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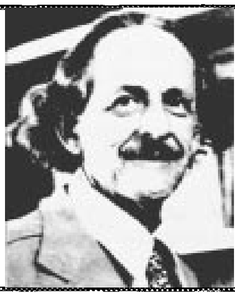

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EUGENE GARFIELD
INSTITUTE FOR SCIENTIFIC INFORMATION®
3501 MARKET ST. PHILADELPHIA, PA 19104

Art and Science. Part 1. The Art-Science Connection

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This two-part essay examines relationships between the worlds of art and science. Part 1 considers various theoretical and historical connections between the two spheres. Photography and other technological developments and their contributions to art are also discussed, as are medical and scientific illustration. The second part will examine various ways in which science and technology have been applied in the service of art.

The interaction between the worlds of science and the humanities, as our readers know, has been a recurring theme in *Current Contents®*. The many connections between art and science have been examined in essays concerning poetry, metaphor, and artwork at ISI®, to name the most recent examples.[1-6] Despite C.P. Snow's well-known construct regarding the "two cultures" of science and the humanities and the alleged gulf of "mutual incomprehension" separating them,[7] there *are* aspects of art and science that intertwine and overlap. In this two-part essay, we will examine just a few of those aspects. However, in so doing, we will first consider the study of art and science as a discipline unto itself by surveying some of its practitioners, publications, and institutions. This is a broad and multifarious specialty, of course, requiring far more space than we could hope to give it; but by selecting a few topics, issues, and examples of scholarship, we can attempt to convey a sense of what is involved in the study of art and science.

Artists, Scientists, and Nature

While their activities may differ, scientists and artists share one essential component in their work. In the words of physiologist A.L. Copley (who creates paintings and graphic art under the name L. Alcopley), "What is common to both art and science is the creative process and the synthetic thinking in both human endeavors."[8] Robert S. Root-Bernstein, Departments of Natural Science and Physiology, Michigan State University, East Lansing, discusses "visual thinking." He notes that many renowned scientists, most of whom were also accomplished in the arts, displayed a knack for "visualizing imagined worlds." Albert Einstein, for one, was adept at the "visual imagining of thought experiments." This form of visual thinking, as Root-Bernstein notes, was essential to Einstein's work.[9]

Creativity is another specialty that we will address in a forthcoming essay. We can say, however, that the scientist who develops a theory or designs an experiment is no less creative than the artist who produces a painting or sculpture. Michael J. Moravcsik, Institute of Theoretical Science, University of Oregon, Eugene, writing on the similarities between artists and scientists, also notes that artists and scientists share certain motivations. These include a drive to be creative and to make something of their talents and capabilities. Artists and scientists, according to Moravcsik, share a sensitivity to aesthetics in their work, although their criteria for "beauty" may be quite different. Many also share a desire to make a positive contribution to the welfare of humanity.[10]

It strikes me that artists and scientists share other characteristics in the way they go about their work. Both groups, for example, are noted for a certain impatience or uneasiness with the conventional demands of social interaction, preferring to toil in comparative solitude in the sanctuary of the studio or the lab. Artists and scientists, furthermore, are often driven by a sense of mission or curiosity that may be compelling and immediate only to them—although both certainly desire to see their ideas and labors appreciated by others. When they do bring forth their work, however, they have no guarantee that it will succeed, or last. The painting or sculpture, whether or not it arouses any interest in the marketplace or the critic's column, will fade or erode over time. Similarly, the scientific paper, if it is typical, may not be widely acknowledged once it is published. A large percentage of papers are barely cited. And even *Citation Classics*® are eventually superseded—aged, in effect—by subsequent work. Obviously, neither scientists nor artists are deterred by such daunting prospects for immortality.

Scientists and artists share another important attribute: their labors depend largely on interpreting nature, or the natural world. Nature, of course, has been one of the main sources of artistic inspiration for as long as humans have made art. Jeannette Murray is art adviser to the American Association for the Advancement of Science (AAAS), Washington, DC. She notes that the paintings applied to cave walls in Ice Age Europe approximately 10,000 to 15,000 years ago represent what is "perhaps the first instance of the interweaving of art and science."[11] These paintings—of animals, weapons, and other images of the hunt—demonstrate that even primitive humans had a drive to interpret and depict their experience of the physical world.

Thousands of years later, this drive is undiminished. Artists in various media still go about observing, interpreting, and rendering nature—activities not at all dissimilar to those performed by scientists. Scientists, however, have at their disposal a variety of technological devices: microscopes, telescopes, cameras, and other sophisticated imaging and sensing devices. According to Michael J. Clark, Department of Geography, University of Southampton, UK, this raises questions regarding the relationship between image and reality. Clark notes that there are several implications to such developments as "image creation using digital data matrices" and "analytical techniques designed to manipulate the data so as to reveal pattern or information that is not initially 'visible.' " Such manipulation, he notes, "highlights the conflict between vision, illusion and delusion in the scientific imaging of the environment.... It underlines the difficulty of handling notions such as accuracy, representativeness and even of truth itself."[12]

The British aesthetician Harold Osborne also discusses artists, scientists, and their relationship to nature. Both groups, he notes, seek a sense of order in the natural world. He notes that, while an aesthetic response may be elicited by "the diverse kinds of order in nature discovered and described by scientists," it is artworks made by artists that are "the most powerfully effective objects for the evocation and expansion of aesthetic experience.... Scientists, on the contrary, discover but do not make the order that occurs in nature. But the statements they make about order may themselves have intellectual beauty."[13] The British mathematician G.H. Hardy (1877-1947) wrote that beauty is the first test in the sciences, as in the arts; there is not, he noted, a permanent place in the world for "ugly mathematics."[14] Philosopher L.L. Whyte (1896-1972), writing in 1957, observed that "both science and art have to do with ordered complexity."[15]

Historical Connections

Prehistoric cave paintings, as noted above, represent what may be the first merging of art and science. In the many centuries since, that relationship has developed. Science historian Alistair C. Crombie, Trinity College, Oxford, UK (now retired), traces the connections between art and science in the modern world. Writing in a 1986 issue of the journal *Daedalus* devoted entirely to art and science, Crombie discusses the influence of ancient Greece and its "moral and intellectual commitments."[16] These included a "mathematically and causally structured science of nature, a morally structured drama, and painting and music each structured to make their aesthetic or dramatic effects." The rational tradition that was manifest in Greek science and art continued into the Renaissance, in a style that Crombie refers to as "experimentally controlled postulation."[16]

The Renaissance gave us some of the more notable figures in the history of art and science—most notably, Leonardo da Vinci (1452-1519). His *Notebooks*, embracing art, architecture, philosophy, astronomy, engineering, and a variety of other physical and natural sciences, provide powerful evidence of the breadth of Leonardo's interests and achievements.[17] His efforts as an artist were informed by extensive self-training in science, including the dissection of human bodies. As historian Diane Kirkpatrick notes, Leonardo believed that it was necessary to master the body's depths to accurately portray its surfaces. Such anatomical drawings as *Principal Organs and Arterial Systems of the Female Body*, says Kirkpatrick, are remarkable not only for their artistic technique and composition, but for their precision and accuracy in recording the structure of the human body.[18]

Another man of the Renaissance whose career combined achievements in art and science was Galileo (1564-1642). As Crombie notes, Galileo lived from Michelangelo's death to Isaac Newton's birth, thus marking the transition between "two great European intellectual movements...from the world of the rational constructive artist to that of the rational experimental scientist."[16] Trained in music and in perspective drawing, Galileo also possessed expertise in mathematics, physics, and astronomy. As science historian Stillman Drake, University of Toronto, Ontario, Canada, notes in the book *Art, Science, and History in the Renaissance*, it was not uncommon for men of that time to be versed in those three separate scientific disciplines. Galileo, however, by applying mathematics to physics and physics to astronomy, was the first to combine these fields in a truly significant way.[19]

Throughout the Renaissance, art and science continued to develop and interact. In particular, according to Murray, Holland in the seventeenth century represented a time and place where scientific inquiry became so pervasive that "science and art were inseparable."[11] Newly developed lenses and mirrors were being applied to astronomy, microscopy, and the study of optical phenomena. These developments offered new views of nature to artists and scientists alike. Murray mentions the paintings of Jan Vermeer (1632-1675), which, with their use of perspective, light, and scrupulous attention to detail, seem to express "a scientist's knowledge of the observable."[11]

The interaction of art and science was not confined to Europe. As historian Brooke Hindle notes, the Renaissance tradition of gifted, accomplished individuals whose contributions encompassed both science and the humanities could also be found in eighteenth-century America. Hindle discusses Charles Willson Peale (1741-1827), the leading portraitist of the Revolutionary period. Peale (who occupies a prominent place in Philadelphia history) turned to painting after a brief career as a craftsman trained in watch repair. Even after achieving success as an artist, he retained his mechanical bent and made a mark as an inventor—of stoves, bridges, and various other mechanical devices. Hindle discusses two other painters: Samuel F.B. Morse (1791-1872), who is better known as the inventor of the electromagnetic telegraph, and muralist and inventor Rufus Porter,[20] who, as we noted in a 1981 essay, founded *Scientific American* in 1845.[21]

Even today, many of our most eminent scientists continue to be trained in the arts. Robert R. Wilson, Fermi National Accelerator Laboratory, Batavia, Illinois, for example, not only designed the particle accelerator for that facility, but also guided the lab's architectural design and produced a number of large-scale sculptures for it.[22]

Modern Science and Modern Art

Just as technology—whether in the form of seventeenth-century microscopes or more modern developments—changed the way science was done (and will surely continue to change it), so did technology change art. One such technological development was the invention of photography in the early nineteenth century. Photography provides another means of recording and interpreting the world—an activity, as we noted earlier, that is fundamental to both artists and scientists.

The history of photography demonstrates that technological change is not always immediately welcome. Jonathan Benthall, Royal Anthropological Institute, London, UK, discussing this point in his book *Science and Technology in Art Today*, relates that in its infancy photography was perceived as a "threat and a pollution" by the academic artists of the day.[23] On the other hand, in *The Painter and the Photograph*, art historian Van Deren Coke, Arizona State University, Tempe, notes that, while some reacted against photography, others "sought inspiration from the simulated realism produced by the camera. In a few years photography changed the artist's viewpoint, both technically and philosophically.... The role of the artist as a recorder of nature was encouraged, as standards for judging art began to be based on the kind of exactitude found in photographs."[24] (p. 1)

Photography, far from remaining an adjunct to painting, was quick to come into its own as an art form. One early photographer whose work endures for its scientific as well as artistic validity is Eadweard Muybridge (1830-1904), who emigrated from his native England to the US in the late 1860s. As Coke points out, Muybridge's motion studies of running horses, for example, recorded for the first time all four of a horse's hooves off the ground at one stage of its stride—a representation that painters had avoided as being unrealistic.[24] (p. 155) In short, here was artwork that offered a new perspective on the physical world, adding to our knowledge of animal physiology and behavior.

Subsequent advances in photographic technology brought a new understanding of physical events and processes that had previously occupied a realm beyond human perception. The strobe light, for example, developed around 1930 by Harold E. Edgerton, Massachusetts Institute of Technology (MIT), Cambridge, permitted the photographic capture of the most instantaneous and fleeting events—a bullet piercing an apple, for example, or the motion of a hummingbird's wings. *Stopping Time*, a book of photographs collected from Edgerton's long and illustrious career, was released in 1987.[25]

The strobe was also utilized to striking artistic effect by photographer Berenice Abbott, who was part of the Physical Sciences Study Committee (PSSC) at MIT in the late 1950s. The PSSC, like many other agencies and committees at that time, had the mission of assessing and improving US science education following the 1957 launch of the USSR's satellite *Sputnik*. Abbott created hundreds of photographs illustrating physical principles for a textbook designed to revitalize high-school physics education. Thirty years later, these images remain engrossing: a pendulum, captured at each stage of its swing, illustrates potential and kinetic energy; light rays strike a prism and change direction; a wrench, caught in perfect profile, spins through black space.

Many of Abbott's photographs were gathered for a show entitled "Berenice Abbott: The Beauty of Physics," which appeared two years ago at the New York Academy of Sciences. The show's program contained a quote from Abbott in 1939 on the need for "a friendly interpreter between science and the layman.... I believe that photography can be this spokesman as no other form of expression can be," said Abbott. "There is an essential unity between photography, science's child, and science, the parent."[26]

More recent developments, which have extended the range of the human eye even further, also lend themselves to artistic consideration. Jean Jacques Trillat, professor of electronic microscopy and diffraction, University of Paris, France, discusses how images produced by X-ray radiography and electron microscopy relate to abstract painting. Comparing, for example, a motion-filled, modernist painting of a running girl with an electron microphotograph of lead telluride decorated by germs of crystallization, Trillat offers several hypotheses. He posits, for instance, that modern artists have been aware of recent work in physics and have taken inspiration from the images produced by modern devices.[27]

Trillat also offers a more fundamental explanation: He speculates that, since many of the paintings he discusses actually *predate* their electron-microscopic counterparts, it is possible that the painter *unconsciously* rediscovers forms that nature has created. In other words, as he puts it, "the painter projects his state of mind on canvas and...often the forms his imagination has created resemble those that the scientist independently discovers with instruments."[27]

Paul C. Vitz and Arnold B. Glimcher, in their book *Modern Art and Modern Science*, discuss at greater length how science and technology have affected the course and content of art. "The period of modern art," they note, "is not interpretable without an understanding of the powerful contributions of modern science."[28]

Scientific Images as Art

As we've observed, images produced by various technological means—an electron microscope, for example—can possess undeniable artistic merit. David R. Kaplan, Institute of Pathology, Case Western Reserve University, Cleveland, Ohio, writes about the images that appear on the covers of such journals as *Science, Nature*, and *Perspectives in Biology and Medicine*. He cites one example and its effect on him: a picture of the cerebral cortex, illuminated by blue light and counterstained with brown dye, does not cause him to wonder about gray matter or white matter or neurotransmitters, but rather to "marvel at the beauty." Noting the "exemplary color, form and composition" that characterize the frontpieces of these journals, he concludes that such covers are unquestionably art. "The covers," he says, "proclaim in artistic terms the value and quality of the science within."[29]

A similar thought is expressed by Richard A. Lippin, a physician with the ARCO Chemical Company, Newtown Square, Pennsylvania. Lippin writes of the beautiful images being produced in hospitals by such technologies as three-dimensional radiography and nuclear magnetic resonance. "Art can be found as well in our research facilities," he notes, "where highly sophisticated scientific computers are producing objective yet artistic models of heretofore unfathomable molecular constructs."[30] Lippin is president of the International Arts-Medicine Association, one of the organizations we'll be discussing in the second part of this essay. The aesthetics of form in the life sciences have also been discussed by science historian Philip C. Ritterbush, in such works as *The Art of Organic Forms*.[31]

Another pertinent field that should not be overlooked is scientific and medical illustration. Frank H. Netter, a surgeon who gave up his career to become a full-time medical illustrator, discusses the history of this field, citing in particular the "unrivaled contributions" of Leonardo, whose work as an anatomist and illustrator we have already mentioned. Netter also discusses the sixteenth-century Belgian anatomist Andreas Vesalius (1514-1564), whose works were the forerunners of many modern anatomic atlases.[32]

Historian William B. Ashworth, Jr., University of Missouri, Kansas City, examines the roots of seventeenth-century scientific illustration. Many illustrations of science in that century, he notes, were not original but were adapted from various sixteenth-century sources, many of them nonscientific; these included emblem books, fable collections, and editions of engravings.[33]

As Netter points out, a technological development that greatly advanced medical illustration was the invention of lithography around 1800. This printing process eliminated the need to reproduce printed illustrations from woodcuts or from copper or steel engravings, allowing for vastly superior reproduction of detail and color. Lithography made possible the printing of several exquisitely illustrated textbooks on anatomy, medicine, and surgery in the nineteenth century. Clearly, as Netter points out, the development of medical illustration was closely tied to improvements in the printing process.[32]

While admitting that the camera can easily outdo the artist in terms of a realistic picture, Netter points out that the medical artist has the advantage of being able to select which details to emphasize and which to eliminate. He demonstrates this point by comparing a photograph of the first artificial-heart implantation with one of his own illustrations of the procedure.[32] The clarity of the drawing is most impressive.

Earlier, we mentioned the Philadelphia artist Peale. Another noted Philadelphia painter who, while not a medical illustrator *per se*, created some of his most striking images in medical settings was Thomas Eakins (1844-1916). In particular, his 1875 painting *Gross Clinic* offers an unflinchingly realistic depiction of an operation to remove dead bone from the thigh of a male patient. As noted by art historian Michael Fried, Johns Hopkins University, Baltimore, Maryland, the use of detail—such as the glistening blood on the hand of surgeon Samuel David Gross, who lectures to a hall full of medical students as he performs the procedure—gives *Gross Clinic* a vivid and unsettling impact.[34] Discussing *Gross Clinic* (as well as other works combining art and anatomy, from the time of Leonardo), Helen Osterman Borowitz, Cleveland Museum of Art, notes that the painting stirred considerable controversy in its day and was largely rejected by art critics and the public. Now acknowledged as a masterpiece, it is permanently located at Jefferson Medical College, Thomas Jefferson University, Philadelphia.[35]

Today, of course, scientific illustration is a full-fledged profession, as witnessed by such organizations as the Guild of Natural Science Illustrators, founded at the Smithsonian Institution, Washington, DC, in 1968. The guild has a membership of over 1,000 worldwide. The craft of scientific illustration has become a legitimate course of study in such schools as the Rhode Island School of Design, Providence, which has offered a certificate program in the field since 1983. In addition to numerous other undergraduate programs, graduate degrees in scientific and medical illustration are offered by the Medical College of Georgia, Augusta; the Rochester Institute of Technology, New York; Johns Hopkins University; and the University of Illinois, Urbana. This past fall the American Museum of Natural History, New York, featured an exhibit of fish illustrations entitled "Drawn from the Sea: Art in the Service of Ichthyology." Some of the artwork was reproduced in the November issue of the museum's magazine, *Natural History*.[36] The practical aspects of scientific illustration, such as finding an illustrator and evaluating quality, are discussed by Elaine R.S. Hodges, an artist with the Smithsonian Institution's National Museum of Natural History, Washington, DC, in a recent issue of *BioScience*.[37]

Artistic presentations of science have shown up in some unusual places—even on currency. Anthony R. Michaelis, editor, *Interdisciplinary Science Reviews*, Bristol, UK, provides a historical review of banknotes with illustrations depicting noteworthy objects and individuals in science and technology. He provides a listing of scientists and engineers who have appeared on paper currency throughout the world; the list includes Galileo, Newton, Einstein, and Louis

Table 1: Selected list of journals reporting on the use of science and technology in art, the use of art in the physical and life sciences, and creativity in art and science. The first year of publication is included in parentheses.

American Imago (1939)	Wayne State University Press	Detroit, MI
Arts in Psychotherapy (1973)	Pergamon Press	Oxford, United Kingdom
British Journal of Aesthetics (1960)	Oxford University Press	Oxford, United Kingdom
Burlington Magazine (1903)	Burlington Magazine Publishing	London, United Kingdom
Computer Music Journal (1977)	MIT Press	Cambridge, MA
Daedalus (1958)	American Academy of Arts and Sciences	Canton, MA
Leonardo (1966)	Pergamon Press	Oxford, United Kingdom
Media Culture & Society (1979)	Sage Publications	London, United Kingdom
Representations (1983)	University of California Press	Berkeley, CA

Pasteur. Michaelis concludes that appearances by scientists on banknotes have been relatively rare—a situation he would like to see corrected.[38]

To Promote the Study of Art and Science

So far we have discussed several individuals who distinguished themselves in both art and science. There is one more person who merits mention here: Frank Malina, an aeronautical and rocket engineer who worked for 20 years in technical fields before switching to painting. In the course of his own work and his discussions with other artist-scientists, Malina discovered that, unlike scientists and technicians, artists had no literary vehicle for exchanging ideas and information. In 1968, he founded the journal *Leonardo* (aptly named, of course, for Leonardo da Vinci).

Twenty-one years later, and eight years after Malina's death, the journal continues to appear, sponsored by the International Society for the Arts, Sciences, and Technology, San Francisco, California. Editor Pamela Grant-Ryan presented a tribute to Malina in a 1987 issue marking *Leonardo*'s 20th year of publication.[39] Articles in *Leonardo*—many of which I have cited in this essay—cover a variety of topics pertaining to the interrelationships between art and science. A 1980 issue included an extensive bibliography compiled by David R. Topper, Department of History, University of Winnipeg, Manitoba, Canada, and John H. Holloway, Department of Chemistry, University of Leicester, UK.[40] Other journals that report on science and technology in the arts are listed in Table 1. A publication that should also be mentioned is *The Sciences*, published by the New York Academy of Sciences. Its essays, commentaries, and features are illustrated with vividly reproduced paintings and graphics by noted artists. The academy often presents exhibitions of artwork that interprets or reflects the world of science. Similarly, AAAS, through its Art of Science and Technology program, presents exhibitions of science-related art. Another such program is conducted here in Philadelphia at the University City Science Center, where ISI has its headquarters. In addition to its art gallery, the Science Center's Art-in-Science projects have featured works in a variety of media.

In Part 2 of this essay, we will look at particular instances where science has been applied in the service of art, including computer art and holography; we'll also examine the use of scientific techniques in conservation and restoration.

* * * * *

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