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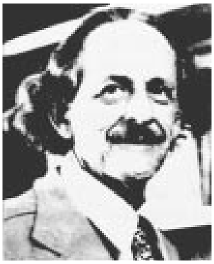

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# Creativity and Science. Part 1. What Makes a Person Creative?

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This two-part essay explores some of the issues raised in the 12th annual Perey Research Lectureship, which I presented last fall at McMaster University, Hamilton, Ontario, Canada. Part 1 covers definitions of creativity and some of the factors, including mentorship and freedom of choice, that may influence its development and expression in various professions and activities.

C.P. Snow's famous distinction between "two cultures" separated science and technology from other highly creative (but less quantitative) pursuits such as art and poetry.[1] But in an article published last year, design engineer Sue Birchmore discussed the imagery that results from believing that scientific creativity is somehow different from artistic creativity.[2]

She notes, for example, that scientists are often depicted in popular culture as cold, rational, unemotional (and sometimes demented); that engineers and technologists may be portrayed as practical, prosaic, and often semiliterate; and that science is somehow bereft of human spirit. However, Birchmore believes that "the best scientists are poets,...[that] the real engineer is an artist," and that poetry and art are in the science itself. She points out that terms such as "quarks" (which may possess "charm" and "beauty"), the "solar wind," and the "big bang" were not coined by humorless intellectuals but by "fully developed people possessing the full range of human emotions"—including, presumably, the kind of creativity usually associated with artists.[2]

I find this link between science and poetry fruitful: there is an economy of words and beauty of concept in poetry that is always found in the best science.[3,4] Yet it is risky to compare science with poetry—particularly since many scientists buy into the popular image that Birchmore rues. They are thus averse to (or at least unaccustomed to) relying on the emotional experience necessary to create or to respond to such artistic pursuits as poetry.

In fact, far from a climate of intellectual freedom and tolerance that might foster an atmosphere of innovative creativity, contemporary science is subject to pressures greater than any it has ever faced. This is the era of Big Science. More and more, it seems, the emphasis is on management, publications, tenure, and scrambling for funds to support research for which the answer is already known. Even more disturbing, a few scientists seem driven to achieve fame, power, and riches by any means available, including fraud. In recent years we have discussed various types of fraud, intellectual dishonesty, and other forms of deviant behavior in science.[5-7]

What is happening to the love of knowledge and discovery for their own sakes? The exhilaration of being close to an understanding of an important unknown? Is scientific creativity taking a backseat to self-promotion, grandstanding, and patent fights? Last year I explored some of these questions in the 12th annual Perey Research Lectureship at McMaster University, Hamilton, Ontario, Canada; this two-part essay on scientific creativity reiterates some of the points I made then and raises some new issues.

## What Is Creativity?

"Creativity" is a modern concept. Joanne R. Euster, president, Association of College and Research Libraries, referring to the *Oxford English Dictionary*, notes that the word "created" appeared around 1393. But "creativity" was not coined until 1875, when it was used to refer to the poetic imagination. It is an even more contemporary notion, according to Euster, that creativity be applied to arenas other than the arts—as in such now-common expressions as "creative thinking," "creative problem-solving," and "creative living." She goes on to discuss means of fostering creativity in the library professions.[8]

Almost 40 years ago, psychologist J.P. Guilford, University of Southern California, Los Angeles, noted that creativity, in its narrowest sense, comprises "the abilities... characteristic of creative people..., which include such activities as inventing, designing, contriving, composing, and planning. People who exhibit these types of behavior to a marked degree are recognized as being creative."[9]

Others have defined creativity by its results, saying that a person is creative whose work or performance is both original (different or unusual) and significant. However, in spite of the efforts of investigators from a number of fields, according to C. Scott Findlay, Departments of Zoology and Medicine, and Charles J. Lumsden, Department of Medicine, University of Toronto, Ontario, Canada, thorough explanations of creative activity have been elusive.[10]

## Creativity Research

Hundreds of research studies have been conducted on the subject of creativity, and numerous theories of creativity have been proposed. In fact, the "creativity literature" has been growing significantly. In her book *The Social Psychology of Creativity*, Teresa M. Amabile, Department of Psychology, Brandeis University, Waltham, Massachusetts, discusses various aspects of creativity and creativity research. As she notes, *Psychological Abstracts* listed 11 articles under the heading "Creativity" in 1950—0.2 percent of the 5,500 articles abstracted that year. This number grew to 0.4 percent by 1960, 0.8 percent by 1966, and 1 percent by 1970—even though the total number of articles abstracted also grew.[11] In 1980 approximately 0.7 percent of the database was devoted to creativity.

Research into creativity, as reviewed by Amabile, has taken many forms. Some studies have examined the biographies and autobiographies of well-known creative individuals. Other researchers have investigated individual differences in creativity under "laboratory" conditions (in which investigators live with their subjects and observe them under "typical" conditions). Some studies have offered comparisons of those who score highly in tests designed to assess creativity with those whose scores are low; while others have employed questionnaires that attempt to place respondents on a continuum indicating their level of creativity. Other studies have concentrated on the cognitive skills necessary for creativity and the environmental factors that influence creativity, including social, political, and cultural trends.[11] The direct (or indirect) object of many of these studies has been to "increase the availability" of creativity and "improve its distribution," according to Russell L. Ackoff and Elsa Vergara, formerly of the Wharton School, University of Pennsylvania, Philadelphia;[12] Ackoff is now affiliated with Interact, the Institute of Interactive Management, here in Philadelphia.

## Factors Affecting Creativity

It is impossible to do justice to the entire range of creativity research, but a few of the ideas contained in these works can be highlighted. One might make an analogy between creativity and the cultivation of fruit from seed: both need the proper conditions to germinate, grow and develop, and finally bloom, come to full maturity, and bear fruit. Of fundamental importance to creativity are social conditions that favor it and enable it to be expressed productively. And yet, conditions that are beneficial for one creative individual may be detrimental to another.

Amabile considers several examples of the creativity-enhancing effect of work done for its own sake, as well as the creativity-inhibiting effect of work done for the sake of achieving an external goal. The British poet and critic T.S. Eliot, for instance, asserted that his receiving the Nobel Prize would destroy his creativity. Russian novelist Fyodor Dostoyevski was practically paralyzed by a large advance given him for writing a novel he had not yet even begun. And American novelist Thomas Wolfe described suffering from numbing doubt and confusion in attempting to write his second novel after the first had met with critical acclaim: faced with the task of following up his success to prove he wasn't a flash in the pan, he found himself able to concentrate on little else.[11]

Yet the promise of rewards and glory can serve as a spur to others, as witness the pursuit of high-temperature superconductors or—the classic example—the description of the double helix structure of DNA. Indeed, the distinguished sociologist of science Robert K. Merton, Columbia University, New York, believes that peer recognition of significant contributions is one of the main driving forces in science.[13]

## Mentor Relationships

In the scientific community, another important facet of fostering creativity is the so-called master/apprentice relationship. Columbia University sociologist Harriet Zuckerman discusses at length the theme of masters and apprentices in science in chapter 4 of her 1977 book *Scientific Elite*.[14] Science writer Robert Kanigel has also written about the transmission not only of technique and the mechanics of "doing science," but also of a particular style or approach to science from one generation to the next in his book *Apprentice to Genius: The Making of a Scientific Dynasty*.[15]

In the book Kanigel[15] explores an interlocking chain of "mentor" relationships between Bernard "Steve" Brodie, often called the father of modern pharmacology for his work on drug metabolism; his young technician Julius Axelrod—who later went on to win the Nobel Prize for his work on the neuronal synapse; Solomon Snyder, the internationally renowned researcher in neuropharmacology who got his start in Axelrod's laboratory; and Candace Pert, who, as a young postdoc, codiscovered opiate receptors in the brain with Snyder.[16,17] Each link in the chain served as the scientific parent of the next, with each first a protégé and then a mentor; in this way lessons learned were passed on and the fabric of science woven. Incidentally, Pert shared her perspective on opiate receptors in a recent *Citation Classic®*;[18] Snyder wrote a *Citation Classic* commentary on the same subject last year.[19]

Mentor relationships have been instrumental in helping young scientists learn to recognize problems that are worthy of attention. In his *Advice to a Young Scientist*, the 1960 Nobel Prize winner Sir Peter B. Medawar writes that "any scientist of any age who wants to make important discoveries must study important problems.... The problem must be such that it *matters* what the answer is—whether to science generally or to mankind."[20] (p. 13)

But most scientists are not formally taught which problems fall into that category; instead, the knack of tackling the right problem in the right way is conveyed by example over years of close working relationships with established scientists. One caveat here: since bad habits can be learned as easily as good ones, perhaps the most important thing a young scientist can do, as Medawar himself notes, is pick the right postdoctoral environment.[20]

And according to A.E. Pannenborg, a research administrator for the Philips Company in Eindhoven, The Netherlands, it is incumbent upon those who are in charge of research groups to create the conditions that will allow gifted young scientists to adequately follow their creative instincts. As Pannenborg observes, such conditions should include "room to move": "The more intelligent, the more creative, the more talented the man is, the more you leave him alone...."[21] This theme is hardly new, having been expounded earlier in this century by, most notably, the German educator Adolf von Harnack (1851-1930), president, Kaiser Wilhelm Institute, Munich (now the Max Planck Society for the Advancement of Science), from 1911 to 1930, and by James Conant (1893-1978), the American chemist and educator who served as president of Harvard University, Cambridge, Massachusetts, from 1933 to 1953.

As Pannenborg and his predecessors clearly imply, an obvious factor in creative productivity that cannot be ignored is a scientist's personality. Table 1 lists some of the personality traits that some studies have indicated scientists share. In a review of the role of personality dispositions in science, J. Philippe Rushton, University of Western Ontario, London, Canada, examines factor analyses of scientists' personalities. Research, as Rushton notes, has suggested that scientists differ from nonscientists by exhibiting a high level of general curiosity, especially at an early age, and in demonstrating a relatively low level of sociability. The implication is that science is conducted by those for whom research is a way of life and social relations are comparatively unimportant.[22]

According to such studies, scientists also tend to be shy, lonely, slow in social development, and indifferent to close personal relationships, group activities, and politics. Other attributes include skepticism, preoccupation, reliability, and a facility for precise, critical thinking. Generally, they are cognitively complex, independent, nonconformist, assertive, and unlikely to suppress thoughts and impulses; and, like successful entrepreneurs, eminent scientists are also calculated risk-takers.[22]

**Table 1: Selected list of personality traits exhibited by scientists.**

- Assertiveness
- Facility for precise, critical thinking
- High level of general curiosity
- Independence
- Indifference to close personal relationships, group activities, politics
- Loneliness
- Nonconformity
- Reliability
- Shyness
- Skepticism
- Tendency toward preoccupation
- Tendency toward taking risks

## Permitting Scientific Creativity

Since creativity takes place in the realm of the mind, it is as slippery and difficult to analyze as is the mind itself. Thus, it is difficult to evaluate which of the ideas above come closest to the mark in their various descriptions of creativity—if, indeed, any of them do. Nevertheless, as A. Carl Leopold, Boyce Thompson Institute, Cornell University, Ithaca, New York, noted a decade ago, "The world community recognizes that progress in the arts, in the professions, and in science and technology relies exquisitely on the creativity of the people in these professions."[23]

Leopold likened the "skills with which a person can fit factual assemblages into new ideas" to "a sort of mysterious 'black box' or kaleidoscopic step." While admitting that such a black-box description is relevant to describe innate ability or talent, Leopold also points out the creative process must also be at least partly the consequence of trained or honed skills. Since skills that can be learned can also be taught, he proposes that the art of scientific thinking be taught by allowing students to experience all the thrills—and missteps—of an actual scientific research program or experiment. Quite relevant to this theme was our essay on undergraduate research.[24] Recently, the National Science Foundation began a new, multimillion-dollar program aimed at stimulating interdisciplinary research in the life sciences at the nation's universities—at the undergraduate, graduate, and postdoctoral level.[25]

I believe that something along the lines of what Leopold suggests is not merely a good idea, but may be essential to the health of science. It may seem absurd to speak of a decline or stifling of creativity at a time when inventions and discoveries—indeed, the flow of new information itself—threatens to become overwhelming. But if scientific creativity is a set of skills that can indeed be taught, then we must not only provide the teachers but the environment in which such skills can be learned, used, and nurtured. If we persist in teaching the facade of science, instead of its realities, then the pressure-cooker, cookie-cutter research programs that seem to be more and more prevalent today will be not just the harbingers of the future of science, but also its death knell.

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