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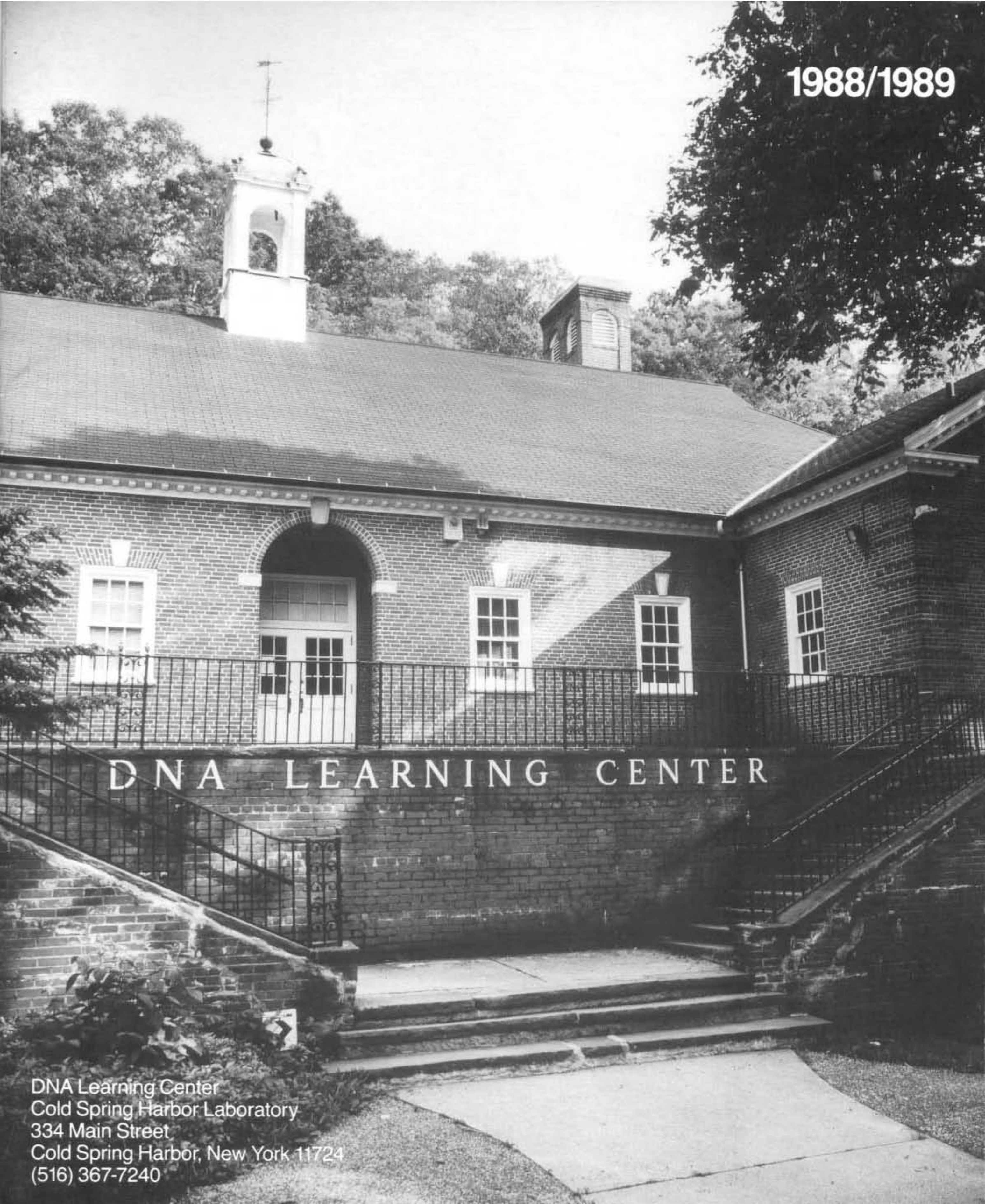

DNA Learning Center
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DNA LEARNING CENTER

David A. Micklos, Director
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This Annual Report marks the emergence of the DNA Learning Center (DNALC) as a new operating unit of Cold Spring Harbor Laboratory. Like its sister Banbury Center, founded in 1976, the DNALC has a separate operating budget and advisory board. The DNALC extends the traditional postgraduate education and research mission of Cold Spring Harbor Laboratory to the college, precollege, and public levels. The DNALC collaborates extensively with the Public Affairs Department and Banbury Center, which have overlapping roles in interpreting science and interacting with segments of the public.

The DNALC is the culmination of the DNA Literacy Program, which was initiated 5 years ago as the nation's first laboratory-based program to retrain precollege teachers in molecular genetics. At that time, many felt that we were a little mad to think that widespread public understanding of one molecule (DNA) could be so important. In fact, our first attempt for federal grant support of this program met with failure.

The dedication of the Learning Center on September 18th, 1988 marked the coming of age of that "crazy" idea. Opening-day tours of the facility were attended by 800 students, teachers, friends, and employees of Cold Spring Harbor Laboratory. A standing-room-only crowd of 400 packed Grace Auditorium for the dedication ceremony, at which Dr. Robert Pollock, Dean of Columbia College, delivered the keynote address, "Reading DNA." Backed by the prestige of Cold Spring Harbor Laboratory, the event sent a clear message that there is now room in the world for at least one institution devoted entirely to biotechnology education.

Scientists have already begun to write the history of discovery that has led us into the biotechnology era. Most of us cannot participate in discovery; however, each of us can help write the history of the first society to dwell in the gene age. Only through widespread education can we ensure a society that shepherds the benevolent use of genetic technology for the good of all its citizens.

Cold Spring Harbor Laboratory has provided for the world a model of what a research institute should be—a quiet place where people can solve the problems of biology. Similarly, we hope that the DNALC will provide a model of how a science education institute can help solve the problems of scientific illiteracy. Now, by our example, we must show the world that there is need for other DNA education units as well. To the extent that we prove that the general public is eager and able to learn about biotechnology, we also provide models of informal science education for other institutions to follow.

Cold Spring Harbor Laboratory Director James D. Watson with Robert Pollock, Dean of Columbia College, who delivered the keynote address at the Learning Center dedication on September 18, 1989. Huntington Town Supervisor Toni Rettaliata (above) also spoke.

The Human Genome Project

Written in the approximately 100,000 human genes is the molecular code-script that, to a large extent, determines the life and health of each individual. This entire complement of genetic instructions encoding human life is called the human genome.

During the last 15 years, biologists have gained the extraordinary ability to dissect precisely the molecules of DNA that comprise the human genome. The molecular dissection of the fundamental units of heredity has added rich detail to our understanding of how human life develops and changes—from fertilized egg to adulthood. It has also enabled scientists to pinpoint changes in the DNA molecule that predispose one to illnesses such as cancer, muscular dystrophy, Alzheimer's disease, and manic depression.

Until recently, the molecular exploration of the human genome has proceeded in a relatively uncoordinated fashion, with many scientific teams working independently on one or several genes of interest. The information so gathered can be likened to the individual squares of a patchwork quilt, each with its own story to tell. The inauguration of the Human Genome Project in 1988 marked the beginning of a national commitment to knit the patches of genetic research into a cohesive whole. Its goal is to determine the sequence of the estimated 3 billion bits of molecular information—the arrangement of nucleotide rungs of the DNA

The Search for Life exhibit includes a multi-projector slide show and a genetic code game. (Photo by Edward McCain.)

ladder—that constitute the entire code-script of human life. The Human Genome Office, established within the National Institutes of Health, now coordinates the collection, storage, and dissemination of research data collected by thousands of scientists throughout the country.

Possession of an increasingly complete code-script of hereditary information will bring numerous benefits to man- and womankind. Gene-mapping techniques have already made possible accurate DNA diagnosis of a number of debilitating illnesses. By pushing back the threshold of early disease detection, DNA diagnosis should increase therapy options and play a positive role in personal health management. Increased knowledge of the molecular basis of disease should lead to therapies that treat the cause, rather than the symptoms, of illness. Similar techniques are now used to produce DNA fingerprints, which are gaining acceptance as the most definitive evidence of identity in rape, murder, and paternity cases.

The day is not far off when medical doctors may maintain personal genetic profiles of their patients, and DNA fingerprints may replace thumb- and fingerprints on file with law enforcement agencies. Guidelines concerning access to and use of this information must be rigorously enforced to ensure protection of individual privacy rights.

Barbara McClintock previewed *The Search for Life* exhibit.

Building DNA Literacy

Biology, and with it, our society, has truly stepped into a new era. It is clear that the science of DNA will increasingly generate important public policy issues. If we indeed believe in the Madisonian concept of an informed citizenry that participates in public decision making, then DNA literacy can no longer be considered an esoteric pursuit.

As applications of DNA science leave the laboratories, trained personnel from nearly every segment of society must interface with this new technology. Young people entering the medical, agricultural, manufacturing, and even legal professions will be expected to have a basic command of DNA science. Within the scientific community, there is concern that shortages of researchers and technicians will retard the growth of biotechnology and limit its full potential.

The nation's schools are the logical place to begin building a DNA literate public. Unfortunately, biology curricula have evolved over the years by simply cramming in more and more facts. Survey data show, for example, that the vast majority of high school biology teachers spend most of class time lecturing from textbooks. Yet even the textbooks they teach from are typically 5 to 10 years out of date! Thus, at a time when scientists are embarking upon the most ambitious project in the history of biology, students are required to memorize terms and definitions of observational biology, a historical science of little relevance to current research or society.

Survey data also tell us that the majority of elementary school students are enthusiastic about science; however, student interest in science decreases dramatically through the junior and senior high school years. This suggests that young people are not turned off to science itself, but to the manner in which it is taught. Children start their lives as natural scientists. Turning over a rock is an expression of a seemingly innate curiosity about the living world. Rather than building upon this natural interest, formal science education effectively squelches young people's interest in science.

Experience-based learning—like the child's rock-turning inquiry—has long been touted as the means to increase student interest and comprehension of science. However, fewer and fewer biology students are given the opportunity for any sort of meaningful laboratory experience, let alone "advanced" experiments with DNA. It is a sad fact that biology education has changed little from the days of our grandparents. Hands-on laboratories are the exception; rote memorization is the norm.

The excitement of the Human Genome Project offers an important opportunity to reorganize public biology education. Now is the time to sweep clean the granny closet of biology education to make room for the excitement of modern biology—to replace recitation of facts with frequent laboratory investigation. It is time to let the awesome beauty of the DNA molecule integrate biological phenomena for young people as it has for the last two generations of scientists.

Laboratory Field Trips to the *Bio2000* Teaching Laboratory

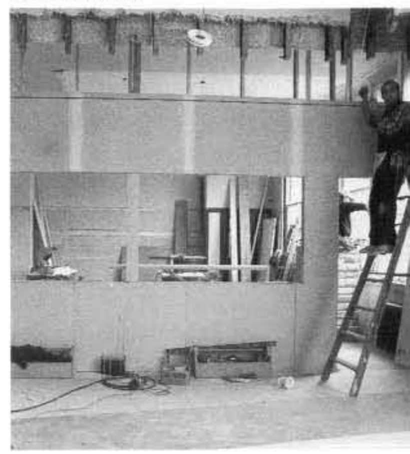
We live in an age when young people are buffeted by all manner of distractions that keep them from pondering the mystery of life. Students socialized to be fascinated by money, and what it can buy, have little time for physics or metaphysics. However, in working directly with DNA, the molecule of life, we may have the last decent chance to interest young people in the intellectual pleasure and social relevancy of that wonderful mystery. Thus, as plans were made for renovation of the Learning Center, priority was given to creating a teaching facility where hands-on laboratory experiences could be offered to the public. Designed to accommodate 24 participants, the *Bio2000* Laboratory was conceived as a model teaching facility of the 21st century. Anticipating that we could never service all the people interested in doing a DNA manipulation lab, we had a glass window-wall installed between the *Bio2000* Laboratory and the adjacent "observation room." We hope soon to add a closed-circuit television system, with monitors in both the laboratory and observation room, that will enable lab participants and observers to have a close-up view of the instructor's demonstrations.

In developing a laboratory field trip program, our aim was to put modern DNA technology within the reach of precollege science students and teachers. Lab experience gives the student a working knowledge of the possibilities and limitations of DNA technology, which is the basis for rational evaluation of the social and personal implications of biotechnology. Practical experience with DNA techniques, which until recently have been the sole province of researchers, reinforces that student experiments have current relevance and are "real science." For the motivated student, a DNA lab experience encourages information-seeking behavior, such as independent reading and research. The laboratory field trip also affords instructors a "micro-teaching" experience, giving them a nonthreatening exposure to DNA lab technology. Observing the Learning Center staff interact with their own students provides convincing proof that it is indeed possible for *real* students to perform DNA experiments.

The laboratory field trip program was initiated in spring of 1988, following completion of the *Bio2000* Laboratory. The program was an immediate success; every lab space has been continuously booked since that time, with a standing waiting list of 30 schools. Two laboratories are currently offered:

Bacterial Transformation. This experiment illustrates the direct link between an organism's genetic complement (genotype) and its observable characteristics (phenotype). Students introduce a new gene into the bacterium *Escherichia coli*, giving it the ability to grow in the presence of the antibiotic ampicillin. Teachers take culture plates back to their schools for incubation and discussion of results.

The *Bio2000* Laboratory, under renovation below, is visited by 2,800 students each year, including these from Hillcrest High School in Jamaica, Queens. (Photo by Mort Kelman.)



DNA Restriction Analysis. This experiment demonstrates that DNA can be precisely manipulated and that it behaves as predicted by the structure discovered by Watson and Crick in 1953. Students use restriction enzymes to cut purified DNA, and the resulting fragments are separated according to size using gel electrophoresis. Students take home Polaroid snapshots of their results.

In an era when fewer teachers have the time or equipment to offer meaningful lab experiences, the laboratory field trip program is a model for a cost-effective means to provide pooled laboratory resources to a local region. The *Bio2000* Laboratory has functioned at full capacity since the day it opened, serving 2800 students (160 classes) in its first year of operation. A DNA teaching lab like ours can be equipped for $10,000–20,000, and a field trip program can be operated at a cost of $30,000–50,000 per year (exclusive of utilities and facility overhead). By making routine the performance of several lab experiences, museums, regional science centers, vocational technology centers, and "magnet" schools can at once take up the slack in laboratory teaching and help to train teachers for independent instruction.

DNA Laboratories Come of Age

Over the years, we have fought the contention of many educators that DNA manipulation labs are too esoteric, too expensive, or too difficult for the high school setting. There is now growing conviction that such laboratories are, in fact, essential to a general biology education. This sentiment has been legitimized by the Educational Testing Service, which will recommend teaching bacterial transformation and DNA restriction analysis labs in the 1989–1990 Advanced Placement (AP) syllabus. These labs will likely become compulsory for AP students in 1993–1994.

As early as 1985, we were training local Long Island teachers to perform these experiments in the high school classroom. So, foresighted Long Island teachers will have been doing these labs as much as a decade before the majority of American biology teachers. Surely the students of these teachers have been similarly ahead of their college-bound peers.

Our experience with rural schools in Alabama and public schools in New York City indicates that DNA laboratories need not be confined to gifted high school students. Labs are perhaps even more important to the nongifted student, for whom involvement of several senses increases chances for internalization of the biological concepts. These students may possess greater manual dexterity, and achieve comparable or better results, than their academically gifted peers. Success with a laboratory manipulation may provide a handle with which the nongifted student can pull a theoretical concept into his or her realm of experience.

In spring 1989, we conducted a learning experiment that supports our contention that there is no intrinsic reason why young people should not be given the opportunity to try their hands at DNA manipulation labs. Eighteen gifted fifth and sixth graders from local school districts were invited into the *Bio2000* for a Saturday laboratory program called "Fun with DNA." During two introductory sessions, the youngsters observed and categorized *Drosophila* mutations, analyzed inheritance of kernel characteristics in corn, used classmates' trait data for a ministudy on population genetics, constructed models of DNA molecules, and learned to handle sophisticated micropipets. In the final session, the students successfully performed the DNA restriction analysis described above.

"Fun with DNA" marked our first venture into primary science education. These gifted 5th and 6th graders were the youngest group of students ever to perform a restriction analysis. The National Science Foundation has challenged science educators to focus attention on improving grade school science.

We found that the students' grasp of concepts was comparable to or better than that of many of the high school students we have taught. Working with these eager and inquisitive young scientists was at once invigorating and saddening: invigorating, because it showed us the full measure of childhood thirst for understanding of the natural world, and saddening, because we can only wonder in how precious few of these the spark of science will be kept alive through the remainder of their precollege schooling.

Vector DNA Science Workshops

The silver *Vector* vans that crisscross the country during the summer to give in-service training to high school and college instructors have become the identifying emblem of the DNA Literacy Program. Our successful *DNA Science Workshop* arose from a collaboration with eight neighboring school districts on Long Island—the Cold Spring Harbor Curriculum Study. These schools were used as a proving ground to develop a laboratory curriculum that illustrates the basic techniques of molecular genetics. Using equipment identical to that found in research laboratories, participants performed nine experiments that culminate in the production and analysis of recombinant-DNA molecules. The laboratory protocols were initially tested in spring 1985, and during that summer, the first training workshop was offered to introduce local high school teachers to the curriculum.

Enthusiasm from participants and interest from numerous educators around the country suggested the desirability of making the workshop available to teachers nationwide. Through a grant from Citibank, N.A., the first *Vector* van was purchased and equipped. In summers 1985 and 1986, a total of 266 educators attended eight workshops.

Receipt in 1987 of major 3-year grants from the National Science Foundation and the Josiah Macy, Jr. Foundation lent legitimacy to the proposition that it is indeed possible to "backpack" a DNA laboratory to essentially anywhere in the nation. These grants provide key support for our teaching staff, as well as stipend and travel expenses for workshop participants. They also allowed us to initiate a program of weekend follow-ups during the fall and winter to keep up the interest of participants and introduce teaching innovations.

Recognizing the educational value of this workshop experience, the State University of New York at Stony Brook agreed to offer a credit option to *Vector* workshop participants nationwide. Teachers who complete both a workshop and follow-up are eligible for three graduate credits from the Continuing Education

Senior Staff Scientist Ed Harlow gave a student lecture on "Recessive Oncogenes," focusing on the childhood cancer, retinoblastoma.

Department. A workshop has been held at the Stony Brook campus each summer since 1987, sponsored by the University's Center for Biotechnology.

Demand for courses in 1987 was great enough to justify the purchase of a second *Vector* van that enables two workshops to be taught simultaneously in different parts of the country. In summer 1987, 307 educators attended 14 workshops around the country. Two additional workshops were conducted for technicians and researchers at the Cleveland Clinic. Nearly 250 teachers were instructed by us at 13 sites in 1988.

The Evaluation Program

Through fall 1989, we have instructed nearly 1100 high school and college instructors in DNA science workshops. The majority of these individuals completed both a pre-survey at the beginning of the workshop and a post-survey at the end of their week-long training experience. In fall 1988, we began a mail survey to follow up on all teachers who had completed the workshop prior to 1988. The response of our "alumni" was overwhelming; 90% returned completed surveys. The good response was in large part due to adhering strictly to a detailed formatting guideline and to a series of follow-up mailings extending over 2 months.

We have just begun the arduous task of entering this mass of data for computer analysis. The amount of information is staggering—each case may have up to 280 bits of data. Furthermore, the amount of data increases each year, as we add new cases and follow up on a new class of "alumni." The total number of cases will increase by nearly one third in winter 1989, when we add some 300 teachers who have independently taught our workshop in collaborative programs in North Carolina, California, and Wisconsin.

By the end of 1989, we will have comparable data on nearly 1600 teachers who have taken the *DNA Science Workshop* over the last 5 years. Taken together, these data represent a substantial sampling of lead biology teachers nationwide and perhaps the most ambitious long-term study of high school biology teachers ever undertaken. From their responses, we hope to determine the characteristics of the "pioneer" teachers who will spearhead biotechnological literacy. We are especially interested in learning how lead teachers seek information and overcome constraints in converting positive attitudes about molecular biology into innovative teaching behavior.

Our data represent a treasure to be used and shared by opinion researchers and educators nationwide. However, we have only begun to scratch the surface of this load of data; layer after layer of insights remain to be revealed. Currently, we do not have sufficient staff time to do justice to the task. We do, however, have the nucleus of a strong evaluation team to carry on this and other educational research. Dave Micklos combines the perspective of a communication researcher with past experience in opinion research with a major public relations firm. John Kruper, who is using part of the survey data as the basis of his doctoral dissertation at the University of Illinois at Chicago, brings an educational perspective. We now need to locate specific funding to develop a full-time evaluation unit that focuses on the interface of biotechnology and society.

Initiating a Collegiate *Vector* Program

Our experience over the past 4 years has strengthened our conviction that the *DNA Science Workshop* is equally valuable to college teaching faculty who have little or no practical experience in molecular genetic analysis. In 1986 and 1987, a total of 28 college faculty teachers participated in our program. Follow-up survey data, collected in 1988, indicate that they were excited about their experience, and most have already begun to implement laboratories from the workshop into their teaching.

Our first workshop geared specifically to college teachers was held at Bethany College in West Virginia in June, 1989. This workshop was supported by a grant from the National Science Foundation to Bethany College and was attended by faculty members from a consortium of eight small colleges from West Virginia, Ohio, and Pennsylvania. Positive feedback from this workshop reinforced our belief that the information needs of college instructors are not far different from those of the high-caliber AP teachers we have regularly encountered. We envision the Bethany workshop as a model for a nationwide series of workshops patterned after our successful high school program.

Colleges and universities provide infrastructures conducive to implementing experiments introduced during the *DNA Science Workshop*. The entire course can serve as the core of a sophomore-level molecular biology course, or individual experiments can be integrated at various levels into the biology curricula, including courses on general biology, cell biology, microbiology, genetics, and biochemistry. Costs to equip and supply a DNA teaching laboratory are well within the means of most college biology departments.

Two-day workshops at regional meetings of the American Society of Microbiology (ASM) provide another means for introducing our hands-on approach to college educators nationwide. The success of workshops held in Seattle, Washington and Valley Forge, Pennsylvania in 1988 prompted us to expand our collaboration to five sites in 1989—East Lansing, Michigan; Louisville, Kentucky; Denver, Colorado; Houston, Texas; and Minneapolis, Minnesota.

Educational Collaborations

The Curriculum Study has grown to include 20 Long Island school districts, which receive numerous benefits, including lectures by scientists, reduced admission to Learning Center programs, teacher in-service workshops, and equipment purchase options. Curriculum Study teachers gain an insider's view of current biological research and of the future of modern biology teaching. As the Curriculum Study continues to grow, we strive to provide a support system for pioneer teachers on Long Island, who are retooling biology education for the next century.

Through our collaboration with the Josiah Macy, Jr. Foundation, we have extended our teacher-training and student programs to Macy-sponsored schools in inner-city New York and New Haven, Connecticut, as well as in rural Alabama and

Arizona. In summer 1988, minority/rural students and teacher chaperones representing each of the Macy-sponsored programs convened for a 2-week workshop at Tuba City, Arizona, within the Navajo Indian Reservation. The first week of the workshop provided a microteaching experience, where students and their instructors learned DNA manipulation techniques in preparation for implementing specialized laboratory courses at their home schools. During the second week, the focus expanded to natural history, geology, and cultural anthropology. In addition to tours of the natural wonders of the Grand Canyon and Monument Valley, and ancient Indian ruins at Wapatki National Monument and Canyon de Chelly, the students also experienced Native American culture first-hand during a 2-day "live-in" with Navajo families. In summer 1989, the format was repeated, this time relying on the cultural offerings of New York, including the Metropolitan Museum, Bronx Zoo, Museum of Natural History, Broadway, and the New York Mets.

Another ongoing collaboration is with the Macy BioPrep program at the University of Alabama, at Tuscaloosa, where a *DNA Science Workshop* has been held each year since 1987. With our assistance, the BioPrep staff has outfitted their own *Vector* van, which carries DNA restriction and bacterial transformation experiments to schools in rural Alabama. Since spring of 1988, the mobile laboratory has visited 39 schools, where BioPrep teachers have instructed 1300 students.

Through our collaboration with the Macy BioPrep Program, we continue to explore creative means to advance biology instruction in the many resource-poor schools in rural America. Beginning in summer 1989, we will provide laboratory instruction over the TI-IN United Star Network. This partnership between public education institutions and private enterprise uses satellite technology to bring live instructional programs to 750 schools in 32 states. The initial three-part broadcast on bacterial transformation, described above, should give AP teachers nationwide the confidence to rapidly introduce this experience into their laboratory program.

In several states, educational consortia have adopted our workshop as a mechanism for introducing teachers to the techniques of DNA manipulation. In many other locations, aspects of our workshop are being implemented one step at a time, as equipment and supplies become available.

The 1986 workshop held at the University of California at Davis prompted the creation of a state-supported instructional program. With funding from the National Science Foundation, a mentor/teacher program was established at San Francisco State University to give high school teachers training in recombinant DNA techniques and access to working researchers who serve as their mentors. Our workshop is taught at three locations in northern California each year, and they

ıddition to students, DNA ıalysis labs are offered to special interest groups. Assistant Director Mark Bloom interprets a DNA gel with seniors from Farmingdale University.

have also "cloned" our *Vector* van approach to teaching. A minivan supplied by Genentech, Inc.—dubbed *Helix I*—carries equipment to participating schools, where teachers and some 600 students have performed DNA experiments.

A 1987 workshop, conducted in cooperation with the North Carolina Biotechnology Center, provided the initial impetus for what has become the nation's most extensive state-supported program in molecular biology education. Lead teachers, selected from throughout North Carolina, were trained at the 1987 workshop and then returned to their regions to assist local scientists in conducting eight local workshops in summer 1988 that reached an additional 172 teachers. The program also makes available, on a rotating basis, 24 equipment sets to help teachers begin to implement DNA laboratories. In 1988, some 100 schools, representing nearly a third of the schools in the state, used an equipment set. One small measure of the program's success is the case of Celeste Posey, a senior at the North Carolina School of Science and Mathematics, who, working under the mentorship of a teacher trained at the 1987 workshop, took fifth place in the 1989 Westinghouse Talent Search.

Another ongoing collaboration is with the Institute for Genetics Education at the University of Wisconsin-Madison, where the *DNA Science Workshop* is one of several modules devoted to the study of genetics and its ethical implications. Reception of the workshop in 1988 was so enthusiastic that it has become a standard part of the Institute's summer program.

Eye-catching banners crafted by Jan Eisenman of Laurel Hollow.

Materials Development

Our goal has been to modify current research protocols to minimize expense while maximizing safety and reproducibility in the teaching laboratory. However, we strive to maintain the integrity of research methods so that novices need not relearn techniques as they progress to advanced lab work or to a research setting. Experiments are not reduced to the "add A to B" mentality that pervades some laboratory experiences and effectively obscures the process of science. For example, we have learned that having controls performed by every lab team is essential to student interpretation and to sorting out anomalies that invariably arise.

The success of our *DNA Science* protocols lies in their extensive testing and refinement over a long period of time. A deceptively large amount of fine adjustment is required to effectively transfer research techniques into the classroom. Thus, research biologists may encounter difficulties when they attempt to transfer their own protocols and reagents into the teaching laboratory. Molecular biology professors who run training workshops for the North Carolina program have been impressed by the consistent results obtained with the *DNA Science* protocols.

In our quest to make the *DNA Science* course as nearly foolproof as possible, we have gone as far as to develop new plasmids—named simply pAMP and pKAN. Restriction digests of these plasmids yield restriction fragments of markedly different sizes, making gel interpretation straightforward. They are highly amplified in *E. coli*, giving consistent yields in minipreparations. These are, to our knowledge, the only DNA molecules specifically engineered for educational purposes. Many teachers have indicated that time for setup and preparation is now the most serious constraint to teaching DNA laboratories. Their need for "one-stop shopping" and quality-assured reagents led us to collaborate with the Carolina Biological Supply Company, which distributes all reagents and equipment necessary to perform the experiments in our lab/text. A range of product options is offered—from bulk reagents, to multi-use reagent systems, to throwaway kits.

Executives from biotechnology and health care companies, pictured here with Banbury Center Director Jan Witkowski (second from left), performed a lab as part of the Baring Brothers conference on immunology.

We regularly test lab equipment to assess appropriateness for student use, and we are collaborating with suppliers to design and adapt equipment to meet the cost and safety requirements of the education marketplace. For example, we helped to test the first ultraviolet transilluminator designed with student use in mind. Our collaboration with Carolina Biological has resulted in the production of low-cost electrophoresis equipment. A colony transformation kit developed at the DNA Learning Center is proving to be very popular among high school biology teachers and should make it easier for large numbers of AP teachers to perform this recommended experiment.

We plan to develop a second set of laboratory exercises that articulate with and build upon those introduced during the *DNA Science Workshop*. These experiments will be published in a second edition of our *DNA Science* lab/text planned for publication in 1991. Envisioned as the basis for a second-level course, the new protocols will introduce three powerful techniques of molecular biology—Southern hybridization, DNA sequencing, and polymerase chain reaction (PCR). In each case, we will collaborate with a corporate partner that has specific expertise in the technology and work with them to optimize research-grade kits.

In spring 1989, we began a collaboration with United States Biochemical Corporation and Perkin-Elmer Cetus to develop PCR for educational purposes. Of great interest is a kit that would allow students to amplify a segment of their own DNA. We regard this as an ideal "entry level" experience in DNA manipulation, combining the involvement of an individually performed experiment with the economy of an instructor demonstration. Although students prepare their own DNA, student samples are run together in separate lanes of an agarose gel. Thus, one or at most two gels would be necessary for an entire class.

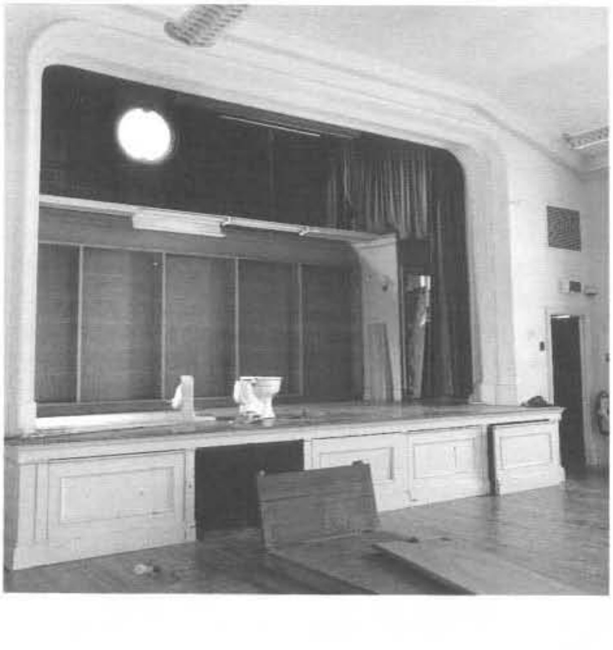
Exhibit Development

In preparation for our museum/teaching function, more than $400,000 was expended in 1987–1988 to entirely revamp the heating, air conditioning, and electrical systems of our 1925 schoolhouse; to renovate laboratory, exhibit, and office space; and to upgrade parking. A world-class museum program was inaugurated with the installation of *The Search for Life: Genetic Technology in the 20th Century*, on loan from the National Museum of American History of the Smithsonian Institution. We now face the challenge of designing and executing new exhibits, revolving around the Human Genome Project, that must be readied to replace the Smithsonian exhibit.

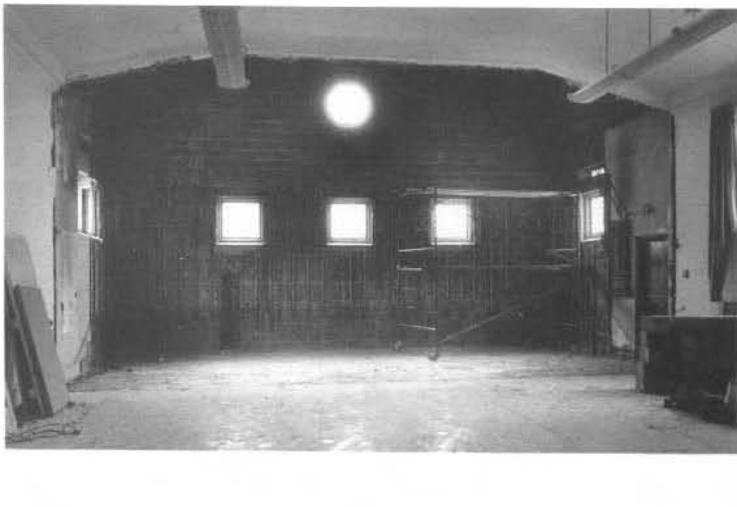
The establishment of the *Exploring the Human Genome* exhibit at the DNA Learning Center will mark one of the first major efforts to spark public imagination about this important endeavor. Cold Spring Harbor Laboratory is an especially fitting host for such an exhibit. The Laboratory's director, James Watson, was the codiscoverer of the structure of DNA and is associate director of the National Institutes of Health in charge of the Human Genome Project.

Exploring the Human Genome Exhibit

Our exhibit will approach the genome project from the standpoint of potential gains in understanding the genetic basis of human disease. Although there are more than 3000 known inherited diseases of humans, the causative gene has been identified for only a fraction of these. Mapping disease genes to their exact locations on the chromosomes will facilitate diagnosis, and determining the genetic instructions they encode should lead to improved therapies. The exhibit will focus on several model genetic diseases, including thalassemia, sickle cell anemia, muscular dystrophy, Burkitt's lymphoma, familial colon cancer, retinoblastoma, Alzheimer's disease, manic depression, and Huntington's disease—which illustrate different molecular mechanisms of disease. This case study approach will allow the visitor to learn about both genetic disease and methods of molecular genetic analysis.



Installation of the *The Search for Life* exhibit required major renovation of our building, which was built in 1925 as the grade school of Cold Spring Harbor Village.



DNA Detective/DNA Diagnosis

The natural variability of human life—eye color, hair color, body features, and physical and mental abilities—is determined by genetic instructions encoded in DNA molecules that make up the chromosomes of our cells. Thus, it is not surprising that biologists have identified specific chromosomal regions where the chemical structure of the DNA molecule varies from person to person. Such variable regions are called DNA polymorphisms—for "many forms." Like physical traits, DNA polymorphisms are passed on from parent to child in a Mendelian fashion. The ultimate expression of individual identity, DNA polymorphisms are now revolutionizing forensic medical science, paternity determination, and disease diagnosis.

The *DNA Detective/DNA Diagnosis* exhibit and the DNA manipulation laboratories are the first elements of a coordinated interpretive program on the Human Genome Project that captures the importance and excitement of human molecular genetics. The exhibit, which emphasizes the interaction of science and society, is situated adjacent to the *Bio2000* Laboratory, where hands-on experiments emphasize the methods of science.

The exhibit consists of five Formica-laminated modules—two video modules and three case modules. The video modules, each containing a television monitor, confront visitors as they enter the exhibit area. A short video cycles continuously on each monitor, presenting the scientific basis of DNA polymorphisms and the steps involved in making a DNA fingerprint.

Each case module consists of three back-lit visual displays that highlight an actual case study involving DNA fingerprinting. Using a montage of photographs and newspaper reports, the first display presents the facts of the case and sets the stage for the DNA fingerprint data. The second display is composed of tempered glass panels with the stylized DNA fingerprints of individuals involved in the case. The observer slides the panels to juxtapose fingerprints: A match results in an obvious color and pattern change of the overlapping "bar codes."

We intend to develop new cases throughout the year, rotating them into the exhibit on a regular basis. The serialization of cases and the ease of exchanging case materials between one or more modules make it cost effective to create a rotating "gallery" of DNA fingerprint cases. The Technology Center in Silicon Valley, San Jose, California, plans to install a unit for its opening in 1990, and several other museums have expressed serious interest. The initial cases illustrate various applications of DNA fingerprinting and historical precedents in law, medicine, and society:

Ghana Immigration Case (*1985*). In this case, DNA fingerprints were used to prove the family relationship between an English woman and her child, who wished to emigrate from Ghana. This was the first use of DNA fingerprints in a court of law. Original case materials were provided by Alec Jeffreys, University of Leicester.

Murder at Rodman Dam (*1988*). DNA fingerprints were used to help convict the suspect in a double murder/rape case. This was the first case involving DNA fingerprint evidence in which the death penalty was handed down. Original case materials were provided by Cellmark Diagnostics and the Florida State Attorney's Office.

DNA Diagnosis of Muscular Dystrophy (*1988*). This case shows one of the first uses of DNA fingerprints in family genetic medicine. The inheritance of a DNA polymorphism, linked to a causative gene for muscular dystrophy, is traced from "carrier" mother to affected son.

Exploring the Uses of Multimedia

In the last several decades, we have witnessed the virtual perfection of several audiovisual technologies: television, video, computers, and random-access laser discs. Taken alone, none has lived up to its potential as a teaching tool. This is because each learning exercise is only as good as its creator. To the extent that the producer's or programmer's conceptual framework for linking ideas overlaps that of the learner, the presentation will be more or less successful.

Recently, computer researchers have begun to explore methods to link these computo-audiovisual technologies into a flexible system that potentially allows individuals to structure their own learning experience. Multimedia can essentially be thought of as an extension of "windows" technology that allows one to access and display information, from several different sources, simultaneously on a single screen.

The multimedia network consists of an array of stored audiovisual and textual information – an information field – and a set of computer-encoded decision points at intersections of pathways through that field. A command issued at a decision point (by keyboard or mouse) allows one to select a pathway and to rapidly access information stored at addresses along that pathway. Textual information is retrieved from storage in the computer's random-access memory, and audiovisual information is retrieved from an optical laser disc. The information is presented on a high-resolution television monitor.

The open-endedness of the learning experience increases with the number and connectivity of decision points. By choosing their own pathways to explore the information field, individuals may structure the learning experience according to their own preferences of information use. Thus, it is plausible that the pathway individuals take through an information field in some way mirrors the cognitive structure they use to make sense of the world. For example, some people may prefer an analytic pathway, where one begins with general information and progresses to specific information. Others may prefer a synthetic pathway, beginning with specific information and progressing to the more general.

DNA Detective/DNA Diagnosis is the first major exhibit designed by the staff of the DNA Learning Center. (Photos by Mort Kelman.)

The combination of multimedia with parallel distributed processing (PDP) offers even more tantalizing prospects for education. There has been initial success in creating PDP systems that function in a manner analogous to the human nervous system. These simple neural networks can "learn" to identify patterns of input information, for example, words and shapes.

If a person's choices at various decision points in a multimedia information field are input into a neural network, could it then use these choices as feedback to predict the person's best learning path through that field? After extrapolating a Feedback Predicted Learning Path, could the neural network then direct the multimedia computer to structure (edit) the available information into a personalized learning experience that might even be more effective than one selected by the individual? This is possible, considering that without foreknowledge of every bit of stored information and its access points, individuals must wind their way through the information field. In this sense, periodic input to the neural network would produce a Feedback Corrected Learning Path that would, at the least, straighten out some bends and avoid dead ends.

As yet, multimedia systems are not being widely used in educational or museum settings. This is partly due to the fact that every system is essentially custom-made, and development costs are not trivial. Therefore, we hope to set up a facility like the Apple Multimedia Lab in San Francisco to explore the uses of computer/video disc interfacing in science education. The insights we gain and the programs we develop will serve as models for other science educators. In conjunction with a multimedia laboratory, we hope to set up a student laboratory with 10–15 student stations. Here, students would work with computer programs for DNA sequence analysis and molecular modeling to perform simulations of laboratory procedures and to participate in the testing and development of multimedia productions.

Staff

In June 1988, Mark Bloom was promoted to Assistant Director of the DNA Learning Center in recognition of his dedication to the program. Mark remains primarily responsible for the smooth running of our laboratory teaching programs, including the *Vector* workshops and the *Bio2000* Laboratory. Greg Freyer, currently an assistant professor at Columbia University College of Physicians & Surgeons, continues to supply the specially designed DNA molecules used in our workshops and, together with Mark, conducts research to translate the techniques of molecular biology to the teaching environment.

We were fortunate to obtain the services of John Le Guyader as our new education manager. John comes to us from the Woodmere Academy, where he taught advanced placement biology. He has research experience at the State University of New York at Stony Brook and is an adjunct professor at Dowling College. Arriving in November, John quickly assumed the burden of instructing our daily lab class visits. His background and enthusiasm make him an ideal manager of our *Bio2000* teaching laboratory and strengthen our understanding of the problems facing today's biology educators. The teaching load was also lightened by the arrival of part-time volunteer Kelly Flynn. She is a perfect addition to our teaching staff, with a degree in biology from Cornell University and experience in the laboratory of Amar Klar, a former CSHL staff scientist.

In January 1989, Susan Zehl left the Laboratory's Public Affairs Department to join our permanent staff as designer. Sue came to Cold Spring Harbor Laboratory in 1985 as a photographic intern for Public Affairs and began a full-time position as photographer/artist following her graduation from The Cooper Union in 1986.

DNA Learning Center staff and associates (left to right) John LeGuyader, David Micklos, Greg Freyer, Susan Zehl, John Kruper, and Mark Bloom.

While a member of the Public Affairs Department, Sue played an important part in the development of the DNA Literacy Program. She has already launched us into the age of computer-aided design, using our Sun computer and plotter to generate exhibit concepts and artwork for our textbook, *DNA Science: A First Course in Recombinant-DNA Technology.*

Interns, ranging from high school juniors to graduate students, provide critical assistance to our teaching staff. Deserving special mention are John Kruper and Jeff Mondschein. John, who is completing his doctorate in science education at the University of Illinois at Chicago, has had primary responsibility for our evaluation program, which tracks the many hundreds of teachers who have participated in *Vector* workshops over the years. Jeff, who is currently in the pre-med program at New York University, was the first DNA gypsy, traveling coast-to-coast with the first *Vector* tour in 1986. He was joined in summer 1988 by Ken LaMontagne, a native of Williston Park, presently a senior at James Madison University in Virginia. Lab aides Steve Malloy and Chris Inzarillo, both juniors at Cold Spring Harbor High School, have been key to the smooth functioning of the *Bio2000* Laboratory.

In summer 1988, we bid farewell to Ellen Gene Skaggs, who departed to Israel with her husband Jesse. Seemingly possessed of two sets of arms, she with calm precision administered the Curriculum Study and *Vector* workshop programs at a time when they were cottage industries of the Public Affairs and Development Department. She, more than anyone else, is responsible for building the "family" feeling that has made our small group so productive. We miss her every day.

Anne Zollo, gamely stepped in to fill Ellen's shoes and has managed to clear up the residual confusion left from having moved our office quarters too many times in a single year. She contributes greatly to the smooth operation of the Learning Center—juggling travel schedules, appointments, and reservations and maintaining daily contact with educators nationwide.

The opening of the DNA Learning Center to the general public also required organizing a group of volunteers to administer our museum program. Besieged by new responsibilities, we gratefully accepted the help of Anne Meier and Sandy Ordway to solicit and coordinate the participation of volunteers. With their help and that of the other volunteers, the DNA Learning Center is growing, striving to reach its potential as an "exploratorium of DNA."

Volunteer directors Sandy Ordway and Anne Meier in the bookstore, which was renovated with funds provided by the Banbury Fund of Lloyd Harbor.

PUBLICATIONS

Kwong, A., J. Kruper, and N. Frenkel. 1988. Herpes simplex virus host shutoff function. *J. Virol.* **62:** 912.

Micklos, D. 1988. *The first hundred years: A history of man and science at Cold Spring Harbor.* (Video) Cold Spring Harbor Laboratory, New York.

Micklos, D. 1988. Making the American public DNA literate. In *Proceedings of Biotech USA, 5th Annual Conference, San Francisco,* California.

Micklos, D. and M. Bloom. 1988. DNA transformation of *Escherichia coli. Carol. Tips* **51**.

Micklos, D. and M. Bloom. 1988. A laboratory introduction to DNA restriction analysis. In *Proceedings of the Association for Biology Laboratory Education, 9th Annual Meeting, Minneapolis.*

Preiss, J., D. Cress, J. Hutny, M. Morrell, M. Bloom, T. Okita, and J. Anderson. 1988. Regulation of starch synthesis: Biochemical and genetic studies. *Biocatalysis in agricultural biotechnology. ACS Symp. Ser.* **39**.

In Press, Submitted, and In Preparation

Kruper, J. 1989. The computer in the biotechnology classroom. *Biotechnology Education* (Submitted.)

Micklos, D. and M. Bloom. 1989. DNA restriction analysis. *Carol. Tips* **53**.

Micklos, D. and G. Freyer. 1989. *DNA science: A first course in recombinant DNA technology.* Cold Spring Harbor Laboratory Press, New York. (In press.)

Micklos, D. and G. Freyer. 1989. A laboratory introduction to DNA restriction analysis. *Biotechnology Education* (in press).

Curriculum Study Membership 1988–89

Cold Spring Harbor Central School District
Commack Union Free School District
East Williston Union Free School District
Great Neck Public Schools
Half Hollow Hill Central School District
Harborfields Central School District
Herricks Union Free School District
Huntington Union Free School District
Jericho Union Free School District
Lawrence Public Schools
Locust Valley Central School District
Manhasset Public Schools
Northport-East Northport Union Free School District
North Shore Central School District
Oyster Bay-East Norwich Central School District
Plainview-Old Bethpage Central School District
Portledge School
Port Washington Union Free School District
Sachem Central School District at Holbrook
Syosset Central School District

VECTOR WORKSHOP SITES 1985–89

ALABAMA	University of Alabama, Tuscaloosa	1987, 1988, 1989
ARIZONA	Tuba City High School	1988
CALIFORNIA	University of California, Davis	1986
CONNECTICUT	Choate Rosemary Hall, Wallingford	1987
FLORIDA	University of Florida, Gainesville	1989
GEORGIA	Fernbank, Inc., Atlanta	1989
ILLINOIS	Argonne National Laboratory, Chicago	1986, 1987
	Wheaton College*	1988
INDIANA	Butler University, Indianapolis	1987
IOWA	Drake University, Des Moines	1987
KENTUCKY	Murray State University	1988
MANITOBA	Red River Community College, Winnipeg	1989
MARYLAND	Annapolis Senior High School	1989
	McDonogh School, Baltimore	1988
MASSACHUSETTS	Beverly High School	1986
	Dover-Sherborn High School	1989
	Randolph High School, Boston	1988
	Winsor School, Boston	1987
MICHIGAN	Michigan State University, East Lansing*	1989
	Troy High School	1989
MINNESOTA	University of Minnesota, Minneapolis*	1989
MISSOURI	Washington University, St. Louis	1989
NEW HAMPSHIRE	St. Paul's School, Concord	1986, 1987
NEW YORK	Albany High School	1987
	Bronx High School of Science	1987
	Cold Spring Harbor High School	1985, 1987
	DNA Learning Center	1988 (3), 1989
	Huntington High School	1986
	Irvington High School	1986
	State University, Purchase	1989
	State University, Stony Brook	1987, 1988, 1989
	Wheatley School, Old Westbury	1985
NORTH CAROLINA	North Carolina School of Science, Durham	1987
OHIO	Cleveland Clinic	1987
PENNSYLVANIA	Duquesne University, Pittsburgh	1988
	Germantown Academy, Philadelphia	1988
	Gwenyde Mercy College, King of Prussia*	1988
SOUTH CAROLINA	Medical University of South Carolina, Charleston	1988
	University of South Carolina, Columbia	1988
TEXAS	University of Houston*	1989
VERMONT	Champlain Valley Union High School	1989
VIRGINIA	Jefferson School of Science, Alexandria	1987
WASHINGTON	Department of Public Health, Seattle*	1988
WEST VIRGINIA	Bethany College	1989
WISCONSIN	Marquette University, Milwaukee	1986, 1987
	University of Wisconsin, Madison	1988, 1989

*Two-day workshop, all others five days.

Grantor	Program	Duration of Grant	Total Award
FEDERAL GRANTS			
NATIONAL SCIENCE FOUNDATION			
	Teacher Enhancement Program	6/87–11/90	415,928
STATE GRANTS			
New York State Legislature	The Search for Life	1988	74,595*
NONFEDERAL GRANTS			
Boehringer Mannheim Biochemicals	Core Support	1988	$ 2,000*
Brinkmann Instruments, Inc.	Core Support	1988	10,000*
Harweb Foundation	Core Support	1988	1,500*
J.M. Foundation	Core Support	1988	25,000*
Richard Lounsbery Foundation	Core Support	1988	30,000*
Josiah Macy, Jr. Foundation	Core Support	7/87–6/90	490,850
The Banbury Fund	Renovation	1988–1989	56,200*
Center for Biotechnology, SUNY Stony Brook	Vector Workshop	1988	10,550*
Fotodyne Inc.	Vector Workshop	1988	4,000*
Samual Freeman Charitable Trust	Vector Workshop	1988	10,000*
Cold Spring Harbor	Curriculum Study	1988	500*
Commack School District	Curriculum Study	1988	500*
East Williston School District	Curriculum Study	1988	500*
Great Neck School District	Curriculum Study	1988	500*
Harborfields School District	Curriculum Study	1988	3,000*
Herricks School District	Curriculum Study	1988	500*
Huntington School District	Curriculum Study	1988	500*
Jericho School District	Curriculum Study	1988	500*
Lawrence School District	Curriculum Study	1988	500*
Locust Valley School District	Curriculum Study	1988	1,500*
Manhasset School District	Curriculum Study	1988	500*
Northport-East Northport School District	Curriculum Study	1988	500*
North Shore School District	Curriculum Study	1988	500*
Oyster Bay-East Norwich School District	Curriculum Study	1988	500*
Plainview-Old Bethpage School District	Curriculum Study	1988	500*
Portledge School	Curriculum Study	1988	500*
Port Washington School District	Curriculum Study	1988	500*
Sachem School District	Curriculum Study	1988	500*
Syosset School District	Curriculum Study	1988	500*
Aboff's Inc.	The Search for Life Exhibit	1988	50*
Agway Petroleum Corporation	The Search for Life Exhibit	1988	200*
Amity Westchester	The Search for Life Exhibit	1988	100*
Andrew Goetzs Sons, Inc.	The Search for Life Exhibit	1988	100*
Apple Bank	The Search for Life Exhibit	1988	150*
Automatic Data Processing	The Search for Life Exhibit	1988	1,000*
Badge Agency, Inc.	The Search for Life Exhibit	1988	1,000*
Barek-Karpel Industries, Inc.	The Search for Life Exhibit	1988	100*

* New Grants Awarded in 1988

Grantor	Program	Duration of Grant	Total Award
Bethesda Research Laboratories Life Technologies, Inc.	The Search for Life Exhibit	1988	10,000*
Blackman General Offices	The Search for Life Exhibit	1988	200*
Brinkmann Instruments, Inc.	The Search for Life Exhibit	1988	1,000*
BRL Life Technologies	The Search for Life Exhibit	1988	10,000*
Brunswick Appraisal Corp.	The Search for Life Exhibit	1988	150*
Budget Instant Print	The Search for Life Exhibit	1988	200*
Dale Carnegie & Associates, Inc.	The Search for Life Exhibit	1988	100*
C.N.D. Supply Corp.	The Search for Life Exhibit	1988	1,000*
Damson Oil Corporation	The Search for Life Exhibit	1988	1,000*
Dunkin Donuts, Inc.	The Search for Life Exhibit	1988	1,000*
Fairchild Weston System, Inc.	The Search for Life Exhibit	1988	1,000*
Grumman Corporation	The Search for Life Exhibit	1988	10,000*
Harris Trust	The Search for Life Exhibit	1988	90*
Hickey's Carting, Inc.	The Search for Life Exhibit	1988	1,000*
Huntington Business Products	The Search for Life Exhibit	1988	100*
Huntington Market, Inc.	The Search for Life Exhibit	1988	1,000*
I. Janvey & Sons, Inc.	The Search for Life Exhibit	1988	250*
Jeff's Seafood	The Search for Life Exhibit	1988	300*
Kollmorgen Corporation	The Search for Life Exhibit	1988	1,000*
Limco Manufacturing Corp.	The Search for Life Exhibit	1988	1,000*
Meenan Oil Company, Inc.	The Search for Life Exhibit	1988	1,500*
Meyer, Suozzi, English & Klein	The Search for Life Exhibit	1988	1,000*
Miller, Anderson & Sherrerd	The Search for Life Exhibit	1988	5,000*
New York Telephone	The Search for Life Exhibit	1988	1,000*
Northville Industries Corp.	The Search for Life Exhibit	1988	1,000*
Official Offset Corp.	The Search for Life Exhibit	1988	2,500*
Pall Corporation	The Search for Life Exhibit	1988	5,000*
Peat Marwick	The Search for Life Exhibit	1988	1,000*
The Roslyn Savings Bank	The Search for Life Exhibit	1988	1,000*
Servo Corporation of America	The Search for Life Exhibit	1988	1,000*
Spinnaker Travel, Ltd.	The Search for Life Exhibit	1988	1,000*
The Stebbins Fund	The Search for Life Exhibit	1988	500*
James F. Straub, Inc.	The Search for Life Exhibit	1988	500*
Tambrands, Inc.	The Search for Life Exhibit	1988	5,000*
Thermo Electron	The Search for Life Exhibit	1988	1,000*
The Tiles Investment Company	The Search for Life Exhibit	1988	1,000*
Vecco Instruments	The Search for Life Exhibit	1988	1,000*
W.A. Baum Company	The Search for Life Exhibit	1988	150*
Wentworth Films, Inc.	The Search for Life Exhibit	1988	100*
Winston Foundation	The Search for Life Exhibit	1988	5,000*
Individual Contributors	The Search for Life Exhibit	1988	8,105*
Mr. and Mrs. G. Morgan Browne			
Bernadette Castro			
Mr. Peter O. Crisp			
Katya Davey			
Eleanor Greenan			
Mrs. Sinclair Hatch			
Phyllis Satz			
Cynthia R. Stebbins			
Mr. Byam K. Stevens, Jr.			
Joseph A. Suozzi, Esq.			
Mr. and Mrs. Walter C. Teagle, III			
Mr. and Mrs. Richard Wesley			

* New Grants Awarded in 1988

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Damson Oil Corporation	The Search for Life Exhibit	1988	1,000*
Dunkin Donuts, Inc.	The Search for Life Exhibit	1988	1,000*
Fairchild Weston System, Inc.	The Search for Life Exhibit	1988	1,000*
Grumman Corporation	The Search for Life Exhibit	1988	10,000*
Harris Trust	The Search for Life Exhibit	1988	90*
Hickey's Carting, Inc.	The Search for Life Exhibit	1988	1,000*
Huntington Business Products	The Search for Life Exhibit	1988	100*
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Limco Manufacturing Corp.	The Search for Life Exhibit	1988	1,000*
Meenan Oil Company, Inc.	The Search for Life Exhibit	1988	1,500*
Meyer, Suozzi, English & Klein	The Search for Life Exhibit	1988	1,000*
Miller, Anderson & Sherrerd	The Search for Life Exhibit	1988	5,000*
New York Telephone	The Search for Life Exhibit	1988	1,000*
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Official Offset Corp.	The Search for Life Exhibit	1988	2,500*
Pall Corporation	The Search for Life Exhibit	1988	5,000*
Peat Marwick	The Search for Life Exhibit	1988	1,000*
The Roslyn Savings Bank	The Search for Life Exhibit	1988	1,000*
Servo Corporation of America	The Search for Life Exhibit	1988	1,000*
Spinnaker Travel, Ltd.	The Search for Life Exhibit	1988	1,000*
The Stebbins Fund	The Search for Life Exhibit	1988	500*
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Tambrands, Inc.	The Search for Life Exhibit	1988	5,000*
Thermo Electron	The Search for Life Exhibit	1988	1,000*
The Tiles Investment Company	The Search for Life Exhibit	1988	1,000*
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Winston Foundation	The Search for Life Exhibit	1988	5,000*
Individual Contributors Mr. and Mrs. G. Morgan Browne Bernadette Castro Mr. Peter O. Crisp Katya Davey Eleanor Greenan Mrs. Sinclair Hatch Phyllis Satz Cynthia R. Stebbins Mr. Byam K. Stevens, Jr. Joseph A. Suozzi, Esq. Mr. and Mrs. Walter C. Teagle, III Mr. and Mrs. Richard Wesley	The Search for Life Exhibit	1988	8,105*

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