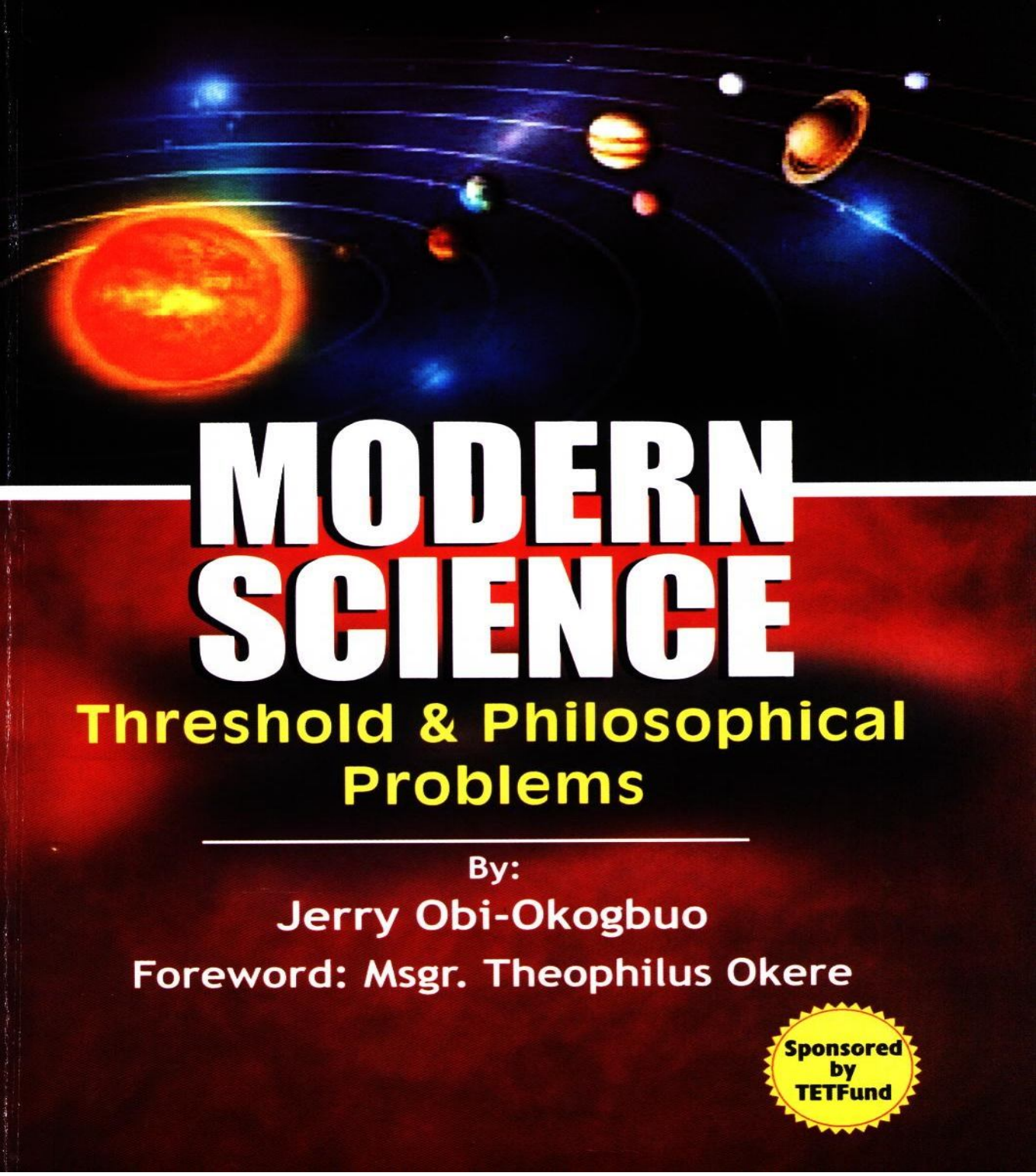

Part One

PHILOSOPHICAL ISSUES INVOLVED IN THE DEFINITION OF SCIENCE

CHAPTER 1

THE MEANING OF SCIENCE

The word science is used in so many senses. Some of the uses are analogous and some honoric (to confer dignity on the thing it is applied. To come to have a denotative meaning of science, there is the need to contrast it with other cognitive forms or knowledge-modes like common-sense, religious knowledge and philosophical knowledge. Here we begin with a clarification of the nature of common-sense knowledge. The reason is not to suggest – as some people are apt to do – that common-sense ontologically precedes scientific knowledge or that common-sense stopped after the emergence of scientific knowledge. No. We started this way because common-sense is a separate reference concept which easily aids the clarification of science. It is also a familiar launching-pad upon which to take-off in the search for a denotative meaning of science.

COMMON-SENSE: As early as the time man first appeared on earth, he started acquiring reliable knowledge about his environment with the objective of understanding, explaining and controlling it. Man did not have to wait for the occurrence of the modern scientific revolution and its method to start getting spontaneous convictions about the world around him. From the very early times, humanity has been awed and challenged. In an effort to explain and survive nature, he has acquired pragmatic knowledge about all aspects of life. He has also acquired techniques, instruments and skills for dealing with his natural environment. Man has always had knowledge about which plant was food, which raw material was processed for shelter and clothing, his primary needs. He discovered ways of farming, communicating, transporting heavy objects by way of carts with wheels. He could observe some regularity in nature and from that the measurement of fields and other standard schemes for other things developed. Calendars were also developed for calculating the seasons; and he could record these. Stephen F. Mason clearly conveys the a-historical roots of science when he says: "No matter how far back in history we go there were always some technique,

facts, and conceptions, known to craftsmen or scholars that were scientific in character."[1] There are, however, different ways man cognizes and relates to nature: "To conciliate the forces of nature, the most natural course was to invent religious rites based on myths. Myths were the first responses to the questions which humans continually ask themselves about the existence of the world and their own existence."[2] Human developments have come a long way and today man's cognition of the world falls, among others, into the following major categories: common-sense, religion, philosophy, and science.

What distinguishes the knowledge-modes common-sense and science is not that the latter is accurate and the former inaccurate, both may be accurate. But common-sense is unaware of the reasons of its accuracy and consequently does not know the limits within which it is valid. For instance, a community which acts on the belief that applying fertilizer keeps the soil fertile will continue to do that even if it brings about reduction of the fertility of the soil and subsequent low productivity. Common-sense knowledge is the result of routine habit and tradition. As an explanation it is incomplete. If it were complete it would know exactly when to and when not to apply fertilizer and the exact quantity to apply. Science aims to complete, and fine-tune the inadequacies of common-sense explanation.[3] Science does this by providing evidence, empirical evidence. Every scientific proposition is empirically verifiable. Every scientific explanation of a fact has directly testable proposition deducible from it other than the one asserting it. But unscientific explanations do not have any other directly testable proposition deducible from it.

Common-sense knowledge is spontaneous conviction: mere prejudice held to be absolutely certain or true. It is not questioned or challenged because: "Our people have always held it to be true" or because "everybody knows it is true." The only reason for holding it is its popularity not any evidence. Sometimes the evidence for holding common sense is authority: The authority of an individual, a religion, the revelation of religion; or the decree of the state. Common-sense is seen as so certain that there is no need to look for evidence in its support.

The different attitudes to scientific and pre-scientific common-sense convictions help to clarify their distinct features. Attitude to pre-scientific common convictions is dogmatic. It is dogmatic not simply because it is not questioned but because the disposition is never to question it. It is taken to be absolutely true. It cannot be improved or amended. In the Middle Ages, for instance, Aristotle was dogmatically regarded as the ultimate authority that decided any matter of dispute.

A schoolman turned down the telescope given to him by Galileo to look at the newly discovered moons of Jupiter simply because Aristotle had not mentioned the possibility of the existence of any such thing. On the other hand, the attitude to scientific knowledge is tentative and provisional. Scientific explanation is just taken as a hypothesis – more or less probable depending on the availability of relevant evidence.[4] The question of its truth or falsehood is open and it will continue to search for evidence, sensible or experiential, to decide that issue. Experience (observation) is a test of truth in science.

Scientific knowledge is the product of an institutionalized system of inquiry; that is, scientific knowledge is the product of scientific method. This is not to mean that there is a prescribed procedure which if mechanically followed will lead to a scientific discovery. On the other hand, common-sense is the product of spontaneous conviction.

Common-sense knowledge is generally provincial; that is, it bears on a particular value or need of man. On the other hand theoretical science is interested in the "relations of dependence between things irrespective of their bearing upon human value". It is apparently abstract, remote and formulated in universal language yet its bearing to particular needs is undoubted. Common-sense explanation uses abstract formulations too. The main difference lies in the fact that the abstract formulations of theoretical science is about "pervasive structural properties."

Compared to scientific knowledge, common-sense beliefs are apparently more stable. They have survived centuries of successful application. The reason common-sense knowledge seems to be surviving longer than scientific knowledge is that it is vague, imprecise and indeterminate. The language in which it is formulated is usually vague and lacking in definitive specificity and as such it cannot easily be faulted or contradicted. If I predict that it will rain next week, this prediction is not as precise as predicting that it will rain mid-day Wednesday next week. If it rains Friday or anytime next week, the first prediction remains confirmed. But if it rains Wednesday evening next week, the second prediction is faulted. Again it is common-sense that when water is sufficiently heated it will boil. Science will go further to explain what is meant by water, distinguishing it from other liquids like hard water. And science will also tell you the specific degree meant by "sufficiently heated." Scientific prediction is of the nature of our second prediction. It is exact and precise, the language has clear-cut meaning and that is why it is easily refuted.

From the discussion, we can deduce some of the essential features of common-sense thought-pattern. In the first place, common-sense is speculative. Speculation in this context is an intuitive and visionary mode of cognition which roams unlimited and unchecked. It is tainted with fantasy and wrapped up in imagination. Today speculation is not allowed to encroach into the realm of science. On its part, scientific reasoning is checked by verifiable fact. Both have the intention to explain, unify and order; to underpin the chaos of experience.

Common-sense is not really prelogical or ignorant of cause and effect as some people argue. The disposition to reason logically has always existed but in common-sense people cared less to apply logic. The fact is that there is emotional attitude toward it. Common-sense is subjective. In it thought is not autonomous. People are involved in things and as such could not distinguish between the objective and the subjective. Everything is personified, a Thou. What common-sense lacked is just the impersonal, mechanical and law-like functional view of things and events in nature. On this objectified and impersonal perception typical of science is based critical and analytical procedure by which it progressively reduces the individual phenomena to typical events subject to universal laws.

In common-sense or pre-scientific thought-pattern, there is no distinction between appearance and reality. Whatever affects the mind is as real as any other physical thing that affects the external senses. Dreams and ghosts are as real as impressions got by the external senses when one is awake. Hallucination is as good as the vision of sight. The dead are still part and parcel of the living. They intimately relate to us. But science is able to make a distinction between appearance and reality. For instance, in science we see the sun rise in the east and set in the west, but rather think of the earth as moving round the sun. That is the extent to which science has distinguished between phenomena and the conceptions by which we explain them.

In common-sense there is no distinction between symbols and what they symbolize; both coalesce. In the same vein, the part stands for the whole. Man's shadow can stand for the man.

In the general effort to understand, explain, unify; order and underpin the chaos of experience we can deduce from what has been said that common-sense has contributed so much. From the wandering times of the early man to date, common-sense has increased man's knowledge of his environment. It is even pertinent to the development of the scientific endeavour. The question we now ask is this: if so much has been achieved by common-sense in the task of acquiring

knowledge, what then is science? What special refinement does science contribute to the acquisition of knowledge?

PHILOSOPHY AND SCIENCE: To grasp the meaning which modern people give to science, we have to trace the history of the gradual detachment and eventual independence of science from philosophy. In its broad sense, science, from the Latin *scientia*, is the "systematic application of the human intelligence for the purpose of knowing causally...all of reality in its ultimate principles...."[5] It is born of the fact of man's desire to explain his origin, his place in the world and his final destination. The origin of science in this general sense is ontological or a-historical. It did not start with any particular historical individual at any particular time. This is what Aristotle means when he says, "It is owing to their wonder that men both now begin and at first began to philosophize."[6] In this grand sense of science, reason plays an important role. Reason is derived from the Latin *ratio* which means to 'reckon' or 'account'. It is analogous to *logos* which means knowledge. Reason enables us to express cogently the coherency of the world. Rationality is the meeting point of empirical reality and the conceptual system explaining it. Also in this grand sense, philosophy is science *par* excellence: the ideal science, the *matrona sciencia*. As the queen of the sciences; the particular (natural) sciences are her daughters delegated to study parts or aspects of reality.

It is a historical fact that from the time of Greek antiquity to the time of Immanuel Kant in the 19th century, what we today regard as the philosophy of nature and natural science were one and the same corpus. The Greek conception of science did not so much derive from such fields as astronomy, mechanics and biology as from *episteme* rooted in metaphysics and the theory of knowledge. This unified view of the sciences was typified by Aristotle's notion of science in his *Posterior Analytics* and the accounts of nature given in his extensive biological works as well as in his *Physics* and *On the Heavens*. In these it is observable that he considered natural philosophy, cosmology, chemistry, and biology as one unified science. This view was taken-over by the schoolmen of the medieval period who swallowed Aristotle's philosophy hook, line and sinker. This unified view of the sciences is even noticed in Newton's magnum opus *The Mathematical Principles of Nature* (1687); and also in John Dalton's *A New System of Chemical Philosophy*, (1808); around this period there was another study titled "Experimental Philosophy". These mathematical, chemical, and experimental philosophies have today come to be considered as science proper – a term that

with the foundation of the British Academy of Science in 1831 became current and came to designate only modern physics, chemistry biology and closely related disciplines.[7]

The steps to separate science and philosophy and restrict the meaning of science to the later conception of the British Academy of science were taken during the modern period. Aristotle had contrasted physics (which studied material realities in terms of the four causes: *matter, form, agent and end)* with metaphysics. Francis Bacon (1561-1626) and Rene Descartes (1596-1650) restricted the scope of physics. Bacon removed *form* and *end* from physics and included them within the ambient of metaphysics; Descartes removed from physic the concern with final causality. In line with his dualism, he distinguished two kinds of substances in nature: the spiritual and the corporeal; with the attributes of thought and extension respectively. He conceived the world of nature as a machine and identified the physical with the mechanical. Around this period Galileo Galilei (1564-1642) had combined experiment with rationalization (the explanation of reality or part of it in strictly rational framework to give birth to modern science). Up to the time of Galileo in the 17thC, there has been logical rationalization of reality without the support of experiment. These movements destroyed philosophy of nature as a physical science, leaving the material world to be studied by those disciplines officially labeled science in the 1831 sense of the word by the British Academy of sciences. Bacon and Descartes did not vanquish metaphysics but eventually in a series of moves that climaxed in the philosophy of Immanuel Kant (1724-1804), metaphysics was declared impossible as a science. Kant holds that there are two levels of reality: the phenomenal and the noumenal levels. The phenomenal level, according to him, is studied by science. Science is unable to know things-in-themselves. The questions of science are irrelevant to the real problems of mankind, the problems of beauty, freedom and ethics. The noumenal level is studied, according to him, by critical philosophy. Thus the subject of critical philosophy is transcendental because the noumenal level transcends man's intellect; it is the spiritual reality which supports man's ethical and religious problems. Transcendental philosophy (metaphysics) as a science is impossible. However, Kant presents a solution for those who wish to hold both the reality of ethics and the reality of the objective world. It is not God but man who is the source of the order he perceives in nature. There is the *a-priori* fact that a systematic knowledge of objects is possible. Objective knowledge is not passive; it forms its object. When we take a phenomenon as the object of experience, we

assume *a-priori* before we actually experience it that it obeys a given set of principles. In so far as it is perceived as a possible object of knowledge, it is the product of our mind's synthetic activity. The *a-priori* conditions of experience are also conditions for the existence of the objects of experience. This is the celebrated Copernican revolution achieved by Kant in philosophy. The subject no-longer revolves round the object trying to discover it, now the subject imposes its laws and this fashions the object.

Kant destroyed metaphysics as a science, and left it possible only as critical and epistemological speculation. Science stood alone in the spirit of Newton and his contemporaries as the only legitimate study of physical nature.

MODERN CONCEPTION OF SCIENCE: What is the modern conception of science? What is the conception of the science associated with people like Galileo, Kepler, Boyle, Newton, and Einstein? What is the conception of the science which the British Academy of Sciences at its foundation helped to create and promote? In Nagel's opinion:

> ...the distinctive aim of this scientific enterprise is to provide systematic and responsibly supported explanations...for individual occurrences, for recurring processes, or for invariable as well as statistical regularities. This task is not the sole preoccupation of the sciences, if only because much of their effort goes into ascertaining what the facts are in fresh areas of experience for which explanations may be subsequently sought.[8]

He quickly added that the contentious issue "that the sciences describe but do not explain," is a mere verbal polemics bordering on the ambiguous use of description – a linguistic usage that is neither important nor interesting.

This conception of science ensued as a result of the scientific activities of the precursors of modern science and the activities of scientific societies or academies such as *Academia dei Lincei* in Rome (C. 1609). The Royal Society of London (1660), chartered 1662. The First Class, later renamed *Academie Royale des Sciences* (1666) or The Academy of Sciences in Paris and the British Association for the Advancement of Science (1831), founded in York. These Academies were founded and chartered by absolute monarches like Louis XIV, Fredrick II, and Catharine the Great.[9]

Galileo is reputed to have initiated this conception of science when he desginated as scientific the explanations of the "immediate how" as against the

"ultimate why" of physical events, motions and processes. Science before him, in the Aristotelean/Thomistic tradition meant a kind of perfect knowing – *scire simpliciter*. For Aristotle science is the knowledge of an object which one possess when one knows its cause, the ultimate why. For Thomas Aquinas in the same tradition, science is the knowledge of something through its proper cause. Thus science was rational or intellectual knowledge not sense knowledge. It was mediate knowledge not immediate knowledge. Sense or immediate knowledge was untrustworthy and therefore not scientific. Galileo destroyed many of the "truths" of the ancients, especially of Aristotle, using the experimental scientific method. With the experimental and mathematical demonstrations which he developed, he was able to disprove many of Aristotle's positions and recorded some great achievements.

Robert Boyle (1627-1691) contributed to the articulation of the modern conception of science when he said that the knowledge of experimental sciences was meager and tentative. Its knowledge was comprised of hypotheses which could be discarded on verification through experiments. Boyle was a member of an informal group called the 'Invisible College', which later became the Royal Society. This group was devoted to the scientific experimental method. Its members held that truth could only be gained from experience and experiments.

Newton's scientific endeavours marked the culmination of modern conception of science as comprised of the laws stating "the exact mathematical formulation of the processes of the natural world."[10] Science is not concerned with anything that is not immediately deduced from the phenomena. The attempt to explain the nature of the forces or causes revealed in motion is not susceptible to experimental verification and therefore is not scientific. For instance, the ultimate nature of the force of gravity is unknown to science and it is in actual fact unnecessary that science should know it. Science simply seeks to know how gravitation force acts, not what it is.

Albert Einstein's contribution to the articulation of the conception of modern science is remarkable. He says that the "Theoretical physicist", the scientist is concerned with:

> ...the highest possible standards of rigorous precision in the description of relations, such as only the use of mathematical language can give. In regard to his subject matter, on the other hard, the physicist has to limit himself very severely: he must

> content himself with describing the most simple events which can be brought within the domain of our experience...[11]

The scientist improves our knowledge of natural things and our knowledge of useful art; he does not meddle with divinity, metaphysics, morals, politics, grammer, rhetoric, logic or all complex event and order beyond the power of the human intellect to reconstruct with mathematical accuracy and precision.

More than the contribution of any individual, the conception of modern science was formally articulated largely by the Royal Societies and The Academy of science. The Royal Academy of Sciences in Paris defined science much more than its counterpart the Royal Society in London. From the very beginning, the French Royal Academy of Sciences has a claim to science in its title which the British Royal Society did not have. Also the French Royal Academy had official status; it was backed by government. This is not, however, to minimize the contributions of the British Royal Society to the definition of modern science. The Royal Society was also concerned with experiment but it occasionally involved with natural philosophy and knowledge generally rather than with science exclusively. The members of the Royal Society could not properly be called scientist until the 1830s when the British Association for the Advancement of science was founded. The 18/19 centuries British secularization and restriction of the term science to denote the knowledge of the natural world and which devalued the idea of the medieval world that theology was "the queen of the sciences" was already anticipated in France before 1800; and the idea was accentuated by the aftermaths of the French Revolution of 1789 (The Society became totalitarian and everything including science was centralized and officially monitored).

The French Royal Academy of Sciences defined and controlled science by setting out the following procedures by which scientific discoveries could be acknowledged: scientific papers of savants (as scientists were then called) must be sent to it; and the Academy required that papers sent to it must minimize "vague speculation" while demanding increased "precise reporting of experimental evidence, in a subject amenable to mathematical treatment, appropriate equations would be welcome."[12] With these guidelines, the Academy was able to distinguish between real science on the one side and on the other side bogus science, non-science or pseudoscience, or fringe science; i.e., science outside the one recognized by the Academy. Since the Academy was state-sponsored, it spoke for the whole of France; any scientific paper it accords recognition automatically is science with official status.

FEATURES OF MODERN SCIENCE: One of the distinguishing characteristics of modern science is that it is a marriage between theory and practice. Ancient science was a system of logical coherent theory without a foundation upon experience; exemplified by Euclid's geometry. Modern science accepts rational systematization but insists it must have reference to experience. But howsoever science tries to be concerned with observable facts, it reaches a point where it indulges in highly speculative notions far removed from the possibilities of direct experience. A good number of scientific theories are not directly verifiable. We cannot observe entities like molecules, atoms, electrons and protons. Newton's law regarding the attraction of particles of matter is not directly verifiable. Modern science has a feature of objectivity. This ensues from the scientist's attitude of disinterested advancement of the value of truth. The scientist does not pursue personal utilitarian end while doing science. This is the abnegation in science. Truth is sought for its own sake irrespective of its use: applicability or inapplicability, profitability or unprofitability, pleasantness or unpleasantness. In science the self is completely forgotten. This, in part, explains the meaning of the purported saying of Bacon to the effect that knowledge is power. Bacon means luciferous (enlightening) power more than lucreferous (sordid profit or gain) power.

The other essential feature of modern science is that the practitioners are concerned to solve problems about the behaviour of nature; and each practitioner is concerned with the details about a tiny part of nature. The scientists possess enquiring and skeptical mind, methodic doubt. They insist on observation as the foundation of gathering facts and holding these facts tentatively until proved by experiment. They are not so much interested in possessing a large amount of knowledge. They are open to new ideas.

There is a unity of science. Science is one. Modern science is international or do we say supranational. It is practiced against the backdrop of a cosmopolitan cooperationist ideology. This is the highly prized and celebrated feature of the universality of science. A number of elements make this possible. In the first place, there is a "well-defined community of the scientist's professional compeers."[13] Scientists are in constant contact and communication among themselves. This communication is brought about through the literature of science. With communication, the end of one investigation may be the beginning of another. With the foundation of Royal Societies and Academies and English being

almost generally accepted as an international language from the 19th century (Latin was the scientific linguafranca); communication between different parts of the world was possible; dialogue between scientists was enhanced; consequently science became international. Also the units of measurement and the periodic table were one. The scientist from Asia understands the one from Africa, Europe or America. This is not the case in Art where there are many goals. Science has one goal all scientists aim. Before then there could be some justification for talking about national science; especially in France with absolutist system of administration that centralized everything. In Britain there was independence. Every scientist was on his own.

Another feature of modern science closely tied to the above and perhaps the feature that made the triumph of modern science complete is that it is free and public. This was not the case with earlier Greek and Medieval sciences. The Pythagoreans of ancient Greece were a secret society or more appropriately a cult group. They kept their mathematical discoveries to themselves. The alchemists of middle ages deliberately obscured their writings to keep their discoveries to as small a circle as possible. Even as late as the 16th century, the Italian mathematician Niccolo Tartaglia saw nothing wrong in keeping secret the method of solving cubic equations which he discovered.[14] Today, no scientific discovery is reckoned as genuine if kept secret; and it remains invalid until it is published and at least one other investigator has repeated and confirmed the experiment. Modern science is not the product of the individual but that of what Thomas Kuhn called the "scientific community". This scientific community – a group of professional scientists is the final arbiter about scientific issues. One of the strongest though unwritten rules of scientific activity today is that appeals are not made to rulers or the larger society about scientific matters but to the scientific community.

> Science is ultimately cumulative. It progresses by improving and building on earlier achievements. Stephen Mason writes: "The scientific method is essentially a means of discovering new phenomena, and of formulating new theories, so that the sciences constitute an ever-expanding system of knowledge, old theories being overthrown constantly by new ones, so long as that method is practiced."[15] This is one goal of science all the scientists cooperatively (even if they do not wish) are aiming at. A reading of the history of science makes this clear. There are four important historical phases in the development of science:

> The first is the empirical development of ancient Egyptian and Mesopotamian knowledge. The second is the building of a rational foundation of astounding beauty and strength by the Greeks. The third, and until recently the least known, is the medieval period – many centuries of groping; immense efforts were spent to solve pseudo-problems, chiefly to conciliate the results of Greek philosophy with religious dogmas of various kinds. Such efforts were naturally sterile, as far as their main object was concerned, but they brought into being many incidental results. The main result, as I have just explained, was the incubation of the experimental spirit. Its final emergence marks the transition between the third period and the fourth, which is the period of modern science."[16]

It is obvious that each phase builds on the achievements of the preceding phase making science, in that very sense, cumulative.

DEFINITION OF SCIENCE: The long cognitive experience of man proves that there is no one single knowledge-mode. This is true because reality has diverse dimensions; and diverse dimensions of reality demand different modes of study. For instance, the natural sciences require observation and experimentation; mathematics is a deductive construct starting from few initial axioms; social sciences demand a completely different approach. It follows that there cannot be a univocal notion of science. Science is analogous. In the same vein there cannot be a univocal definition of science. However, some definitions are too broad that they fail to demarcate between science and non-science; while some definitions are too narrow that they severely limit the scope of science leaving out legitimate notions of science.

Juan Jose Sanguineti offers what could go for an inclusive definition of science, he opines: "....science is the systematic use of the human intelligence for the goal of knowing causally a part of reality (particular sciences), or all of reality in its ultimate principles (philosophy)."[17] This definition is an attempt to recognize the two major senses of science. One could talk of science in the sense of one exact science, like physics; studying only an aspect of reality. One could also talk of science in a generic science, that is, in the sense of studying reality englobe; for instance, philosophy. That is why a little further he also writes: "Science is the systematic study of beings and their properties."[18] In the definitions so for considered the, word "systematic" has been re-current. This is to underscore the organized or ordered nature of science. This organization is impressed on science

by the method of science. Every science has a recognized method. Science is not random, haphazard, personal, or spontaneous; it is not art, metaphysics or theology. In the vein of regarding science as free, public and objective, Ernest Nagel defines science as "an institutionalized art of inquiry..."[19]; meaning scientifically methodic system of enquiry into "the perceptible phenomena of the world."[20] Science is defined as the discovery of explanations built into the logical structure of nature;[21] for instance, modern atomic theory, quantum theory, relativity theory or molecular biology (genetics). In this strict sense of science, the empirical or experimental natural sciences, physics, chemistry and biology become the paradigms of science.[22] Science is the grand war against the unknown, the attempt by man to understand events in nature; "to find a logic in the mysterious" and an order in the chaotic. Science is an explanation.

In modern terms, however, we can say that science is the investigation of the natural world using the scientific method. But sure the scientific method had room for the personal touch of the scientist; we can then simply define science as what practicing scientists do while doing science.

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