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To see a World in a grain of sand,
And a Heaven in a wild flower,
Hold Infinity in the palm of your hand,
And Eternity in an hour.
—WILLIAM BLAKE

THERE is no doubt that recent dramatic events have stirred up a new awareness of the importance of science in our civilization. But it is still a question whether we see this new impact of science in its true perspective or not. For not only has science in our day given the human race, through atomic energy, a reservoir of physical power many orders of magnitude greater in quantity and in intensity than any power we have possessed in the past, it has also presented us with an unprecedented ability to direct and control this power with refinement and complexity. The underdeveloped countries are making a frantic bid to achieve the scientific manpower and technological advances already achieved by the so-called civilized countries. The Philippines, not to be outdone, is training its more talented personnel in the field of nuclear physics, chemistry and engineering; wide scale improvement of science in high schools, colleges and universities is being carried out. Thus, thanks to atomics and automation, we are standing today on the threshold of a truly new world.

A hundred years ago, science was referred to as natural philosophy. It embraced both laboratory experimentation and

mental speculation. Fact and fancy were part of the same pattern. During the last fifty years, science and philosophy seem to have parted company and to have gone their separate ways. Someone has remarked that fact went along with the scientists and fancy with the philosopher. But today whether we like it or not, understanding of the fundamentals of science requires more and more the philosophic approach. Through more refined experimental techniques we are being led away from basic concepts normal to our ordinary senses. We are being driven into new realms where fundamental entities can be particles one moment and waves the next, or may be both at the same time. While today these unusual ways of thinking may be limited to certain relatively narrow areas of science, there is every reason to believe that they will spread rapidly into other fields.

Science has become a cohesive force in modern society, the ground on which may be built a secure way of life for man and his community. We may be tempted to smile at a certain naiveté in all this; but it springs from insights deeper than we sometimes realize. For it seems to many that within science there is such understanding of man and his place in the scheme of things, such power to create and destroy, such magnificence of pattern and splendour of success, that it can fulfill the deepest urges and longings of man's spirit. This, which is sometimes called the scientific attitude, has been well expressed by C. H. Waddington: "Science can . . . provide a way of life which is firstly self-consistent and harmonious, and secondly is free for the exercise of that objective reason from which our civilization depends."[1]

But, granted that science has given us atomics and automation, air-conditioning and television, neobium and nobelium, does a scientific theory, however deep, ever reach the roundness, the expression of a whole personality that we get from, say, works like Shakespeare's **Othello** or Handel"s **Messiah?** A fact is discovered, a theory is invented; is any theory ever deep enough for it to be truly called a creation?

[1] C. H. Waddington, *The Scientific Attitude,* p. 124.

Most non-scientists would answer No. "Science," they would say, "engages only part of the mind—the rational intellect—but creation must engage the whole mind." Science demands none of that "ground swell of emotion", none of that rich substratum of personality which fills out the work of art.

This picture drawn by the non-scientist of the scientist at work is, of course, the wrong picture. A gifted man cannot handle equations or bacteria without taking fire from what he does and having his emotions engaged. Sir Cyril Hinshelwood, at the recent centenary celebrations of the Chemical Society of London, illustrates the process of scientific research remarkably; he speaks of Chemistry but his statement is valid for all science: "What the Society is and must continue above all else to be is a fellowship of those who share the love of Chemistry, that most excellent child of intellect and art. Chemistry provides not only a mental discipline but an adventure and aesthetic experience."

"The ardor of the creative artist," says George Russel Harrison in *Science and the Whole Man*, "fills the scientist too when he pursues a discovery and hopes for the perception of previously unknown truth." Though a law of nature is phrased in abstract language and is itself seemingly devoid of passion and sensibility, the history of its discovery may be an epic worthy of Homer. Despite the impersonal objectivity of scientific knowledge, the pursuit of science is a fabric of passion, feeling, and fascination. The individual cannot be eliminated from it. In science, it is the individual who observes, who selects, who relates, and who experiences the joy of discovery. Most scientists agree that the moment of discovery is a moment of delight and satisfaction to the individual, reminiscent of Spinoza's definition of pleasure, "the passion by which the mind passes to a higher state of perfection." And it was Jacques Maritain who said that subjectivity has become the very vehicle of penetration into the objective world.

The scientist achieves communication with his fellow scientists in a very precise and quantitative message of sym-

bols and formulae. But such a message may be used in another way. The scientist may see in it a manifestation of the power of the human mind; he may ponder on the implications of Newton's or Einstein's creative insight and genius. Thus used, it may function as a work of art, though it does not have that appearance. The French mathematical physicist Lagrange is sometimes called the "Shakespeare of Mathematics", on account of the extraordinary beauty, elegance and depth of the Lagrangian Method. But perhaps the clearest expression of this is in an unpublished article written by N. R. Campbell: "Some algebraic formulae caught my eye . . . it was part of a paper by a Dr. N. Bohr, of whom I had never heard . . . I began to read. In half an hour I was in a state of excitement and ecstasy, such as I have never experienced before or since in my scientific career. It was like a thrill of a new revelation such as must have inspired Keat's most famous sonnet." When we see things like this, we begin to see why Pursewarden called science the poetry of the intellect.

Science deals with the chaos of experience from the point of view of efficient, intellectual and practical performance. Science is out to find laws and general rules, because the discovery of a single law or rule enables us to understand an indefinite number of individual happenings. The scientist's demand that nature shall be lawful is a demand for unity. When he formulates a new law, he links and organizes phenomena which were thought different in kind. For example, general relativity links light with gravitation. In such a law we feel that the apparent disorder of nature has been made to reveal a pattern, and that underneath the chaos, there rules a profound unity.

We have come to see the scientific implications of some of those things which Kant had said in the eighteenth century: that the raw material of science is the set of experiences, observations, measurements of the scientist and his task is to find a pattern of relationship between these experiences. To many scientists, a thing of beauty is not a joy until it con-

forms to discipline, bringing form out of chaos, fulfilling the stern definition of St. Thomas: Beauty is the essence and glory of order.

What made his theory seem simple to Copernicus was an esthetic sense of unity. The motion of all the planets around the sun was both simple and beautiful to him because it expressed the unity of God's design. The same thought has moved scientists ever since: that nature has a unity and that this unity makes her laws beautiful in simplicity. The creative mind is a mind that looks "for unexpected likenesses between things'", and this gives man a sense of richness, of harmony, and of understanding. The whole personality is committed in science fully as much as in the arts.

"Art," says Thomas Merton, "creates its own forms, and they are significant by reason of their own beauty. The meaning of a picture is not to be sought merely in a 'message' or in the 'subject' but in the interrelation of forms, colors, lines, etc., in an integrated, living, creative unity."[2] Recent investigation of the giant molecules has shown how nature achieves, in extraordinary perfection, the aim of art; in the molecule, function is the expression of structure; it is what it is because of the way it is made.

As an important result, the way in which the scientist looks at the world has come close to that of the artist. For example, science is now preoccupied less with facts than with relations, less with numbers than with arrangement. This new vision, the search for structure, is as marked in modern science as the search for form is in modern art.

Men of science complain of the lack of a wide appreciation of scientific knowledge; but what else can they expect if they offer to the world only the dry bones of knowledge from which the breadth has departed? When we so often hide what is best in science and display only its less admirable features, it is not surprising that laymen should doubt its ultimate intellectual value. There has been in recent years

[2] Thomas Merton, "Notes on Art", *Jubilee Magazine* (Nov. 1956).

a great improvement in the general appreciation of the meaning of science; but open antagonism has been in part replaced by an "armed neutrality" which indicates no better understanding but merely caution.

It is curious how even today the laity seem unaware of the part played by the genius of great men in the development of science. They recognize perhaps that the oft-cited examples of the greatest achievements of science, the discovery of Neptune or of Hertzian waves or of the theory of relatively, represent something not easily attained by the common mass of mankind; they are willing to admit that Newton and Einstein, Maxwell and Hertz, must have had some qualities to distinguish them from lesser folk. But they have no knowledge of what these qualities are; they have no idea that their work was an expression of their personality just as much as the work of Leonardo Da Vinci, of Shakespeare, or of Bach. They still tend to contrast the "cold-blooded rationalism" of the man of science with the passionate dreamings of the artist. But science too has its dreamers, and their dreams come true; they dream, and messages flash across the empty ocean; they dream again, and a new world springs into being and starts upon the course that they have ordained.

By his imagination, the scientist fashions new universes which are "nearer to the heart's desire". The sorcery and charm of imagination, and the power it gives to the individual to transform his world into a new world of order and delight, makes it one of the most treasured of all human capacities. As John C. Eccles puts it:

> An entirely different order of image-forming is involved in the creative imagination, the most profound of human activities. It provides the illumination that gives a new insight or understanding. In science that illumination takes the form of a new hypothesis. Such a creation of the imagination has immediate esthetic appeal in its simplicity and scope; it must nevertheless be subjected to rigorous criticism and experimental testing.[3]

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[3] John C. Eccles, *The Physiology of the Imagination.*

This "illumination" sometimes has the suddenness of a flash, as with Kekulé and the benzene ring, Darwin and the theory of evolution, Hamilton and his equations; but most great scientific hypotheses are the offspring of more labored births. They developed in stages, being perfected and shaped by critical reason, as with Planck and the quantum theory, as with Einstein and the theory of relativity.

According to Alfred North Whitehead, the pilgrim fathers of the scientific imagination are the great tragedians of ancient Athens, Aeschylus, Sophocles, Euripides. Their vision of fate, remorseless and indifferent, is the vision possessed by science. Fate in Greek tragedy becomes the order of nature in modern thought.

It has recently been shown how greatness in science is associated not only with facts, but first and above all, with imagination. Max Planck once said:

> Science is a created work of art, because when the pioneer in science sends forth the groping feelers of his thoughts, he must have a vivid, intuitive imagination, for new ideas are not generated by deduction, but an artistically creative imagination[4]

The scientific imagination can no more be developed and vivified by tedious laboratory practice alone than the artistic imagination can be stimulated by the laborious study of Greek particles, by uninspired practice on a musical instrument, or by the mere touring of art galleries. It must come from direct and intimate contact over the widest possible range with the great original works which represents its noblest expression. It involves an act of the imagination, a seeing of what others do not see; indeed, Dr. Pierce uses the phrase "creative observation" to describe the pioneer vision of Leonardo Da Vinci.

To Archibald Macleish, at any rate, the real crisis in the life of our society is the crisis of the life of the imagination. Far more than we need an intercontinental missile or a moral re-armament, we need to come alive again, to recover the

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[4] William & Norgate, *A Scientific Autobiography*, chapter 3.

virility of the imagination on which all earlier civilizations have been based.

The act of creative imagination initiates an experience whose fulfillment lies beyond time and space. This is how science becomes an adventure of the mind, in which beauty and elegance link it with wider experience. As we understand more about the nature of the universe in which we live, more about the nature of life itself and the fundamental psychological and epistemological patterns of our thinking and perception, "the creative aspects of literature, arts and even music are bound to be affected."[5] And to us, as scientists, it would certainly seem that if the arts and humanities are to be regarded as serious intellectual endeavors, then "humanism-in-depth" and "disciplined thought" must go hand in hand.

In the *Common Sense of Science*, J. Bronowski illustrates how the layman's key to science is its unity with the arts. It is in literature, in the arts, and in social studies that students may learn to recognize the scientific outlook and to be aroused to the romance, the wonder, the adventure of modern science. This is more clearly expressed by Alfred Whitehead in *Science And The Modern World*:

> Wisdom is the fruit of a balanced development. It is this balanced growth of individuality which should be the aim of education to secure. The most useful discoveries for the immediate future would concern the furtherance of this aim without detriment to the necessary intellectual professionalism. What is wanted is an appreciation of the infinite variety of vivid values achieved by an organism in its proper enivronment. When you understand all about the sun and all about the earth, you may still miss the radiance of the sunset. There is no substitute for the direct perception of the concrete achievement of a thing in its actuality. We want concrete achievement of a thing in its actuality. We want concrete fact with a high light thrown out on what is relevant to its preciousness.[6]

The true artist and the true scientist are not really estranged. They go forth into nature like two friends. Their approaches to the universe are widely different, yet in no true

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[5] Alfred Whitehead, *Science and the Modern World*, p. 194.
[6] *Ibid.*

sense are they hostile or mutually destructive. On rare occasions, and Rachel Carson's book, *The Sea Around Us*, is one of them, they become a single person. Novelists and poets before her had described the beauty, terror and mystery of the sea, scientists before her had recorded in dry and perishable prose the "facts" of the sea. It remained for Miss Carson to fuse the science and the poetry into one magnificent, brilliantly executed work.

It is hard to see how the artist and humanist can hope to have any universality in their creations today without a considerable understanding of the fundamentals of science. If we recognize the essential role that the arts and humanities play in the formation of a well-educated scientist, the inverse must be recognized too. No one puts this more finely than George Sarton when he says that "a true humanist must know the life of science as he knows the life of art and the life of religion". In the lovely words of Thomas Traherne, the seventeenth-century philosopher:

> He that knows the secrets of nature with Albertus Magnus, or the motions of the heavens with Galileo, or the cosmography of the moon with Hevelius, or the body of man with Galen, or the nature of diseases with Orpheus, or of poetry with Homer, or of grammar with Lily, or of whatever else with the greatest artist; he is nothing if he knows them merely for talk or idle speculation or transient and external use. But he that knows them for value, and knows them his own, shall profit infinitely".[7]

[7] Thomas Traherne, Meditation No. 341 from *Centuries of Meditation.*