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For the Sake of Science, the Arts Deserve Support

By Robert S. Root-Bernstein

THE SCIENCES AND THE ARTS too often are considered to be polar opposites. The sciences are supposed to be objective, intellectual, analytical, reproducible, and useful; the arts are thought to be subjective, sensual, empathic, unique, and frivolous. In the competition between the two for dominance in modern society, the arts have clearly lost: U.S. support for all of the arts combined is less than what any single scientific or technological discipline receives. The current attempts by members of Congress to eliminate support for the National Endowment for the Arts underscore this point.

Yet many scientists employ the arts as scientific tools. Moreover, various artistic insights have actually preceded and made possible subsequent scientific discoveries. The arts thus can stimulate scientific progress, and we dismiss them at our peril.

History shows that the sciences and technology have never flourished in the absence of a similar flourishing of the arts. The reasons for this connectedness have become apparent in the past several decades, as a result of studies by historians of science and technology, psychologists, and other scholars who study creativity. A consensus is emerging that scientists and engineers need skills associated with, and often learned from, the arts.

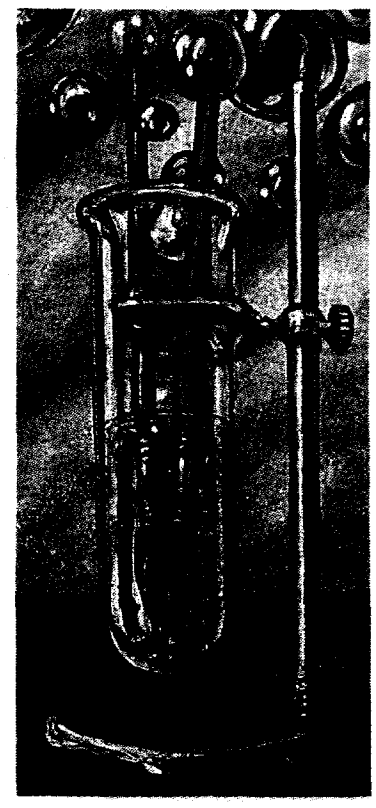
These skills include the abilities to observe acutely; to think spatially (what does an object look like when I rotate it in my mind?) and kinesthetically (how does it move?); to identify the essential components of a complex whole; to recognize and invent patterns (the "rules" governing a system); to gain what the Nobelist Barbara McClintock called "a feeling for the organism"—empathy with the objects of study; and to synthesize and communicate the results of one's thinking visually, verbally, or mathematically.

Such skills or tools for thinking are not learned within the standard science curriculum but almost exclusively through the practice of the arts, including music and writing. Several recent studies of very successful scientists and engineers—including research by Robert Milgram of Tel Aviv University, Suzanne Merritt of the Polaroid Corporation, Leonard Humphreys and his colleagues at the University of Iowa, and my own work with colleagues at the University of California at Los Angeles—have shown that active participation and demonstrated ability in one or more of the arts are far more predictive of success in science than standard measures such as I.Q., scores on tests such as the SAT, or academic degrees.

One can take this argument another step. Several scientists and engineers, including Henry Petroski of Duke University, Brooke Hindle of the Smithsonian Institution, and I, have documented that a person's scientific eminence is correlated not only with participation in art, music, and literature, but, more important, with the actual *use* of the skills and sometimes even the materials of the arts in generating advances in science and engineering.

We can find this both historically and currently. For example, Robert Fulton, the inventor of the steamboat, and Samuel F. B. Morse, the inventor of the telegraph, were wonderful painters who took up inventing only in middle age. Morse actually built his first telegraph out of a modified canvas stretcher. As Brooke Hindle has shown in his book *Emulation and Invention,* artistic thinking made an indelible impression on these men's processes of invention.

As unexpected as it may sound, artists often invent techniques that outstrip the methods of contemporary science and technology. Consider Abbot H. Thayer, a turn-of-the-century nature painter sometimes described as Audubon's successor. Thayer discovered the concept of camouflage. He not only revolutionized our understanding of the co-evolution of animals and their environment, but also suggested that the principles of camouflage be applied to protecting soldiers and their equipment on the battlefield.



THOMAS KERR FOR THE CHRONICLE

During World War I, his ideas were put into practice by artists in Great Britain and France who had been drafted into military service. Cubist painters, for example, already had experimented in their art with breaking up images into fragmentary parts—an essential component of camouflage. Picasso is supposed to have said as a troop of camouflaged soldiers marched past him in 1918: "We made that possible."

Indeed, artists still develop ideas with military applications. Todd Siler, who received a Ph.D. in art and psychology from the Massachusetts Institute of Technology, recently patented a method of distinguishing friend from foe during battle (the details of which are secret for security reasons) and also has invented a novel way of visualizing computerized images in three dimensions.

Many scientists draw on their dual backgrounds in science and art. Some biologists, such as Harvard University's Bert Höldobbler, a Pulitzer Prize–winner, illustrate their own books and papers. Thomas Eisner, of Cornell University, takes photographs of insects that are not only great science but also award-winning art. Roger Kingdon, a painter and researcher who has focused on how monkeys communicate in the wild, consciously applies his "artist's eye" to his scientific research. Interviews with these and many other scientists demonstrate clearly the adage: "That which has not been drawn has not been seen."

The arts have informed many other sciences besides biology. The invention of geodesic domes by Buckminster Fuller and of "tensegrity sculptures" by Kenneth Snelson are two classic cases. Fuller's geodesic domes can be used to describe not only architectural buildings and soccer balls, but also the structures of viruses and a whole new class of recently discovered chemicals called "buckminsterfullerenes," commonly known as "buckyballs."

Snelson created his tensegrity sculptures by juxtaposing stiff rods and flexible cords; the tension that the cords exert on the rods keeps the structures intact. First created purely as art, tensegrity structures now are also being considered as a method of constructing platforms for use in outer space. Cell biologists recently have suggested that tensegrity is the principle that controls the very shapes of our cells.

And Marilyn Emerson Holtzer, a chemist at the University of Washington who specializes in studying protein folding, is also an internationally recognized weaver, and the winner of several awards for her weaving innovations.

Her science and her weaving intersect because, in each, she explores the patterns that she works with in the other field. As a result, "fiber folding" has become another way to explore protein folding.

Another practical application of pure art comes from the Jet Propulsion Laboratory of the National Aeronautics and Space Administration. Milton Halem, who is in charge of analyzing data from the Landsat satellite, has collaborated with the artist Sarah Tweedy, of the Corcoran School of Art in Washington, to determine how to display the important points in the data without losing their nuances. How to make data intelligible calls on the art of design, and it is an art that every scientist needs to master.

MUSIC can also produce insights useful to science and technology. Take "frequency hopping," in which coded signals are sent along a constantly changing set of frequencies so that the signals can be neither intercepted nor blocked. In 1942, the composer George Antheil and the actress Hedy Lamarr suggested using the melody of a song as a way of sending signals in Morse code. The person receiving the message would already know what song was being used and would constantly retune his receiver to the frequency of the next note in the song to hear the Morse-code version of the next letter in the message. Someone who didn't know which song was being used would have no idea what frequency to listen to. The concept has spawned hundreds of patents and is the basis of many of the secure communications systems now used by the U.S. military.

Another important invention with a musical component is the heart pacemaker. The portable version of this device is based on the bioengineer Earl Bakken's recognition that an electronic metronome could provide a timed pulse to stimulate the heart with regular bursts of electricity.

Music also is providing a new way to analyze data. Researchers at several university laboratories, as well as at companies such as AT&T and the Xerox Corporation, have found that converting complex data into musical notation greatly facilitates analysis. For example, gene sequences or economic trends involve hundreds of different variables that can be represented in much the same way as multiple levels of sound and pitch for drums, violins, horns, and other instruments in a symphony orchestra. This kind of notation makes patterns easier to see than simply using numbers or words. An unexpected spinoff of these studies is that aural data analysis makes scientific results available to visually handicapped individuals.

CLEARLY, the arts are not the useless, frivolous, or purely subjective pastimes they are often portrayed as being. My thesis is therefore very simple: If we let the arts atrophy in this country through lack of public support, we also will lose an important part of the creative base from which the next generation of scientific and engineering breakthroughs will emerge. As the Nobel laureate Irving Langmuir once said, you can't predict discoveries, but you certainly can create the conditions that favor them. Art for art's sake also encourages scientific innovation.

We must make sure that Congress and state legislatures get this message and understand why increased—not diminished—appropriations for the arts are important. The National Endowment for the Arts also should foster joint programs with the National Science Foundation and the National Institutes of Health to encourage cross-pollination of ideas and a better understanding of the historical connections between arts and sciences.

Furthermore, educators must make the arts essential components of all curricula that teach students how to think, invent, and create. We must recognize that although we can never be certain which art will bear what fruit, we can be positive that, collectively, the arts are a rich source of insights. As William Blake put it: "Art degraded, imagination denied."

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