# EDITORIAL

## Evolution of Scientific Research

History tells us that the frontiers of science will change. A review of the past hundred years of physics provides partial guidance as to future research in other natural sciences. Instrumentation and knowledge pioneered by physicists have improved capabilities in other sciences and medicine. A useful indication of the role of physics is provided by the October 1993 issue of *Physics Today* devoted to a centenary of the *Physical Review.* From 1893 to about 1960 this journal published most of America's important physics papers. A sudden blossoming of American physics occurred about 1930. *Physics Today* provides information about names and activities of key scientists of that exciting decade. In the period 1946 to 1960 knowledge underlying much of today's instrumentation and high technology was created.

The centenary articles in *Physics Today* were prepared by distinguished authors, some of them Nobelists. The topics (briefly treated) include lasers, fiber optics, nuclear magnetic resonance (NMR), semiconductors, superconductors, nanostructures, and medical cyclotrons. Today most of them are of technological and economic consequence while having impact on other sciences. For example, according to Nicolaas Bloembergen:

> ...The widespread commercial applications of lasers include their use in fiber optic communication systems, surgery and medicine, printing, bar-code readers, recording and playback of compact disks, surveying and alignment instruments, and many techniques for processing materials. Laser processing runs the gamut from sculpting corneas by means of excimer laser pulses to the heat treatment, drilling, cutting and welding of heavy metal parts in the automotive and shipbuilding industries by $CO_2$ lasers with continuous-wave outputs exceeding 10 kilowatts.
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> ...Lasers have revolutionized spectroscopy, and they have given birth to the new field of nonlinear optics. They are used extensively in many scientific disciplines, including chemistry, biology, astrophysics, geophysics and environmental sciences.
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> ...[T]he physicists who did the early work were ...intrigued by basic questions of the interaction of molecules and magnetic spins with microwave and millimeter-wave radiation. Could atoms or molecules be used to generate such radiation, they asked themselves, and would this lead to better spectroscopic resolution?

NMR techniques were originally developed to investigate nuclear properties. But soon it was discovered that the technique was a powerful tool for structural chemistry, biochemistry, and later for medical imaging. A series of improvements in the technology now lead to the belief that nuclear magnetic imaging (NMI) will surpass x-rays for medical diagnostics. George Pake has evaluated the motivation leading to the discovery of NMI:

> Magnetic resonance imaging could arise only out of the nondirected research, not focused upon ultimate applications, that gave rise to what we know today as NMR. The key was the series of basic quests to understand the magnetic moments of nuclear spins; to understand how these nuclear magnets interact in liquids, crystals and molecules; and to elucidate the structures of molecules of chemical interest. Out of these basic quests came the knowledge that enabled a vision of an imaging technique. Without the basic research, magnetic resonance imaging was unimaginable.
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> Magnetic resonance imaging is an irrefutable testimonial to the enormous value of basic research.

Initial motivation for research on semiconductors was the possibility of developing a solid-state substitute for the vacuum tube. Encouraging experimental results were obtained in 1947. Achieving practical applications and reliability required tremendous efforts, much of which occurred in the Bell Laboratories. In the development of semiconductor devices, including computers, thousands of solid-state physicists were involved. They worked with engineers, and some of them became engineers. A residue from the efforts is an electronics industry with annual revenues of hundreds of billions of dollars. Another result is that most scientific instrumentation today includes computers. An enormous reservoir of knowledge of solid-state physics has been accumulated. But the future looks less rosy than the past. The number of corporations supporting semiconductor research has declined steeply, and operations in the remainder have been curtailed. Alan D. Fowler comments that a slowdown in the pace of technological development will inevitably erode the military advantages of the United States. A decrease in the federal support of condensed-matter physicists will have a like effect and in addition slow the ultimate progress of science, technology, and medicine.

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