DISCLAIMER

SCIENCE: CHANGE, GROWTH, OR PROGRESS?

During the 17th century, a new approach to understanding the nature of the world developed in Europe. Individuals such as Galileo began to describe the motion of objects in mathematical terms. Others, including Newton, began to emphasize the importance of comparing theoretical descriptions of phenomena to careful, quantitative observations of experimental results. Organizations were formed throughout the Continent to criticize, fund, and direct the activities encouraged by this new approach. Although this activity is the first clear expression of what we think of as "modern" science, it is equally clear that science has changed dramatically over the last four hundred years. As we take this opportunity to recognize the efforts of some of our young scientists, perhaps we can reflect on the nature of this change.

One view of scientific change has been described as "progress" so often that it is often accepted uncritically as the only view. Progress implies a directed change, a change that is evaluated with regard to some final goal or standard. The mathematical nature of much modern science creates an obvious goal for the creator of a scientific theory. The description of nature inherent in the theory should produce a description of phenomena that results in precise, quantitative agreement with the outcomes of experiments. Throughout the last four centuries, the success of many a scientific theory has been evaluated largely with regard to its ability to provide accurate numerical predictions. If quantitative accuracy is the standard, then closer agreement between theory and experiment is understandably described as "progress."

However, progress toward accurate numerical descriptions of Nature does not necessarily imply movement toward a "better understanding" of the universe. At the same time that science has quantified the universe, it has also functioned as an attempt to "understand" the fundamental processes of Nature. One can imagine scientific theories that produce very accurate numerical predictions, but do not provide insights into the operations of the universe. Many would argue that such scientific theories are not understandable in the everyday sense of the word. Indeed, Richard Feynman is famously quoted as having said, "I think it is safe to say that no one understands Quantum Mechanics." Quantum mechanics has repeatedly generated the most precise numerical predictions science has ever produced, but physicists have struggled for over 80 years to create a common interpretation, or "understanding," of the theory. This is due, at least in part, to the subjective nature of understanding. This makes it difficult to define progress, for there may be no agreement on a "best" level of understanding. This is particularly apparent if we consider how society as a whole understands scientific theories. It is certainly arguable that the current understanding of the "nature of the universe" by the general public is no better than it was 400 years ago. According to this view of science, theories may "change," but they do not (necessarily) progress.

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So, are scientific theories nothing more than algorithms to predict the future? Consider a third alternative, the development of "scientific knowledge" imagined as a process analogous to the growth of a living organism. Scientific theories take root in particular social and scientific environments that encourage the investigation of particular types of problems. As scientists interpret the results of their investigations, new theories are born. Many of these do not survive, cut down by unfavorable experimental results. However some live for a long time, posing new questions for investigation, generating new connections among old facts, and finding new environments in which to proliferate. One of the finest examples of this vision of science would be Darwin's theory of evolution. In 19th century Europe, the environment was right for the "birth" of a theory of evolution. Indeed, Lamarck, Wallace, and Darwin independently developed theories of evolutionary change. Darwin's conception is the version that has survived the pruning process. As this theory matured, it raised many questions in biology and allowed biologists to apply a single explanatory principle to areas as divergent as genetics, paleontology, and medicine. In addition, the theory has borne fruit in other fields such as artificial intelligence, economics, and psychology. Scientific theories flourish, in other words, insofar as they are able to bear copious intellectual fruit.

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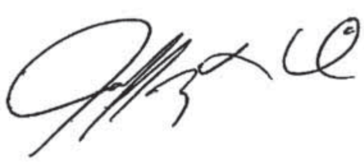
Each of these three views of scientific change has its proponents and detractors, but whether you adhere to a vision of science as a process of change, growth, or progress, the future of science depends on the continued education of young scientists. This 7th volume of the *Journal of Undergraduate Research* documents the process by which the Department of Energy's National Laboratories participate in the education of our new generation of scientists. Laboratory scientists and engineers have mentored these students just as many past generations mentored students. The work presented here illustrates how these young people changed during their internships. They have grown as scientists by developing new skills and abilities. They have progressed toward a particular, perhaps unspoken, image of an "ideal" scientist. We thank each mentor for the important role they have played in this process and congratulate the students for a job well done.



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NATIONAL LABORATORIES: AGENTS OF CHANGE

Adapting to change is one of the great human attributes. From the very moment we are born, we begin to observe, see opportunity, and strive to reach new places in our lives. Realizing the potential to crawl, walk, talk, and reach new goals, we continuously assess our capabilities, recall our experiences, and synthesize ways to accomplish our mission, progressing toward some new state of being. Achieving change and progress is not always easy. We persevere through trials and tribulations, overcoming frustrations, making advances, sometimes suffering setbacks, but constantly driving forward. This is true of us as individuals, as communities, and as a Nation.

As a Nation, we are assessing our capabilities in terms of energy independence and national security. Realizing that great change may be necessary, we are identifying ways to utilize our existing infrastructure and new technologies to overcome these challenges. At the same time, as members of a global community, we are working to integrate new energy sources into climate-friendly production models. The solutions to these problems will come from many sources and will bring many other benefits. Our ability to work at the nanoscale with a new collection of tools will certainly serve the energy mission well. Nanoscience will become a revolutionary force with an impact akin to that of the automobile and airplane, and more recently, computing and the internet.

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Over the past eighteen years, I have had the opportunity to be part of an agency that is at the forefront of national and, indeed, global change. Little did I know that contributing to the U.S. Department of Energy's mission was going to be such an addictive occupation. My military service made me proud of my contribution to our national security, my stint in corporate America was educational, but my work supporting science at the DOE's Brookhaven National Laboratory has been exciting. It is exhilarating to help shape the future of society through science, supporting facilities and staff that are tearing apart molecular and atomic structures, rearranging them in new ways, and developing the underlying basis for scientific, medical, and life-changing technological advances. Nowhere is this done better than at our world-renowned Department of Energy National Laboratories, seventeen in all, ten of which are run by the Office of Science.

As we embrace the challenges of finite fuels, national security, and climate change, as we seek to advance medical capabilities, combat viruses and diseases, and improve food and water sources, it is the DOE's facilities, researchers, and support staff that will bring solutions forward. Recently the Center for Functional Nanomaterials at Brookhaven was placed in operation. This is the fifth of five such facilities within the DOE. These facilities, along with others in high energy physics, synchrotron light, and other priority areas, provide an infrastructure for science that continues to be unparalleled in the world, even as other countries seek to emulate our passion for discovery and its resulting economic rewards. These laboratories are the places where basic science discoveries will be made that facilitate renewable and clean energy sources, develop detection systems for national security, and advance our understanding of the universe, dark matter, and dark energy.

Leading such change is complicated by challenges facing our educational systems, the desire of other countries to build scientific infrastructures to retain their domestic talent, and the added challenges of bringing foreign researchers into the United States. Once again, the DOE's role is clear. The National Laboratories are a place where scientists of all ages — and those who teach them — can come to experience the excitement of science. A renewed focus has been placed on developing increasing numbers of our own technicians, engineers, and scientists, both through direct involvement, and by engaging teachers and professors.

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This is an exciting time to be leading educational programs at one of the DOE's National Laboratories. Building the science and technology workforce of the future, the people who will use these extraordinary facilities and make these discoveries, is quite a satisfying way to spend a career. From my vantage point, the future is indeed bright. Our facilities are prepared to nurture the intelligent and inquisitive minds of youth who are anxious to address our Nation's challenges. As I write this, we have a new crop of 140 talented and curious undergraduate interns who arrived today to share our passion for discovery. I guess for now, the addiction to my work — helping our nation meet the challenges of change — will continue.

Ken White
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