The Scientific Enterprise

4. Attitudes and Approaches in Science

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The Search

Human beings are constantly in action, often in search of something or other. From the most ancient times they have been in search of food and shelter, have sought to control animals and the elements to their advantage. They have explored the seas, climbed to mountain peaks, and voyaged to the poles to see what lies there and beyond. People have searched for lost treasures, for mythical lands, and for Noah's ark. They want to know about their neighbor's life, and about what is going on in the world. Governments seek information on its citizens and on foreign governments. Police departments are constantly in search of criminals, as criminals are looking for victims. Scientists too are engaged in an endless quest.

Clearly, not every search is an example of the scientific quest. What then are some of the characteristics of the scientific quest? How are the results of that quest formulated?

Insatiable Curiosity

There is an anecdote about a little boy who kept asking his rather poorly informed father a number of questions as to the how and the why of things. To each question the father merely scratched his head and said, "I'm afraid I don't know, son." At one point, after this had gone on a number of times, the boy began a question, but terminated it abruptly, saying in frustration, "Oh, never mind!" To this, the father gave his son a precious piece of advice: "Keep asking, my boy. That's the only way you'll learn."

The man may have been ignorant, but he had understood the golden rule of the scientific quest: Keep asking, whether you get an answer or not. Incessant probing arises from insatiable curiosity. Curiosity may kill the cat, but it kindles the scientist; some have warned that it will kill humankind eventually.

In principle, the range of inquiry is not restricted in any manner. It embraces the relevant and the irrelevant, the useful and the useless. It may well be that the answers we get after years of patient and painstaking search turn out to be partly or totally incorrect in the long run. Yet for the scientist, one should never stop asking.

Upanishadic sages recognized that those who contemplate on the nature of existence and of the world are truly enlightened. Nachiketas' probing into the secret of death (*Katha Upanishad)* is an example of irresistible curiosity and fundamental questions. Many keen minds in the ancient world were scientific in that they were engaged in the quest for knowledge about the world in which we live. Often their search for answers relied more on what seemed to them to be reasonable than on whether they corresponded with everything that they observed, or on a well-defined methodology for their quest.

Francis Bacon's pithy phrase *scientia potesta est* (knowledge is power) was articulated (in the spiritual context) in an interesting verse the *Taitiríya Áranyaka* (*Yajur Veda*) that is regularly recited in Hindu rituals. There it says that one who knows the nature of flowers, water, air, the sun, the moon, etc., obtains many things and becomes well established in himself: *Ya evam veda … áyatanavaan bhavati*.

Joy in Discovery

If knowledge is power, it is also pleasure. The Latin poet Virgil's dictum that the man who has learned the causes of things is truly happy *(felix, qui potuit rerum cognoscere causas*) expresses another important ingredient of the scientific quest. Associated with a selfless quest for knowledge is the excitement that comes with discovery. An inquiring mind and the excitement of recognition have always permeated the human spirit. The non-practitioner may find it difficult to understand the excitement of the scientific investigator who recognizes the inner workings of the world. But this excitement has been experienced by virtually everyone that has done even a modicum of science voluntarily and with dedication.

It may not be a discovery for humanity at large, but just a personal acquisition of knowledge that is new to the individual. The following passage from the biography of Marie Curie (Eve Curie, *Madame Curie,* Tr. Vincent Sheen, 2001 ed.), discoverer of Radium, brings home the point: "Powerful and tranquil, he (the professor) ventured into the most tenuous regions of knowledge, he played with numbers, with the stars; and as he was not afraid of imagery he pronounced in the most natural tones, accompanying the words with the easy gesture of a great property owner, 'I take the sun, and I throw it.' The Polish girl on her bench smiled with ecstasy. Under her great swelling forehead, her gray eyes, so pale, were illuminated with happiness. How could anybody find science dry?"

The story of Archimedes (Marcus Vitruvius Pollio*: de Architectura, Book IX*, 1914) running stark naked from his bathtub, screaming 'Eureka!'(*I have found it*!) upon discovering a scientific principle is symbolic of the heights of joy a scientist may attain in his explorations. The neuroscientist Santiago Ramón y Cajàl compared an original scientific discovery to

delivery of a baby: intense effort and even pain, followed by immense joy (E H Craigie and W C. Gibson, *The World of Ramón y Cajal*, 1968).

Of course, not every student of science goes through the courses with such ecstatic feelings. Nor is the average scientific investigator necessarily motivated by pure curiosity. This is because, in our own times, science has become a mass activity. Thousands of people are involved in mammoth scientific projects, be it marine biology, high energy physics, space exploration, or whatever. These and similar enterprises would be practically impossible without the technical participation of thousands of individuals. Countries train technical people to keep these projects alive, irrespective of some of the unscientific beliefs they hold. Only a fraction of them may be truly motivated by the scientific spirit. One does not become a scientist simply by being associated with a laboratory or a research center, any more than one becomes a truly religious person by regularly attending a temple or doing the rituals.

Skepticism

From a technical philosophical point of view, a skeptic is someone who doubts everything except the contention that it is impossible to achieve correct knowledge. In this sense the working scientist is far from being a skeptic, for she believes that the human mind can get a correct picture of the world. Philosophical skepticism has a very long history, and every great civilization has had its critical doubters who not only question the validity of currently accepted truths, but have little confidence in our ability to ever know the right answers. Pyrrho of Elis in ancient Greece was so confused by different claims of truth that he gave up trying to find out where the truth lay. Wang Chong in China rejected most of the common beliefs of his contemporaries and insisted on evidence for any claim. Charvaka in India, one of the keenest skeptical minds with a no-nonsense attitude to mystical obscurantism, was vilified and ostracized for his views. To this day his views are looked down upon by Hindu orthodoxy. Such thinkers questioned in no uncertain terms the thoughts and practices of their contemporaries.

Scientific skepticism does not consist in a denial of human potential for acquiring true knowledge, but rather in being guided by an ever-present doubt in the search for knowledge. The scientist and the dogmatic skeptic are, in fact, at opposite ends. The latter holds that it is impossible for us to comprehend and explain the world by the exercise of human faculties; the former contends that such hopes are not vain and unrealizable. What they do have in common is that they both hesitate to accept as true whatever may appear at first blush to be so.

The word skepticism comes from the Greek *skeptesthai*: to consider, to examine. In this etymological sense, the scientist is a true skeptic, for what she does is to carefully examine every datum of experience and every statement made about the phenomenal world. The habit of

thorough examination is an intrinsic feature of the scientific spirit, if not of every scientist in every walk of life. In systems of dogmatic philosophies there is great resistance to attempts to challenge established and long accepted truths. In the scientific enterprise there is great resistance to attempts at introducing totally new ideas. The distinction is very important.

One might think that the net effect must be the same in both instances. This is not so. Challenge to venerated ideas is considered to be blasphemy in a world where dogmas reign supreme. In the world of science every bit of heresy is tolerated, even encouraged. Indeed one may look upon a research project as an endeavor to describe or analyze some aspect of the world from entirely new perspectives. According to one school of philosophy of science, the avowed goal of scientific research is to falsify, rather than verify, what is taken to be the truth. What is important is that the claims and conclusions of the individual scientist are subjected to pitiless critique by a body of experts in the field. This inevitable fate of one's findings compels the investigator to think twice before he or she presents the results to the scientific community at large.

The scientific mind generally holds the view that the strength of the scientific enterprise arises from its proclivity to doubt. It subscribes to Cicero's aphorism that it is by doubting that one arrives at the truth. Scientists rarely defend whatever faith they might have in their enterprise, but they proclaim their proclivity to doubt. This provoked Robert Browning (*Easter Day*) to say:

> 'Tis well averred
> A scientific faith's absurd.

Bertrand Russell wrote (*Skeptical Essays*, 1928), "William James used to preach the 'will to believe.' For my part, I should wish to preach the 'will to doubt.' What is wanted is not the will to believe, but the wish to find out, which is the exact opposite". One reason for the scientist's skeptical attitude is that with the passage of time and the acquisition of new knowledge, older worldviews have often been given up. There are many defunct theories which were once regarded as scientific truth. That is why, as Hans Reichenbach pointed out (*The Rise of Scientific Philosophy*, 1957): "The development of science, with its repeated elimination of older theories and their replacement by new ones, supplies good reason for … doubt."

Attitude to Authority, Humility, and Collective Nature of the Scientific Enterprise

Over 2500 years ago the great teacher Gautama Buddha is said to have counseled his disciples something to the effect: "Do not believe in something simply because it is tradition and old. Do not believe in anything on authority of myself or of any other person". This injunction was in the context of religious truths and practices. But it also sums up the motto of the scientific

community to truth. All through the ages independent thinkers have expressed these views. C V Raman, wrote (G Venkataraman, *Journey into Light: Life and Science of C. V. Raman*, 1988) that after reading Edwin Arnold's *Light of Asia*, he was "deeply moved by the story of Siddhartha's great renunciation, of his search for truth and of his final enlightenment."

In the world of science, the idea is not that we should reject what others have said or taught, much less that authorities must necessarily be in the wrong. Rather, the view is that nothing is true simply because it originates from a long respected individual or institution. In fact, the longer a scientific authority has held sway, the more vulnerable his or her theories are likely to be. This is because, as the years roll by, the bulk of human knowledge is steadily increasing. Need for refinements and modifications of long held notions become a matter of routine.

Yet, the scientific community is not without its authorities. In every field of science and at every period of history not one, but several authorities hold power in the world of science. These are individuals who, by virtue of detailed study and years of research, have not only mastered all the available information of interest to a particular field, but have also contributed personally and significantly to its advancement. Hence an authority in science is respected and relied upon for depth of knowledge and understanding, but never for infallibility. The potential for erring is considered so human that no one is regarded as immune from it. When a student performs an experiment in the laboratory to verify a result that was expounded in a lecture, the act is, in fact, equivalent to an expression of distrust of what he had been told by a learned professor. "You may be right, Professor," the student is essentially saying, "but let me double check, just in case." This may be disrespectful in social contexts, but it is a virtue in science.

Authorities in science are generally referred to as *experts*. The real authority (in the sense of one who holds power) in science is not an individual, but a body of experts in the field. This body is not elected, nor vested with special powers, but it forms itself by dint of the efforts and accomplishments of its members. Its members include the peer-reviewers of professional journals.

However, in the world of science, the majesty of even the greatest authority may eventually crumble down if facts and phenomena so require. This heroic picture of science must be qualified. Although eventually and inevitably objective evaluation alone determines the acceptance or rejection of new contributions to science, this is true only in the long run. For there are also specific instances of non-scientific coercions and influences by some scientific authorities to advance or hold on to their own theories and convictions. Many young researchers have been obliged to take up topics for investigation, and to pursue them along prescribed lines simply because the research director wants it that way. Opportunities and

possibilities for publication may be thrown open or closed, depending on the affiliation of a worker to a particular person or institution, or the sympathies the new person is able to generate.

Thus, for example, when Pierre Duhem presented his doctoral thesis in physics (1884) in which he challenged Marcelin Berthelot's principle of maximum work, the eminent French chemist became so furious that he saw to it that Duhem would never get an opportunity to teach in Paris for the rest of his life (P Brouzeng, *Duhem, 1861-1916 : science et providence*, 1987).

Or again, in the 1930s, the eminent astrophysicist Arthur Eddington vehemently opposed young S Chandrasekhar's revolutionary result on the size of a star which can become a supernova, and tried to put every impediment on its way (Kameshwar C Wali, *Chandra: A biography of S. Chandrasekhar*, 1984). But eventually Eddington lost and Chandrasekhar won, not just in the acceptance of his theory, but the Nobel Prize also. (This is a great example to belie the nationalistic/colonialist interpretation of science that some thinkers in Non-Western countries still hold onto.) Science itself marches on with ideas and points of view that seem most appropriate to an intellectually consistent interpretation of the world at any given epoch. Such imperfections merely underscore the fact that science is after all a human enterprise, subject to all the nobility and pettiness that humans are capable of.

The universe of phenomena is limitless. So vast is the phenomenal world and so numerous are its intricate aspects that even the best of human mind can hope to grasp only a small fraction of it all. Hence another important ingredient of the scientific quest is humility. As Henry David Thoreau said (*Walden; or, Life in the Woods*, 1854) "Humility like darkness reveals the heavenly lights." But it is a strange kind of humility. For it recognizes not only one's own limitation but also those of others. The progress of science is effected, not by a single individual, not even by a single nation or generation, but by the collective world of many who, by mutually correcting one another's errors and by taking advantage of the results of others, form a sort of super-personal mind. This mind, which is strengthened by the collectivity, and rendered relatively immune from major blunders by the vigilance of its many parts, attempts to disentangle the mysteries of the universe.

Attitude to the Phenomenal World

In some specific ways, the scientist's attitude to phenomena depends on whether one is a physicist or a biologist, a geologist or an astronomer, etc., but a good many factors overlap. Generally speaking, the scientist does not attach any particular significance to the existence of the universe. While doing science, one is not looking for meaning or purpose behind it all. One believes that the universe itself is quite indifferent to the presence and activities of human beings or of any life forms on the planet Earth. The world has been functioning in accordance

with well-defined laws for many eons before human beings entered the scene, and will continue, perhaps for much, much longer, after we leave the scene. As Steven Weinberg famously said (*The First Three Minutes*, 1979) "The more the universe seems comprehensible, the more it also seems pointless."

The scientist adopts this attitude only *qua* scientist, that is to say, while working or thinking as a scientist. As an individual interested in matters beyond one's professional work, one may well adopt a quite different attitude in other contexts. In moments of philosophical or metaphysical reflection, a scientist may well consider, or even accept, that there is meaning and purpose to the universe. In fact, throughout the history of science there have been many good scientists who have been devout believers in the tenets of one religion or another that give humans a special place in the universe and worship anthropomorphic deities. The scientist may accept, reject, or put forward his or her own meanings and purposes to human existence or even to the universe. Such attitudes are generally extrapolations or convictions resulting from one's upbringing and from cultural factors which, however, have little to do with science. Thus we can find good scientists who practice Christianity or Islam, Hinduism or Judaism, Jainism or Buddhism or Sikhism, or take Dialectical Materialism as their religious belief. This says nothing about science, but a great deal about the power and conditioning of culture on the human mind.

Now one may ask: Why does science have an attitude of indifference to matters concerning the deeper meanings and purposes of life and of the world? The reason for this is that for more than two thousand years such questions had been raised and answered in mutually contradictory ways. Questions like, "Who made the Universe?", and "Why was it made?" may be interesting, But they have led us nowhere in terms of understanding and explaining particular phenomena. There are many other interesting questions about the universe that we may ask for which we are able to get clearer and more reliable answers. It is the fruitlessness, rather than a negative judgment of their intrinsic value, that has turned science away from the more fundamental questions that intrigue the human mind.

To the scientist, the world of phenomena arises from the operation of innumerable laws and principles that give rise to a labyrinth of causal chains, intertwined and interlinked. Nature taken as a whole is an infinite chain of causes and effects The physicist seeks to reduce them to intelligible relationships. The poet William Cowper wrote (*The Task*):

> Nature is but a name of an effect
> Whose cause is God.

But the scientist is concerned, not so much with the cause of Nature, as with the specific causes of its various facets.

Nature to the scientist is one vast puzzle that must be resolved. The sun rises and sets; the sky is blue; fruits grow and fires glow; magnets attract and things fall to the ground; metals expand on heating; the prism splits white light into multi-colors; sound is not transmitted through a vacuum; and there are thousands of other facts of experience that need to be understood. Every situation is a riddle, and each must be solved. This is the collective goal of the scientific community.

The world is a complex system to begin with. As soon as we probe into any one aspect of it and look for the details, the complexity begins to stare us in the face. But by ingenious application of human intelligence, order and harmony emerge from what initially seems to be utter chaos. Look into the spectra of the elements, and all you will see is a jumble of lines and blurs. Classify and analyze them: order will appear in them. Consider the plethora of substances we see around us. When they are studied patiently, they seem to fit into well-defined patterns.

Thus, the world is like a bundle of twisted knots that must be disentangled. Consider the rocks in a region, or the plants in a forest, or the stars in the sky. They all appear as a horrendous heap strewn at random. Study their properties and classify them: they fit into clear-cut classes.

The phenomenal world is also like an endless volume of cryptography that needs to be decoded. Nature and its laws do not lie all clearly spelled out before human faculties. The language in which they are written is not intelligible to us right away. They are clothed in symbols and in situations that we must decipher. Planets move in elliptical orbits. Light bends on changing media. Electric currents heat the wire through which it passes. Each is an expression of a physical law. The recognition of a physical law is the decoding of a cryptic note in the Book of Nature.

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