THE ROYAL BANK OF CANADA
MONTHLY LETTER

VOL. 46, No. 12 HEAD OFFICE: MONTREAL, DECEMBER 1965

The Spirit of Research

AN EXTENSIVE and important venture into world-wide research has been launched by the General Assembly of the International Council of Scientific Unions. It is to study the relationship of the human race to the changes in its environment caused by the demands of civilization.

This research is not trying to decide whether civilization depends upon science or science upon civilization: that is like the question: "Which came first, the chicken or the egg?" It merely recognizes that something is happening every day in countless laboratories throughout the world, and wonders whether human beings are measuring up physically and mentally and socially to application of the discoveries.

The scientific culture is here to stay, at least for some generations. It involves a way of life quite different in many respects from that which seemed to our fathers right and natural. It embraces not only the devices and gadgets which industry develops out of scientific discoveries, but our thinking, our hopes and our fears.

Because the rise of science is the most important fact of modern life, no student should be permitted to complete his education without understanding it. Otherwise, he will grow up still viewing science with mere primitive wonder and the childish glee that greets a new toy.

Adult education, too, should emphasize science and research to encourage the growth of a scientific mental attitude in the discussion and study of problems, to emphasize and explain the social repercussions of science, and to enable people to cope with new conditions.

Scientific research takes no account of likes or dislikes, of parties or sects or nationalities. Its business is to find out the truth, to discover exactly what things are and how they work. The scientist distrusts the plausible and the easy and the customary, not because he believes it is not so but because he knows it may not be so and he seeks ground on which to plant his feet firmly. He knows that the result may not turn out to his personal liking, but he hears Socrates saying: "Either we shall find what we are seeking, or at least we shall free ourselves of the persuasion that we know what we do not know."

Research is the challenging of self-evident truths. It seeks systematized positive knowledge. It wants not only to explain some part of the whole, but to see the pattern entire, and determine how the parts hang together. It glories in the lucid beauty of a solution reached after effort.

Let's look at research

Research is good for the mind and spirit. If you are engaged in research, whether scientific, social or commercial, or simply looking for a way in which you can live more happily, you are unlikely to sink into a series of third-rate things.

Research is an activity where truthfulness is essential; in fact, truthfulness is the measure of its success. Truth does not inhabit the same orbit as vagueness and ambiguity, but insists upon definiteness and completeness. Truth refers to the way things are, and it is your job as a researcher to find it out.

You are not a myth-maker. Either your hypothesis survives as a verified fact or valid principle or it dies a clean-cut and final death.

There is a custom in some cases of appraisal of a situation or judgment of a person to appoint a "devil's advocate" — one who brings out every possible fact that can be opposed to the favourable evidence. The research man has to be his own "devil's advocate", conducting his own cross-examination of his findings. Research invites the detection of error and welcomes it, even though the discovery upsets complacency. A theory, whether about distant stars or family life, is untenable if it embraces even one false principle.

Everyone is involved

It is not to be thought that only men in laboratories do research. The information on which we conduct our business and our private lives, and on which we base our plans for the future, is a catalogue of the results of a vast number of experiments. The smallest

piece of research will be the better for application of the principles that guide the biggest. Every business man, politician, engineer, teacher and homemaker borrows a bit of the glory of the scientific spirit when he examines his ideas in an objective way.

What does research mean in terms of everyday life? A woman is doing research when she tries detergent after detergent until she finds the one that works most efficiently under her conditions of washing clothes, her equipment, the sort of water that comes out of her tap, and the kind of soil to be removed. The merchant is doing research when he studies the market so as to match his goods to his potential customers at a profit and without waste.

The scientific method introduces some degree of system and order into the study of any subject, and forces us toward clear thinking and direct expression. We see for ourselves how things behave under conditions we can control, instead of arguing about how they ought to behave.

Pure and applied research

Paul Sears placed professional research on a high pedestal when he wrote in his book *Charles Darwin:* "It is the great destiny of human science, not to ease man's labors or prolong his life, noble as those ends may be, nor to serve the ends of power, but to enable man to walk upright without fear, in a world which he at length will understand and which is his home."

Nothing is easier to start than a fruitless debate on the issue of pure science versus applied science. It is not very important to most of us to pin labels on laboratories. We lump together science and technology, making the word "science" cover astronomy and medicine, relativity and synthetic chemicals, automobiles and radio-activity, electric toasters and space flights. But scientists designate as "pure" or "fundamental" or "theoretical" science such things as Einstein's relativity, the constitution of matter and the electro-magnetic theory of light and heat, while to applied science or technology they assign all the instruments and machines used in industry and the home, paints, plastics, electric lights and even the atomic bomb.

From the labours of those who were interested only in advancing knowledge have come the ideas and the instruments which have created new industries. But neither branch would be possible without the other, for without the advance of science the techniques would fossilize into unchanging crafts, and without the stimulus and products of technology science would become a vain display of learning.

Has the course of history been changed by scientific research? Certainly our way of living has been. Scientists' discoveries in the past half century, turned into inventions by innovators and put into productive shape by technicians, have raised people's expectations to the level of fantasy.

And so, while the urge to reach the moon may be essentially research of a high order, the necessity of cleaning rocket fuel to unprecedented standards is producing techniques which may one day be embodied in the household washing machine.

T. H. Huxley, who wrote prolifically on science matters in the nineteenth century, said: "The history of physical science teaches that the practical advantages, attainable through its agency, never have been, and never will be, sufficiently attractive to men inspired by the inborn genius of the interpreter of Nature, to give them courage to undergo the toils and make the sacrifices which that calling requires from its votaries. That which stirs their pulses is the love of knowledge and the joy of the discovery of the causes of things."

Even while the results of their discoveries are being turned by "practical" people into goods and wages, the basic researchers are already far away over the ocean of the unknown.

Dr. Hans Selye, Director of the Institute of Experimental Medicine and Surgery at the University of Montreal, wrote a significant paragraph along this line in a *Saturday Evening Post* article, later published in *Adventures of the Mind* in 1958, and recently included in his own book *From Dream to Discovery* (McGraw-Hill Book Company, 1964). He said: "Without basic knowledge of the behavior of distant stars, we would not be placing satellites in orbit today. Without knowledge about bacteria, there would be no vaccines, serums and antibiotics. And without those observations [Mendel's] on the inheritance of color in peas, modern genetics — with all its importance to agriculture, animal breeding and medicine — could never have developed."

It is industry that takes science from the ivory tower into the market-place, applying pure science to particular classes of problems.

It would be stupid not to make good use of the discoveries of others, but if we rest upon that without seeing and discovering for ourselves we are denying ourselves expression of the greatest human attribute.

Are we, like the Athenians when war was threatened by the Spartans, sowing only quick-growing things? Dr. Alan T. Waterman seemed to think so when he was director of the National Science Foundation ten years ago. He deplored the fact that the nature of basic research is far from being understood by the people of the United States. "At a critical juncture in our history," he said, "when much in our future may depend upon the soundness and originality of our basic research, the tendency has been to hold its support to an absolute minimum."

Despite the advances in organized research, the creative power of the individual still counts most. "It would be a disaster," said Prince Philip, "if the individual inquirer working in his own laboratory were discouraged out of existence."

The qualities needed

What are the qualities needed for research? To suspend judgment with patience, to meditate with pleasure, to say "it is finished" with caution, to abhor imposture: these are some of the qualities. Experience, observation and experiment enable us to single out the essential factors in a situation and to see how they are related to one another.

Research is ongoing. Static thought is knowing exactly where Darwin bagged all his theories, ideas and suppositions: constructive thought is linking these together so as to learn how he arrived at conclusions: research thought is starting where Darwin ended and going on from there.

Research must be objective. Objectivity is not a virtue in the evidence you gather but in your attitude toward the evidence. The wise man is wary of his inclination to view every fragment of evidence in the light of facts and suppositions and old wives' tales he had previously acquired.

Research starts from curiosity, which is a manifestation of man's love of understanding things. It is one of the most permanent and certain characteristics of a vigorous intellect.

Curiosity must be active, and must lead to the asking of questions which yield significant answers. Ninety-five per cent of us imagine that because we are wondering about something we are considering it. A really restless mind has wrenched itself from its fixities and is challenging things hitherto accepted as being obvious. Anything that is unknown is important to it.

Research broadens the mind, for this reason: every discovery, every question answered, forces new questions upon us. At the uttermost reach of our discovery there arises the question: "What lies beyond?" Whether you ever reach the ultimate is not nearly so important as that you maintain an inquiring mind.

Observation is a prime requisite in research. Our intellects are not their own true selves when they are talking or chopping logic, but only when they are seeing and ascertaining, providing us with facts to be explained. Galileo's way was to choose his vantage point for looking and then to describe as simply as he could what he saw. He perceived the unwelcome facts as well as those which suited his suppositions.

Imagination and ideas

We need some suppositions. We should give imagination a loose rein, and let it roam around our objective. Many of us are afflicted, without having realized it until now, with what some people call "ideational inertia". That means simply having difficulty in moving from one idea to another idea, perhaps a conflicting one.

Research compels us to think new thoughts. It doesn't matter how small your idea or supposition may be, it requires some originality in your mind.

An idea is not something final, but only a thought about something. It may be an urge to do something, develop something, create something, improve something, facilitate something, accomplish something. We must take the idea and formulate specifications of how to bring the idea into reality. Even the wildest ideas may be tamed into the best behaved and most profitable.

Ideas are not always the outcome of bearing down on a problem. H. P. Maxim was asked by his daughter how he got his idea for the Maxim silencer. "By watching the way water behaved when it went down a drain," he replied. A new twist, a different look, or an added idea may open a wide vista.

It is evident that research is not merely the classifying of information: you must think, even if it hurts. The ability to seek for the causes of phenomena is what makes man supreme among animals.

Many creative thinkers reach the solution of the problem long before they work out any logical proof. Karl Friedrich Gauss, great mathematician, confessed: "I have had my solutions for a long time, but I do not yet know how I am to arrive at them."

If the imagination is to yield any real ideas, it must have received a great deal of material from the external world, and it must have retained much of the freshness of outlook associated with childhood. Imagination can be as simple as that of Anne of Green Gables picturing herself in a beautiful dress, or it can be as sophisticated as that of Copernicus when he put the sun in the centre of the Solar System and saw all the planets moving in orderly and dignified orbits.

Hypotheses and experiment

Sparked by imagination, our minds become subject to sudden insights into problems they have worked on.

Some things turned up in this way may seem to point very straight to one conclusion, but if you shift your point of view a little you may find them pointing to something entirely different. That is why it is wise, in all matters where your judgment is called for, to walk around the proposition and see it from every side. In other words, the insight must be subjected to a test of its validity and worth.

Scientific thinking includes these steps: you determine what is your problem; you collect facts for and against, through observation and experience; you form an hypothesis or scientific guess after discarding what you believe to be irrelevant; you test your hypothesis by patient experiment.

Do not allow yourself to be discouraged by the all too common sneer that greets an hypothesis. What more have we to guide us in nine tenths of the most important affairs of our daily life than hypotheses? The great thing is to test the hypotheses before acting

on them: it is of the essence of scientific method that you do not employ hypotheses which cannot be tested. Darwin's writings are for all time a model of refusal to go beyond the direct evidence, and of careful examination of every possible hypothesis.

This evaluation should be done with a fresh eye. This is not brought about by using eye-drops or a jeweller's loupe, but by turning over the thinking apparatus behind your eye. Your hypotheses must not become untouchable sacred cows. You will not form sentimental attachments for them. You will know that research is a history of mistakes, but the mistakes led to exactitudes and the exactitudes led to the computer and interplanetary flights.

Even when an hypothesis fails to meet the test and must be discarded, the negative information it yields is not useless. It has narrowed the range, and by so much has increased the probability of finding the truth. It has helped to clear the ground, so to speak.

Preparation and effort

Effective research does not arise from going into a laboratory or a factory or an office and saying "what shall I look for now?" It does not construct anything out of nothing. It requires knowledge sparked by an idea. A great deal of solid foundational work appears under every discovery.

This is the real reason for accumulating knowledge: so that you may have an abundance of material in your mind upon which an idea may alight and germinate a thought.

The research man needs to be a good pupil, but he has to go further. The pupil picks up information; the student casts the facts into new forms; the philosopher-scientist energizes the facts with new ideas. This is not a pursuit for shallow wits or timid heart or dragging feet, because it implies a leap taken by your mind across a dark gulf of nothingness into new regions of thought, and the establishing there of a bridge-head.

It also demands effort and energy. Coming out of an intense creative experience a man may feel his mind all bruises.

We have not yet devised an accounting system that will produce a clear-cut balance after adding up the research man's joy in success and his agony in defeat; his frustrations and rebuffs; and the occasional, indeed very rare, entry that marks a spot where results came readily and proved out perfectly.

Discovery is made easier today by the fact that research people have access to computers and other mechanical aids, but great discoveries have been made under harsher circumstances.

Western European people have, over the years, done an immense amount of fruitful work with apparatus which a Canadian high school teacher would scorn as a "hay wire and binder twine" contraption. Intelligent improvisation has its proper place in research. The research man should be able to cope with the unexpected, the unpredictable and the non-existent through originality and ingenuity.

Research is cumulative

Science is a pedestrian, step-by-step advance from lowly beginnings. It is sufficient for the scientist to penetrate a few millimetres further into the darkness. A lot of people have taken thousands of years to add these millimetres into the eight-day orbit of *Gemini V*.

Obviously, research demands patience, and that is a virtue belonging to the strong. The person who truly wants something does not snatch. He carries on systematic inquiry, and is grateful if he is able to draw aside a corner of the veil that hides truth.

The world does not stop when the researcher pulls out his plum of discovery, nor should he stop. Every successfully completed experiment is a challenge. There is much work to do. Noah sent out a dove, and it returned with a leaf in its beak signifying the end of the flood. But that was only a new beginning. There was still the harbour to be found, and the fire to light, and the house to build.

A visitor to Venice stands in awe before the great mosaics of St. Mark's Cathedral. There is nothing he can say of any single stone, save that if it were not what it is and where it is the mosaic would lose some of its effectiveness. As the poet Arthur Hugh Clough wrote in "Say not the struggle naught availeth", the waves breaking on the beach do not seem to gain an inch, but "Far back, through creeks and inlets making, Comes silent, flooding in, the main."

The future

We now know that the scientific attainment which abounds in this latter half of the twentieth century can trace its ancestry to dew-scented knowledge gathered at first hand in the morning of the world. It is coming to fruition fast on a large number of fronts, so that the science fiction writers are hard pressed to catch up with the scientific scientists.

Bernard Shaw pointed out in his preface to *Saint Joan* that the medieval doctors of divinity, who argued about how many angels could dance on the point of a needle, cut a very poor figure beside the modern physicists, who have settled to the billionth of a millimetre every movement and position in the dance of the electrons.

The natural and social sciences so much dominate our age that, for sheer survival, we must know about them and participate in their advancement.

Given the increase of wisdom that should follow the gaining of knowledge, nothing that does not infringe the laws of Nature need be regarded as impossible or frightening.

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