already been said upon the subject, much light can also be thrown upon the nature of ethics by comparing it with other sciences that more or less closely resemble it, but from which it is to be kept clearly distinct.

In the first place, it has much to do with physical science. The facts and laws of physical science greatly help us to choose wisely because they enlarge our environment and give us a more accurate appreciation of the conditions. They also enable us to tell with considerable accuracy what the effects of different kinds of action will be. They do not, however, bear directly upon the principle we ought to follow. They cannot make or unmake the ultimate rule under which we ought always to proceed. Furthermore, there is no place for an end in nature ; and even if there were it would not be an end for human conduct. It would not give us the most essential element in determining the character of the ultimate ideal.

Much is made in our day of the relation of ethics to biology. But we must not forget that ethics deals with persons, biology with things. Ethics seeks the final cause, biology the efficient cause. Biology has accomplished its mission when it has shown how efficient causes have brought about human consciousness. Hence biology is essentially an empirical science, while ethics is a teleological science. Biology, it is true, deals with the tendency of organisms to adapt themselves to their environment and thus to work out an end, but the beings that do it are unconscious of the fact that they are doing it, while in ethics the end is consciously sought.

The relation of ethics to psychology is a very close one. We cannot rightly lay down rules of conduct for man until we have determined what he is capable of doing. The answer to the question, What am I ? must precede the question, What ought I to do ? Of course a detailed knowledge of psychology is not an absolute necessity, but no duty can rightly be prescribed for man unless he is known to possess the intellectual ability to comprehend it and the will power to perform it. It is no exaggeration to say that the material for a correct conception of the ultimate goal of life comes more from psychology than any other single source, if not all other sources combined.

Aristotle's famous dictum, that man is by nature a political animal, rightly emphasizes the fact that he is as truly a member of a community as an individual. Politics is, therefore, inseparably connected with ethics. The ideal for the individual must be regarded as the standard for the community. The community cannot justly require anything antagonistic to this ideal and should do everything in its power for its realization. Inasmuch as ethics has to do with the motive or purpose, it necessarily precedes politics, which deals with external manifestations or overt acts. Sound political institutions rest upon a conception of man as primarily and supremely subject to an ultimate moral law. Ethics takes into consideration all human conduct; politics, the one department of society organized into a state. For this reason a demand of moral science is higher than any civil statute. Ethics sits in judgment upon all political institutions and is the final arbiter of their character and right to be.

The relation of political economy to ethics has never received so much attention as in our day. It is the chief feature of the new economics. As usually defined, political economy is said to have to do solely with the production, exchange, and distribution of material commodities. Its mission is often regarded as merely the multiplication of those objects that satisfy our animal wants, such as food, clothing, shelter, and the like. But these things are all subordinate in value to the one end of ethics. Wealth is not the chief thing and ought never to be produced, exchanged, or distributed by means that nullify the supreme end of all human activity as laid down by ethics. The failure to recognize the dependence of political economy upon ethics was what led such writers as Carlyle and Ruskin to call political economy "the dismal science." It is so only when divorced from ethics and pursued in defiance of its superior mandates.

Between ethics and theology there are many contrasts and points of resemblance. Ethics looks at everything pre-eminently from the standpoint of man's relation to man. Theology takes the point of view of man's relation to God. Ethics seeks the ultimate rule for man, and shows how he ought to conform to it. Theology has to do chiefly with the nature and activities of God. The two sciences are related together as the art of morality is related to the art of religion. When intelligently and wisely practised, both arts conform to the demands of the sciences upon which they are based. True morality is action in voluntary accord with the moral law, while true religion is the worship and service of the author of that law. Ethics is not morality, nor is religion theology, but ethics is the science that deduces the rules of a sound morality and theology is the science that prescribes the duties of a true religion.

While it is true that no valid science on any subject can be formed without a resort to theistic conceptions for its fundamental ground, this is doubly true of ethics. In a real and vital sense the voice of conscience is the voice of God and the moral law an expression of his will. "A moral world order," as Professor Bowne well says in his *Principles of Ethics*, "a future world, and a moral world governor who assures the final triumph of goodness, are the assumptions to which we inevitably come when we attempt to think the moral problem through." In other words, a satisfactory system of ethics postulates, as modern philosophy postulates, the existence of God and the immortality of the soul. Kant was right in maintaining that belief in God and in another world is inseparably interwoven with the moral law: "Thou oughtest; therefore thou canst."

Yet it would be a great error to suppose that either the Christian religion, or any other, makes known to us any of the great fundamental truths of ethics. For they are as necessary as the great fundamental truths of mathematics and just as eternal and unchangeable. "The moral precepts of Christianity," to use the language of W. S. Lilly in an able article on the subject (*Forum*, January, 1890), "do not derive their validity from the Christian religion. They are not a corollary from its theological creed. It is a mere matter of fact patent to every one who will look into his Bible, that Jesus Christ and his apostles left no code of ethics. The Gospels and the Epistles do not yield even the elements of such a code." Yet Christianity has immensely enlarged our conception of God and clarified our ideas of the origin and destiny of man. It has also cleared away much of the mystery of human life and imparted to death a new significance. In this way, while it has not introduced any new moral principles, it has vastly extended the range of the old ones and deepened their meaning. Rights have been made far more sacred by it, the sense of obligation has been greatly intensified, and love and loyalty to an all-wise and beneficent Father have taken the place of reverence for an abstract law.

Of the usefulness of ethics in our daily life it may not be wholly out of place here briefly to speak. While it may be neither possible nor desirable to solve each problem of conduct as it arises by an explicit reference to its rules and principles, yet it is always helpful to right conduct and necessary for rapid progress in the formation of a noble character to appeal to them in every case of doubt or of actual deviation from the course of virtue. It is with ethics as it is with music or painting or any similar study. So long as there is no divergence from the principles upon which it is based, the principles themselves are not kept distinctly in consciousness. But when mistakes are made the only sure way of rectifying them is by a speedy recalling of the rules and maxims that have been violated and by a readjustment of the course under their guidance.

But it is not only in this negative manner that ethical science is helpful to right living. No character of any great dignity or worth can be acquired except in its explicit recognition. By conscious obedience to its mandates one virtue after another becomes habitual and, as it were, self-perpetuating. The energy thus freed can then be turned to the cultivation of new ones. It is in this way that a lofty and symmetrical character, which is a storehouse of virtues, is built up and made permanent. By failure to recognize and apply its teaching, a weak or even a positively bad character is easily acquired. And although it is always possible to change a wrong character, as President Hyde remarks in his *Practical Ethics*, " it can be done only with the greatest difficulty, and by a process as hard to resolve upon as the amputation of a limb or the plucking out of an eye."

The importance and worth of the study of ethics are still further seen in its relation to our influence upon others. Every leader in public life of any sort is constantly called upon to discuss and enforce moral positions often of the gravest moment. Every organization in the community has its rights and duties which must be allowed or disowned. Even those movements that are destructive of the social order are usually based upon some call to right a fancied wrong. The chief function of the leading minds in any body politic is to pass judgment upon matters that concern the rights and duties of their fellows. "The argument of every lawyer," says Porter, "the charge of every judge, the verdict of every jury, the sentence of every culprit, supposes some principle of moral science either asserted or derived." The same thing is true of teachers, journalists, and leaders of every sort. Whether they wish it or not, they are by the very nature of their position the expounders and representatives of ethical science.

The people at large who are beginning to look at other forms of truth from the scientific standpoint will no longer be satisfied with thoughtless and superficial presentations of their moral obligations. The institutions that give expression to the ethical codes that they are asked to support will be radically modified, if not overturned altogether, unless the grounds upon which they rest can be fully vindicated to their maturing powers of thought.

CHAPTER XI

PHILOSOPHY AS THE SCIENCE OF THE SCIENCES

THE word philosophy has had a great variety of meanings in the course of history, and no slight divergence in the use of the term exists among students of the subject even in our own day. The word is of Greek origin and literally means love of wisdom. According to a doubtful tradition, Pythagoras, a native of Samos, was the first to assume the title of philosopher. As handed down to us by Cicero and others, this tradition runs somewhat as follows: Pythagoras once upon a time made a visit to Leon, the ruler of Philus, a city of Peloponnesus; and while there he so impressed the prince with the greatness of his mind and his marvellous wisdom that he asked him to what art he had principally devoted himself. Pythagoras in reply declared that he professed no art, but was simply a philosopher. "Life resembles a spectacle," he is reported to have said. "Some attend it in order to participate in the contests; others to do business; the best to look on. So it is in life; the vulgar seek fame and money; the philosophers, truth."

The first authentic use of the word occurs in Herodotus, who, in describing the visit of Solon, the great Athenian lawgiver of the ancient world, to Crœsus, represents him as making great journeys over the world merely to philosophize. Here the expression means, of course, to gather information and to re-

15

flect. Later the distinction between a sophist and a philosopher was made much of. This was chiefly due to the influence of Socrates, who declined the title wise man and preferred the more humble one of lover of wisdom, no one being truly wise, in his opinion, but God. A sophist in the time of Socrates was a man who made a business of retailing knowledge for money. He travelled from city to city and sold what he knew to the highest bidder. The pupil bought the instruction offered in order to increase his influence and fortune thereby. Socrates did nothing of the kind. He made no trade of his wisdom, and sought no compensation. The one object of his life was to search after truth and dispel error. If others were induced to follow this course by his exhortations and example he had fulfilled his calling and obtained his reward. We first meet a more definite and concise conception of the vocation of a philosopher in Plato. Speaking of philosophers in the fifth book of the *Republic*, he describes them as "those who see the absolute, the eternal and the immutable"; those who are "able to distinguish the idea from the objects which participate in the idea, neither putting the objects in the place of the idea, nor the idea in the place of the objects." Still Plato did not make much use of this conception. For he places all the then known departments of knowledge under the one head of philosophy.

The first attempt to divide up the whole field of reality into separate sciences was made by Aristotle, the great encyclopedist of the ancient world. To each and every science he prefixed an investigation of the principles assumed by that science, which he called the "first philosophy," though it came to be designated later, accidentally, perhaps, by the title metaphysics.

But even Aristotle did not restrict philosophy to any definite field of inquiry. He included in it not only logic and ethics, but mathematics and many such studies as would to-day be put under the general head of physics.

The Stoics emphasized the practical side of life, and with them philosophy was almost identical with ethics. They defined a philosopher as one who lives according to the rules of practical wisdom, about as Tennyson uses the term.

In the early part of the middle ages philosophy was regarded for the most part as the handmaid of theology, its business being to develop and defend the dogmas of the Church. Later it had to do in a general way with all the so-called speculative sciences. The title of Master of Arts, handed down to us from the medieval universities, is a recognition of this fact. Every "Master" was required to lecture for two years after graduation, and he held himself ready to take any subject in the course of instruction that was assigned to him. Sometimes the matter was determined by lot. The degree of Doctor of Philosophy that arose in the sixteenth century meant the same thing. Every "Doctor" was regarded as equally competent to teach mathematics, astronomy, physics, metaphysics, logic, rhetoric, ethics, or politics.

"Melancthon," says Paulsen, "lectured on all the sciences which belonged to the curriculum of the philosophical faculty, and often described them in text-books that remained in vogue a long time. As late as the last century, Christian Wolff taught mathematics and physics, as well as logic, psychology, practical philosophy, and political science. Kant would scarcely have declined a chair of physics or of mathematics, astronomy, or geography, it it had been offered to him." Most of these studies and many others were regarded as properly coming under the head of philosophy, as the term was then used.

Another conception of philosophy that soon appeared made it consist solely in the way we handle the material of our knowledge. According to this view, philosophy has the same subject-matter as the sciences properly so called, but treats it in a peculiar manner, being distinguished from them by its method. This is the conception of philosophy that reaches its culmination in Hegel. It claims that all reality can be treated in two ways, a philosophical and a scientific. The business of the sciences is to acquire a knowledge of the facts; of philosophy, by a wholly different method, to find out the inner essence of those facts. This distinction assumes the possibility of gaining an *a priori* knowledge of reality by the mere development of logical concepts, a position which in our day meets with little favor. In fact, the truth is now clearly recognized that to think we must have something to think about. We cannot admit the existence of such a thing as pure thought. For it is only through experience that we arrive at any knowledge of reality. All so-called pure speculation is always over some product of that experience real or imagined. There is in fact no "high *a priori* road" that leads to actual knowledge.

Another view of philosophy begins with the rejection of the doctrine that there is any special philosophical method, and claims that the only difference between philosophy and the other sciences is in the subject-matter. Its special field, it is said, is knowledge, a field not claimed by any other science. Unscientific philosophy is that which reasons about things, but the philosophy that takes its place alongside of the other sciences as a science of knowledge is philosophy properly so called. In other words, it arbitrarily limits philosophy to the sphere of logic, doing violence to the common use of language without any valid reason in justification of the act.

Others, separating philosophy from natural science and confining it to the realm of mind alone, make it equivalent to mental science. This is preëminently the view of Sir William Hamilton. With him the terms, Philosophy, Metaphysics, and Mental Science are used synonymously. His chief work, entitled *Lectures on Metaphysics*, is mainly taken up with what belongs strictly to psychology. Ueberweg places at the beginning of his *History of Philosophy* a definition of philosophy as the science of principles. This brings philosophy into too narrow limits. Besides it is too vague and general to be of any great value. Uncertainty at once arises as to what is meant by principles. If the term refers to the fundamental notions that precondition each separate science, the term metaphysics far more properly applies to that study.

A new conception of philosophy was advanced by Auguste Comte. He held that the race as well as the individual passes through three intellectual stages, the theological, the metaphysical, and the positive. In the first stage a supernatural origin is sought for phenomena. They are attributed to the activity of some god. In the second or metaphysical stage the supernatural agents are set aside for abstract forces which are regarded as inhering in various substances and capable of producing phenomena. In the last stage all attempts to find out the causes or essences of things are abandoned and the mind confines itself exclusively to the discovery of the laws of phenomena. This is the realm of the so-called positive philosophy, and there is, according to Comte, no other. All knowledge, he holds, is attained by sensuous perception. This power alone gives us positive facts. All theological and metaphysical inquiries are futile. All questions as to the how or why of things are set aside by this definition of philosophy, and the mental sciences are merged wholly into the physical. Hence the classification of physical phenomena according to their actually observed relations of coexistence, succession, and resemblance is, in Comte's opinion, the proper business of philosophy and constitutes its only legitimate sphere.

According to Herbert Spencer, the object of philosophy is to deduce the fundamental principles of all the special sciences from the one supreme principle of evolution. Starting with an original chaotic condition of matter, its function is to show how, under fixed mechanical and dynamic laws, all the special phenomena of the universe have been evolved. Regarding psychology and ethics as departments of biology, the philosophy of evolution makes the attempt to account for all existing phenomena in terms of the redistribution of matter and motion. The special laws of all classes of phenomena are, according to this view, to be regarded as different aspects of the elementary laws under which the redistribution takes place.

In marked contrast with this vast scheme, elaborated by Herbert Spencer under the title of philosophy, the term is often used in England and America in the most haphazard and trivial manner. Sir William Hamilton, after giving a most learned summary of the chief definitions of philosophy that have arisen in the course of history, such as philosophy is "the science of things divine and human"; "the science of effects by their causes"; "the science of sufficient reason"; "the science of things possible"; "the science of science"; "the science of the absolute," concludes by saying: "We not only call physics by the name of natural philosophy, but every mechanical process has with us its philosophy. We have books on the philosophy of manufactures, the philosophy of agriculture, the philosophy of cookery, etc. In all this we are the ridicule of other nations. Socrates, it is said, brought down philosophy from the clouds,—the English have degraded her to the kitchen." But we in America have descended a step further. For we not only call microscopes and barometers philosophical instruments, but we talk about philosopher's eggs and philosopher's oil, philosophic wool and philosophic cotton.

With this brief enumeration before us of the chief conceptions of philosophy that have been held in the course of history, we are prepared to consider the question, What view ought to be taken of the matter in our day? What place ought philosophy now to have in every rational scheme of human knowledge? Some hold that the time has arrived to dispense with philosophy altogether. Including at the outset the whole sphere of knowledge, one science after another has been differentiated from it until, it is claimed, nothing is now left to which the term can be applied. The sciences are, according to this view, the goal and the grave of philosophy. In one sense of the term philosophy, this opinion has much in its favor. If it is regarded as identical with all knowledge, the progress of the individual sciences is rapidly limiting its legitimate field. But there is another way of regarding the matter that causes this difficulty to disappear.

We shall be helped on towards the discovery of this way by first considering some of the fields of inquiry with which philosophy in our day should not be confused.

No one in modern times would think of identifying philosophy with religion or mythology, but not a few to-day fall into the error of making it equivalent to physical science. But the business of physical science is over the moment it has arranged and systematized the happenings of the material universe in harmony with the laws of matter and motion. This is all the chemist can do, or the geologist, or the student of physiology. Even if this task, which has only just been begun, had actually been completed, of reducing all the ongoings of matter to its ultimate laws, other problems and far more important ones concerning the universe in which we find ourselves would still await investigation. The human mind with all its capabilities and powers would still have to be accounted for.

Yet philosophy can never ignore physical science. At the outset it was identical with it. It grew up out of natural science, just as natural science arose out of mythology. Thales of Miletus is rightly called the first philosopher, because he made the first attempt to establish a general theory of reality without resorting to a mythological explanation of things. But inasmuch as all the facts that had then been observed were physical facts, such as the condensation of water into ice, its expansion into air, the necessity of moisture to the germination and growth of things, he very naturally assumed that "the principle of all things is water; from water everything arises, and into water everything returns." In the same way the successors of Thales reasoned about the then known facts. Some maintained that air is the original element; some, that fire; others asserted that the four original elements or innumerable atoms are the universal principles of reality. Anaximenes, Heraclitus, Empedocles, and Democritus, the leaders of these respective schools, are properly regarded as the philosophers of their day, and cannot be too highly extolled for their ability and labors, but with the material of our time before them, they would be far from deserving of our attention and regard. Philosophy in our day, while inseparably connected with the phenomena of matter, has also to do with a vastly more important field of knowledge and research.

On the other hand, philosophy should not be confounded with psychology. True, there would be no philosophy without a mind endowed with power to construct it. But the facts of mind do not make up the sum total of the universe. Psychology is itself a clearly recognized science, having its distinct field of inquiry and its system of carefully classified facts. There is no good reason why two terms should be employed to designate this science when we have one already in use that meets all the requirements of the case in a perfectly satisfactory manner.

Nor should the term philosophy be used as equivalent to logic or epistemology. For logic, or the theory of knowledge, has always been regarded as only one of the philosophical disciplines. It is contrary to the common use of language to confound it with philosophy, and entirely unnecessary. Logic has been cultivated from the time of Aristotle as a distinct science, and there is no valid reason for exchanging the term for another which has from the first had a different and a wider signification.

The same objection holds against making it identical with ethics. As the science of human conduct, ethics is one of the oldest fields of inquiry in history. It has always been regarded as closely related to philosophy, but Döring and others go too far when they define philosophy as having only to do with the investigation of "goods and values," which is chiefly, at least, the field of ethics. For it covers a much broader sphere than any single individual science.

It is far more common to identify philosophy with metaphysics or ontology, but even this is wholly unnecessary, and leads to great confusion of thought. Metaphysics is the science of the ultimate nature of reality. As its etymology implies, it goes beyond physics and its view of nature. It also goes beyond psychology properly so called. It endeavors to investigate being in general and explain the most universal notions and attributes common to all being. Some deny the possibility of such a study, and claim that the physical sciences and the theory of knowledge exhaust the sphere of the knowable. One writer compares the student of metaphysics to a person trying to look down his own throat with a lighted candle in his hand, and bids him take care lest he set his own head on fire. It is true that metaphysics as the science of things beyond all possible experience, if such a thing ever existed at all, has had its day. But the endeavor to answer the ultimate questions that are put to the mind by actual contact with reality has always attracted the greatest thinkers of the race and always will. Such questions will never die out so long as man remains capable of reflective thought.

Some of these ultimate problems presented from the standpoint of the physical sciences are clearly and concisely stated in a recent paper by President Schurman. Supposing, he says, that physics in all its branches had been carried to perfection, "we should still have to ask such questions as these: What is that matter whose laws you have formulated? What is that space in which particles of matter move? What is that time by which that velocity is measured? Are matter and space and time self-existent, or are they dependent either for their being or for their attributes upon the mind that we say knows them? What is the relation of mind to the objects of knowledge? Is there for both a common ground which we call God?"

Important as these inquiries are for every thoughtful mind, still it is an erroneous view of the matter to make them identical with philosophy, which has its own peculiar mission and is not to be confounded with any individual science.

Philosophy is related not to one but to every science. Just as each separate science takes the individual objects with which it has to do and arranges them into a system, so philosophy treats the individual sciences. In other words, philosophy, as Paulsen well says, is "the sum total of all scientific knowledge." It cannot be separated from the sciences, but is, on the contrary, a unified system of the sciences, each individual science being an essential part of one grand whole. It is the work of philosophy to reduce all the sciences to unity, to show the place of each in one grand total. While each science investigates a definite field of reality,—physics, for example, corporeal reality, and psychology, reality so far as it is conscious,—its true significance can be seen only as it is regarded in its relation to the whole of reality, as a consistent part of a rational system. This makes philosophy something far different from what some characterize as the "altogetherness of everything." For the unity that philosophy seeks is the unity of an organism. Each science is a member of this organism as the hand is of the body. To show what this unity is and vindicate it is the function of philosophic thought.

The tendencies of our day are critical rather than constructive. Our age is giving itself almost exclusively to the dissecting of every proposed system, to the exposition of difficulties and the accumulation of objections. Yet, in spite of all this, "the desire to comprehend the universe as the revelation of a single principle is the genuine impulse to philosophy."

This conception of philosophy as the science of the sciences, or the sum total of scientific knowledge, is no new thing in history. In all periods of actual progress in philosophy it has always been its dominant thought. Only when the minds of men have descended into the dismal abysses of superstition and magic, or ascended into the empty spaces of pure *a priori* thought, has it been otherwise. All the early Greeks held to this view of philosophy. Plato and Aristotle taught it, though with occasional aberrations, making logic, physics, and ethics the three great divisions of philosophy. It is especially emphasized by the two chief founders of modern philosophy, Francis Bacon and René Descartes. In his *Advancement of Learning*, Bacon thus describes his view of the matter: "In philosophy, the contemplations of man do either penetrate unto God, or are circumferred to nature, or are reflected or reverted upon himself. Out of which several inquiries there do arise three knowledges, divine philosophy, natural philosophy, and human philosophy or humanity." Bacon's intention is to include here all scientific knowledge. He excludes history and poetry, but only on the ground that they are not sciences. For they deal with the particular and concrete, while science has to do with general concepts.

Descartes's chief work is entitled *Principia Philosophiæ* and its main divisions are metaphysics, physics, and such applied sciences as medicine, mechanics, and the like. Locke, in his *Essay on Human Understanding*, speaks of philosophy as "nothing but the true knowledge of things." Natural science, however, constitutes a very large part of his philosophy. For he deals chiefly with the problems suggested by such thinkers as Boyle and Huyghens and Newton, endeavoring, as he says, to assist "in clearing up the ground a little," that they had already traversed.

Spinoza and Leibnitz both regarded philosophy as a unified system of all scientific knowledge, and this was the current view down to the time of Kant. With him much was made of the distinction between *a priori* knowledge and *a posteriori*, meaning by the former the knowledge that reason may deduce from itself alone, and by the latter the knowledge that comes from actual experience. On this account, he became, against his will, perhaps, the father of what is called speculative philosophy, separating philosophy from the sciences and making it independent of them.

This is the view of philosophy taken by his successors. Fichte declares in his *Characteristics of the Present Age*, that "the philosopher performs his task without regard to any experience whatsoever and absolutely *a priori*." Schelling, in his *Philosophy of Nature*, inveighs against "the blind and thoughtless mode of investigating nature which has become generally established since the corruption of philosophy by Bacon and of physics by Boyle and Newton." With Hegel, philosophy is simply the dialectical development of concepts. It evolves all reality out of itself.

But philosophy in our day is returning from its temporary aberrations and is coming to itself. Separated from the sciences it must perish. Without them it floats off into the mists of airy nothingness, and is lost forever from our view.

As Dr. Edward Caird so well expresses it in his paper on *The Problem of Philosophy at the Present Time*, philosophy must "emerge from the region of abstract principles and show that it can deal with the manifold results of empirical science, giving each of them its proper place and value." He means the same thing when he says: "The task of philosophy is to rise to such a general view of things as shall reconcile us, or make us to reconcile ourselves to the world and to ourselves." Professor Edmund Phleiderer, in his monograph on the same subject, takes essentially the same view.

Nowhere, perhaps, is the true mission of philosophy more accurately stated than in the first chapter of *Cosmic Philosophy* by John Fiske. "Philosophy," he says, "is an all-comprehensive synthesis of the doctrines and methods of science, a coherent body of theorems concerning the cosmos and concerning man in his relations to the cosmos of which he is a part." Wundt sums up his discussion of the subject in his *System of Philosophy* by affirming that philosophy is "the general science whose business it is to unite the general truths furnished by the particular sciences into a consistent system." Fechner and Lotze held essentially to the same opinion. For they regarded a world-system of all facts the goal of philosophy and taught that it is only through the individual sciences that we can ever arrive at this goal.

This conception of philosophy as a science of the sciences makes the construction of a philosophical system a lofty undertaking, but it does not impose upon the mind an impossible task. For, as Sir William Hamilton observes, every man philosophizes. "He may philosophize well or ill, but philosophize he must." That is to say, it is not optional with any man whether or not he will have a philosophy. The only question with him is what kind of a philosophy will he have, whether he will be satisfied with a haphazard collection of straggling thoughts or will demand a logically connected system of veritable facts. One man may rest content with his catechism, another with his fetich, but every normally developed person must form some "working hypothesis" of the universe of which he finds himself a part.

If philosophy be asked to construct a system of thought void of all imperfections, we frankly admit that it cannot be done. Every philosophy, like every individual science, is the product of somebody. That is, it partakes of all the defects and limitations of the men who make it. This fact has not always been duly recognized in the course of history. The people of the middle ages were entirely satisfied with their philosophy. They did not see any need of improvement in regard to it and did not expect that any need would ever arise. It is said of Descartes that although he began by doubting everything, even his own existence, he ended by asserting everything. In his *Principia* he proudly affirms that "there is no phenomenon of nature whose explanation has been omitted from this treatise." Even the modest Immanuel Kant imagined that he had put philosophy upon its ultimate foundations, and that all his successors would have to do would be to fill in the details.

But the fact still remains that philosophy, like the sciences out of which it is constructed, is a human product and cannot transcend the conditions and limitations of its author. We may speak of the philosophy of Aristotle, of John Locke, of Arthur Schopenhauer; of American philosophy, of English philosophy, of the philosophy of the ancient Greeks; but never of a *philosophia ultima* or a philosophy that in any sense can be characterized as the absolute. Such a system of philosophical doctrines is a radical impossibility. We have no more right to talk of a final philosophy than of a final poem or work of art. "He who expects finality in the region of philosophy," as Professor Henry Jones, of Glasgow University, well says, in a recent volume of *Mind*, "and condemns its votaries for not attaining it, condemns it by reference to an unreasonable criterion and an impossible end; nay, condemns it for that which is its highest virtue."

It is with the same thought in mind that Professor William James is led to declare that "we need ever to be reminded that no philosophy can be more than an hypothesis." The man that affirms he will have no philosophy at all until he can find one above all criticism, thinks and acts on a level with the peasant described by Horace, who sat down on the bank of the river he had to cross, waiting for the water to run out of it.

While it is true that a philosophy that has hardened into a tradition has lost its power, it is not true, as George Henry Lewes implies in his *History of Philosophy*, that the labors of the past are of no value except to establish the proposition that nothing whatsoever can be known. Every new philosophy must grow up out of the past. In a certain sense, it is like a work of art. It exists at first in the mind of its creator as an ideal, but the material for the ideal is attained by intimate acquaintance with the products of the past. It does not grow up out of the past, however, by accretions. It is a new creation. Hence it is that each age must construct its own philosophy. For knowledge is always a varying product. Each science as it progresses takes on a new form. Our conception of the whole must ever change with each changing part.

No philosopher of our day would, of course, think of trying to comprehend all scientific knowledge. For each branch of science is now so extended as to claim a man's entire energy. But it is no presumption to attempt to unite existing sciences into a comprehensive whole. Indeed, every investigator who strives after unity of knowledge is a philosopher, whatever be the sphere of his researches.

Philosophy is not now and never has been a bread-and-butter science, but so long as the human race endures and continues to do any thinking, it will not be able to progress beyond the rudiments of a civilization without its service. Never was its assistance more needed than at present. "In no age of the world's history," says another, "was there so imperative a demand for a form of knowledge which can restore to man the consciousness of the unity of the world in which he lives, and counteract the specializing tendencies of modern life which so limit and impoverish our thoughts and actions."

But this demand will never be met so long as philosophers give way to their besetting sin of striving after absolutism in the construction of their systems, or the age continues to call for certainties where probabilities are the only attainable results. The new philosophy will inseparably ally itself to the individual sciences; and the individual sciences, if they are to continue their march of progress, will never lose sight of their relation to philosophy. For philosophy is the life of science, and science is the vital breath of philosophy. If one is severed from the other, both pine away and expire.

CHAPTER XII

THE HARMONY OF THE SCIENCES

IT is a familiar saying of Francis Bacon, that "the sciences can as little grow apart as branches severed from a common tree." The truthfulness of this assertion shows itself even in the very beginnings of scientific knowledge; and from the time of Plato down to our own day every great thinker has strongly emphasized the interdependence as well as the unity that exists in all the different spheres of thought.

Still, as Dr. Shields remarks in his *Philosophia Ultima*, "if we recur to the history of the sciences we shall find that their classification has varied with the advancement of exact knowledge, as well as with the caprices and fashions of philosophers. At one time, whole sciences have been wanting in the scheme, merely because as yet they were unknown; at another time, well known sciences have been ignored or depreciated through some reigning prejudice; and at no time, until quite recently, have they been arranged with any approach to a philosophical order or from a strictly scientific motive."

Plato was probably the first to bring the scattered elements of knowledge together and arrange them under the threefold division of logic, physics, and ethics. All three of these words had a different meaning in his day from that generally given to them in our own, but they characterized and unified with sufficient accuracy the attainments of that period.

A more elaborate effort to arrange all the different spheres of knowledge into an harmonious system was made by Aristotle, and the scheme he perfected remained unassailed in the schools of thought for centuries. He began by dividing all the sciences into three great divisions, as follows: the theoretical, the practical, and the technical. In the first division he put physics, mathematics, and metaphysics; in the second, ethics, economics, and politics; and in the third, technics, poetics, and rhetoric. In this classification it is evident that no attempt was made to separate the arts from the sciences properly so called. Metaphysics was used as equivalent to the "first philosophy," or theology, and physics had a much broader meaning than the term has in our time.

The Stoics accepted these general divisions, but as they regarded virtue as of primary importance, they put the practical sciences before the theoretical, making everything subordinate to ethics. The Epicureans sought to reduce the different spheres of knowledge with which they were familiar to unity by placing physics before ethics and banishing theology or metaphysics from the list altogether. The sceptics carried the matter to such an absurdity that they claimed to bring everything into harmony by denying that there was anything to harmonize. They refused to allow any content to the sciences, and would not permit scientific investigations to have any standing at all.

The Romans did little or nothing to advance the sciences either as to their content or their classification. Most of what they knew or thought, they imported from the Greeks. Cicero did little more than translate Greek ideas into Latin, making such selections as suited his purpose.

In the early Christian centuries theology gained such prominence to the depreciation of the other sciences that at the time of the founding of the great cloister schools, in the reign of Charlemagne, the entire sphere of knowledge had come to be divided into three great groups,—the formal sciences, the real sciences, and theology. The first group was so named because it dealt with words, and the second was characterized as real because it dealt with things. These groups, with their subdivisions, made up what was termed the scholastic classification of the sciences. This in detail was as follows :

Trivium.	*Quadrivium.*	*Theology.*
Rhetoric,	Music,	Ethics,
Dialectic,	Astronomy,	Metaphysics,
Grammar,	Arithmetic,	Mathematics,
	Geometry,	Physics.

Down to the time of the Reformation, with here and there an exception the *trivium* and *quadrivium* were regarded as the seven steps to wisdom, while theology was extolled as the source and queen of all knowledge. But with the revival of letters came also the revival of the ancient philosophical spirit. Luther aroused fresh interest in the theological sciences, Descartes laid a new foundation for the philosophical, and Bacon led forth the physical into ever-widening fields of research. The result was that many new sciences sprang into being and new classifications almost without number were brought forward to take the place of the old.

Yet after three centuries of contention, no one of them has been able to meet all the requirements of the case. The reason of this is the fact that we cannot set any limit to the number of classifiable objects and thus to the possible number of sciences. Furthermore, we may make our classifications from a great number of different standpoints, and a good working classification for one purpose may be quite the opposite for another. As it is our purpose to discover how the sciences may be harmonized from the standpoint of their subject-matter, we pass by all those elaborate classifications where the motive is solely or chiefly one of convenience, such as the alphabetical arrangements in dictionaries or the topical arrangements in great encyclopedias, and even where the utilitarian or pedagogical motive has the first place. Out of the great number still remaining we select only a few of the most prominent for critical study.

Chief among modern examples of the subjective method of classification, is Bacon's scheme of the sciences, elaborated in his *Advancement of Learning*. It may be tabulated as follows :

Memory	Civil Ecclesiastical Natural	History.		
Imagination	Lyric Epic Dramatic	Poetry.		
Reason	Natural Human Divine	Philosophy.	Physics Metaphysics	Nature,
			Ethics Politics	Man,
			Natural Theology Revealed Theology	God.

This scheme has been often praised for its beautiful symmetry and its rhetorical convenience, but it is rendered practically obsolete by the advances of modern science and its defective psychology. The logical powers are those most prominently employed in the formation of every science, and although the powers of memory and imagination are also conspicuous, they never are exercised separately in the pursuit of science, and no science can be founded on either one alone. As in the Aristotelian classification, the arts and the sciences are confused together by Bacon as though no basis for a distinction between them could be discovered.

Elaborate classifications of the sciences, based upon the psychology of the period, subsequently became current in France and Germany. The early French schemes were generally based on the psychology of Locke worked over and elaborated by Condillac. Accordingly, they put in the first group those sciences having to do with the power of forming, expressing, and combining sensations,—ideology, grammar, and logic ; in the second group those having to do with the will,—economics, ethics, and jurisprudence ; and in the third group, those beyond the will,—physics, geometry, and arithmetic. In Germany, for a long time, Christian Wolff was generally followed. He arranged the sciences according to the cognitive and appetitive faculties, and placed ontology, cosmology, psychology, and natural theology in the former class ; ethics, economics, and politics in the latter.

Kant did a great deal towards giving a new direction to these classifications by his distinction between pure reason and practical reason. The most elaborate system of the sciences built up on this psychological basis is known as the Coleridgian classification. It arranged the sciences into the pure and the mixed according as they proceed from the pure reason or the sensuous understanding. The subdivisions of the former were called (1) the formal sciences, which included grammar, rhetoric, logic, and mathematics ; and (2) the real sciences, made up of metaphysics, ethics, and theology. The subdivisions of the latter were (1) the experimental sciences, such as mechanics, hydrostatics, and optics, and (2) the applied sciences, or the useful and fine arts.

The objections to this Coleridgian scheme are the same as to that of Bacon, and to all schemes resting upon a psychological basis. No science can be referred to any one mental power. The faculties employed in the formation of any science are employed in the formation of them all.

Another way of harmonizing the sciences is to start out from the fundamental ideas upon which they are based. The suggestion of this method came from the philosophy of Kant. Whewell elaborated such a scheme in his *Philosophy of the Sciences*, and he began by putting mathematics first as based upon the ideas of space, time, and number; then came mechanics, resting upon the ideas of force and motion; then followed chemistry, grounded upon affinity and likeness; biology came next, having to do with life and final cause; this was succeeded by psychology, resting upon the ideas of emotion and thought; then followed palætiology, treating of the historical cause; and finally came natural theology, dealing with the idea of a first cause.

It is not to be denied that this Whewellian classification was far more profound and philosophical than anything that had preceded it. It showed a rational connection between the sciences, and besides clearly separated them from the arts; but it too lightly regarded the concrete facts with which the sciences have directly to do to furnish such a harmony of the sciences as is attainable with our present knowledge.

The author who carried the logical principle to its greatest extreme is Hegel. Starting out with the assumption that whatever is, is rational, and regarding even nature as "petrified logic," he attempted by mere logical reasoning without being influenced by experience to construct a scheme of the sciences that should be ideally perfect, and one that all future research would be compelled to follow. He began with logic, passed on through the concrete notions of mechanics, physics, and organics, to the more complex conceptions of ethics, politics, and religion, reaching the fulness of the idea in the absolute philosophy.

But the human mind is not competent to discover what the order of nature has been and is and must be simply from its study of the logical categories. All attempts at harmonizing the sciences solely on the basis of the conceptions involved in them, like those founded on the mental powers supposed to be employed in forming them, must fail of their end, and for essentially the same reason. They both unduly ignore the objective facts that go to make up the subject-matter of every science.

In passing now to some examples of the objective principle in the classification of the sciences, we shall continue to follow, in the main, Dr. Shields's learned and exhaustive history of the subject, making such selections here and there as fit in with our purpose.

Thomas Hobbes was the first to make a decided departure from the system of Bacon. He began by basing all knowledge upon facts and their consequences, and thus he had only two divisions of the sciences, the natural and the civil; the former having to do with bodies natural, and the latter with bodies politic. Theology he ruled out altogether as both unscientific and unknowable.

Dugald Stewart divided all the sciences into those that treat of mind and those that treat of matter. The former included the intellectual, the ethical, and the political sciences; and the latter the mathematical and the natural sciences.

The most ingenious and elaborate scheme of the sciences made upon the basis of the aphorism of Descartes, that our knowledge proceeds from things easily learned to those more difficult, or from the general to the special, was the classification of the celebrated French physicist, Ampère.[1] He divided the whole field of knowledge into the cosmological sciences, or those of nature, and the noölogical, or those of mind. The former were subdivided into those dealing with inanimate objects, and those dealing with animate. Each of these was again subdivided into two branches, and the process went on until the two divisions with which he started, including the arts, with which in his scheme the sciences were inseparably mixed, branched out into one hundred and twenty-eight.

It was out of this serial scheme of Ampère, and several of a similar character elaborated by his contemporaries, that Auguste Comte constructed his famous hierarchy of the sciences as set forth in his well-known work, *The Philosophy of the Positive Sciences.*

He began by restricting science to the facts of nature and their laws. He banished theology and metaphysics at once from the realm of science, as they busied themselves with the search for causes with which science, in his opinion, had nothing to do. The scheme he finally adopted may be tabulated as follows :

Organic Physics.	Sociology, Biology, Chemistry.
Inorganic Physics.	Terrestrial Physics, Astronomy, Mathematics.

[1] The work in which he elaborated his views was entitled *A Natural Classification of all Human Knowledge.*

Comte argued, in favor of this classification, that it is the order which the sciences themselves spontaneously assume; that it is their actual historical order; that it verifies his law of the three stages of human knowledge, the theological, the metaphysical, and the positive or scientific; and that it is the only order in which the sciences can be successfully taught.

The fatal objection to it is that it unjustly limits science to natural philosophy. It ignores psychology and all its related sciences. The harmony it offers is like that which might be produced in a contentious political convention by immediately knocking on the head all that were opposed to it. In its limited sphere it contains a large amount of truth. By being almost the exact counterpart of the Hegelian classification it has served a most important purpose in history and is likely to do so for some time to come.

Herbert Spencer, while agreeing with Comte that metaphysics and allied studies must be ignored, as belonging to the sphere of the unknowable, objects to some of the other distinctive features of the Comtean system and proposes one of his own. In his essay on *The Classification of the Sciences*, he shows that no merely linear arrangement can represent the development of scientific knowledge. The progress of the sciences has been simultaneous rather than successive. The newer sciences contribute to the older as well as the older to the newer. The simple depends upon the complex, and the complex upon the simple. New knowledge enlarges all knowledge. The mind in its progress passes from the concrete to the abstract, and after it has attained a generalization it applies it to the further interpretation of the concrete. Therefore we cannot put abstract and concrete sciences into the same series. The true historic order of their succession is spiral rather than linear, as there is a constant play back and forth between them in the general advance.

The Spencerian classification accordingly divides the sciences into three groups, the abstract, the abstract-concrete, and the concrete. With their chief subdivisions they are tabulated as follows:

Abstract Sciences.	*Abstract-Concrete Sciences.*	*Concrete Sciences.*
Logic,	Mechanics,	Astronomy,
Mathematics.	Physics,	Geology,
	Chemistry.	Biology,
		Psychology,
		Sociology.

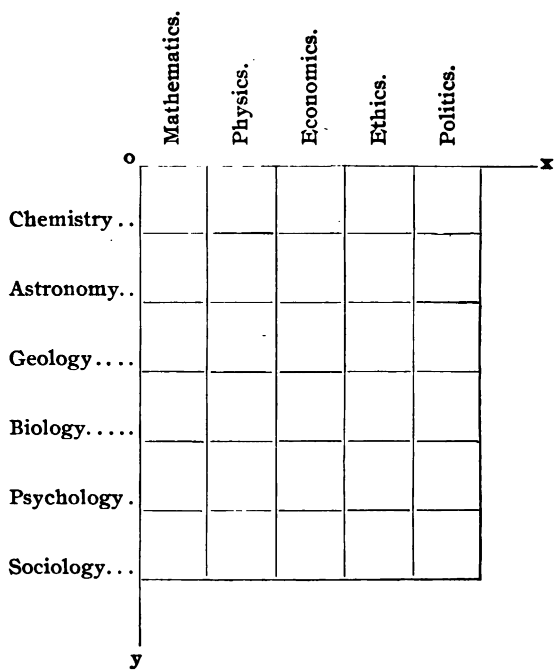
The first group gives an account of relations, the second of properties, and the third of aggregates.

Professor John Fiske of Harvard, in restating Spencer's system, adds to each of the five concrete sciences five others having to do with the genesis of their subject-matter. The first he called astrogeny, or the genesis of our stellar systems; the second, geogeny, or the genesis of our globe; the third, biogeny, or the genesis of species; the fourth, psycogeny, or the genesis of our mental powers; and the fifth, sociogeny, or the genesis of institutions.

But as Professor Giddings points out in his *Principles of Sociology*, "the unnecessary and confusing part of this classification is the abstract-concrete group. An account of properties or forces is as truly an abstract science as is an account of relations."

And then, too, all our knowledge begins with a knowledge of things and not with a knowledge of relations. The concrete sciences should occupy the first place in any scheme of the sciences. For if it were not for the concrete, the abstract would never come into being.

The Spencer-Fiske classification is a great advance upon the Comtean system ; but the scheme proposed by Professor Giddings is much superior to it, for it takes into consideration the criticisms mentioned above, recognizing only two distinct orders of sciences and so relating them that almost any number of cross-classifications are rendered possible. His arrangement is as follows :



"The concrete or y sciences," says Professor Giddings, in explanation of this system, "are descriptive, historical, inductive. The abstract or x sciences are hypothetical and deductive. The concrete become explanatory only because they are traversed, or crossed, by the abstract sciences. . . . On the other hand, the abstract sciences are not abstractions from nothing. They are abstractions from concrete phenomena. That is to say, they presuppose and take for granted the descriptive and historical matter of the concrete sciences."

The defects of this system are as noticeable as its excellences. Such sciences as logic and æsthetics it has no room for. It ignores theology in all its forms and shows no adequate conception, if any, of the place of philosophy in every scheme of the sciences that considers at all profoundly or comprehensively the different spheres of scientific knowledge that are open to our view.

When we look at the matter with care we see that all the objects of our knowledge naturally arrange themselves into two classes: facts or truths that are local, temporal, and changeable; and principles or truths that are universal, eternal, and unchangeable. All that we know concerning nature or the external world are facts, but the fundamental laws of logic—a thing must either be or not be, and the like—are principles. The doings of men in history are facts, but the ultimate rule of all rational conduct, that whatever is true to reason is a law to the will, is a principle. The existence of two objects exactly like a third object would be a fact, but the proposition that two things exactly like a third thing are equal to each other is a principle. It is everywhere true, always true, and immutably true. It has all the characteristics of a principle and none of the characteristics of a fact.

Furthermore, there are different ways of putting facts together into a system so as to make a science. We might begin with the simple isolated facts of botany, for example, and arrange them into classes under more general facts and then put the general facts together into a system. In this way we should construct a science of botany. But we might also begin with a principle and arrange the facts that come under it into their respective groups and thus construct a science. And we should not exhaust the field of science until we had taken all these lower sciences that could be formed and brought them together into one universal science that should account for all the facts and all the principles by putting them together into one harmonious system.

These considerations furnish us with the key to a sound and rational classification of the different fields of scientific knowledge. We thus see that there are three kinds of science and only three: the sciences that begin with single facts and arrange them into systems under more general facts, which we will call empirical sciences, because all their data are derived from direct observation and experiment; the sciences that begin with principles and arrange the facts under them, which we will call normative sciences, because they take a principle or norm of reason as their starting-point; and finally the science that seeks to explain all the other sciences and bring them into unity, which is philosophy properly so called.

A brief outline of a harmony of the sciences based on these distinctions is the following:

	Empirical Sciences	*Normative Sciences*	
Physical	Astronomy,		
	Geology,	Logic,	
	Physics,	Mathematics,	
	Chemistry,	Æsthetics,	
	Biology.	Ethics,	Philosophy.
Psychical	Psychology,	Economics,	
	Sociology,	Politics.	
	Descriptive Theology.		

This classification, while not in any way exhaustive, puts the fundamental sciences into harmonious relations to each other by placing first the concrete or empirical sciences, as is done by Professor Giddings ; by clearly distinguishing between the facts of matter and of mind, as is suggested by Dugald Stewart ; by recognizing the true character of the normative sciences ; and by emphasizing, with Comte, the hierarchy of the sciences, all the lower sciences leading up to and culminating in philosophy. It also leaves room for such additions as Professor Fiske proposes regarding the genesis of existing phenomena and others of a similar character as they shall develop in the future.

This scheme of the sciences also makes clear and vivid the independence as well as the interdependence of the various kinds of science. Science of the first grade, or empirical science, after carefully ascertaining the individual facts, groups them together under more general facts and attains its end when it has brought all its facts into a system. The astronomer, for example, reaches the end of his inquiries, as an astronomer, when he has shown how the facts concerning the earth, the stars, and all the other heavenly bodies are bound together into one harmonious whole.

But no sooner does the mind begin the study of facts and their relations than it at once comes to the knowledge of principles. No fact or collection of facts can ever become a principle, but a few facts even cannot be examined with any care without revealing principles. It is for this reason that no scientific mind can ever stop content with empirical science. It must ask, How are the facts related to the principles? What meaning do they have in the light of the principles and how are they to be scientifically arranged under them?

It is for students of the empirical sciences to observe the facts, and students of the other sciences must take on their authority the results of their investigations. One who is not a chemist must accept on the authority of chemists the facts of the laboratory. One who is not an astronomer has no right to question the well-attested observations of the telescope. But all attempts to account for these facts and unfold their meaning is the work of the philosopher. "To judge of the soundness of scientific data," says Professor Tyndall, "and to reason from data assumed to be sound are two totally different things." And the philosopher, whose whole business is to reason and explain, is the most competent of all scientists to interpret the facts and point out their real significance.

La Place was right in saying that he could not see God with his telescope, but he had no right to deny his existence for that reason. Neither the test-tube nor the dissecting-knife can solve any of the fundamental problems of the universe. In the very act of attempting to do so the physical scientist at once transcends the confines of his science. Each science has its own clearly defined limits. For no more than three grades of science are possible and no less. Each is necessary to the other and no one can exist without the other.

Every object from a pebble up to God himself, before it is known as fully as it can be known, must pass through these three grades.

If this view of the harmony of the sciences be correct, certain practical inferences from it will not unnaturally follow.

1. No science can rightly be pursued as a specialty except in the light of the whole realm of science. The true sphere of a particular science is seen only as its proper place in the circle of the sciences lies before the vision. For without the whole the part would never have been, and we can know the part and find out what it is and what it is made for, only as we know the whole. The true place of any empirical science such as chemistry or psychology can be rightly determined only in the light of philosophy. For philosophy is the science of all the other sciences, and its business is to set forth with clearness the relation of all these particular sciences to itself and to each other. Error, confusion, and discord must ever follow all attempts to find it by any other.

A chemist, as a chemist, is not capable of defining chemistry, nor is a logician, as a logician, a fit person to tell us what logic is. Nearly a dozen different definitions of logic are actually given by writers on the subject. It is safe to say that no student is thoroughly acquainted with the literature of his own science, if this and similar difficulties have not been met with again and again from the very beginning of his researches. And these disputes about the sphere of a science are not to be settled by an appeal to the fathers. Still worse is it to leave the matter to etymology. For often words come to have just the opposite of their original meaning.

The only way to remove the difficulty is to point out the place of the science in the circle of the sciences and its relation to contiguous sciences. Then its correct definition will follow. We must proceed in just the same way as we do in locating the home of any given nation. We must first obtain some idea of general geography and the abode of other nations to which it is adjacent. Then only are we in any condition to answer our inquiry with any definiteness. As the number of sciences increases, the more urgent will this course of procedure become. Any other way of dealing with the matter leads only to still greater chaos.

2. This view of the harmony of the sciences shows us how and where different sciences can assist each other in solving problems that transcend the sphere of any single science. Indeed, the problems are comparatively few and easy that do not require the aid of several sciences for their solution. Descartes introduced a new era into mathematics by combining algebra and geometry in his investigations of the nature and property of curves. Chemistry and optics are both necessary to determine the physical composition of the heavenly bodies through the spectrum. As it has been in the past, so in all likelihood it will be in the future. A happy combination of chemistry and physiology will probably solve many of the problems now waiting for solution, and a union of physiology and psychology still others, while not a few will require the combined aid of many sciences.

It is false to suppose that a science is best advanced by devoting the mind exclusively to it. Oftentimes the most rapid progress is made by solving problems from without, or getting help from many quarters. Mere specialists have never added much to science. Scientific researches are successful only as they are not exclusively special, only as they are illuminated by an ample idea of science. Every one must recognize the fact that the great men in the physical sciences are not mere specialists, but men of the vast generalizations and bold conjectures of a Newton and a Faraday, a Darwin and a Helmholtz. It would be equally idle to argue that any complicated problem in any other grade of science has been solved but by men of wide researches and profound views.

3. Growth in knowledge can rationally proceed only as it is based upon and directed by this view of science. There is a natural order in which the study of the sciences can be pursued, and an unnatural order. One cannot take them up wherever one pleases and in any order one pleases and pursue them with profit. It is fatal to success in ethics to begin it without a previous knowledge of psychology, and no philosophy is worthy of the attention of the thoughtful student that does not involve a thorough acquaintance with the general facts of physical science. The best any individual science can do is to cultivate the mind in a partial and one-sided manner. And every fair-minded thinker must acknowledge that the exclusive study of the physical sciences develops the lower faculties of the mind only, leaving dormant and undisciplined the higher. How can a mind be anything else than abnormal and puffed up with conceit, if it stops short at any one grade of science, and flatters itself that it has compassed the whole sphere of knowledge?

Let every freeman till his acre. Let every science have its devotees. But let no lover of the truth fail to recognize the fact that while there may be such a thing as a republic of letters, there is no such thing as a republic of the sciences. They form, on the contrary, one magnificent kingdom of knowledge, in which philosophy is the queen, the normative sciences are the ministers of state, and the empirical sciences the great body politic. No man can enter the kingdom of science except by the door of the empirical sciences, and only by passing through the normative sciences can he come at last into the royal presence of harmonized truth.

The intellectual confusion and unrest of our time will never be dispelled until this fundamental and comprehensive conception of science receives its full and complete acknowledgment; for only in this way can all the different departments of knowledge be brought to dwell together in harmony and peace.

THE END

INDEX.

C

D

E

F

G