Research on research. Cutting the Gordian knot of science ...with Occam's razor

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Everything, first and last, leads back to the idea.
The idea is the essence of all reasoning and all invention.
Claude Bernard

No problem is soluble./ None of us unties the Gordian Knot; /
we either give up or cut it.
Fernando Pessoa

Research is an attitude, a systematized curiosity, rather than the specific activity it is often made out to be.

The confusion has arisen because research has come to be equated with experiment, whereas in reality, the experiment is only a part of the research.

There are two essentially distinct parts to any research project: the idea and the experiment, and they should be approached in separate ways; and because of their essential epistemological differences, at times even by separate members of the research team.

The idea originates as a creative process; a process that has much in common with the creative process in art and literature. The experiment requires a formal application of the "scientific method" to try and find data, which supports the hypothesis.

It is a rare genius who has not only the creative capacity to formulate new concepts, but the scientific consistency to carry through the necessary experiments. For in many ways they require an entirely different psychological make-up, a separate paradigm even, as we shall explore in this paper.

First there is the idea without which no research is possible. The idea is what establishes the starting point or the *primum movens* of all scientific reasoning.

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Ideas given form by facts embody science. A scientific hypothesis is merely a scientific idea, preconceived or previsioned. A theory is merely a scientific idea controlled by experiment. Reasoning merely gives form to our ideas, so that everything, first and last, leads back to the idea.

While we may carry out experiments without an idea; repeat previously published studies with minor modifications, or collect all available data on some subject to see if statistical analysis will reveal something new (it hardly ever does), this is not research, for though these are commonly employed techniques in science, only creative ideas can lead to new concepts. If you do not know what you are looking for, you are unlikely to find it (leaving aside for the moment the complex concept of *serendipity*, which only favors the prepared mind and which I have heard described somewhere as "looking for a needle in a haystack and finding the farmer's daughter"). Bacon fuelled the confusion when he categorically "rejected" the "mental operation which follows on the act of sense" and proposed instead that "the mind itself be from the very outset not left to take its own course, but guided at every step: and the business be done as if by machinery," thus effectively not only eliminating creativity from the scientific process, but mechanizing it also.

An idea originates from the knowledge and experience of the scientist, sometimes spontaneously, or as a response to some problem or question he has set himself (perhaps without realizing it), and as a result of thinking about that problem. It does not arise in a controlled, direct and linear fashion, but unexpectedly, chaotically, unpredictably.

An original research idea frequently arises from the subconscious as a fully formed concept. Careful introspective reports from the writings of such varied scientists as Claude Bernard and Albert Einstein reveal that it is not a gradual process, but a sudden occurrence or revelation, similar in many ways to the creative process described by poets and artists. Obviously, the subconscious memory must contain something if it is to project these often-unexpected flashes of insight. The mind must be well stocked... with disorder, according to the poet Paul Vàlery, and must contain all that we perceive with our senses; principally all we see and observe and read, all we hear. It is uncertain whether all that we perceive through our senses is somehow registered and retainedin the memory (as in Luria's patient Sherashevsky or Borges' fictitious character Funes) and then arranged and linked, or if we only register and remember what we perceive with attention. The extraordinary memory capacity frequently documented in "idiot-savants," who have an otherwise very limited mental capacity, may lead us to cautiously speculate that much of what we perceive is retained, somehow, somewhere in the brain. From all this information, the brain extracts and synthesizes useful concepts considered important for everyday survival, which are then presented to us as memories. Whatever the mechanism may be, the subconscious memory continues to mystify and delight. Since a scientific hypothesis is basically linguistic, there is a predominance of literary and auditory information, as well as rationally interpreted visual observations. From the research point of view it is more useful to read ten different books on a subject than one book ten times.

The subconscious then will toss up an idea; often unexpectedly following an unusual stimulus, as in Newton's falling apple metaphor or in Archimedes' bathtub experience. Einstein has described this as a fully formed "artistic" concept, and Kekule vividly described how the benzene ring came to him in a dream.

The idea must be tested and analyzed as an abstract symbolic model. [This is the advantage we have over other animals, in that by symbolic abstraction we can rapidly test the viability of a large number of possible variations of a particular concept, until we find one that seems to fit; animals must laboriously try out each alternative separately.] the idea is turned over in the mind, thought about, discussed perhaps, and compared to the existing literature on the subject. Many ideas are rejected outright at this early stage, but some survive, to be translated eventually into a formal hypothesis and perhaps an experimental design.

The second part of the research is the experiment. Once we have developed "the idea", we can apply the scientific method. The scientific method consists of three parts:

1. Observing the significant facts
2. Arriving at a hypothesis (by induction), which if it were true, would account for these facts.
3. Deducing from this hypothesis (by deduction) consequences, which can be tested [again] by observation.

A hypothesis is formulated, an experiment designed and implemented, and the results analyzed to confirm our generalization which may then be submitted to further (independent) experiments as necessary before the hypothesis has any chance of being generally accepted.

This was first formulated by Leonardo da Vinci more than four centuries ago, and well over a hundred years earlier than Francis Bacon, to whom this method is usually attributed. Leonardo wrote in one of his notebooks:

> First I shall test by experiment before I proceed, for it is my intention to consult experience first and then with reasoning show why such experience is bound to operate in such a way. And this is the true rule by which those who analyze the effects of nature must proceed: and although nature begins with the cause and ends with the experience, we must follow the opposite course, namely, begin with experience and investigate the cause.

When the hypothesis has been formulated, we must design an experimental array which will confirm it. [An experiment is generally designed to confirm our hypothesis, for a negative experiment is unusual unless we are disproving a previously accepted or established hypothesis, but then we should already have formulated a counter-hypothesis which we are in fact attempting to confirm.]

This again requires considerable creativity to take into account experimental design, available funds, materials and abilities. Up to this stage, the research requires nothing more costly than time. "It is free" would be the mercantile response, but time is our single most valuable possession, and it cannot be translated into economic terms. "Time is money" Benjamin Franklin said, and that may well be the most foolish saying he ever coined, for though time must be invested to earn money, an excess of money can never be translated back into time, it is a one-way investment which should be carefully contemplated. Money is time, but time is not money.

Often it makes sense to run a "pilot" study before the experiment is formally embarked on; to test the experimental setup and adjust it if necessary, or even revise the hypothesis. Then the formal experiment is run without interference. Once we have put our question to nature we must wait for the answer, and accept it as it is given, never answering for her. The observation should be made without preconceived ideas, the researcher becomes observer! Any attempt to interfere or "adjust" the results at this stage will alter the experiment and make it worthless. Creativity must be put firmly on hold at this stage, so that a second important conceptual change is required of the investigator: first from creative to technical and then from technical to observational. Finally, when all the necessary data has been collected comes the analysis and interpretation. Information in the absolute sense, independent of context does not exist, so all data must be related to previous facts and theories.

If the results do not confirm the hypothesis it may be necessary to revise the experimental design or even the hypothesis, and repeat the experiment.

Only then should the results be presented to the scientific community as a written paper in a journal or an oral presentation in a conference. As the word implies, it is presented, a gift to the scientific community, for which there is rarely a direct remuneration.

Looking back we have then identified a number of steps in the research process, each of which often require considerable conceptual adjustments on the part of the investigator:

1. Initial "nurturing" or feeding of the subconscious memory with a large variety of information from observation, books, papers, conversations.

2. The obscure and mysterious origins of the idea, developed from subconscious processes and presented unexpectedly under unknown stimuli via complex symbolic mechanisms—in the arts this is attributed to the muse, still, the scientist is also subject to her whims and impulses.

3. The analysis, discussion and orientation of the idea (thinking, talking and reading relevant bibliography) to examine feasibility.

4. Formulation of a working hypothesis which can confirm or reject the idea.

5. Experimental design to test the hypothesis, which must take into account all necessary details from financing to available laboratory skills.

6. Observation and collection of the experimental results; unbiased recovery of data provided by the experiment, with careful avoidance of intentional or unintentional interference or adjusting of data.

7. Analysis of the data, with statistical application where relevant.

8. Interpretation of the results in relation to known facts.

9. Presentation of the idea and its "proof" to the scientific community; writing the paper which is submitted to peer review and critique.

10. Follow-up; acceptance or rejection. Adjustment of the current paradigm or of the hypothesis in accordance with feedback from the scientific community.

The creative process is involved to a greater or lesser degree in all but points 6 and 7 (where paradoxically we often see them so liberally employed). But since these processes are largely subconscious and not very amenable to rational analysis, they tend to be suppressed by scientists who are prepared to contemplate only "facts". They are often a little embarrassed to admit that much of their work is not based on structured, clearly delineated rational thought processes, but on vague, chaotic and contradictory subconscious processes. The emphasis on the rational, observational and interpretational aspects of the scientific method, inevitabbly results in a bias towards those aspects of research, with a gradual elimination of creative ideas.

These creative processes, rather than being swept under the table as embarrassing details, need to be carefully analyzed to determine how they may be optimized, and how greater benefit may be obtained from them. Since they are only accessible to introspection, we may have little choice but to include introspection as a valid "scientific" instrument.

The moment we accept this, we must also begin to stimulate good scientific writing, which has been neglected almost to the point of extinction, for it is the writers and poets who are able to express subjective experiences adequately for others to understand. Every step must be carefully analyzed, for only then are we in a position to teach research adequately.

REFERENCES

Chalmers, David (1995), "Explaining consciousness: The hard problem," *Journal of Consciousness Studies*. 2(3): 200-219.

Bacon, Francis (1905 [1620]), *Novum Organum*. *The Philosophical Works of Francis Bacon.* London: Routledged.

Bernard, Claude (1957), *An Introduction to the Study of Experimental Medicine*. New York: Dover Publications.

Borges, Jorge Luis (1974); *Funes, el memorioso*. *Obras Completas*. Buenos Aires: Emece.

Luria, A. R. (1987), *The Mind of a Mnemonist*. Boston: Harvard University Press.

Russell, Bertrand (1931); *The Scientific Outlook.* London: Unwin.

da Vinci, Leonardo, (manuscript e folio 55).

Valéry, Paul (1933), *L'idée fixe*. Paris: Gallimard. (*La idea fija*. Madrid: Visor 1988.)