The Alchemy of Ideas

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THIS ARTICLE PRESENTS an assessment of the power of ideas and their role in initiating change and progress. The enormous potential cascade effect is illustrated by examining the movement of Modernism in the arts. Next, the immense scope and capabilities of the modern scientific endeavor—with robotic space exploration at the scale of 10^9 meters at one extreme and the wonders of nanoscience at the scale of 10^{-9} m at the other—are examined. The attitudes and philosophies of neurological surgery are related to those involved in the Modernist movement and placed on the defined scale of contemporary scientific activity.

KEY WORDS: Creativity, Ideas, Modernism, Nanoneurosurgery, Nanotechnology, Neurological surgery, Progress, Space, Stardust

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I knew Ted Kurze initially from the vantage point of Yale University in New Haven, CT, where, as a resident, I saw him as one of the iconic figures who established the operating microscope as a neurosurgical tool, opening a new era in the field. Later, he offered me an opportunity that would prove to be my longstanding and only academic position for more than a generation. That opportunity was in the magnificent setting of the immense, cathedral-like Los Angeles County Hospital at the University of Southern California Medical Center. It was there that I made the turbulent emergence from resident to neurosurgeon in a challenging, rich, and largely unforgiving environment. Ted was an engaging and charismatic man, truly complex and eclectic—as at home at the helm of an ocean racing sailboat or on a tennis court as in the operating room or when engaged in intimate conversations related to philosophy, metaphysics, history, music, geography, psychology, religion, or the assessment of human nature. He was a primary mentor to me, and for this I will be forever grateful.

—Michael L.J. Apuzzo,
Chicago, 2008

In the spirit of Ted Kurze (Fig. 1B), this article will touch on diverse topics with a number of common themes. It is configured in 3 sections; in the first section, the power of ideas and their role in initiating change and progress are assessed. This potential cascade effect will be illustrated by an enumeration of the movement of Modernism in art. In the next section, the immense scope and capabilities of "modern" scientific endeavors are discussed. And in the final section, the realities and philosophies of modern neurosurgical attitudes are defined in hopeful and theoretical terms.

FIGURE 1. *Left, Los Angeles County/University of Southern California Medical Center; Center, Theodore Kurze; Right, Michael L.J. Apuzzo.*

Alchemy, Ideas, and Modernism

In the history of science, alchemy was a chemical discipline and speculative philosophy aiming to achieve the transmutation of base metals into gold, to find a universal cure for diseases, and to discover a means of indefinitely prolonging life. Fundamentally, it was the

FIGURE 2. Arrival of the Normandy Train, The Gare Saint-Lazare, *1877, by Claude Monet, National Gallery, London.*

FIGURE 3. Composition 8, *July 1923, by Wassily Kandinsky, Guggenheim Museum, New York.*

FIGURE 4. *Mark Rothko,* Orange and Yellow, *1956, oil on canvas, unframed: 91 × 71" (231.14 × 180.34 cm.), Albright-Knox Art Gallery, Buffalo, New York, Gift of Seymour H. Knox, Jr., 1956. © 1998 Kate Rothko Prizel & Christopher Rothko/Artists Rights Society (ARS), New York.*

power or process of transforming something common into something special.

An idea can be a transforming or transmuting agent capable, in its most potent form, of initiating a cascade of influence and change; indeed, it can be a catalyst for transmutation and change from the ordinary to the elevated. An example of the cascade effect in operation is evident in an examination of the genesis and development of the Modernist movement in the arts.

Fueled and instigated by the emergence of industrialism and the railroad, "modern" cities such as Paris and London became lodestones that attracted artists and they provided an immense picture gallery where modern artists could properly read from the "immense dictionary of modern life" (10). For more than 100 years, Paris was "ground zero" for the Modernist movement in art, architecture, music, dance, design, literature, and poetry.

Beginning around 1860, the idea of "change" began to emerge and was met with resistance, particularly from the bourgeois. However, the idea held sway, and those drawn by what art historian Peter Gay has termed the "lure of heresy" pressed forward, creating what was considered the birth of the Modernist movement in 1910, according to Virginia Woolf. The fundamental idiom of the idea base, as defined by Ezra Pound in 1935, was, "Make it new."

Hallmarks of the spirit of the Modernist movement were its generally utopian nature, the attitude that progress in all things was assumed, the acceptance of the inevitability of scientific and social process, and the premium placed on innovation and discovery. Those engaged felt pressure to reinvent themselves, to divest themselves from the past, and to be astonished with the future (10). The cascade effect is readily appreciated with reflection on and recollection of the works of iconic Modernist figures, which include, for example:

In painting:

Claude Monet: the father of French Impressionism, who championed the idea of the artist expressing his perceptions of a subject (Fig. 2).

Pablo Picasso: whose excursion into Cubism expressed deconstruction and reconstruction of the subject in geometric forms, presented in monochrome brown and neutral colors.

Wassily Kandinsky: creator of the first modern abstract work based on geometric progressivism, color symbolism, and psychology (Fig. 3).

Mark Rothko: who used broad patterns of monotone color for psychological effect (Fig. 4).

Jackson Pollock: purveyor of a chaos of paint in color and disorder over broad surfaces.

In architecture:

Charles Edouard Jeanneret-Gris: who, at age 33, reinvented himself as "Le Corbusier" to champion aesthetic spareness and the "machine aesthetic" as an urbanist (Fig. 5).

FIGURE 5. *Villa Savoie, Poissy, France, designed by Charles Edouard Jeanneret-Gris (Le Corbusier), 1929.*

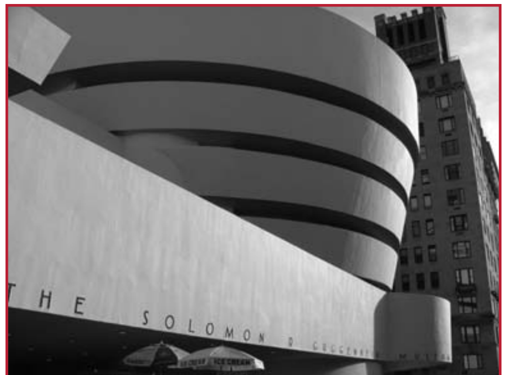

FIGURE 6. *The Solomon R. Guggenheim Museum, New York, designed by Frank Lloyd Wright, 1959.*

FIGURE 7. *Walt Disney Concert Hall, Los Angeles, designed by Frank Gehry, 2003.*

FIGURE 8. Satyagraha, *Act III Metropolitan Opera New York, composed by Philip Glass, April 2008.*

Frank Lloyd Wright: the master of personal reinvention, who, over a 60-year career, introduced concepts of "organic" architecture and robust modernity through novel employment of cement (Fig. 6).

Mies van der Rohe: the self-educated son of a stonecutter from Aachen, Germany, who sought to represent the modern age through extreme clarity, with "skin and bones" minimalist employment of steel and glass.

Frank Gehry: the Romantic Modernist, who presents sensual geometry in titanium "jackets" (Fig. 7).

Consider the recent performance of Philip Glass' 1979 Modernist opera *Satyagraha* at New York's Metropolitan Opera (Fig. 8). Given its form and content, would this have been created or accepted 100, 75, or even 50 years ago?

Scope and Scale of Modern Science

One of the Modernist denizens of Paris was Diego Rivera, a young Mexican artist from Guanajuato. He had dabbled in Cubism and became enamored with the concept of fresco painting, traveling to Italy to study the 2000-year history of that art form. He went on to become the world's most accomplished muralist. As the final stages of construction of Rockefeller Center in Manhattan were under way in 1932, he was invited to create a massive mural to commemorate the spirit of the times (Fig. 9). His creation, however, incorporated an image of Vladimir Ilyich Lenin and was rejected. His fresco, with some variations, was ultimately completed at the Palace of Fine Arts in Mexico City. It was titled *Man, Controller of the Universe*. The center of the piece depicted man at the controls of the Universe Machine and looking into the heavens with a sense of confidence and power (Fig. 10). This idea of comprehension and control of the environment has led to mankind's quest for thousands of years, from the Egyptians to the Mayans to today, to grasp the details of the skies above. The concept of comprehension of the stars has created a cascade effect of activities.

The Cosmic Scale

In 1965, Penzias and Wilson at Bell Laboratories in Murray Hill, NJ, discovered that, beyond the simple visual appreciation of the heavens, an invisible cosmic microwave background radiation could be detected. This phenomenon was later found to have variations, called anisotropy, which could

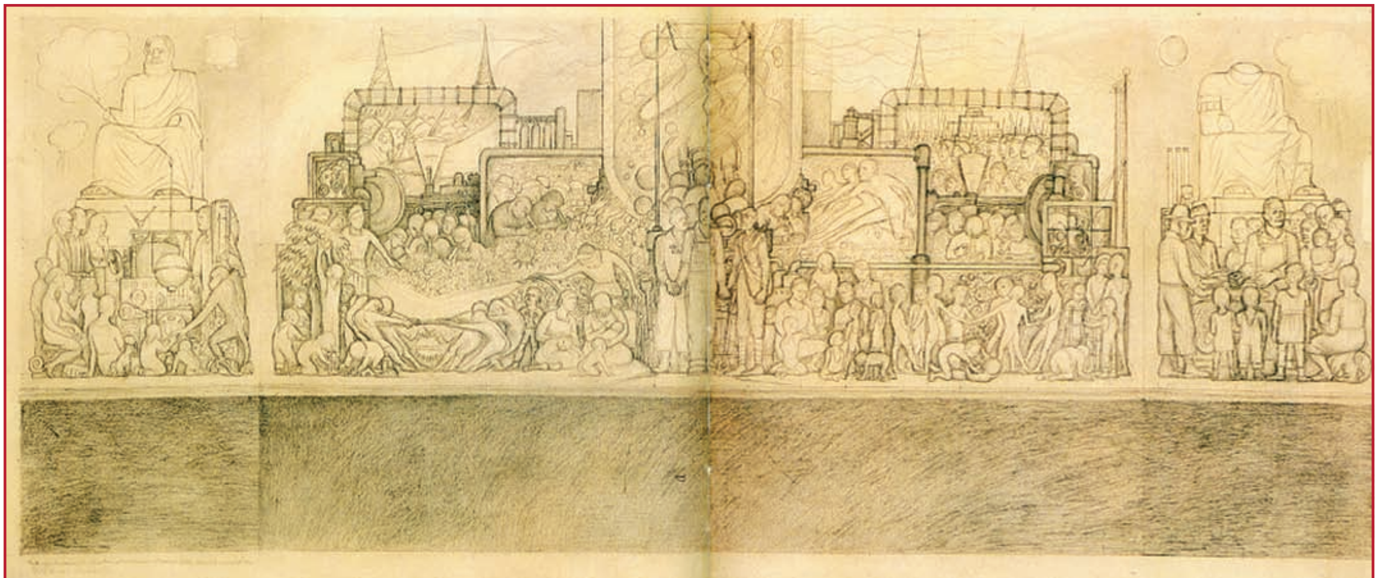

FIGURE 9. Man at the Crossroads with Hope and High Vision to the Choosing of a New and Better Future *(study for the destroyed mural at the Radio Corporation of America Building, Rockefeller Center), New York, by Diego Rivera, 1934. From Rochfort D:* Mexican Muralists: Orozco, Rivera, Siequeros. *San Francisco, Chronicle Books LLC, 1998.*

be measured, thus giving a calculated depiction of the afterglow of the Big Bang—the creation of our universe 13.6 billion years ago. In 1980, the Wilkinson Microwave Anisotropy Probe was launched to give a detailed rendering of the skies, and it provided a "baby picture" of the universe (Fig. 11). This project, which is ongoing, has provided enormous insight into the composition and time of creation of the universe, its stars and galaxies, and our solar system. It is estimated that our solar system's age is 4.6 billion years (Fig. 12). The composition of the universe has been a topic of great interest. According to the periodic table, the atoms that we comprehend comprise only 4% of the universe and are termed "ordinary matter." Twenty-three percent of the universe is unknown "dark matter." The remainder, nearly 73%, is composed of a strange "dark energy," which is believed to be an antigravity force that is creating an ongoing expansion of the universe and will cause its demise millions of years hence.

During the formation of the solar system, some of the products were the comets, which course in regions beyond Neptune (1). Comets, which are comprised of a nucleus of carbon, dust,

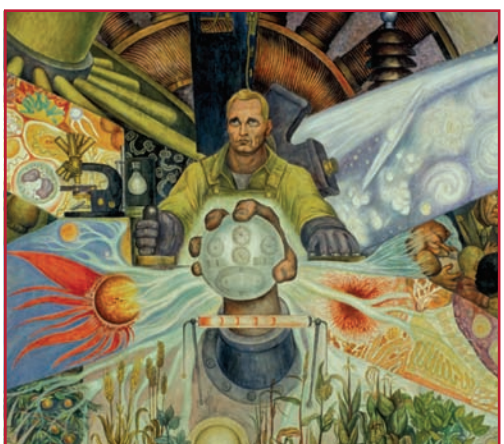

FIGURE 10. Man, Controller of the Universe, *Palace of Fine Arts, Mexico City (detail), by Diego Rivera, 1934. Photograph by Bob Schalkwijk.*

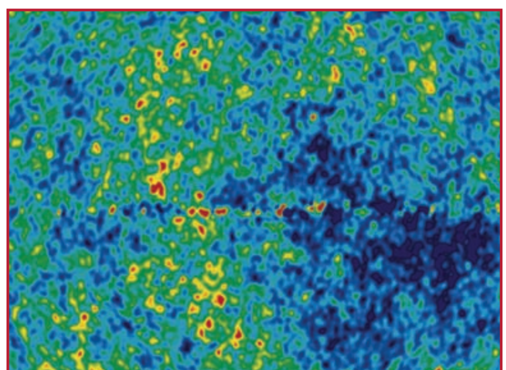

FIGURE 11. *Image of the infant universe illustrating 13.7 billion-year-old temperature fluctuations (color differences) that correspond to the cosmic materials that developed to become the galaxies. (Courtesy of the National Aeronautics and Space Administration [NASA]/ Wilkinson Microwave Anisotropy Probe [WMAP] Science Team[http://map.gsfc.nasa.gov/media/080997/080997_5yrFullSky_WMAP_4096W.tif].)*

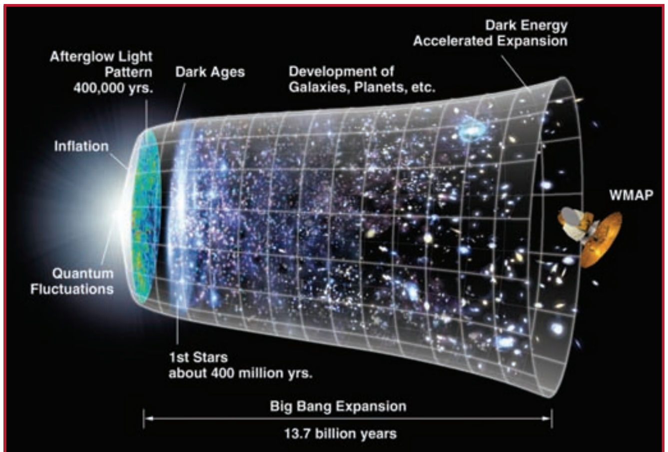

FIGURE 12. *Illustration depicting the time course and evolution of events during the formation of the universe. During the 13.7 billion years since the Big Bang, stars and planets were formed, while the universe has continued to expand. (Courtesy of the NASA/WMAP Science Team [http://map.gsfc.nasa.gov/media/060915/060915_CMB_Timeline150.jpg].)*

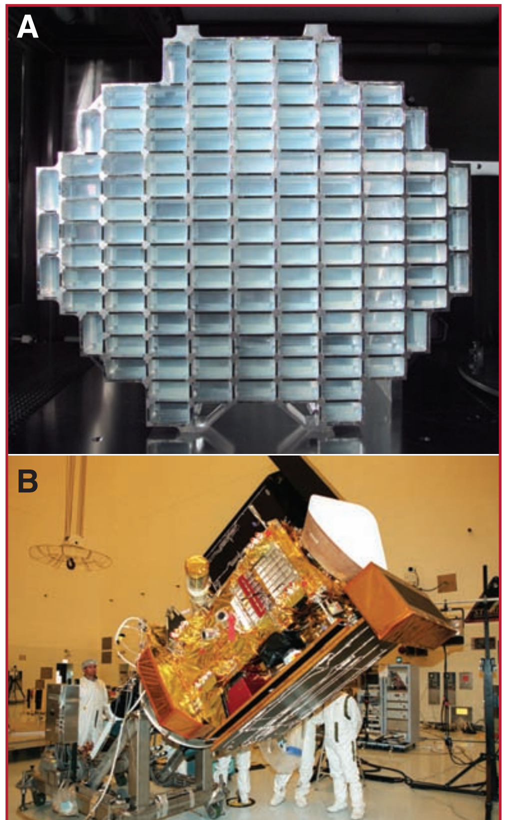

FIGURE 13. **A**, *aerogel molded into individual blocks and configured into a collector grid. (Courtesy of NASA/Jet Propulsion Laboratory [JPL]-California Institute of Technology [CIT] [http://stardust.jpl.nasa.gov/photo/spacecraft.html#ksc].)* **B**, *NASA's* Stardust *spacecraft is lowered before deploying panels for lighting tests. The length of the* Stardust *main bus is 1.7 m (5.5 ft). The spacecraft weighs 385 kg (849 lb). (Courtesy of NASA/JPL-CIT [http://stardust.jpl.nasa.gov/photo/ksc990111.html].)*

and ice, develop what is called a "tail," made of dust, ice, and water, as they begin to change configuration on the basis of their proximity to the sun and the impact of solar winds. This tail was considered by astronomers and astrophysicists to contain clues to the composition and formation of the planets and our universe in general. An idea was formulated to access a comet's tail! Investigators at the California Institute of Technology, Lockheed Martin, and the University of Washington then conceived the elements of practicality of the project. The comet Wild 2 was identified as being accessible by modern spacecraft. A material called aerogel (13) was created at the Jet Propulsion Laboratories by Peter Hsu. This spun silicon, the world's lightest solid, would be used as a catchment substance to gently retrieve materials during the encounter. It was incorporated into a detector grid that was deployed by the spacecraft as it was carefully angulated, at a speed of 13,000 miles per hour, through the comet's tail (Figs. 13 and 14).

On February 7, 1999, a Delta II rocket carrying the 849-pound, solar-powered spacecraft was launched from Cape Canaveral, FL. The successful encounter occurred on January 2, 2004, and the capsule containing the detector grid was returned to the Utah desert on January 15, 2006, completing a 7-year journey of 2.9 billion miles (500×10^9 m). More than 1000 particles measuring 5 to 300 μm were retrieved, and the samples are currently undergoing analysis in multiple laboratories throughout the world. These were the first rock samples returned to earth from any place beyond the moon—a fantastic achievement of modern science at an extreme scale (Figs. 15 and 16).

The Medical Universe and Neurological Surgery

Medicine exists in a global, social, economic, political, and scientific universe driven by forces of national economic vitality, popular attitudes and demands, emerging intellectual, affectual, and economic buoyancy, parallel progress in transferable technical and biological areas, and crisis situations, real and perceived. Perhaps most importantly, the principal catalyst for progress is the seminal idea. The innovative notion has been particularly operative in neurological surgery, in which, over the past generation, the concept of progressive minimalism has fueled a cascade of progress with new dimensions in the field. The continuum has been progressive—microsurgery, stereotaxy, navigated endoscopy, radiosurgery, endovascular techniques, and cellular and molecular adjuvants. What area of endeavor will follow molecular biology as a seminal innovative concept?

An idea conceived at the California Institute of Technology by Nobel Laureate and Professor of Theoretical Physics Richard Feynman has proved remarkably prescient. In December 1959, he delivered a keynote lecture to the American Physical Society in which he described a concept of "manipulating and controlling things on a small scale" and stated that there exists "a staggeringly

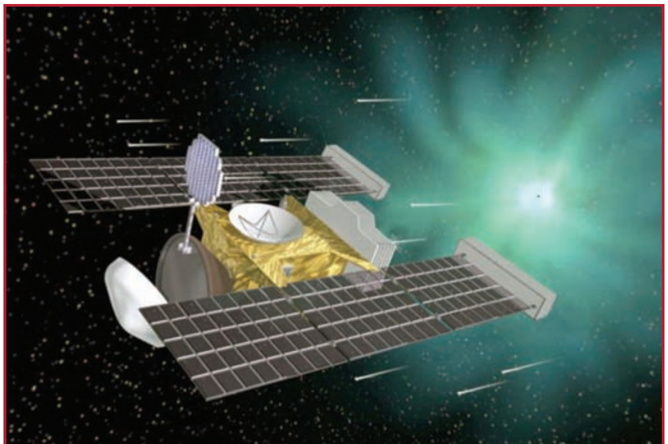

FIGURE 14. *Illustration depicting the rendezvous of* Stardust *with Wild 2. As the spacecraft flies through Wild 2's coma, it deploys its tennis racket-shaped collector grid to capture cometary particles. Traveling at 13 000 miles per hour, the solar-powered spacecraft makes its way safely through the coma as its bumper shields protect the spacecraft from damage by larger pieces of the comet. (Courtesy of NASA/JPL-CIT [http://stardust.jpl.nasa.gov/photo/artist.html#row7].)*

small world that is below" and "there is plenty of room at the bottom." This was the conceptual birth of what we now term "nanotechnology."

Nanotechnology

A nanometer is a billionth of a meter (10^{-9}) and spans approximately 10 atomic diameters. Nanotechnology encompasses the design, fabrication, and application of nanoscale systems, or nanosystems, and is a synthesis of multiple disciplines including electrical engineering, biotechnology, chemistry, and physics. In addition, nanotechnology has been defined by the National Aeronautics and Space Administration as "the creation of functional materials, devices, and systems through control of matter on the nanometer length scale (1–100 nm) and exploitation of novel phenomena and properties (physical, chemical, biological, mechanical, electrical . . .) at that length scale." Molecular nanotechnology is the 3-dimensional control of atoms and molecular structures to create materials and devices with molecular precision.

Since the introduction of the concept in 1959, there has been a progressive escalation of activity, highlighted by innovative concepts and Nobel Laureate discoveries. Thousands of sophisticated laboratories involved in nanotechnology research have heralded the "nanotechnology gold rush" that is changing the way mankind approaches its everyday life on our planet. We are currently involved in the definition of nanoscience, with its concepts and principles being defined and applied in mesoscale (1000+ nm) (17).

We now have elements and building blocks for the creation of products in the nanoworld: nanoparticles, nanowires (12), nanotubes (19), and the 60-carbon construct "fullerene" (Fig. 17), originally discovered in spectral analyses of cosmic dust by Nobel Laureate and Gene and Norman Hackerman Professor of Chemistry and Professor of Physics and Astronomy Richard Smalley and his associates at Rice University in Houston. We have tools and methods for manipulation and investigation in nanoscale dimensions. Most importantly, nanotechnology has yielded new concepts in computer science that are essential for the field's development. The silicon microchip, which has been an essential feature in the development of all modern science, has been moving toward the end of its refinement capabilities. We need to apply nanoscale manufacturing methods for further minimalization. Additionally, fundamental limitations of binary logic exist. Therefore, new methods of computing, namely, quantum computing and molecular computing, are being developed by the use of novel methods of fabrication, such as the self-assembly principles demonstrated in Mark Reed's laboratory at Yale as part of so-called bottom-up methodology. Current large-scale microprocessor production uses top-down manufacturing methods, which employ a technique termed electron beam lithography to fabricate objects in single-crystal silicon.

New technologies in imaging allow nanoscale observations and have the advantage of compatibility with living tissue. These instruments are part of the scanning probe microscope group, which includes the scanning tunneling microscope, the scanning capacitance microscope, and the atomic force microscope. With the use of these nanowire probe-oriented devices, both visualization and manipulation at the atomic level have been realized (Fig. 18). Another tool for manipulation is termed optical tweezers (4), which use a stream of photons to effect movement and

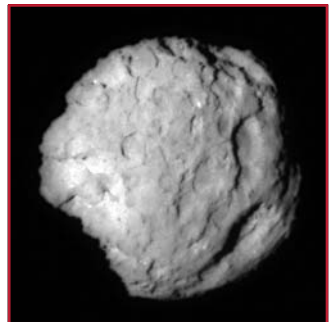

FIGURE 16. *Photograph of the comet Wild 2 taken by the approaching* Stardust *spacecraft before collection of comet debris. (Courtesy of NASA/JPL-CIT [http://stardust.jpl.nasa.gov/photo/cometwild2.html#row2].)*

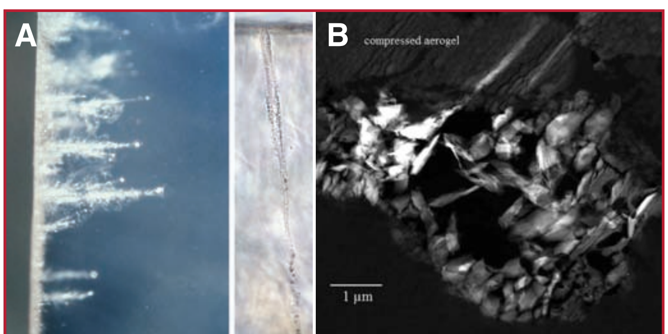

FIGURE 15. **A**, *side view of the aerogel collector grid, showing particles from the comet's tail as well as the tracks left by these particles as they entered the aerogel. (Courtesy of NASA/JPL-CIT [http://stardust.jpl.nasa.gov/photo/aerogel.html#row5].)* **B**, *microscopic image of cometary particle in compressed aerogel. (Courtesy of NASA/JPL-CIT [http://stardust.jpl.nasa.gov/news/news113.html].)*

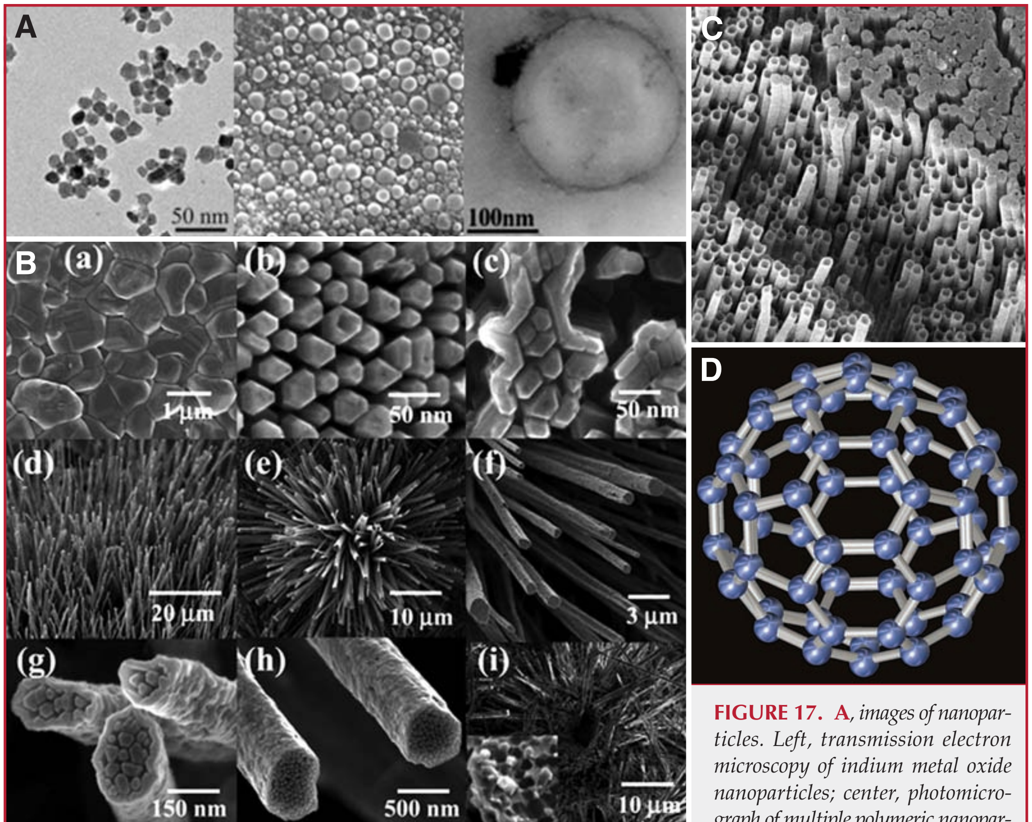

FIGURE 17. A, *images of nanoparticles. Left, transmission electron microscopy of indium metal oxide nanoparticles; center, photomicrograph of multiple polymeric nanoparticles loaded with deoxyribonucleic acid; right, individual polymeric nanoparticle.* **B**, *scanning electron micrographs demonstrating variations in crystalline SiC nanowire structure and stages of synthesis using principles of self-assembly. a, numerous grain boundaries on copper foil film; b, faceted nanocrystals deposited on the film; c, nanocrystals coalescing along the grain boundaries; d, array of vertically aligned nanowires; e, multitude of nanowires growing radially with bush-like structure; f, flat nanowire tips; g and h, close view of tips with various diameters shows numerous nanowires contained within hollow wires; i, nanowires after being cut with a "scalpel"; inset, cross sectional view.* **C**, *scanning electron microscopic image of highly ordered carbon nanotube arrays.* **D**, *illustration of a C60 Buckminster-fullerene (buckyball) molecule made up of 60 carbon atoms arranged in a series of interlocking hexagonal shapes. (Image copyright © Dr. Robert C. Wagner, University of Delaware.)*

desired fabrication at the atomic level (17). Amazingly, a biomolecular motor powered by F1-adenosine triphosphatase has been created as a nanoelectromechanical device (Fig. 19).

Nanomedicine Today

Nanomedicine encompasses medical diagnosis, monitoring, or treatment at the atomic and single-molecule level. It is currently being applied to areas of imaging, diagnosis, and therapy (6, 7, 13).

In imaging, quantum dots (9, 11), magnetic nanoparticles, and cross-linked iron oxide nanoparticles are elements of active research, the latter two as contrast agents, and quantum dots as fluorescent labels for live cells, receptors, and neoplasms (Fig. 20) (9, 11). Quantum dots are particularly interesting. They fluoresce without quenching throughout the usual visual spectrum and offer striking markers of cellular components and cell constructs in vivo (Fig. 21). They also offer the capability for delineating the extent and location of neoplastic burden (Fig. 22).

Nanoconstructs are currently valuable in the detection of deoxyribonucleic acid and proteins—a boon to medical diagnostics (5). These constructs include gold nanoparticles, silica nanoparticles, gold nanoshells, nanotubes, nanowires, nanoarrays, nanofluidics, nanoelectromechanical systems, and nanocantilevers (Fig. 23).

Nanoconstructs have been used therapeutically for drug delivery and gene therapy; these include nanoshells, liposomes, hydrogels, fullerenes, polymeric nanoparticles, polymeric micelles, dendrimers, implantable constructs, and "smart" surfaces. A major advantage of nanoscale delivery appears to be enhanced membrane penetration. Additionally, targeted nanotherapy offers improved safety and compliance, increased efficacy, reduction of secondary effects, and, importantly, target-specific drug release.

Potential nanosurgery devices include the ultra-efficient femtosecond laser system, nanoneedles, nanotube nanotweezers, and optical tweezers (Fig. 24) (4). Quantum dot localization (9, 11) and hemostatic effects of self-assembled nanoparticles (12) have also been demonstrated.

Nanoneurosurgery is the application of nanotechnology to the spectrum of nervous system disease. It will ultimately employ elements, principles, and capabilities of nanotechnology to diagnose and treat potential or existing central and peripheral nervous system diseases.

The Future

Molecular nanotechnology is the 3-dimensional positional control of atomic and molecular structures to create materials and devices with molecular precision (16). Ultimately, nanomedicine will involve designing and fabricating molecular devices and then using them in patients to establish and maintain health. Mature nanomedicine will require the ability to build these devices with atomic precision. Molecular nanotechnology and molecular manufacturing will be the key to enabling technologies for nanomedicine.

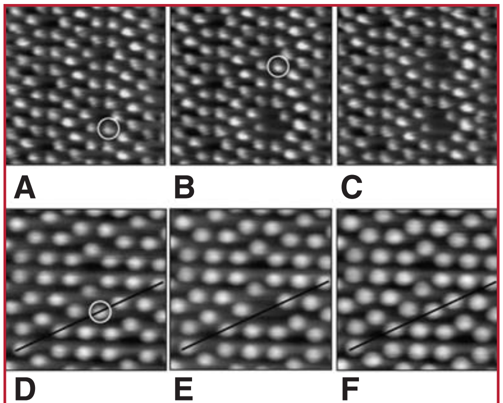

FIGURE 18. *Atomic force microscopy used to manipulate single selected silicon atoms.* ***A–C****, sequential mechanical extraction of 2 single silicon atoms (marked with circles in* ***A*** *and* ***B****) from a silicon surface.* ***D****, removal of the silicon atom circled in* ***A****;* ***E****, the created cavity;* ***F****, the atom was then replaced.*

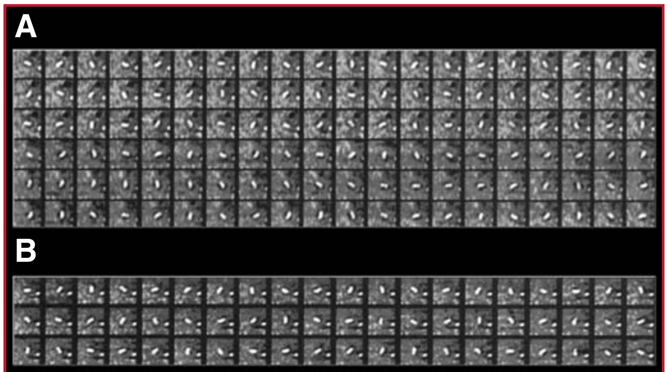

FIGURE 19. *Series of images demonstrating nanopropellers being rotated anticlockwise at 8.3 rps (****A****) and 7.7 rps (****B****) by an F1-adenosine triphosphatase biomolecular motor. From Soong RK, Backand GD, Neves HP, Olkhovets AG, Craighead HG, Montemagno CD: Powering an inorganic nanodevice with a biomolecular motor.* ***Science*** *290: 1555–1558, 2000.*

Consider that we have now entered the early stages of creating novel drug delivery devices, bioprosthetics, new biomaterials, engineered tissues, engineered "organs," and robotic devices (8). Later, we will see an ever-decreasing scale of operation and the ability to recapitulate every function. Through process engineering, we will create genetic content, gene expression, protein products, cell structure and function, and thus, organ structure and function. Largely, these capabilities will offer the re-creation of the human being. There is, indeed, "plenty of room at the bottom" in medicine and for us in neurological surgery as we consider these concepts to be realities and future capabilities (7, 14, 15).

Neurosurgical Modernism

Over the past generation, we have reinvented neurological surgery through a culmination of scientific, social, and economic

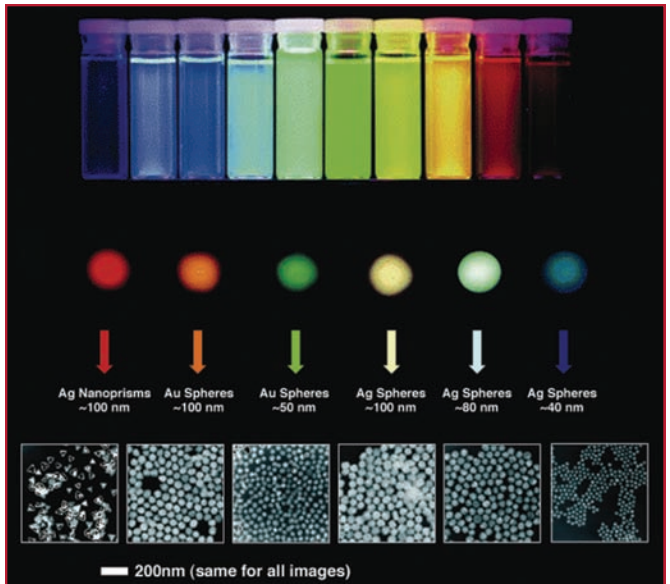

FIGURE 20. *Illustration showing that quantum dots fluoresce at different wavelengths depending on their physical properties and composition. From Ilic B, Yang Y, Craighead HG: Virus detection using nanodectromechanical devices.* ***Appl Phys Lett*** *85:2604–2606, 2004; Rasi NR, Markin CA: Nanostructures in biodiagnostics.* ***Chem Rev*** *105:1547–1562, 2005.*

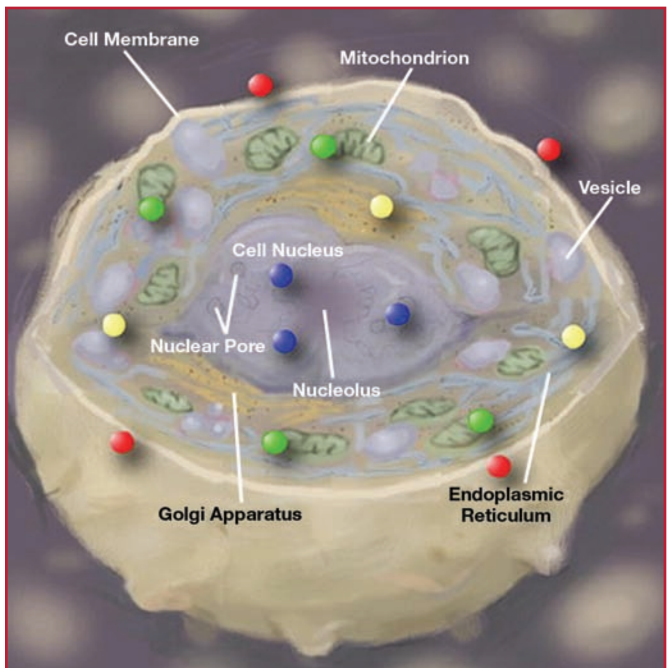

FIGURE 21. *Illustration showing potential targets for quantum dots of varying dimensions within a cell. Varying the composition and physical dimensions of quantum dots allows control over the color of light emitted.*

events (2, 3). We all want to be modern; however, at times, there is a feeling of insecurity related to this movement and the rush of new ideas and methods. Consider the statement in 1927 from

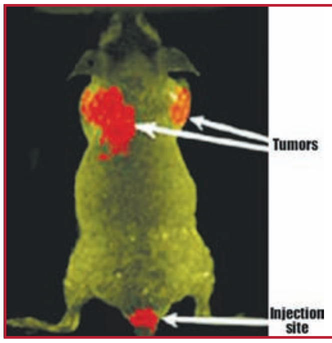

FIGURE 22. *Spectral imaging of a live mouse harboring human prostate cancers labeled with bioconjugated quantum dots. Multifunctional bioconjugated quantum dots injected into the tail vein demonstrate dramatic preferential labeling of subcutaneous prostate tumor tissue.*

the foreward by Le Corbusier (Fig. 25) to his classic, impassioned "manifesto of the modern," *Towards a New Architecture:*

> *"Man's stock of tools marks out the stages of civilization, the Stone Age, the Bronze Age, the Iron Age. Tools are the result of successive improvement; the effort of all generations is embodied in them. The tool is the direct and immediate expression of progress; it gives man essential assistance and essential freedom, also. We throw the out-of-date tool on the scrap-heap; the carbine, the culverin, the growler and the old locomotive.*

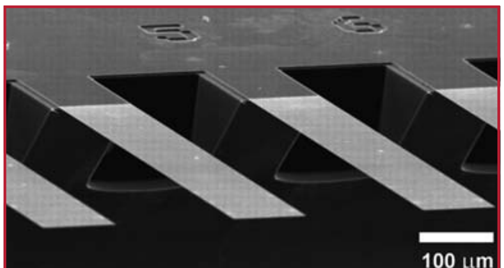

FIGURE 23. *Scanning electron micrograph of a portion of a nanofabricated functionalized silicon nanocantilever array.*

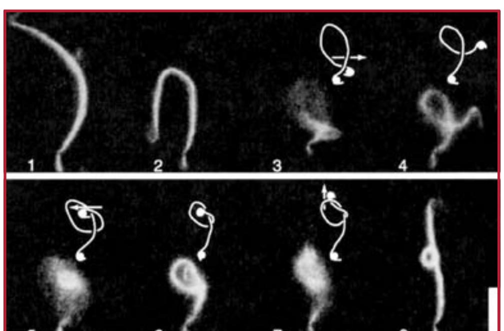

FIGURE 24. *Optical tweezers used to tie a knot in an actin filament. To manipulate the filament, 2 polystyrene beads coated with myosin were held by optical tweezers, and 1 end was manipulated to form a knot. Scale bar, 10 μm.*

> *This action is a manifestation of health, of moral health, of morale also; it is not right that we should produce bad things because of a bad tool; nor is it right that we should waste our energy, our health, and our courage because of a bad tool; it must be thrown away and replaced."*

We, during our time, have the scope and capability of activity that span a realm from 10^9 to 10^{-9} meters—an incredible thought! With the reinvention of neurological surgery, we, in many ways, will and must reinvent ourselves both in spirit and in practical realities. Consider the hallmarks of the Modernist movement in the arts and literature and the attitudes of those who truly participated in giving society the fabulous progress and fresh ideas that attended the concept of Modernism.

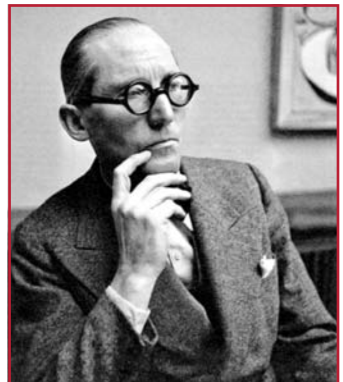

FIGURE 25. *Charles Edouard Jeanneret-Gris (Le Corbusier).*

The passion for progress, the premium placed on innovation and discovery, the pressure to reinvent, and the need to astonish ourselves with the new, the future, are things to which we should all adapt to move neurological surgery forward. The quest for modernity should be an inveterate passion for all of us who would call ourselves neurosurgeons!

Disclosure

The authors have no personal financial or institutional interest in any of the drugs, materials, or devices described in this article.

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COMMENTS

In this wonderful tribute to Ted Kurze, Apuzzo et al. provide the reader with several unique insights into the way new ideas bring about change and progress in our civilization. They accomplish this by focusing on the broad effect that the Modernist movement has had on European thought and the specific role that individual Modernists have had on developing our society's acceptance of the inevitability of innovation and discovery. As the field of neurosurgery and individual neurosurgeons move to reinvent themselves in response to today's scientific, social, and economic events, it is particularly useful to be aware of our Modernist roots. Understanding the roots of the passion we share for bettering the lives of our patients will undoubtedly allow us to move more gracefully, with fewer missteps.

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It is often instructive to step back and reflect on the realm of science in our lives. This article explores the subject, ranging from the immensity of a universe beyond comprehension to the nanometer world beyond perception. It is inspirational as well as humbling. One of the major attractions of neurosurgery is the capacity to use the same concepts that help us understand the laws of physics, biochemistry, and molecular biology to devise novel methods for treating neurological disease. In some ways, a career in neurosurgery also is the most inspiring and humbling of any career I can imagine. The future of our discipline will depend on incorporating some of the concepts and themes in this article into new treatment methods. Our willingness to collaborate with other disciplines in science is necessary to make this happen.

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This special article was presented at the 2008 meeting of the American Association of Neurological Surgeons in Chicago, IL, as part of the Theodore Kurze Lecture. Dr. Michael L.J. Apuzzo, former colleague of Ted Kurze, delivered the original presentation. The senior author is a well-known master surgeon, teacher, and innovator of numerous technologies in both surgery and radiation oncology. In his characteristic style, he skillfully examines the power of ideas, the movement of Modernism in the arts, and their role in sculpting the future of neurosurgical practice. This all-embracing essay is organized into 3 parts: an assessment of the power of ideas in initiating change and progress, the capabilities of "modern" scientific endeavors, and the realities of modern neurosurgical attitudes.

In the first part, "Alchemy, Ideas, and Modernism," the authors illustrate, through art, architecture, and music, how an idea is capable of influencing both scientific and humanistic thought. Provocative and influential works of Modernist figures are cited: Wassily Kandinsky's *Composition 8*, 1923; Villa Savoie, designed by Charles Edouard Jeanneret-Gris, "Le Corbusier"; Frank Gehry's "jackets" at the Walt Disney Concert Hall. These works reflect the cascade effect and how artistic thought eventually progresses to innovative diagnostic techniques and surgical approaches.

The authors begin the second part, "Scope and Scale of Modern Science," with Diego Rivera's 1934 mural *Man, Controller of the Universe*, which depicts man in control of the universe machine (resembling a surgeon behind a DaVinci robotic apparatus). The image serves as a symbol of where neurosurgery has ventured in the past (microsurgery, stereotaxy, endoscopy, radiosurgery, endovascular techniques) and perhaps will go in the future: nanotechnology. The authors assert that nanotechnology, the 3-dimensional control of atomic structures, may expand the field of neurosurgery to include anatomic engineering with nanoneedles, nanotubes, nanotweezers, and femtosecond laser systems.

The third part, "Neurosurgical Modernism," summarizes the scope of neurosurgery and spans from the cosmos (a scale of 10^9 m) to nanoscience (a scale of 10^{-9} m). Parallels are drawn between the Modernist movement in arts and architecture with true practitioners of medicine today. The ultimate outcome of this push for "the new" will inevitably result in improved neurosurgical capabilities.

Traditionally, the goal of the Theodore Kurze Lecture has been the integration of neurosurgical scientific endeavors with those of the humanities. Dr. Kurze's legacy and intellectual spirit are proudly displayed in this exceptional essay.

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