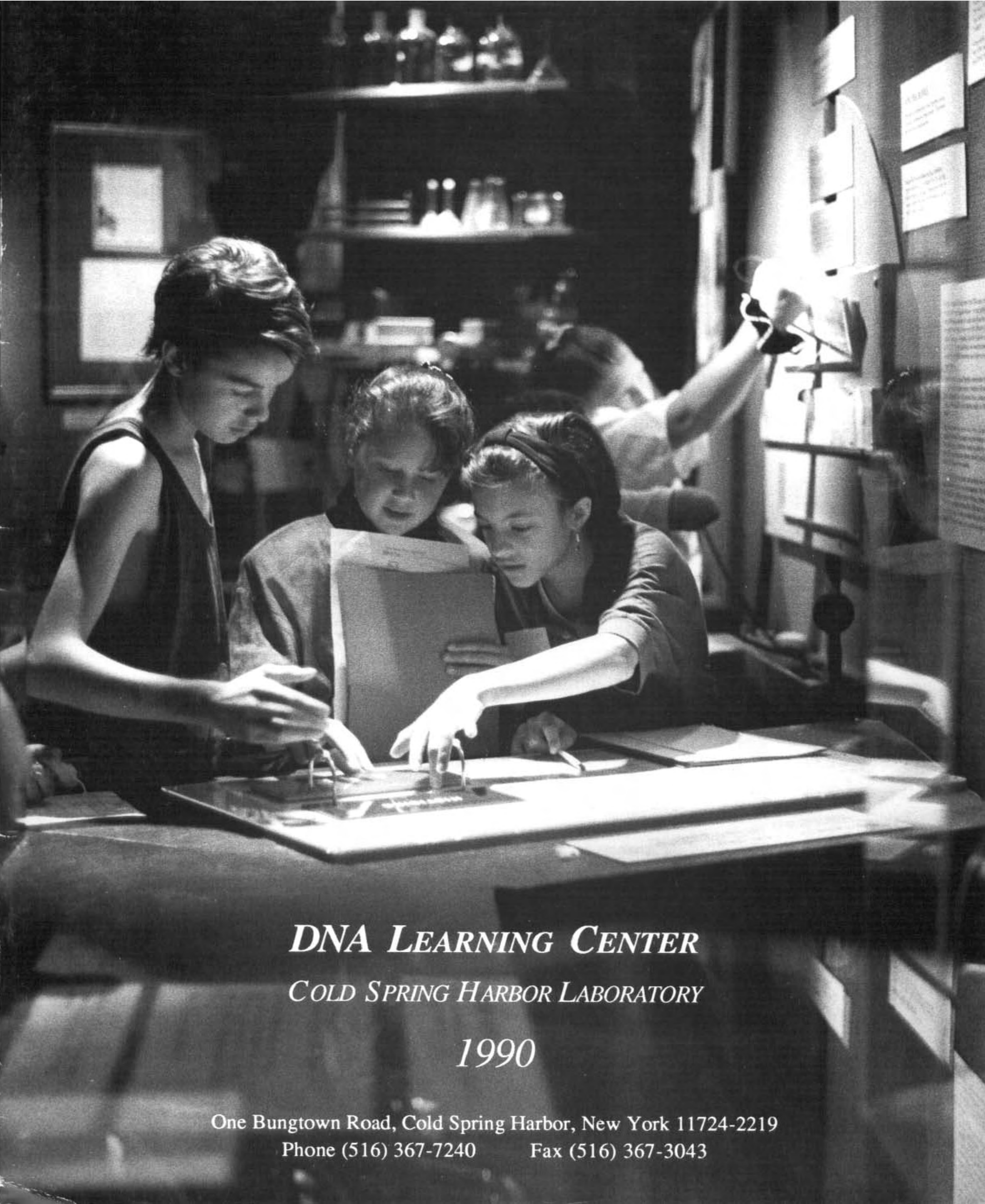

DNA LEARNING CENTER

COLD SPRING HARBOR LABORATORY

1990

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DNA LEARNING CENTER

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Periodic studies conducted since 1959 show that general scientific illiteracy is a persistent problem in the United States. Recent studies sponsored by the National Science Foundation (NSF) suggest that only about 6% of Americans can be considered functionally literate in scientific matters and that college graduates are only marginally more literate.

Clearly, Americans have had enough difficulty understanding developments in a postmodern world clouded by questions of nuclear fission/fusion and increasingly controlled by devices crammed with computer microprocessors. Now, the proliferation of gene-manipulation technology adds a new dimension to our national science confusion. Indeed, a 1987 Office of Technology Assessment survey found that 63% of Americans claim to have heard or read relatively little or almost nothing about "genetic engineering" and 44% cannot give any meaningful definition of the word. The NSF-sponsored studies show that only 10% of the American public can explain what a molecule is, and only 22% can define DNA correctly.

At the same time, we have a national research agenda to identify all of the approximately 100,000 different human genes, the Human Genome Project. The impact of this work is already being felt. In September 1990, a 4-year-old girl suffering from a severe immune deficiency received an infusion of genetically altered cells, in the first attempt to replace a defective gene with a normal one. Gene therapy such as this promises the ultimate cure for the thousands of known genetic diseases, and the molecular tracings of DNA fingerprints provide the ultimate evidence in rape, murder, and paternity cases nationwide. These activities also throw into sharp relief the potential risks of gene manipulation, the difficulties of fairly allocating resources for biological research, and the issues of proper uses of and access to personal genetic profiles.

The good news is that 57% of Americans appear able to understand a simple problem dealing with the inheritance of a genetic illness, suggesting that they find this topic relevant to their personal lives. We also have a self-professed "education president," and some two dozen bills to encourage science, math, and engineering education were considered by Congress in 1990. In the context of this renewed sense of urgency, the social importance of the Human Genome Project offers an opportunity to reorganize substantially biology and health education to include new emphasis on human molecular genetics.

Ideal and Reality of Biology Education

Public education has long been viewed as a key enabler of democratic pluralism, providing individuals with access to elements of cultural, political, and scientific literacy. If we take stock in this Madisonian concept of an informed citizenry that participates in public decision making, DNA literacy must be considered an essential element of precollege public education. In this view, science teachers, who interface with a cross section of America's youth, constitute a major conduit through which understanding of the uses and misuses of genetic technology can flow broadly to society.

One assumes that children begin life with curiosity for the natural world. Indeed, data from the 1986 National Assessment of Educational Progress (NAEP) study show that the vast majority of American third graders both like their science lessons (67%) and find them interesting (78%). However, there are many indicators that this enthusiasm for science erodes dramatically with increased exposure to formal science during junior and senior high school. The NAEP study shows that whereas 67% of third graders believe that things learned in science class will be useful in everyday life, only 54% of seventh graders and 49% of eleventh graders see the practicality of their science studies. A recent study by the International Association for the Evaluation of Educational Achievement found that American fifth graders rank eighth in science achievement among their peers in 14 developed and developing nations; however, advanced high school seniors rank last in biology achievement among their international peers.

It is not that we don't have the chance to influence high school students to pursue any native interest they may have in living things. Biology is the most frequently studied science in high school and is taken by 90% of all American students. In spite of, or perhaps because of, this exposure, only 6% of high school students take an advanced course in biology, and only 3.7% of college freshmen intend to major in the biological sciences.

All this suggests that it is the manner in which science is taught that causes young people to become so disinterested in science. The NAEP study paints a disturbing picture of the American precollege science classroom, where the "preponderance of class time [is] spent listening to teachers' lectures" and where

DNA Learning Center staff: (*standing*) David Micklos, Sandy Ordway, Margaret Henderson, Mark Bloom, (*seated*) Susan Lauter, Amy Phillips there are "few opportunities to explore natural phenomena directly or engage in discussions about the limited experiences that they did have." The scientific content in these classes "appears to be largely textbook- and workbook-driven, reflecting little—or not at all—the recent technological advances in the domain of science." Students interviewed in the NAEP study gave the following report on their eleventh grade science classes:

- 79% listen to a lecture daily or several times per week.
- 54% read their textbooks daily or several times per week.
- 47% do not participate in experiments on at least a weekly basis.
- 41% had never written up experiments.
- 52% had never done an oral or written report.
- 39% had never read articles on science.
- 86% had never been on a field trip.

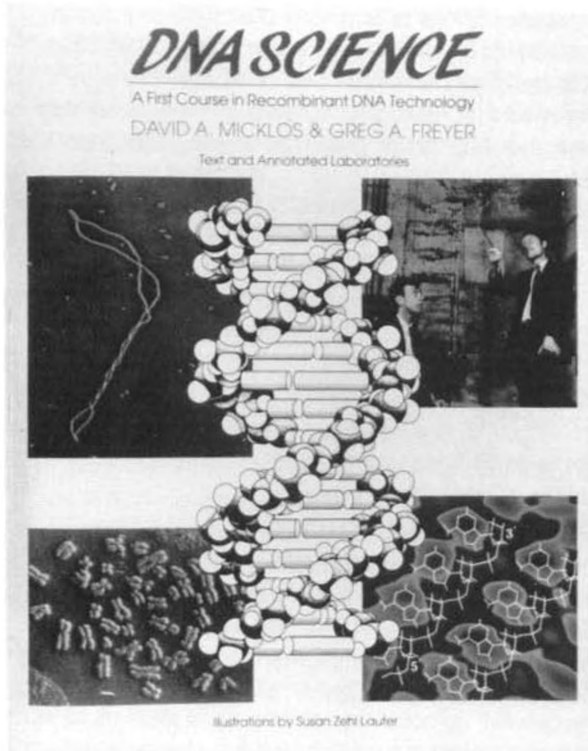
According to the NAEP study, more than one-third of eleventh grade science teachers do not have access to a general purpose or specialized science laboratory. Our conversations with high school biology teachers in a number of states indicate that science departments typically have annual supply budgets calculated at just several dollars per student and that capital equipment purchases are limited to replacement of existing items. Many older high schools are functioning with essentially the same basic set of equipment purchased with the bond issue with which they were constructed during the "baby boom" of the 1950s–1960s.

Although the nature and practice of biology is forward looking, the burden of evidence shows that teaching high school biology is reactionary. In many ways, biology education has changed little from the days of our grandparents. Hands-on laboratories are the exception, and rote memorization is the norm. This is in large part because high school biology curricula have evolved in the twentieth century essentially by cramming in more and more facts. Faced with the specter of a standardized test that covers a vocabulary-driven syllabus, the teacher is often constrained to spend his or her time lecturing on science facts. Meager equipment/supply budgets and a lack of teaching laboratories preclude any but the most simplistic laboratories, which reflect primarily the observational traditions of biology. Missing are meaningful experiments that reflect the quantitative and biochemical basis of modern molecular genetics.

Publication of *DNA Science*

Since 1985, Cold Spring Harbor Laboratory has expended $2.5 million to infuse genetic literacy through the public education system. The publication of *DNA Science: A First Course in Recombinant DNA Technology* marked the culmination of our effort to influence biology curricula at the advanced high school and beginning college levels. The combined lab and text was coauthored by Dave Micklos and Greg Freyer (now at Columbia University), with computer-generated illustrations by Sue Lauter. We believe it is the first integrated *learning program* to introduce novice biology students to the theory, practice, and applications of DNA manipulation.

Unlike "super texts" that can only be sampled by even the most ambitious instructor or student, the 477-page *DNA Science* is designed to be read from cover to cover. The eight text chapters are written in a semi-journalistic style and



DNA Science was released in October 1990, and by year's end, plans were already made for a second printing.

adopt an historical perspective to explain where DNA science has come from and where it is going. Combining the unique perspectives of a research biologist and a science writer, the topical treatment integrates up-to-the-minute examples drawn directly from research literature. For these reasons, we believe the text is suitable for introducing recombinant DNA in science and society courses.

Extensively tested by thousands of biology instructors nationwide, the ten laboratory experiments cover the basic techniques of gene isolation and analysis. The experiments engender systematic repetition to build student confidence and mastery of techniques. Extensive preliminary notes for each experiment explain how to schedule and prepare them, and flow charts and icons make the protocols easy to follow. A discussion section at the end of each experiment reviews the laboratory in a rhetorical style, analyzing controls and showing both ideal and "less-than-ideal" results. A final section suggests simple research projects that extend the techniques learned in the laboratory and require few, if any, additional reagents.

Truly a first course in recombinant DNA technology, the laboratory sequence presupposes no prior experience on the part of instructor or student. Structured to follow directly from an introduction to principles of biology, the experiments are equally appropriate for the advanced high school student and the beginning college student. It can be used as the first course in a molecular biology sequence, integrated as a genetics/DNA structure component of a general biology course, or used as a unit within a microbiology or genetics course. Laboratories 3 and 5, which illustrate methods to analyze DNA and to introduce genes into bacteria, are recommended by the Educational Testing Service as part of the laboratory curriculum for Advanced Placement (AP) students who take a college level biology course.

DNA Science is a copublication of Cold Spring Harbor Laboratory Press and Carolina Biological Supply Company, which is one of the nation's oldest purveyors of laboratory supplies and curriculum materials for biology teachers. The laboratory course is completely supported by quality-assured Carolina products to satisfy a range of teaching applications, from bulk reagents to reusable reagent systems to single-use kits. Kits designed to introduce teachers to the AP laboratories have quickly become among the company's largest sellers. Also completed in 1990 was "Easy Gene Splicer," which is a simple kit that allows students to construct safely and screen for small recombinant DNA molecules.

Renewed NSF Support for *DNA Science* Workshops

The 5-day *DNA Science* Workshop is our most well-known effort to update biology teaching faculty. Through 1990, the DNA Learning Center staff have instructed 1,400 high school and college educators at 66 workshops in 27 states and Canada, and allied programs in California, North Carolina, Wisconsin, and Florida have used the curriculum as the basis for training an additional 700 teachers at 30 workshops.

The continued influence of the *DNA Science* Workshop was assured with the renewal in 1990 of our core grant from the NSF. This three-year support will allow us to teach 15 workshops, extending our coverage to the midwestern states in 1990 and to the deep south and southwestern states in 1991. Implementing workshops nationwide is a complex task, involving liaison through numerous local organizers, coordinating the travels of two *Vector* vans and six staff, and shipping perishable reagents. However, this task has become sufficiently routine that we intend to target the Rocky Mountain region for workshops in summer 1992.

Recognizing the educational value of the workshop experience, the State University of New York at Stony Brook offers a credit option to *DNA Science* Workshop participants nationwide. Teachers who complete both a workshop and a follow-up are eligible for three graduate credits from the Continuing Education Department. The University's Center for Biotechnology has sponsored a *DNA Science* Workshop at Stony Brook each year since 1987. Travel support is also provided for workshops held at distant sites.

We were honored when Howard Hughes Medical Institute (HHMI) Vice-President Joe Perpich asked us to help establish a model genetics program in its home area of Montgomery County, Maryland. The HHMI grant provides $46,500 to the DNA Learning Center over three years to support teacher/student training workshops and curriculum-enrichment activities. A coordinate grant was awarded to the Montgomery County Public Schools Educational Foundation, Inc., for the implementation of the new curriculum. HHMI is respected as the largest nongovernment contributor to medical research, and the Montgomery County program is considered a test for wider support of precollege and public science education in the next several years.

Measures of Success

Statistics derived from our student field-trip program and our hectic schedule of teacher-enhancement activities (see list at back) give evidence that we have been busy at our work to stimulate widespread DNA literacy. In 1990, DNA

Learning Center staff logged 11,000 person-hours of contact with precollege students and 25,000 person-hours of contact with teaching faculty.

However, funding agencies, particularly the NSF, have found that hard data gauging the effects of faculty enhancement programs are difficult to attain. Therefore, educators greeted with enthusiasm the results of a long-term study of 390 biology teachers trained at 22 *DNA Science* Workshops in 1987 through 1988. The report, "Retooling Biology Education for the Gene Age," was coauthored by Dave Micklos and John Kruper.

Formerly a summer intern with the *Vector* Workshop program and now a postdoctoral fellow at the University of Chicago, John was responsible for the sophisticated computer analysis that included several types of multivariate statistics. The data set for each teacher consisted of answers to surveys administered at three time points: a 60-item presurvey completed at the beginning of the summer workshop, a 95-item postsurvey completed at the end of the workshop, and an 87-item follow-up mail survey that was completed approximately 17 months after the workshop.

The analysis confirmed that participants in the *DNA Science* Workshop are a rather select and highly professional group. Of ten, eight taught AP, honors biology, or advanced biology electives. Seasoned teaching professionals, most had taught at least 6 to 20 years, achieved a master's degree, and carried a full teaching certification in biology or science. The typical respondent was likely a member of several professional organizations and actively participated in professional-development and curriculum-development activities. Many reported regular participation in student-enrichment activities, including science field trips (58%); science fairs and competitions (45%); after-school student research (34%); and joint activities with research scientists (25%).

A majority of teachers appear to have made substantive changes in their classroom behavior during the year after participation in the workshop. Two-thirds or more of all respondents affirmed that they had in several ways integrated concepts from the workshop into their teaching. This included relating a personal account of the making of a recombinant DNA molecule, giving new examples for topics already included on their teaching syllabi, and presenting new topics not yet on their syllabi.

Significant numbers of teachers had attempted new laboratory techniques in their classrooms in the school year after the workshop. Two-thirds had tried experiments in bacteriology, which can be considered the entry into molecular genetics. Thirty-five percent had implemented an AP-type lab on DNA transformation, which requires no specialized equipment. Fewer (25%) had implemented an AP-type lab on DNA restriction analysis, which requires an investment in electrophoresis equipment. Based on a conservative estimate of 25 students per lab (the median reported class size), the teachers in this study were responsible for 5,775 student exposures to the AP labs on DNA transformation and restriction analysis. Furthermore, a number had performed relatively sophisticated experiments on DNA recombination (18%) and plasmid DNA isolation (13%) that require a major investment in equipment and preparation time.

A number of respondents carried on networking activities to educate other teaching professionals. More than one-third had made presentations about their workshop experience to local teachers or school officials, while 7% had made a presentation at a professional meeting. Most important, 18% had conducted a laboratory demonstration for other educators, and 9% had led a teacher-training workshop. Based on the assumption that each reported lab activity involved five

Margaret Henderson discusses results of a DNA restriction analysis with high school students in the *Bio*2000 Laboratory.

other teachers, we estimate conservatively that workshop participants demonstrated or taught new lab techniques to 520 additional educators.

Half of all respondents attempted to secure funds with which to implement new labs, typically approaching one or two sources. Fewer (29%) attempted to secure donations of equipment or reagents from various sources, including universities, hospitals, and industry. Of those who tried, 64% were successful in securing monetary or equipment gifts. Respondents reported receiving a total of $507,000 in funding, including monetary donations of $381,000 and reagent donations valued at $126,000. This was equivalent to $1,144 per participant, which more than matched the average per-person training cost of $928. We believe this level of fund-raising success is unprecedented in the history of American biology education.

We judged that about 70% of teachers, although progressive, were primarily *adapting* their new knowledge within the framework of the existing educational system. In contrast to these "adaptors," true innovators had substantially revamped their teaching style to make room for a considerable amount of new experimentation in molecular genetics, including the suggested AP labs on bacterial transformation and DNA restriction analysis.

We used several statistical measures to highlight key attitudinal and behavioral determinants that distinguish adaptors from innovators. Taken together, the analysis emphasized that the innovative teacher is not a "lone wolf," but, rather, is an active professional who operates within a social system. A teacher's involvement with and positive evaluation of the "relevant others" within his/her work environment (students, parents, administrators, and other teachers) belongs to a set of core evaluations and attitudes that are highly resistant to change and appear to be reliable predictors of innovative behavior. This "silent" background of positive attitudes empowers the innovator to seek means to overcome difficult infrastructure constraints to innovation: insufficient lab time, space, and equipment. A decreased reliance on textbooks and an ability to seek out information from primary sources allows the innovator to overcome the curriculum constraints of poor texts and an overly ambitious syllabus.

Ironic Situation in Freshman Biology

Five years ago, high school teachers had neither the training nor equipment for hands-on experimentation with DNA. This situation has changed dramatically, thanks to teacher-training institutes sponsored primarily by NSF, the incorporation of molecular genetics labs into AP biology, the unprecedented fund-raising success of precollege biology teachers, and the availability of suitable teaching kits from science suppliers. Extrapolating from the results of our study and estimated sales of teaching kits, plus the actual numbers of students taught by ourselves and others, we estimate from 50,000 to 70,000 student exposures per year to the AP experiments on DNA transformation and restriction analysis in American high schools.

This figure points up an ironic situation in American biology education. Advanced high school students perform DNA manipulation labs to fulfill a college level biology curriculum; however, these labs are absent from the vast majority of introductory college biology courses. Even at the largest and best of our universities, laboratory instruction on gene manipulation is confined mainly to upper-level courses for biology majors. Thus, beginning college students who had been excited by doing DNA experiments at the high school level are now frustrated to learn that they will not likely work again with DNA until their junior or senior year.

One assumes, prima facie, that college biology professors are up-to-date on advances in research biology; however, many American students are introduced to biology by *nonresearch teaching faculty*. As with their high school counterparts, most of these individuals do not specialize in molecular biology and have been out of school for a number of years. Molecular techniques have not effectively filtered down through the collegiate education system, in part because of a psychological schism between *researchers* and *teachers* that thwarts the flow of laboratory innovation. This is a remnant of separation previously achieved by a bicameral system of research universities and teacher-training colleges. Teaching faculty may be reluctant to seek advice from research colleagues for fear of appearing less "professional." The problem is especially acute at small institutions or state colleges lacking active research programs.

Our experience suggests that college teaching faculty are eager to learn and incorporate new laboratory teaching methods in molecular biology. A preliminary study of college faculty we have trained at *DNA Science* Workshops showed that they implement new laboratories at a significantly higher rate than do high school teachers and that they carry on more networking activities. College biology departments have infrastructures conducive to implementing new labs, and faculty have easier access to funds for new equipment. College instructors reported obtaining an average of $4,700 in start-up funding for new labs, compared with $1,200 per high school trainee.

The Forgotten Biology Teacher

The lack of laboratory teaching in molecular genetics in freshman biology is, in part, another sorry legacy of Reaganomics. Precollege and college faculty alike have long relied on faculty-enhancement programs funded by the NSF to keep up with advances in research science and for instruction on implementing new student labs. NSF funding for precollege and undergraduate programs was greatly expanded after the launch of Sputnik and the attendant perception that the United States was falling behind in the technology race. After peaking at $89 million in 1968, NSF support for precollege and undergraduate programs (funded through its Directorate for Science and Engineering Education [SEE]) declined in the 1970s.

However, President Reagan added insult to injury during his first term in office. Budget cuts during the early 1980s essentially dismantled the SEE Directorate, when *total* precollege and undergraduate funding fell to a pre-Sputnik level of $3.82 million in 1982. This was a national disgrace and shows that even the best efforts of this lead agency are not immune to the vagaries of our legislative process.

College biology teaching suffered most during this period, and funding for undergraduate faculty enhancement programs was eliminated from 1982 to 1987. This coincided precisely with the isolation of the first human cancer genes, the explosive development of the biotechnology industry, and the development of key methods for analyzing human genes. It was a period during which researchers themselves had difficulty keeping apace with the flurry of discovery. Thus, the lack of NSF enhancement programs during this critical time in effect put undergraduate faculty nearly a decade behind in the meaningful transfer of genetic technology to the college teaching laboratory.

Only in 1989 did NSF undergraduate funding regain a pre-Reagan funding level of $28 million, with precollege funding reaching a record high of $104 million. This new heyday of NSF funding for precollege science education appears to be spurred by a growing perception that the United States is now losing the technology race with Japan. The looming shadow of Gramm-Rudman-Hollings notwithstanding, recent history suggests that we can't afford to entrust the retraining of our biology teaching resource entirely with the federal government.

NSF Funding for a *DNA Science II* College Workshop

Against this backdrop, we were happy to receive word in December that the NSF had approved funding for a two-year enhancement program for college faculty to begin in 1991. The program will be administered by Assistant Director Mark

Dr. Greg Freyer, coauthor of *DNA Science*, assists college workshop participants with a DNA hybridization experiment.

Bloom, who developed a second series of 11 laboratories that articulate with and extend the concepts in *DNA Science*. A bacterial system (*Escherchia coli*, plasmids, and bacteriophage λ) is used as a simple model to illustrate techniques for constructing and screening gene libraries, including the techniques of non-radioactive hybridization and polymerase chain reaction.

The NSF-sponsored program will consist of a 10-day workshop and 2-day follow-up program conducted at urban sites: Atlanta and San Francisco in 1991 and Boston and Baltimore in 1992. The labs will be further refined in manuscript during the 1991 workshops. After incorporating feedback from the 1991 workshops, we hope to speed production work so that the laboratories can be formally published early in 1992 as *DNA Science II: An Introduction to Methods of Genome Analysis.*

The success of the NSF proposal was, in large part, due to core support from the Josiah Macy, Jr., Foundation, the J.M. Foundation, the Richard Lounsbery Foundation, and the Banbury Fund, which allowed Mark and the high school interns to do extensive preliminary lab work. Core support also allowed Mark to field test the new lab program at a workshop held in July, which was attended by 24 college faculty from 19 metro-area institutions.

NSF Funding for the *Exploring Human Genetics* Workshop

Advanced high school teachers in the study mentioned above rated genetics along with ecology as the biology topics "most important in preparing students for adult life." Considering this perceived social and personal relevance of human genetics, it is beginning to occur to many educators that introduction to human genetics should, in fact, begin at the middle school level (grades 5–8). Making best use of this window of opportunity may have two important effects. First, it can inculcate basic tenets of scientific literacy that are essential for all children as they grow into adulthood. Second, it may light an academic spark for science that will survive into the college years.

Although human health is a prevalent middle school science topic, many teachers emphasize drug and sex awareness rather than principles of science. Human genetics at once not only builds on this traditional health emphasis of middle school science, but also offers an entree to pure science. Genetics emphasizes science as a problem-solving venture involving the collecting, sharing, and analyzing of data. It is also consistent with the across-curriculum approach that incorporates science, math, and social studies and emphasizes the impact of science and its practical applications.

Thus, we were happy to receive funding in the spring from the National Science Foundation for a model program to train 336 middle school instructors in New York and Maryland to teach a 15–20-hour unit, *Exploring Human Genetics*. The process began in summer 1990 with a 4-day workshop to train 12 pairs of lead teachers from school districts throughout New York State. In 1991, we will have the difficult task of supporting and coordinating the activities of these teachers as they lead "second-round" workshops for 12 pairs of additional teachers in each of their local areas. The entire schedule of lead and second-round workshops will be repeated in the state of Maryland, hopefully proving the suitability of the program as a model for similar programs nationwide.

The workshop presupposes no specific experience in genetics, and it is aimed at both 5th and 6th grade classroom teachers, as well as 7th and 8th

David Micklos discusses a corn cross with middle school teachers in a pretest of the *Exploring Human Genetics* Workshop.

grade life science teachers. Each participant is provided with a teaching kit containing text and all necessary lab materials needed to initiate an experience-based program at his or her school. Regular follow-up activities will further encourage implementation and networking between participants.

Continued Popularity of Local Programs

The Laboratory's current involvement in public education began with the establishment, in 1985, of a consortium of eight local school districts. This consortium, the Curriculum Study, has grown over the years, reaching a new high of 27 districts with the addition in 1990 of Garden City, Kings Park, and Roslyn. Curriculum Study schools have served as a proving ground for both the *DNA Science* and *Exploring Human Genetics* curricula, and their teachers frequently form ad hoc committees to advise us on future projects. It is a tribute to the enthusiasm with which local teachers adopted our ideas that, despite the lack of a major biotechnology industry, the metropolitan New York area ranks along with San Francisco as a national leader in advanced biology teaching at the high school level.

Curriculum Study schools receive reduced admission fees to DNA Learning Center programs, spaces in student/teacher workshops, and equipment purchase options. Students and teachers receive an insider's view of current biological research through the "Great Moments in DNA Science" Lecture Series held each spring. The 1990 lecturers and topics were the following:

William Gergits, Lifecodes Corporation. *From Antelopes to Zebra Finches: The A to Zs of Animal DNA Fingerprinting.*

Carolyn Truncer, Health Science Center at the State University of New York, Stony Brook. *Clinical Applications of Genetic Technologies.*

Robert Franza, Cold Spring Harbor Laboratory. *DNA-binding Proteins and Gene Function.*

David Helfman, Cold Spring Harbor Laboratory. *Protein Diversity through Alternative RNA Splicing.*

The laboratory field-trip program conducted in the *Bio2000* Laboratory continues to operate at capacity, drawing both Curriculum Study members and schools from throughout metropolitan New York. In 1990, 3,758 students and 270 teachers (180 classes) conducted the AP laboratories on DNA restriction analysis and bacterial transformation. The field-trip program is subsidized by core grants from the Esther A. and Joseph Klingenstein Fund, the Josiah Macy, Jr., Foundation, the J.M. Foundation, Boehringer Mannheim Biochemicals, and United States Biochemical Corporation.

Since the opening in September 1988 of the DNA Learning Center, 22,000 visitors have toured the exhibits housed here. *The Search for Life: Genetic Technology in the Twentieth Century*, on loan from the National Museum of American History of the Smithsonian Institution, chronicles the study of heredity from Darwin to DNA and confronts the visitor with the promise and concern of genetic technology. *DNA Detective*, which opened in September 1989, examines the uses of DNA fingerprinting in forensic and paternity law.

Exploring the Uses of Multimedia in Biology Education

During the last several decades, we have witnessed the virtual perfection of several audiovisual technologies: television, video, computers, and random-access laser disks. Taken alone, none has lived up to its potential as a teaching tool. However, "multimedia" or "hypermedia" programs now offer the potential to link these technologies into a flexible system that allows individuals to structure their own learning experiences. With the help of our new Laboratory trustee Owen Smith and senate majority leader Ralph Marino, we received a grant of $66,300 from the New York State Legislature to develop multimedia learning experiences in human genetics.

Thus, at the end of 1990, Sue Lauter began to equip a multimedia development laboratory. Her system is centered around a Macintosh IIci computer, which has adequate memory and processing speed to display various types of analog and digital information, including video, photographs, artwork, sound, and text. The information is accessed from CD-ROM and laser video disks, which have the capability to store high-resolution images that are input from a scanner and video camera/recorder. Authoring software, including a digital "paintbox," Hypercard, and Macromind Director, allows Sue to merge the various media into a seamless, interactive system. Our objective is to create open-ended learning experiences, in which students can actively explore a complex information field, that access multiple analog and digital sources according to their preferences of information use.

After pretesting with students from Curriculum Study schools, the multimedia experiences will be offered as student field trips and will be incorporated into a new public exhibit, *Exploring the Human Genome*. Because of its location and specialization, the DNA Learning Center can never expect to draw significant numbers of off-the-street visitors. However, it can influence widespread science literacy by producing high-quality multimedia exhibitry for the use of other museums. Our in-house expertise in science interpretation and easy access to the major figures in the world of molecular biology make the DNA Learning Center an ideal interface between genetic science and society.

With assistance from the Albert and Mary Lasker Foundation, Sue is developing a new exhibit, *Eye on the Prizes: Milestones in Molecular Genetics and Genetic Medicine,* highlighting recipients of the Nobel Prize and the Albert Lasker Medical Research Award. Through a time line of prizewinners, the exhibit will chronicle the development of modern genetics. We already have a small collection of Nobel Prizes, and the Lasker Foundation is donating one of its award statuettes of the Winged Victory of Samothrace.

Doing Our Part for Soviet Glasnost

Steven Malloy, one of our student interns, combined his interests in Russian studies and DNA to spark a collaboration between the DNA Learning Center and the Shemyakin Institute of Bioorganic Chemistry (part of the of Soviet Academy of Sciences). Through the New York State/Moscow Telecommunication Project, sponsored by the Copen Family Foundation, Steve contacted Moscow student Nikita Skryabin, whose father is Vice-Director of the Academy's Engelhardt In-

Mark Bloom (*left*) and David Micklos (*right*) with Dimitri Debabov from the Engelhardt Institute in front of Moscow State University during their visit to the Soviet Union in May.

Laboratory Director James Watson (*center*) speaks with Soviet scientists (*left to right*) Leonid Barsukov, Irina Severtsova, Nikolay Zvonok, and Dimitri Debabov during their visit to the DNA Learning Center in August.

stitute of Molecular Biology. Discussion centered on the notion of creating a *DNA Science* education program in Moscow modeled after the DNA Learning Center.

During a visit to the Soviet Union in May, Dave Micklos and Mark Bloom reached an agreement with their counterparts from the Soviet Academy of Sciences to initiate a joint education program. At that time, it was agreed that the immediate objective was to set up a Moscow DNA Learning Center within the Science-Education Center at the Shemyakin Institute. The Moscow DNA Learning Center will adapt our successful *DNA Science* laboratories to suit the Soviet educational system. The DNA Learning Center agreed to seek donations from American and European manufacturers to equip and supply the Moscow Center. The participating institutions further agreed to seek funding for a van to carry equipment and reagents to schools in Moscow modeled after our *Vector* Mobile DNA Laboratory.

Our trip to Moscow and Leningrad was a real eye-opener and pointed up the potential impact of the proposed collaboration. In spite of a history of achievement and strong public support, Soviet biologists are suffering under perestroika. Lack of hard currency makes it very difficult to pay for imported equipment and reagents. All orders for supplies must go through the central bureaucracy, whose already slow distribution system has been further stymied. If it is difficult to obtain meat in Moscow, imagine the difficulty of obtaining a centrifuge. Even biologists employed by the prestigious institutes of the Academy of Sciences have grown used to waiting a full year for the arrival of even the most trivial reagent.

The shortfall of hard currency and supplies makes it difficult for researchers to plan their experiments, but it makes it virtually impossible for undergraduate students to obtain any practical experience with the tools of molecular biology. There simply are not enough supplies and equipment to "waste" on students. The science laboratories of the monolithic Moscow State University, the nation's finest, look unchanged from the days of Stalin (except for the dust and the missing squares of parquet flooring). Few high schools appear to have anything comparable to a teaching laboratory. Clearly, rote learning reigns in the Soviet Union.

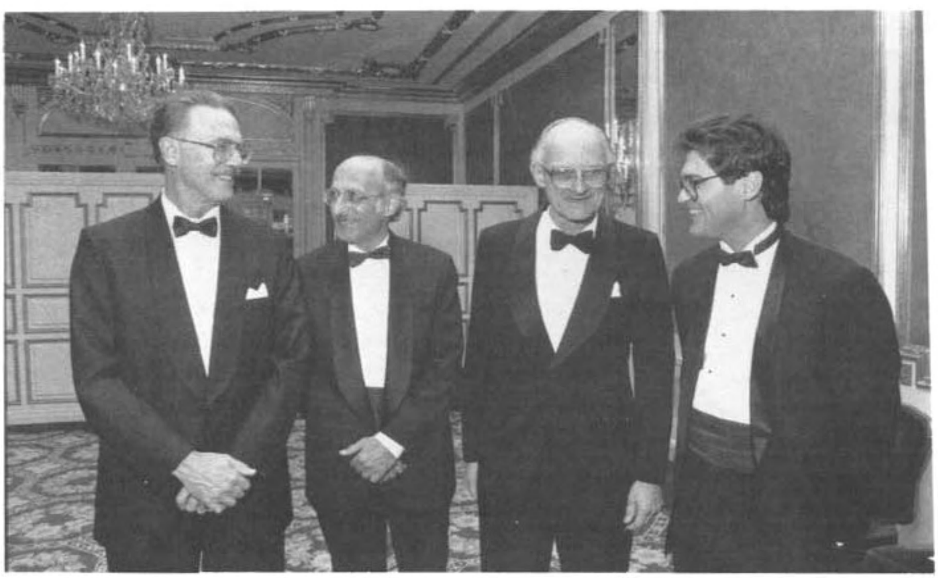
Our experiences in the Soviet Union made us realize that the implementation of a DNA Learning Center-style program to put micropipets in the hands of Soviet high school students would be truly revolutionary. We saw the real possibility that our ongoing collaboration might stimulate a general reform of biology education in the Soviet Union similar to that which is occurring at the AP/college level in the United States.

A delegation of four Soviet scientists from the Shemyakin and Engelhardt Institutes visited New York in August to participate in a *DNA Science* Workshop at the DNA Learning Center. During their visit, they met with American educators, observed our teaching methods, and performed the *DNA Science* laboratories. We traveled with the delegation to Washington, where we met with NSF Assistant Directors Luther Williams and Mary Clutter to discuss our plans for collaboration. We also finalized plans to conduct jointly a *DNA Science* Workshop at the Shemyakin Institute in early 1991 to open the Moscow DNA Learning Center.

The Soviet scientists returned home carrying with them enough supplies and equipment to begin implementing student experiments. The DNA Learning Center had coordinated donations valued at $14,000 for the Moscow DNA Learning Center: digital micropipets and a microcentrifuge from Eppendorf-Netheler-Hinz GmgH of Germany (through arrangements by Brinkmann Instruments of Westbury, New York); electrophoresis chambers, power supplies, and laboratory manuals from Carolina Biological Supply Company of Burlington, North Carolina; and a transilluminator/Polaroid camera system from Fotodyne, Inc., of New Berlin, Wisconsin. Publications, reagents, and expendable supplies were provided by Cold Spring Harbor Laboratory Press and the DNA Learning Center.

Charles A. Dana Award for Dave Micklos

On November 8th, director Dave Micklos was one of four individuals honored by the Charles A. Dana Foundation for pioneering achievements in health and education. The Dana Awards, given annually since 1986, are the only ones made exclusively to recognize innovative ideas in health and disease prevention and are among the largest awards for innovations in education. Recipients of the $50,000



David Micklos (*far right*) with other 1990 Dana Award winners (*from left*) John W. Farquhar, M.D., Norbert Hirschhorn, M.D., and David P. Billington at the presentation banquet at the Plaza Hotel.

award are selected from nationwide nominations by a jury of leaders in health and education.

David Mahoney, chairman of the Charles A. Dana Foundation, presented the award to Dave "for conceiving and directing a national scientific center's pioneering mission to carry the concepts and applications of the modern biological revolution—and the protean potential of recombinant DNA technology—to future biological scientists and all future citizens in the nation's schools."

David P. Billington, Professor of Civil Engineering and Operations Research at Princeton University, received the other award in education; the recipients of the health award were Norbert Hirschhorn, Vice-President of John Snow, Inc., and a lecturer at Harvard Medical School, and John W. Farquhar, Professor of Disease Prevention at Stanford University and Director of Stanford's Center for Research in Disease Prevention. Past honorees have included Donald Henderson, for his work in the eradication of smallpox, and F. Sherwood Rowland, for his research and advocacy to prevent further depletion of the earth's ozone layer.

Staff Changes

Sandy Ordway ably stepped up to the hectic responsibilities as administrative assistant, following the departure of Anne Zollo in June. Sandy needed no instruction on her new position. She had served as a volunteer to prepare for the opening of the DNA Learning Center and had worked part-time on our evaluation study and organizing special summer programs. Poised and polished, Sandy is a wonder of organization. We all feel confident in her ability to orchestrate with aplomb our many programs and collaborations.

After the departure of John LeGuyader for a position in the biotechnology department of the U.S. Patent Office, Margaret Henderson assumed the responsibilities of Education Manager. A native of London, Ontario, Margaret has an undergraduate degree in biology and a graduate degree in library science; her husband Scott is a postdoctoral fellow in electron microscopy on the main

Sandy Ordway guides students through the *Search for Life* exhibit.

Laboratory campus. She gamely stepped up to the demands of teaching six student labs per week, getting rave reviews on her patience and providing an excellent role model for male and female students alike. Her library skills will be put to use in a collaborative program with Biosis, the publisher of *Biological Abstracts*, and in designing a proposed student research library.

Kelly Flynn continued to share some of the teaching duties in the *Bio2000* Laboratory and also acted as editorial and photo researcher for *DNA Science*. After contributing to the summer workshop program, Kelly entered the master's program in genetic counseling at Sarah Lawrence University. While completing her master of fine arts degree at Long Island University, Carrie Abel assisted Sue Lauter with artwork for *DNA Science*, continuing on to a career in graphic design.

Interns, ranging from high school sophomores to graduate students, provide critical assistance to our teaching staff. Amy Phillips, a senior at Huntington High School, joined the staff in the spring and traveled with the *Vector* van this summer. Amy helped to develop two new educational kits to be marketed by Carolina Biological Supply Company and supervised newer interns Mark Staudinger and Richard Chiang. Chai "Sol" Chen graduated from Rensselaer Polytechnic Institute in June and reliably assisted the senior workshop instructors throughout the summer. He continues to keep us informed of his travels.

Publications

Bloom, M. Mapping and Sequencing the Human Genome. *Cabisco Biotechnology Tips*, Vol. 1, No. 1. March, 1990.

Micklos, D. and G. Freyer. *DNA Science: A First Course in Recombinant DNA Technology*. Carolina Biological Supply Company and Cold Spring Harbor Laboratory Press: New York, 1990.

Micklos, D. DNA Science and Education. *Carolina Tips* 53, 1990.

Micklos, D. "Preparing for the Gene Age." Essay for the Fifth Annual Charles A. Dana Awards for Pioneering Achievements in Health and Education, New York, 1990.

Micklos, D. and J. Kruper. Retooling Biology Education for the Gene Age: A Profile of Innovative High School Science Teachers. Submitted.

Curriculum Study Membership 1989–1990

Cold Spring Harbor Central School District*
Commack Union Free School District
East Williston Union Free School District*
Garden City Union Free School District
Great Neck Public Schools*
Half Hollow Hills Central School District
Harborfields Central School District
Herricks Union Free School District*
Huntington Union Free School District
Island Trees Union Free School District
Jericho Union Free School District*
Kings Park Central School District
Lawrence Public Schools
Lindenhurst 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*
Plainedge Public Schools
Plainview-Old Bethpage Central School District
Portledge School
Port Washington Union Free School District
Roslyn Union Free School District
Sachem Central School District at Holbrook
South Huntington Union Free School District
Syosset Central School District*

*Founding members

Sites of Major 4–8 Day Workshops 1985-1990

ALABAMA	University of Alabama, Tuscaloosa	1987, 1988, 1989, 1990
ARIZONA	Tuba City High School	1988
CALIFORNIA	University of California, Davis	1986
CONNECTICUT	Choate Rosemary Hall, Wallingford	1987
GEORGIA	Fernbank, Inc., Atlanta	1989
HAWAII	Kamehameha Secondary School, Honolulu	1990
ILLINOIS	Argonne National Laboratory, Chicago	1986, 1987
INDIANA	Butler University, Indianapolis	1987
IOWA	Drake University, Des Moines	1987
KENTUCKY	Murray State University	1988
LOUISIANA	Jefferson Parish Public School, Harvey	1990
MANITOBA	Red River Community College, Winnipeg	1989
MARYLAND	Annapolis Senior High School	1989
	McDonogh School, Baltimore	1988
	Montgomery County Public Schools	1990
MASSACHUSETTS	Beverly High School	1986
	Dover-Sherborn High School, Dover	1989
	Randolph High School	1988
	Winsor School, Boston	1987
MICHIGAN	Athens High School, Troy	1989
MISSISSIPPI	Mississippi School for Math & Science, Columbus	1990
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, high school workshops	1988(3), 1989(2), 1990(2)
	DNA Learning Center, college workshop	1990
	DNA Learning Center, middle school workshop	1990
	Huntington High School	1986
	Irvington High School	1986
	State University at Purchase	1989
	State University at Stony Brook	1987, 1988, 1989, 1990
	Wheatley School, Old Westbury	1985
NORTH CAROLINA	North Carolina School of Science, Durham	1987
OHIO	Case Western Reserve University, Cleveland	1990
	Cleveland Clinic	1987(2)
	North Westerville High School, Westerville	1990
PENNSYLVANIA	Duquesne University, Pittsburgh	1988
	Germantown Academy, Fort Washington	1988
SOUTH CAROLINA	Medical University of South Carolina, Charleston	1988
	University of South Carolina, Columbia	1988
TEXAS	J.J. Pearce High School, Richardson	1990
VERMONT	University of Vermont, Burlington	1989
VIRGINIA	Jefferson School of Science, Alexandria	1987
	Mathematics and Science Center, Richmond	1990
WEST VIRGINIA	Bethany College	1989
WISCONSIN	Marquette University, Milwaukee	1986, 1987
	University of Wisconsin, Madison	1988, 1989

1990 Workshops, Meetings, and Collaborations

January 6–7	Follow-up Workshop, National Science Foundation Athens High School, Troy, Michigan
January 13–14	Follow-up Workshop, National Science Foundation State University of New York at Purchase
January 17–18	Workshop, Cornell University, Ithaca, New York
January 20–21	Follow-up Workshop, National Science Foundation Fernbank Science Center, Atlanta, Georgia
January 26	Banbury Workshop for Congressional Aides DNA Learning Center, Cold Spring Harbor, New York
January 27–28	Follow-up Workshop, Curriculum Study DNA Learning Center, Cold Spring Harbor, New York
February 17–18	Follow-up Workshop, Red River Community College, Manitoba, Canada
March 3	Workshop, New York City Biology Teachers DNA Learning Center, Cold Spring Harbor, New York
March 10	Workshop, Long Island Biological Association DNA Learning Center, Cold Spring Harbor, New York
March 14	Follow-up Workshop, Curriculum Study DNA Learning Center, Cold Spring Harbor, New York
March 24	Follow-up Workshop, Curriculum Study DNA Learning Center, Cold Spring Harbor, New York Workshop, New York Microscopical Society DNA Learning Center, Cold Spring Harbor, New York
March 16–17	Workshop, Smith College, Northampton, Massachusetts
March 20–21	Conference, National Academy of Sciences, Washington, D.C.
April 6	Workshop, National Science Teachers Association Meeting, Atlanta, Georgia
May 5	Board of Trustees Meeting, Lunch DNA Learning Center, Cold Spring Harbor, New York
May 5–19	Meetings, Soviet Academy of Sciences, Moscow and Leningrad, Soviet Union
May 12	Workshop, Long Island Biological Association DNA Learning Center, Cold Spring Harbor, New York
May 17–18	Workshop, Macy Foundation A. Philip Randolph High School, New York, New York
May 21–26	Workshop, Case Western Reserve, Cleveland, Ohio
June 11–15	Workshop, Macy Foundation, University of Alabama, Tuscaloosa, Alabama
June 13–15	Workshop, Pretest for Middle School Program DNA Learning Center, Cold Spring Harbor, New York
June 18–22	Workshop, National Science Foundation Mississippi School for Math and Science, Columbus, Mississippi Workshop, National Science Foundation Jefferson Parish Public Schools, Harvey, Louisiana Workshop, Kamehameha Secondary School Honolulu, Hawaii Workshop, Republic of Singapore
June 25–29	Workshop, National Science Foundation J.J. Pearce High School, Richardson, Texas
June 27	Workshop, Seminole Community College, Sanford, Florida
July 9–13	Workshop, Howard Hughes Medical Institute Wheaton High School, Wheaton, Maryland
July 16–20	Workshop, National Science Foundation Mathematics and Science Center, Richmond, Virginia
July 18–28	Workshop, College Faculty DNA Learning Center, Cold Spring Harbor, New York
July 29–30	Workshop, Curriculum Study DNA Learning Center, Cold Spring Harbor, New York

July 31	Workshop and Seminar, Florida Department of Education Honors Science Symposium, Orlando, Florida
August 6–10	Workshop, National Science Foundation Westerville North High School, Westerville, Ohio
August 13–19	Workshop, Curriculum Study DNA Learning Center, Cold Spring Harbor, New York
August 13–15	Conference, UNESCO University of Maryland, College Park, Maryland
August 20–24	Workshop State University of New York at Stony Brook
August 21	National Science Foundation Assistant Directors Meeting Washington, D.C.
August 27–31	Workshop, National Science Foundation Middle School Program DNA Learning Center, Cold Spring Harbor, New York
September 29–30	Follow-up Workshop, National Science Foundation Mississippi School for Math and Science, Columbus, Mississippi
October 6	Workshop, Ohio College Biology Teachers Columbus, Ohio
October 10–11	Workshop, Board of Cooperative Education Services State University of New York at Binghamton
October 13–14	Follow-up Workshop, Howard Hughes Medical Institute Wheaton High School, Wheaton, Maryland
October 27–28	Follow-up Workshop, National Science Foundation Mathematics and Science Center, Richmond, Virginia
November 1–3	Workshop, National Science Teachers Association Meeting Long Beach, California
November 3–4	Follow-up Workshop, National Science Foundation J.J. Pearce High School, Richardson, Texas
November 7–11	Seminar, National Association of Biology Teachers Meeting Houston, Texas
November 14–17	Workshop, United States Biochemical Cleveland, Ohio
November 29	Workshop, National Science Teachers Association Meeting San Juan, Puerto Rico
November 30–December 1	Follow-up Workshop Case Western Reserve, Cleveland, Ohio
December 8–9	Follow-up Workshop, State University of New York at Stony Brook Follow-up Workshop, National Science Foundation Westerville North High School, Westerville, Ohio
December 10	Workshop, New York Association of Independent Schools DNA Learning Center, Cold Spring Harbor, New York
December 14	Workshop, National Science Teachers Association Meeting Washington, D.C.
December 15–16	Follow-up Workshop, Curriculum Study DNA Learning Center, Cold Spring Harbor, New York

DNA LEARNING CENTER

Grantor	*Program/Principal Investigator*	*Duration of Grant*	*Total Award*
FEDERAL GRANTS			
NATIONAL SCIENCE FOUNDATION	Teacher Enhancement Program	6/87 – 11/90	415,928
	Teacher Enhancement Program	3/90 – 4/93	474,036 *
	Teacher Enhancement Program	9/90 – 6/93	252,614 *
NONFEDERAL GRANTS			
Howard Hughes Medical Institute	DNA Science Workshop Program	5/90 – 4/93	46,500 *
Josiah Macy, Jr., Foundation	DNA Literacy Program	7/87 – 6/90	490,850
Josiah Macy, Jr., Foundation	DNA Literacy Program	7/90 – 6/91	98,905 *
The Banbury Fund	Core Support	1990	30,000 *
Brinkman Instruments, Inc.	Core Support	1990	2,500 *
The Esther and Joseph A. Klingenstein Fund, Inc.	Core Support	1990	25,000
North Carolina Biological Supply Co.	Core Support	1990 3,125	*
Nancy VanVranken	Core Support	1990	500 *
Case Western Reserve University	Vector Workshop	1990	11,075 *
Center for Biotechnology, SUNY Stony Brook	Vector Workshop	1990	10,500 *
Cornell University	Vector Workshop	1990	1,550 *
Jefferson Parish School District Louisiana	Vector Workshop	1990	2,000 *
Kamehameha Schools, Hawaii	Vector Workshop	1990	12,000 *
Richmond Mathematics & Science Center	Vector Workshop	1990	2,000 *
Mississippi School for Math and Science	Vector Workshop	1990	1,550 *
J.J. Pearce High School, Richardson, Texas	Vector Workshop	1990	2,000 *
Ohio Academy of Science	Vector Workshop	1990	2,000 *
Smith College	Vector Workshop	1990	1,550 *
Commack School District	Curriculum Study	1990	500
East Williston School District	Curriculum Study	1990	500
Garden City School District	Curriculum Study	1990	2,000 *
Great Neck Public Schools	Curriculum Study	1990	500
Half Hollow Hills School District	Curriculum Study	1990	500
Harborfields School District	Curriculum Study	1990	500
Herricks School District	Curriculum Study	1990	500
Huntington School District	Curriculum Study	1990	500
Island Trees School District	Curriculum Study	1990	1,500
Jericho School District	Curriculum Study	1990	500
Kings Park School District	Curriculum Study	1990	2,000 *
Lawrence School District	Curriculum Study	1990	500
Lindenhurst School District	Curriculum Study	1990	1,500
Locust Valley School District	Curriculum Study	1990	500
Manhasset School District	Curriculum Study	1990	500
Northport-East Northport School District	Curriculum Study	1990	500
North Shore School District	Curriculum Study	1990	500
Oyster Bay-East Norwich School District	Curriculum Study	1990	500

* New Grants Awarded in 1990

Grantor	*Program/Principal Investigator*	*Duration of Grant*	*Total Award*
Plainview-Old Bethpage School District	Curriculum Study	1990	500
Plainedge School District	Curriculum Study	1990	1,500
Portledge School	Curriculum Study	1990	500
Port Washington School District	Curriculum Study	1990	500
Rosyln School District	Curriculum Study	1990	2,000*
Sachem School District	Curriculum Study	1990	500
South Huntington School District	Curriculum Study	1990	1,500
Syosset School District	Curriculum Study	1990	500

* New Grants Awarded in 1990