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ABSTRACT

Oberlin College's strength in science and mathematics is discussed by its president, along with the state of these fields in the United States and the contributions that liberal arts colleges can make. Of concern nationwide are declining enrollments in science and mathematics, low performance in these fields of U.S. students compared to other developed countries, and a projected future undersupply of math and science teachers. Oberlin College's strength in the sciences and mathematics is due in large part to the quantity and quality of student-faculty contact. Faculty members, rather than graduate students, teach undergraduates at the college, and Oberlin faculty also involve undergraduates in their research projects. The college emphasizes fundamentals and breadth, since only one basic introductory course per scientific discipline is offered. The recruitment of the gifted in science and mathematics is a priority at the college, which also has created over 33 new science and mathematics courses since 1983. Competitive salaries, grants, and paid research leaves are important to recruiting faculty, and well-equipped laboratories and an overall climate favorable to science and mathematics are also emphasized. (SW)

# Science and Liberal Education at Oberlin

*S. Frederick Starr, President*

> *—Science is the child of the imagination. It is but a complete knowledge of that nature from which all art and poetry are drawn, and it opens the way for a grander sweep of the creative power.*
>
> Charles Martin Hall, Commencement Oration, 1885

This year's annual report focuses on just one issue, the current and future status of science and mathematics at Oberlin College. In concentrating on these areas I do not imply that they have grown weak and now require resuscitation. On the contrary, science and mathematics at Oberlin have never been stronger, nor have they ever contributed more to the intellectual vitality of the College as a whole. But at Oberlin, as at other leading liberal arts colleges, they are easily taken for granted. That we refer to such schools as "liberal arts colleges" rather than "colleges of the liberal arts and sciences" may perhaps reflect this tendency.

At no time in this century has there been a more urgent need to examine the place of mathematics and science in higher education. These fields are transforming our lives, generating epochal changes which, for better or worse, set apart our era from all that have gone before. They are altering fundamentally the way we view ourselves, our place in nature, and nature itself. Careening forward, the process of change arising from new scientific knowledge seems inexorable. Yet it throws in our faces numerous and fundamental choices. A free society must be able to recognize these crossroads as it approaches them and make responsible decisions before undesirable consequences are forced upon it. Unless we are to deny our democratic principles, such decisions require an informed public, one that is at least conversant with the processes and main principles of modern science, if not with its endless complexities. Unfortunately—perhaps fatally—the United States today approaches each crossroad desperately unprepared. Disastrous conditions in our schools leave most members of the general public wholly unequipped to participate in such decisions and even suspicious of or alienated from science. The failure of higher education to rectify the situation means that before long, even the majority of our educated populace will face issues posed by science as *terra incognita*.

This report is intended, first, to draw the attention of the Oberlin family to this fearful situation, second, to inquire into the appropriate response to it by liberal arts colleges in general and by Oberlin College in particular, and, third, to evaluate Oberlin's current posture and plans in that light. It is not expected or intended that notions advanced in this brief study will "fix" the problem of science and mathematics in the College, leaving us free thereafter to turn our attention to other issues. Rather, it is hoped that these pages might place the fields of science and mathematics more solidly on the College's regular long-term agenda and make them the object of steady solicitude over many years.

## Science and Mathematics at Oberlin: The Heritage

Many of the three-quarters of Oberlin alumni who did not major in science or mathematics might well ask, as they read this report, about the place these fields have traditionally occupied in the life of the College. To some it may seem that such attention as will be proposed here represents a departure from customary practices, an alteration of the

College's tradition. In fact, the reverse is true.

Science and mathematics have always held a central place in the life of Oberlin College. From the moment of its foundation, the curriculum embraced both science and mathematics. Student interest was keen. A letter home from an undergraduate of 1837 reports that Professor Dascomb's scientific course was "an extremely interesting study." The following year the College erected a laboratory building, one of the first permanent brick structures on the campus, for Professor Dascomb's use. By mid-century, the curriculum of virtually the entire junior year was given over to science and mathematics.

Yale and other colleges created separate schools of science. But nineteenth-century Oberlin treated science and mathematics as integral parts of the curriculum, to be pursued for both their practical value and their intrinsic worth. Students a century ago wanted more science, not less. Under Presidents James Harris Fairchild and Henry Churchill King—roughly from the Civil War through World War I—the sciences flourished at Oberlin, for both of these great educators saw scientific learning as the fulfillment of their Christian faith, rather than as a threat to it. It is no wonder that many of Oberlin's most distinguished alumni—from Charles Martin Hall and Robert Millikan in the nineteenth century to Wallace J. Eckert, Roger Sperry, J. William Schopf, and Donald A. Henderson in the twentieth century—have been scientists, and that many other Oberlin luminaries have been enriched by their education in mathematics and science.

Cardinal Newman once observed that an educated person has the "power of viewing many things at once as one whole." Oberlin College has always shared this view and has considered a knowledge of science and mathematics to be among the essential requisites for attaining that end.

## *Imperial Science*

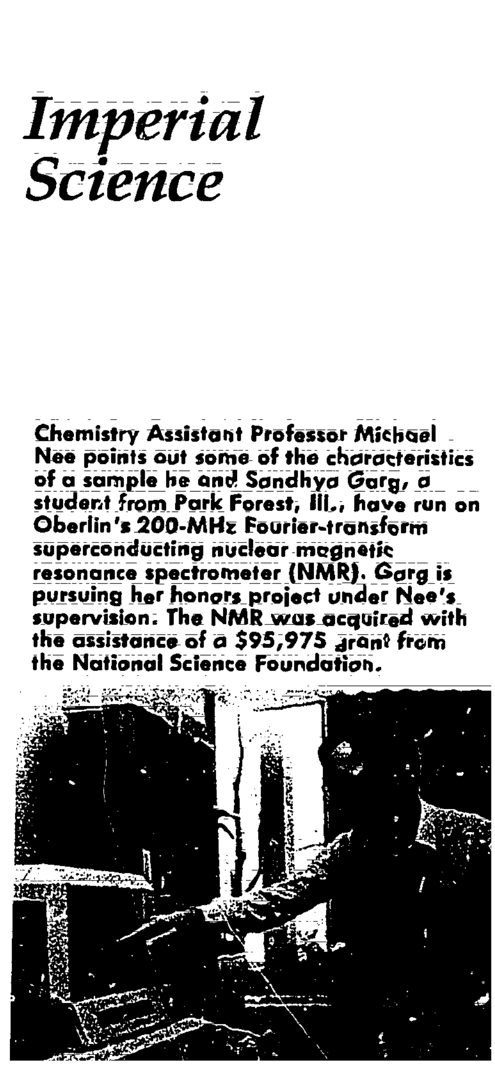
Oberlin, then, has been committed since its earliest days to the notion that educated persons must be literate in the science and mathematics of their era. This is no simple matter today, when the quest for new scientific knowledge occupies the full-time attention of millions of our population, and its practical development has become one of the central preoccupations of our culture. Dr. Erich Bloch, director of the National Science Foundation, estimates that 44 percent of all increases in America's industrial productivity now come from scientific and technical innovation. The industrial revolution has given way to the scientific-technological revolution.

It is hard to think of any aspect of life that has remained untouched by science. Diseases once thought to be beyond the reach of medicine are now under attack by teams of scientists drawn from many disciplines. Techniques of genetic engineering are being applied to redesign life forms. Age-old problems of food and agriculture are yielding to this assault, but analogous techniques applied to human beings themselves are raising grave ethical questions.

Charles Babbage, the English mathematician, invented his first "analytical engine" in the same year Oberlin was founded. Computers, the descendants of Babbage's device, are now making possible the storage and analysis of staggering volumes of data, opening new horizons for human freedom and, at the same time, creating efficient tools for those who would restrict our freedom. The phrase "artificial intelligence" is barely a generation old, but it already denotes a formidable reality. Artificial intelligence may liberate human workers from some forms of drudgery. However, it also is at the "heart"—I still grasp for the human metaphor—of the fiendishly destructive "smart weapons" that imperil world peace.

These and other developments in science and technology go far

**Chemistry Assistant Professor Michael Nee points out some of the characteristics of a sample he and Sandhya Garg, a student from Park Forest, Ill., have run on Oberlin's 200-MHz Fourier-transform superconducting nuclear magnetic resonance spectrometer (NMR). Garg is pursuing her honors project under Nee's supervision. The NMR was acquired with the assistance of a $95,975 grant from the National Science Foundation.**



toward defining the distinctive aspects of the world in which we live. Breakthroughs occur so rapidly that news media can scarcely keep abreast of them, let alone reflect adequately upon their implications. Public policy on the national and international levels often tries to address problems of scientific progress, but it, too, fails to keep up with the unfolding realities. Often, by the time a scientific or technological breakthrough is translated into political or economic terms it has already gained an unstoppable momentum.

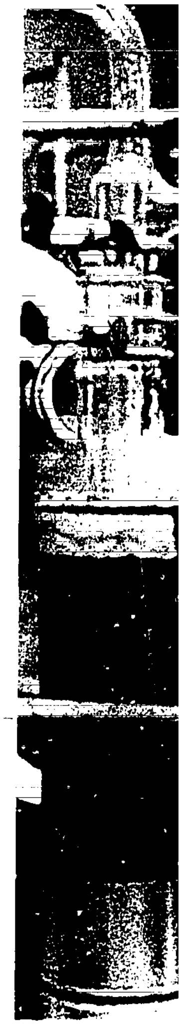
During the nineteenth century optimistic leaders strove to uncork the genie of science, never thinking that it might come to dominate the life of society. Today we strive at best to guide the juggernaut into benign channels. We have accepted the truth of the words of Swiss playwright Friedrich Durrenmatt, who wrote in *The Physician* that "what is thought cannot be unthought." We also understand that our striving for new knowledge holds as much potential peril as promise. We recognize ourselves in the figure of Goethe's Faust, the frustrated scientist who so yearned for the secrets of life that he sold himself to Mephistopheles in the hope of obtaining them. The title of Albert Jacquard's 1985 book, *Endangered by Science?*, may be overly pessimistic, but it does not understate the degree to which science, mathematics, and technology have become powerful forces looming over our world. To master these forces is the single most urgent challenge facing civil society today. Doubtless, history will judge us by our success or failure at this task.

Thus far I have underscored science and technology as forces shaping our objective world. The speed and extent of their impact on the world around us are bewildering, telescoping into decades changes that might earlier have required millennia. Yet if this were the full extent of their significance, their meaning for education would be very different from what is in fact the case. One might then simply declare, as many do, that we need only bring to bear eternal human values and old-fashioned common sense in order to tame the beast. Following this line of reasoning, one would require future scientists to take more of the existing courses in the humanities and give graduates of traditional humanities programs as much control as possible over the supposedly value-free world of mathematics, science, and technology.

Life is not so simple. For as much as science has changed our outer world, it is also reshaping our inner lives. Indeed, virtually all of the touchstones of our world view today are profoundly affected by the insights of science.

Back in 1912 the mathematician and philosopher Bertrand Russell wrote a tidy volume titled *The Problems of Philosophy*. (When this same Bertrand Russell was a guest at the Oberlin president's house, he left his shoes outside his bedroom door to be polished. President Stevenson, not wanting to disappoint the great man, polished them himself.) Russell summarized the problems of philosophy in terms of a few simple relationships: the relation of humanity to God, to nature, to our fellow men and women, to time and history, etc. Under the impact of modern science, every one of these relationships is undergoing profound changes.

Does the universe have an edge, and does time have a beginning or an end? How did life begin, and how long is it fated to endure? Such questions have preoccupied human beings from the dawn of human time. They have been central concerns of thinkers from the times of Plato, Aristotle, and the founders of the world's religions. It is necessary and fitting that philosophers, theologians, and poets continue to ponder them and to plumb their meaning for our lives. Yet in our century it has been the physicists, mathematicians, biologists, chemists, and geologists who have stood on the cutting edge of these cosmological issues. Whether we accept or reject the hypotheses advanced by



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Fred Johnson (left), a senior from West Alexander, Pa., explains the operation of the vacuum chamber for atomic beam work to Paul Kimoto (right), a junior from Martinez, Calif. Looking on is physics Professor Joseph Snider, who built the apparatus. The vacuum chamber, which is divided into two separately pumped smaller chambers that can be evacuated to a pressure of about one-billionth that of normal pressure, is used by advanced physics students and honors students to study the dependence of beam intensity on electric or magnetic fields, and to learn about the size and internal structures of the atoms in the beam.

these people, we cannot pretend that their discoveries have not occurred or live our lives in ignorance of them.

The questions posed by scientists today are awesome in scale. The physicist John Wheeler asks "What is the machinery of existence?", realistically expecting to find the answer in some grand unifying theory of nature of the sort sought by thinkers since the time of Leibniz. The very title of the recently translated book by two Russian scientists, Ya. B. Zeldovich and I.D. Novikov, expresses this grand aspiration: *The Structure and Evolution of the Universe.*

Bold new ideas even on the nature of thinking itself are emerging. Nobel laureate Roger Sperry speaks of recent models of the human brain in which "the causal potency of an idea, or an ideal, becomes just as real as that of a molecule, a cell, or a nerve impulse." Thus, discussions on human consciousness that began in probability theory are leading this distinguished Oberlin alumnus into the realms of commitment and belief. Science, in short, is deeply engaged with most of the great questions that are still thought by many to be the exclusive concern of the humanities and social sciences. William W. Lowrance of Rockefeller University writes eloquently on this point in his recently published monograph, *Modern Science and Human Values:*

> *Science has transmuted quite a few major cultural myths; negated many superstitions; left us living in a "dis-enchanted" world; imparted substance to a host of miasmas, humours, auras, scourges, and vital forces; recast the mind-body, nature-nurture, and other classic mysteries; and conspicuously revealed the hand of Man where none was seen before but Fortune's. Science reveals fundamentals about the occurrence and causes of mortality, genetic inheritance, and material wealth; gives us insights into where we have come from, and into our place in the universe; enables us to understand how we perceive what we see and mean what we say; and not only describes particular cultures, but helps us elaborate the very notions of "culture" and "society."*

# America's Retreat from Science and Mathematics

One would think that Americans, confronted by so vast and provocative a frontier, would rush to acquire the equipment essential to cross it. One might think that those for whom the philosophical aspects of science hold no interest might at least seize on its practical implications. At a minimum, one might think that anyone who feels threatened by the claims of science would speedily gain the modicum of scientific knowledge necessary to oppose them.

Nothing of the sort is occurring. The percentage of entering college students intending to major in basic science or mathematics has fallen by one-third within a decade; their absolute number has diminished by nearly 40 percent. Those who actually complete such majors, of course, are still fewer in number. Some fields have fared particularly poorly. For example, over 27,000 Americans received bachelor's degrees in mathematics and statistics in the early 1970s. By 1982 the total had fallen to approximately 11,000, a 60 percent decrease that can be only partly explained by the rise of computer studies. No sector of higher education, including research universities and Ivy League schools, has been immune to these general trends.

In light of the appalling record of American high schools in mathematics and science, there is no reason to think that the situation will soon improve. Fewer than half of U.S. high school graduates have studied mathematics and science for even one year, and only one in ten has taken any physics prior to graduation. The number of American high school graduates who have received adequate preparation in these fields is minuscule and falling.

By comparison, in Japan, West Germany, and the Soviet Union, *all* high school graduates have had at least four years in each area. In the Soviet Union, every high school senior has taken five years of algebra and geometry and two years of calculus. Since 97 percent of each age cohort continues through to graduation there, it is obvious that the Soviet Union's prospective intellectual resources in these key areas are now, or will soon become, vastly superior to ours.

It is not only the Soviet Union, Japan, and West Germany that surpass us. A recent comparative study of the mathematical knowledge of American eighth graders and that of eighth graders in seventeen other nations revealed that American students outperform only those from certain Third World countries. A study of the top 10 percent of eighteen-year-olds in ten different nations placed the United States last in calculus, algebra, and other areas of mathematics. Stated differently, high school graduates in all other countries but the least developed are now expected to have studied enough mathematics to follow the outline of Newton's argument in his *Principia* of 1687. Few Americans can do so, and their ranks are scarcely expanded by the time they graduate from college.

Inevitably, the erosion of basic science and mathematics in secondary schools and universities is affecting graduate education as well. Over the past decade the absolute number of doctoral degrees granted in basic science and mathematics has declined by 21 percent. The reduced number of graduate students now on American university campuses combined with the bleak demography for college-age students from now through the mid-1990s assures that this decline will continue. Again, critical fields have been especially hard hit, with the number of Ph.D.s granted in mathematics falling by fully 40 percent in the same decade to only 728 in the nation in 1981. As this occurs, the average age of America's specialists in science and mathematics is rising, with only 12 percent of the total now under thirty-five years of age.

Given these facts, will there be qualified men and women available to lead some future renewal of these disciplines in schools and on university campuses? It is doubtful. The shrinking pool from which future teachers and professors can be drawn will limit any efforts at rebuilding these fields. Moreover, the lure of better salaries in industry is proving irresistible to many who are qualified to fill posts in education. In the field of mathematics, for example, twice as many Ph.D.s are finding work in industry than a decade ago. It is no wonder that the proportion of students entering college who declare their intention to become college teachers has fallen by 80 percent since the late 1960s. Dr. Edward E. David, Jr., of Bell Laboratories predicts an annual shortfall of 150 Ph.D.s for college-level faculty positions in mathematics within a few years. Clearly, the National Science Board did not exaggerate when it warned that "the specter of a major shortage of qualified college mathematics faculty looms on the horizon." The same specter hangs over all scientific fields and threatens primary and secondary education no less than it does colleges and universities.

**Sharon Sutherland (seated), a senior honors student from Oberlin, Ohio, examines a mouse embryo through an inverted microscope fitted with micromanipulators. Her honors project, the formulation of new organic dyes that can be used as tracers, is directly related to the research of her honors adviser, biology Assistant Professor Yolanda Cruz (standing). The dyes will be injected into the cells of mouse embryos, enabling Cruz to track the lineage of the embryonic cells. On the table beside the microscope is a photograph of a three-day-old mouse embryo taken through the inverted microscope.**

With so few American nationals entering science and mathematics, American graduate schools have filled available places with recruits from abroad. In 1983, over half the students in all post-doctoral programs in physical science and mathematics were foreign-born, as were one-third of those in biology. Most of those who stay in the United States take jobs in industry rather than in education. Hence, to think that this country can solve its looming deficit of science teachers and professors by enticing immigrants to work in our educational system is as naive as to think that our need for manufactured goods can be met by closing domestic factories and turning to imports.

What are the consequences of this situation? On a practical level, they are already evident in Americans' diminishing ability to innovate. The number of patents issued to United States citizens declined by 40 percent between 1971 and 1981, a period in which the full impact of the educational crisis was yet to be felt.

No less ominous are the implications for our civic life. Gerard Piel, for years the publisher of *Scientific American*, warned an Oberlin audience last year that "on such vital issues as energy and the arms race the American people share no common body of knowledge nor mode of judgment to form a consensus." In terms of science, we are becoming a nation of Brahmins and paupers. Just as democratic society cannot exist where the financial wealth is concentrated in only a few hands, so too will democracy wither when scientific and technological knowledge is limited to a small elite within the nominally "educated" public and wholly lacking among the populace at large. This unhealthy situation already exists. And the trends are worsening.

## Can Liberal Arts Colleges Affect This Situation?

Given the enormity of the problem, one might well wonder if anything short of a national mobilization can check the downward spiral. Surely, one might think, liberal arts colleges are simply too small, too few, and too marginal in their commitment to science and mathematics to have any real impact on the situation, assuming that they had the inclination and resources to try.

This, at any rate, appears to be the reasoning that underlies a study on the health of America's colleges and universities issued by the White House Science Council in 1986. The word "college" appears in the title of the panel's report but then drops from sight. Of 150 persons with whom the group consulted, only Alfred F. MacKay, dean of the College of Arts and Sciences at Oberlin, hails from a liberal arts college. The same disregard for such institutions has long prevailed at the National Science Foundation, which has never devoted more than a trivially small percentage of its budget to strengthening educational programs at four-year institutions. The State of Ohio has reached similar conclusions about private four-year colleges and therefore excluded them from competing for monies to support science education under its well-funded Program Excellence. With a few notable exceptions, corporations have also shunned liberal arts colleges in their major gift programs for science, directing their largess mainly to public multiversities, which the same firms are otherwise supporting through state taxes. For the most part, private liberal arts colleges have been ignored and left to fend for themselves in the area of science education.

But research conducted by Oberlin's provost, Sam C. Carrier, and director of institutional research, David Davis-Van Atta, refutes the view that four-year colleges can have little impact on the fate of American science as a whole. Working on behalf of the presidents of fifty liberal arts colleges that have distinguished themselves in science and mathematics, the Oberlin researchers have shown that the role such schools play in American science is completely out of proportion to their size. On the average, fully 27 percent of entering students at these institutions intend to major in science or mathematics. Not only does this exceed the national average (6 percent) by more than a factor of four, it far surpasses the rate at even the most selective "elite" private universities (17 percent). And while the proportion of first-year students at elite universities intending to major in science or mathematics fell from twenty-six to seventeen per hundred between 1976 and 1984, these fifty colleges experienced no decline at all. Since many of the colleges' student bodies expanded during these years, the actual number of mathematics and science B.A.s prepared at these top schools actually rose over the past decade by 23 percent. By contrast, the number of B.A. graduates in basic science and mathematics from the twenty institutions ranked by the National Academy of Sciences as the premier "research universities" fell by nearly 20 percent.

The disproportionate and growing contribution of liberal arts colleges

**Geology honors student Kathryn Schubel of Setauket, N.Y., works with her adviser, Associate Professor Bruce Simonson, on the geology department's Nikon petrographic microscope. For her honors project, Schubel is performing a textural analysis of chert from deposits in salt lakes in Kenya. Nonmarine chert is relatively rare and no one has done a textural analysis of it before, according to Simonson.**

to American science can be appreciated by considering specific disciplines. For example, more than half of all American physics majors each year come from schools that do not award doctoral degrees. At the colleges included in the Oberlin study, the number of physics majors has increased 70 percent since the mid-1970s, a period in which total undergraduate enrollment in physics declined nationally. As a result, twenty of the fifty institutions with the largest percentage of graduates going on to earn Ph.D.s in physical science are liberal arts colleges. Similar figures can be cited for biology, chemistry, and other fields. Is it surprising that liberal arts colleges should constitute at least half of the most productive institutions, measured by the percentage of their alumni who receive National Science Foundation fellowships, who earn Ph.D.s in science or mathematics, or who are listed in *American Men and Women of Science* and *Who's Who in Frontier Science and Technology?*

The liberal arts colleges, with Oberlin very prominent among them, have proven to be the most efficient and effective category of schools in the United States for the preparation of scientists and mathematicians. Whether one speaks of quality or quantity, this assertion holds true, and it has been acknowledged by the National Science Board and the National Research Council, as well as such publications as *Technology Review*, *Science*, *Nature*, and *The New York Times*.

A top liberal arts college, then, stands as an exception to virtually all the negative trends that account for the current crisis in American science. If, and when, the American public faces up to this crisis, it will perforce be drawn to the experience of Oberlin and its peer institutions. When that time comes, Oberlin will be called upon to exercise leadership in an area crucial to the nation's economic and intellectual well-being. It is all the more important, therefore, that Oberlinians be able to articulate the main elements underlying their school's approach to science.

## *Why Liberal Arts Colleges Like Oberlin Succeed Where Multiversities Fail*

It may not be obvious why a liberal arts college like Oberlin should produce more graduates who go on to earn the doctorate in science or mathematics than such premier universities as Cornell, Harvard, Yale, and Columbia. Nor is it immediately evident why the works of Oberlin-educated scientists should be cited more frequently in the scientific literature than that of scientists trained as undergraduates at Stanford or Brown (not to mention all liberal arts colleges except Swarthmore). Yet some of the reasons for these successes are well known to every Oberlin graduate and other reasons have only recently emerged through the research conducted at Oberlin and elsewhere. All these studies point to three main factors: the amount of direct student-faculty contact; the curricular emphasis upon fundamentals and breadth, rather than upon applied studies and specialized learning; and the degree to which education goes forward in an environment of scholarship and research. Each factor warrants our closer attention.

**1. Student-Faculty Contact**

No factor is more important to Oberlin's strength in the sciences and mathematics than the quantity and quality of student-faculty contact. The point at issue here is not merely the much-cited "faculty/student ratio." It is true, of course, that Oberlin and other colleges have far fewer students per regular faculty member than the multiversities, but they are equalled or surpassed in this regard by many of the elite private universities. The difference is that at Oberlin all faculty members teach undergraduates, and no Oberlin undergraduates are taught by graduate students. This results in an *effective* student/faculty ratio that is far more favorable than that at any university. Nor are senior faculty members at Oberlin "rewarded" by being released to serve as consultants to off-campus projects or otherwise freed from what should be their first responsibility—teaching. Finally, the close physical proximity to each other of lecture halls, faculty members' offices, and laboratories (not to mention faculty homes) further enhances the opportunities for easy interchange between Oberlin students and their professors.

Such factors help explain the relatively low attrition of prospective scientists into other fields. Equally important, they account for the ability of leading liberal arts colleges to stimulate a sense of vocation for science and mathematics among groups that until recently were scarcely represented in those fields.

Women number only one-third of science majors throughout the country, but at leading liberal arts colleges they now make up nearly one-half the overall total and nearly three-fifths of the total in biology. At Oberlin, 45 percent of all science graduates are women. To be sure, only about one-tenth of all science faculty members are women, but this figure represents a trebling over the past decade.

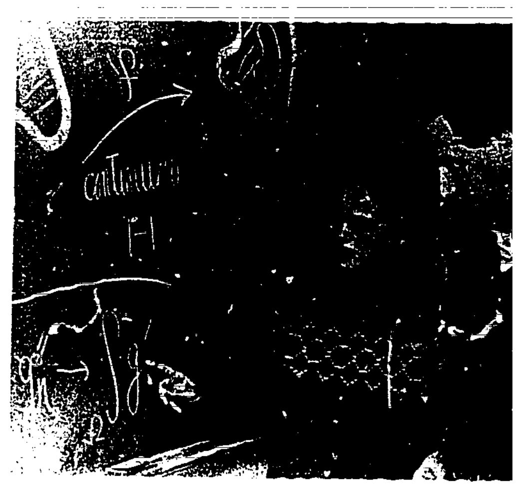
The ability of liberal arts colleges in general and of Oberlin in particular to educate minority students in science is even more pronounced. Fully two-thirds of all current black and Hispanic undergraduate majors in physics in the United States are studying at the main liberal arts colleges. Oberlin's unusually strong showing in this area can be attributed in part to the strength of its initial recruiting, and also to the fact that both science faculty members and the staff of the Office of Developmental Services extend help to all students requiring special tutoring.

**2. A Stress on Breadth**

Breadth, the second factor contributing to the liberal arts colleges' strength in science, is in part a product of necessity. Universities often offer three or four different introductory courses in each field, every one of them tailored to the specialized needs of future doctors, engineers, or other professionals. At Oberlin and other colleges there is generally only one basic introductory course per scientific discipline. Professors offering such courses must stress general principles rather than the more parochial concepts pertinent to separate professions. This is the easier because fully 62 percent of introductory courses in science and mathematics at Oberlin are taught by senior members of the faculty, seasoned men and women with the broadest overview of their subjects.

**3. Climate for Research**

Much has been written about the baneful effect on teaching of excessive faculty involvement in research. Yet faculty research of the type conducted at Oberlin and other liberal arts colleges is integral to the success of the teaching program. Knowledge outpaces the textbooks in virtually every field. Richard Levin, professor of biology at Oberlin, seeks to shrink that gap in his forthcoming introductory text, just as professor Thomas F. Sherman has done in his widely-used general biology textbook. The surest way to expose students to the latest thinking, however, is not merely to use up-to-date textbooks but to engage them directly in the actual processes of science by means of laboratory research. Thanks to extensive faculty research at Oberlin and other liberal arts colleges, undergraduates at these schools gain such first-hand exposure. With no graduate students to serve as research associates, Oberlin faculty members turn to undergraduates and devote the time necessary to initiate them into the complexities of their research projects. Hence, an undergraduate's association with a major research project at Oberlin is far more common and educationally rewarding than would be the equivalent experience in a university, where graduate students and post-doctorals would guide their work. So close is the collaboration that develops that some twenty to twenty-five published



Mathematics honors student Elizabeth LaFond, a senior from St. Joseph, Minn., discusses Brouwer's Theorem on the Invariance of Domain with mathematics Professor Robert Young. Young is supervising LaFond's honors project in the area of real and functional analysis, in which Brouwer's Thearem plays a fundamental role.

articles on research are co-authored by Oberlin students and their faculty mentors each year. The system under which they collaborate is akin to apprenticeship.

Not all scientific research is appropriate to the scale of a liberal arts campus. Daniel Kleppner, writing in *Physics Today*, hails the intensity and focus of "small-scale science" such as that practiced in the colleges. At Oberlin, biologist Dennis N. Luck's work in genetic engineering, chemist Richard C. Schoonmaker's experimental studies with the dynamics of gas-surface interactions in the mechanism of condensation, physicist Robert E. Warner's research on multi-particle breakup reactions between light nuclei, or biologist Michael Zimmerman's studies on how flowering plants manipulate their insect pollinators with food rewards are but a few of the many faculty projects that create superb learning conditions for students. Some thirty-five undergraduates have been involved with Professor Zimmerman's work alone, which has been supported by grants totaling $200,000 from the National Science Foundation and the U.S. Department of Agriculture.

Research is absolutely essential to the success of Oberlin's pedagogy. As C. S. Weisskopf wrote in the *Bulletin of the American Scientist*, it is important "not just for what it produces, but because, through it, an atmosphere of creativity is established which permeates every cultural frontier." Through participation in research, students are linked with what the late Derek Price called the "invisible national college" of men and women on the frontiers of their field.

Close interchange between faculty members and students, an emphasis upon fundamentals and breadth, and direct student exposure to the world of research are the three pillars undergirding Oberlin's approach to scientific and mathematical education. None of these, however, is so firmly established that its existence can be taken for granted. Each has been sustained by conditions that have existed in the past but which will not necessarily continue into the future.

For all Oberlin's strength, a number of unsettling conditions can be discerned. The upward leap of mathematics SAT scores in this year's freshman class sets a twenty-year record for improvement in a single year, but there was a slight decline in the number of those intending to major in mathematics or science. While overall science enrollments are holding steady, several fields and key subfields have witnessed uncharacteristic declines. The decade-long freeze on faculty hiring, lifted last year, discouraged innovations in curriculum that required new staffing. Support for faculty careers, while adequate a generation ago, does not meet today's expectations. And laboratory equipment in several areas is outmoded or wearing out.

The correction of these shortcomings, as well as the anticipation of new needs, head the College's agenda in science for the coming period. Let us, therefore, review current actions and future plans in each area, mindful that such efforts will determine Oberlin's ability to meet the needs of its students and to fulfill its national mission.

Chemistry Assistant Professor Albert Matlin and David McGarvey, a senior from Lorain, Ohio, work together to distill a solvent for use in their photochemical studies of organic molecules.

# *Oberlin's Present Actions, Future Plans*

## Recruiting the Gifted in Science and Mathematics

The long neglect of mathematics and sciences in American schools has lowered the general level of preparation in these areas and shrunk the pool of qualified candidates for admission to major colleges and universities. Until recently, Oberlin's Office of Admissions has lacked the requisite expertise for successful recruitment in these areas. Many talented potential students have been lost to other schools simply because the opportunities at Oberlin were not made sufficiently well known to them.

To help remedy this situation, Oberlin's new director of admissions in the College of Arts and Sciences, Elizabeth A. DeLaHunt, has appointed J. Leon Washington to her staff. In addition to his work in the recruitment of black students, Washington, whose background is in biology, will serve as a kind of "conscience of science" in the admissions office. Other admissions staff members are becoming more conversant with the College's programs in this area.

This is but one of several recent Oberlin initiatives involving secondary schools. The newly founded Oberlin Teachers Academy has made contact with all science department chairpersons in regional high schools, exploring ways in which the College can assist them in their work. As a result, the Teachers Academy has mounted a series of intensive programs for secondary-school teachers. Summer or weekend courses titled "Laser Technologies Now and Tomorrow," "Concept and Experiment in Physics," "Social and Scientific Issues in Genetics," and "Mathematical Problem Solving" as well as computer science workshops have all elicited enthusiastic responses.

Meanwhile, the Department of Mathematics has appointed Dr. Rudd Crawford to spearhead its work in the schools. Crawford, recently honored as a Teacher of the Year and the 1984 Ohio winner of the Presidential Award for Excellence in Science and Mathematics Teaching, will expand the department's outreach to high-school mathematics teachers across the country. He will also offer courses for Oberlin students interested in teaching mathematics at the precollege level.

Madeleine Msall, a senior physics major from Oak Park, Ill., discusses the next stage of her honors project with her adviser, Assistant Professor Daniel Styer. The project involves writing a computer program to draw pictures of diffusion limited aggregation clusters and analyze the results. The ultimate goal of the project is to gain an understanding of the growth of such dendritic structures as snowflakes.

National efforts to increase the disastrously low number of black students being prepared in basic science and mathematics have failed. Suffice it to say that only 3,741 black college students received bachelor's degrees in these fields nationwide in 1983, just 4.7 percent of all such degrees. Patrick Penn, Oberlin's acting dean of developmental services, is seeking to mount an innovative summer program that will bring promising black high school juniors to campus for carefully planned programs of study. Although still in the planning stage at this writing and still awaiting funding, Penn's initiative should open new horizons to many black teenagers and provide a useful model for other colleges and universities to emulate.

## A Curriculum for the New Century

It is no secret that Oberlin's curriculum no longer assures that all students will graduate with a basic grounding in mathematics, let alone science. Only 32 percent of recent humanities graduates have taken the minimum number of courses in mathematics or science recommended (but not required) by the faculty's published guidelines. Therefore, in May 1985, the faculty elected a committee chaired by Professor Robert W. Tufts to address this problem. Using the existing requirement in expository writing as its model, the Tufts committee has recommended that all students be required to demonstrate competence in those quantitative skills needed for college-level work in the natural and social sciences. Moreover, the committee has recommended that the College, in Professor Tufts' words, "identify science as one of the fields of knowledge in which a liberally educated person needs at least a college-level introduction." Since the faculty has only begun to debate these proposals and the larger curricular reform of which they are a part, one can only guess about the likely outcome. It is clear, however, that few consider the present system of guidelines to be adequate.

The sheer dynamism of modern science presents a heady challenge to college and university curricula. Cautious and laudably suspicious of fads, the professoriate must nonetheless respond to new areas of knowledge that take root in our world. Oberlin's faculty has accepted this challenge, creating two entirely new programs and some thirty-three new science and mathematics courses in existing departments since 1983. More new courses are planned.

The discipline of computer science was born in the 1940s with the invention of the stored-program electronic computer. Oberlin jumped in early and by the 1960s had become a leader in the educational use of computers. Today's challenge is to integrate computer studies into the curriculum. With roots in mathematics and logic, computer science at Oberlin is now a full-fledged program offering some nineteen courses. Oberlin's computer science curriculum, with introductory-level courses similar to those offered at M.I.T. and advanced courses of the beginning graduate level, has attracted the attention of employers such as Alcoa Corporation and Bell Laboratories, all of whom have been very pleased with the knowledge and versatility of Oberlin graduates and undergraduates they have hired. Firmly grounded in the liberal arts setting, Oberlin's program in computer science has produced highly qualified computer professionals. The recruitment of new top faculty in this area has proven difficult, however, since the competition for scarce talent is extraordinarily keen.

No recent Oberlin initiative in science has been more innovative than the establishment this year of a Neuroscience and Biopsychology Program. Tracing its origins to a psychobiology major dating to 1972, the program today graduates about eighteen majors per year. Many of these join the large numbers of Oberlin science graduates who enter medical schools. The Neuroscience and Biopsychology Program at Oberlin is, to our knowledge, the only such program approaching this size at a liberal arts college.

The demonstrated ability of Oberlin science departments to review continually their offerings and to create new courses when necessary augurs well for the future. Last year the Department of Geology alone introduced nine new or reorganized courses into its curriculum, while the Department of Biology created eight new offerings. Some of these new courses flow from special areas of expertise among the faculty. Professor Dennis N. Luck, for example, brings to bear his important research on genetic engineering in his new course, "Nucleic Acids and Molecular Genetics."

Are Oberlin's science courses only for scientists? This charge, often heard in the past, is decisively refuted by a series of newly instituted courses in many departments. Professor Terry S. Carlton of the Department of Chemistry, for example, teaches "Energy Technology" and "Nuclear Power," courses specifically designed for students *not* majoring in science. These courses and others, such as Professor Richard Schoonmaker's "Chemistry and the Environment" are particularly valuable for those students interested in questions of public policy. Physicist Robert E. Warner's course "Sound, Musical Instruments, and Acoustics" is a perennial favorite among Conservatory students, while biologist Thomas F. Sherman's course "Size and Form in Nature" draws many students interested in the aesthetics of the natural world. And who can fail to be intrigued by the very title of mathematician Robert M. Young's course, "The Infinite"? With the appearance of the book on this topic which Professor Young is now writing, courses on the infinite may well appear on other campuses.

Every one of these courses made its debut in the curriculum within the past few years. Each of them bridges heretofore encapsulated worlds of learning. Together, they attest to a point made recently by David H. Benzing, chairman of the Department of Biology, that "at no point over the past two decades has there been so much change . . . or opportunity for innovation and improvement."

## Supporting Faculty Careers in Science

The retirements of mathematician Samuel P. Goldberg, biologist Warren F. Walker, and physicist David L. Anderson, along with the untimely death of biologist Anna Ruth Brummett, remind us of the constant need to renew faculty leadership through the vigorous recruitment of young faculty members and through steady support for their careers. Under the leadership of Dean Alfred F. MacKay, Oberlin is taking important steps to achieve these ends. And none too soon, for the competitive environment is fierce; high salaries in industry have drawn many scientists away from academia and intensified competition for the rest. One of the College's highly regarded scientists was recently attracted to another institution in part by a salary 40 percent greater than he had been receiving at Oberlin. Yolanda P. Cruz, a promising Berkeley-trained biologist, might not have been able to come to Oberlin had the College been unable to provide the $50,000 she needed to establish a laboratory here.

Such examples underscore the importance of adequate support through both salaries and facilitating grants. An expanded program of paid research leaves and summer stipends for junior faculty members that is presently being set in place in accordance with the "Tenure Report" will further enhance Oberlin's commitment to its rising faculty leaders.

It would be wrong, however, to conclude that the College is, or should be, the sole source of support for faculty development. Oberlin's scientists themselves have achieved impressive successes in attracting external grants to support their research and course development. Over the last five years they have received over $2 million for these purposes. Another $750 thousand has come for the purchase of research equipment and instruments. Such grants honor the exceptional work being conducted by Oberlin scientists and mathematicians. No less, they testify to long hours spent in preparing grant applications, which in just four years have more than doubled in number. Beginning this autumn, Oberlin became the first liberal arts college to have a fully staffed Office of Sponsored Projects designed solely to assist faculty members in this work; the office is headed by Associate Provost David Love.

The fact that faculty research brings direct benefits to students cannot be overstressed. Recognizing this, the College, with help from the Charles A. Dana Foundation, has established an unprecedented program that pays up to 120 students per year to work as assistants on faculty research projects. One such Dana studentship enabled Lydia Oey of Malone, New York, to work for Professor David H. Benzing analyzing and mapping patterns of industrial metal contamination in Spanish moss in order to determine the extent of air pollution in southeastern Texas. Supported by another Dana studentship, Timothy Pettit of Cedar Grove, New Jersey, built a model of the myoglobin molecule that helped Professor William H. Fuchsman develop new interpretations of existing spectroscopic data. Tim writes that "building this model has helped augment my understanding of these proteins, as well as demystify them." Paul Martin, a chemistry major from Worthington, Ohio, has worked with two of his professors under the Dana-Oberlin program and while doing so confirmed his interests in pursuing graduate education and a career in biochemical research.

## Equipping Oberlin for Science

The National Science Board has recently characterized laboratory instruction on America's campuses as "often uninspired, tedious, and dull." Elsewhere, it notes that a quarter of all laboratory teaching instruments are now obsolete.

The success of Oberlin's science graduates suggests that the Science Board's assertion on the quality of laboratory teaching does not apply to the College. Its characterization of lab equipment, however, may ring true. Instruments used in the introductory physics course are out of date, unreliable, and have what Department of Physics chairman W. Bruce Richards calls "an antique appearance." In many departments,

**Watching brine shrimp (*Artemia salina*) hatch on television? That's precisely what biology Professor David Egloff (right), senior Thomas E. Smallwood of Elyria, Ohio (center), and junior Lynda S. Freundlich of East Syracuse, N.Y. (left), are doing. The video system, which is attached to a dissecting microscope, permits Egloff to demonstrate microscopic objects and events to groups of students in his invertebrate biology course.**

essential instruments for laboratory research by students and faculty members are either lacking or inadequate for modern needs. The rapid pace of change in the field of computer science creates special problems of equipping laboratories in that field.

Such problems are not new. A letter from Professor C. H. Churchill to the College treasurer in 1864 finds the former pleading for permission to spend $3.50 for "one of those little hygrometers." Even earlier, in the 1830s, the parsimonious trustees gave their approval to a request from Professor Dascomb to be allowed to spend $400 to equip his new laboratory—on the condition that he would personally take to the field as financial agent and raise the money. Today, as has been noted, professors themselves are helping raise much of the money needed to equip their teaching and research laboratories. The Office of Development is also committed to finding support in this area and works closely with professors to attract major gifts. A recent product of this collaboration is the formidably named "superconducting Fourier-transform nuclear magnetic resonance spectrometer," purchased last year for $186,000. Another example is the new respiratory physiology laboratory established by Professor Thomas F. Sherman with the help of a major grant from the National Science Foundation. A stunning gift of $500,000 from the Sherman Fairchild Foundation will upgrade scientific equipment across the campus. These, along with timely grants from DuPont, Alcoa, Dow, and Merck and Co. (the latter in recognition of fundamental research in polypeptides by Ralph F. Hirschmann, OC'43), all testify to confidence on the part of many donors in the quality of Oberlin's science faculty and in the commitment of Oberlin College as a whole to the scientific enterprise.

Steps are being taken to improve the maintenance of laboratory equipment as well. A newly appointed electronics technician will serve the needs of several departments, while a recently resuscitated physics shop will have the capacity to build the "one-of-a-kind" equipment often required for work in that field, as well as to modify equipment as needed for work in all fields of science.

Beware the college or university that makes a fetish of its buildings! However, several of Oberlin's science departments are so poorly housed as to impede teaching and research. Eighty-six-year-old Severance Laboratory was never suitable for modern departments of psychology or geology. A complete renovation, to be carried out next year, will result in a building better able to meet the needs of some of Oberlin's most productive scientists. A fully renovated Carnegie Library will soon include offices for the Department of Geology, which over the years has been one of the strongest programs in that field at any liberal arts college. Plans are also under way for an addition to the Kettering Hall of Science that will house the burgeoning Neuroscience and Biopsychology Program. The Wilbur and Orville Wright Laboratory of Physics is not yet scheduled for renovation, but it, too, will require attention during the coming decade.

## A Climate Favorable to Science and Mathematics

Well-equipped laboratories are essential to the practice of science, as are vigorous programs for student and faculty recruitment and firm structures for the support of faculty careers. However, these are all means to an end, and not the end itself. Oberlin's objective must be to assure that the climate of the campus as a whole is hospitable to the pursuit of science and mathematics. Oberlinians can take pride in the many new or revised courses for science majors, and also in the many innovative courses in mathematics and the sciences specifically designed for non-majors. The latter reflect the degree to which mathematics-based fields at Oberlin have been leavened by contact with the social sciences and humanities. But what about the reverse process? To

Geology Associate Professor Bruce Simonson (right) lectures to students in his "Modern and Ancient Sedimentary Environments" class on site at Tinkers Creek, part of the Bedford (Ohio) Reservation. The 350-million-year-old bedrock behind the group, which dates from the Mississippian period, is the deposit of an ancient delta. Simonson's class is one of the core courses for geology majors.

what extent have the approach and insights of science penetrated the other principal fields of learning?

With the help of a handsome grant from the Alfred P. Sloan Foundation, Oberlin has generated a number of new courses in the social sciences and humanities bearing on science and technology. In the Art Department, for example, Professor John Pearson teaches a popular course titled "The Computer in Art," drawing on his considerable expertise in that emerging area. Professor Susan Kane exploits the world of engineering and structural design for her course "The Technology of Ancient Architecture." Analogous links with science exist in recently instituted courses in anthropology and international relations. And beginning next fall, Professor Richard Salter will explore recent innovations in the area of artificial intelligence in his course "Fifth-Generation Computing."

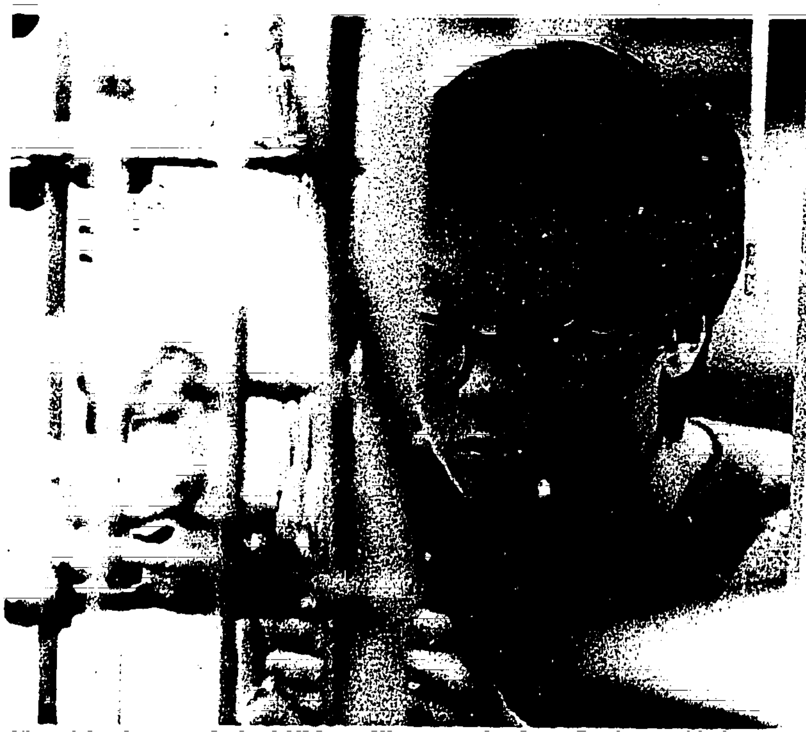
Yet, as a nonscientist myself, I worry about whether the humanities and social sciences at Oberlin—and in American higher education as a whole—have not unduly insulated themselves from the world of science. We are far more disposed to ponder the social role of science than to explore its essential nature, let alone the full implications of its findings for our culture as a whole. Gerard Piel offers a gloomy perspective on this national issue: "Taught in ignorance of science, for the most part, the humanities (Could he not as well have included the social sciences?—*SFS)* convey a deeply false picture of human identity and experience." This may be overstated and hence unfair. What cannot be denied, however, is that very few American professors in the humanities and social sciences have themselves received the kind of grounding in mathematics and science that we are coming to expect of students. Lacking this, they—better, we—are alienated from the basic *process* of scientific inquiry and disinclined to acknowledge the implications of its results for our world view as a whole. In short, many in the humanities and social sciences unintentionally perpetuate the very schism between mathematical and literary learning that they decry in others. Surely, the time has come for educators to address this problem of the "two cultures" honestly and profoundly.

In the beginning of this report I wrote of the crisis arising from the stark contrast in our country between the achievements of science and mathematics and the tragic neglect of these fields by the entire educational system. I suggested that the leading liberal arts colleges, and Oberlin in particular, are called upon to provide leadership in resolving this crisis. Oberlin's accomplishments in science impose this role on the College. Its current actions and plans are intended to equip it to fulfill that role responsibly.

The most fundamental and at the same time urgent need is to reach a serious consensus, however, on the specific amount and type of scientific learning essential for an educated person in the next century. There is no easy answer to this question, nor should we desire one. On the contrary, a facile response, even though it might somehow embrace all our contradictory values at a given moment, would surely become a towering impediment to the kind of questioning and rethinking that the College should be fostering at all times.

As it explores these issues itself, Oberlin is well positioned to exert a positive influence on the course of debate nationally. Thanks to its relatively small size, it can experiment and innovate; its programs in science and mathematics can thus serve as laboratories for universities, and, no less, for the many colleges that lack the resources that Oberlin commands. Oberlin can also bring a useful point of view to the current debates on the role of mathematics and science in the schools. Few elite institutions of higher education maintain contact with as many or as diverse a group of secondary schools as Oberlin does. As competition for admission to Oberlin grows more intense, educators in secondary schools will continue to scrutinize Oberlin's standards more carefully, drawing the appropriate conclusions for their own programs. Finally, Oberlin's expanding personal links with secondary-school educators will provide numerous forums for further discussions on the place of science and mathematics in American education.

All this flows from, and accords closely with, Oberlin's historic purposes. Our challenge in the years ahead is to sustain the commitment and to assure the resources necessary to carry out this mission.



**Chemistry honors student Hidong Kim, a senior from Saginaw, Mich., prepares molecules for study by infrared and Raman spectroscopy. By creating molecules and studying their spectroscopic properties, Kim will learn more about the forces that hold molecules together.**

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