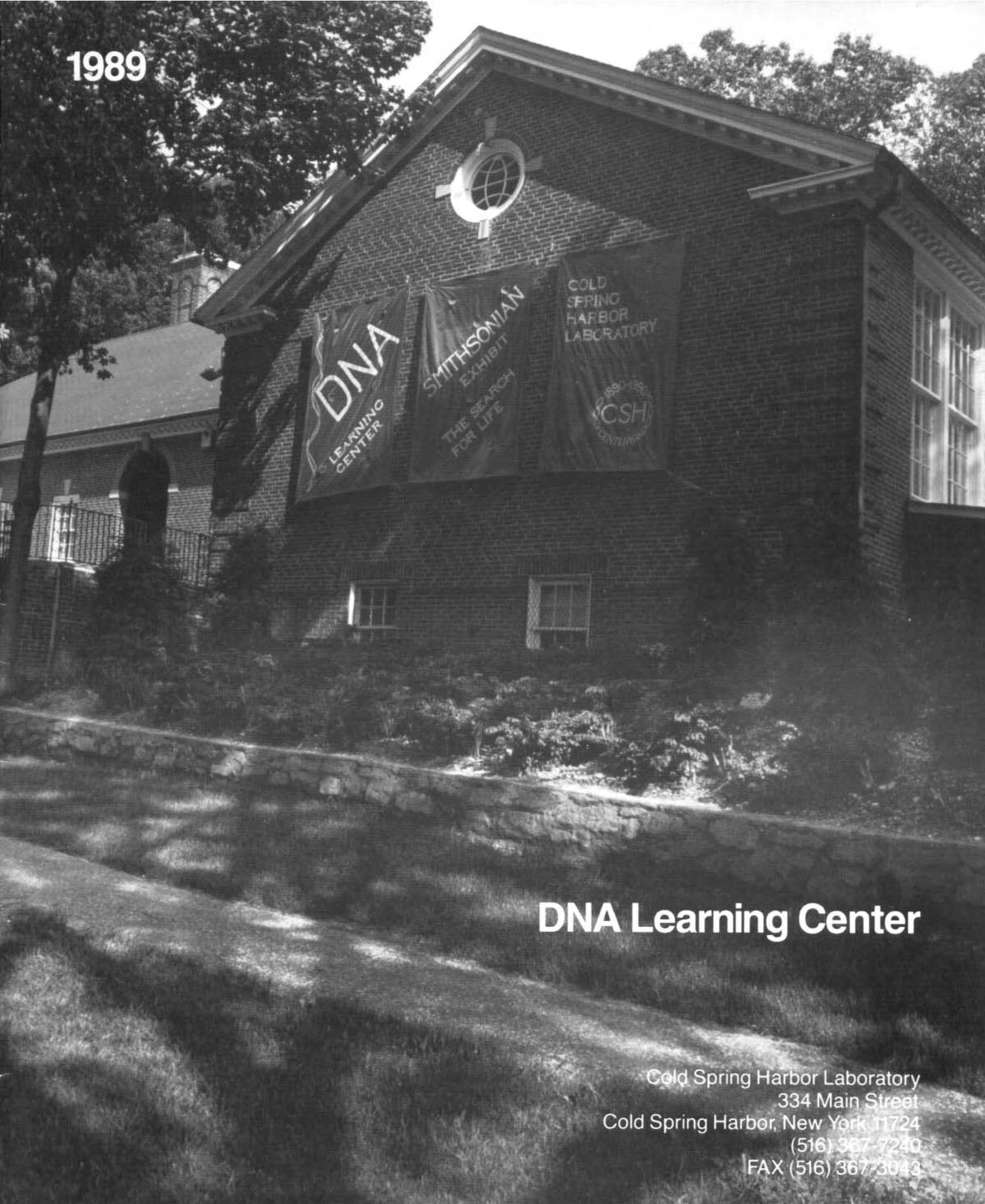
1989



DNA Learning Center

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DNA LEARNING CENTER

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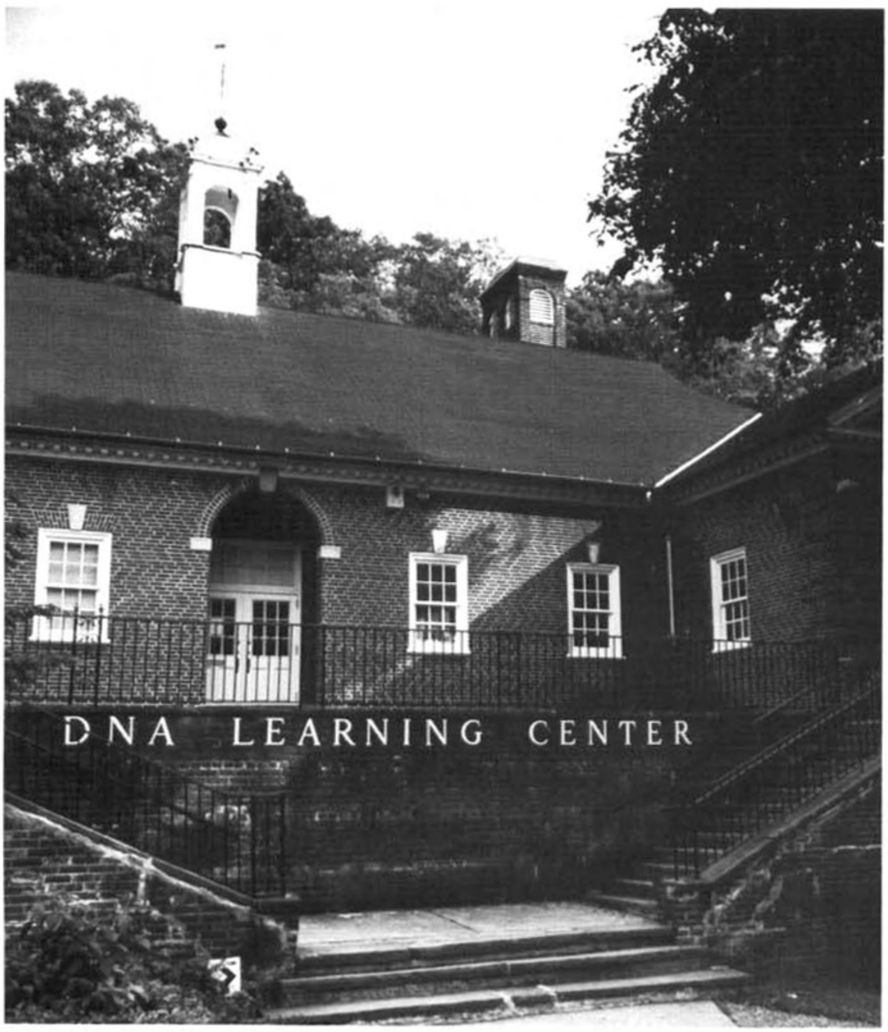
In 1944, the eminent physicist Erwin Schrödinger published a small book entitled *What is Life? The Physical Aspects of the Living Cell*, in which he mused on cracking the molecular "code-script" that governs the inheritance and expression of life functions. Schrödinger, whose wave equation helped describe the structure of the atom, stood in awe of the self-replicating ability of living things. He even went so far as to suggest that the essence of the mystery of life might entail new physical principles: "From all we have learnt about the structure of living matter, we must be prepared to find it working in a manner that cannot be reduced to the ordinary laws of physics."

Schrödinger's book influenced a generation of scientists to quest after the molecular "code-script" of life, including such pioneers of molecular biology as



Francis Crick and James Watson. No new laws of physics were uncovered in cracking the genetic code. The fact that all molecules are constructed according to the same physical chemical rules made it possible for Watson and Crick to deduce the structure of the DNA molecule. With a deeper understanding of the physical principles of DNA structure and function has come the ability to treat DNA as "merely" a molecule with predictable biochemical properties.

During the last 15 years, treating DNA as an ordinary molecule has led to the extraordinary ability to dissect any of the 100,000 human genes that compose the human chromosomes—the human genome. The dissection of the molecular pathway through which hereditary information flows between DNA, RNA, and protein molecules 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 isolate and map to their chromosomal positions the genes responsible for a number of genetic illnesses, including muscular dystrophy and cystic fibrosis.

The Human Genome Project

The inauguration of the Human Genome Project in 1988 marked the beginning of a national commitment to apply DNA technology toward understanding human health and development. Its goal is to determine the sequence of the estimated three billion bits of molecular information—the arrangement of nucleotide rungs of the DNA ladder—that constitute the entire code-script of human life.

Possession of an increasingly complete set of hereditary information will bring numerous benefits to humankind. By pushing back the threshold of early disease detection, DNA diagnosis will increase therapy options and play a positive role in personal health management. Understanding 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

Glasnost—DNA style! In December a group of high school students, visiting from Moscow, came to the Learning Center for an introduction to DNA experimentation. Assistant Director Mark Bloom helps Soviet students with their experiment.

acceptance as the most definitive evidence of identity in rape, murder, and paternity cases.

The day is not far off when a battery of DNA diagnoses will likely be part of a routine visit to the family doctor, providing an extraordinarily detailed picture of an individual's own genetic frailties. DNA fingerprints will join fingerprints and thumbprints kept on file by law enforcement agencies. In 1989, Genetic Therapy, Inc., was formed as the first company to explore methods to replace and repair defective genes.

The Social Imperative

Since the explosion of information made possible by the invention of the printing press, a democracy has needed to be a society of literates. Similarly, the explosive growth of DNA-based technology demands a society of DNA literates. 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.

Unfortunately, all indicators point to the fact that DNA science is moving so fast that the gulf between technological advance and public understanding is wider than ever before in the history of science. For example, a 1986 National Science Foundation study found that 57% of Americans claim to have little or no understanding of DNA. This state of public ignorance threatens the nation's ability to make informed policy decisions about issues generated by the new biology.

To a great extent, public education will determine whether such information realizes its compassionate potential for personal health management or is feared as a sort of science fiction fortune telling. Clearly, society cannot afford another era of abuse of genetics, such as was incurred during the Nazi quest for racial purity. Public involvement is key to the development of guidelines governing access to this genetic information to ensure protection of individual privacy rights.

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. There is growing concern within the scientific community that a predicted shortage of American-born biologists during the next several decades could severely diminish our leadership in health-related research and development.

The Problems of Science Education

We are in the infancy of a scientific and social revolution of monumental proportions. Even so, the exciting prospects and problematic aspects of human genetics remain, for most young people, in the realm of science fiction. Thus, the excitement of the Human Genome Project offers an important opportunity to substantially reorganize science and health education to include new emphasis on human genetics. Failure to do so means failure to examine many of the most exciting topics science has to offer, failure to present socially and personally relevant issues, and, in the final analysis, failure to fulfill teaching's most important function—to prepare citizens capable of informed votes on policy issues.

We live in an age when young people are buffeted by all manner of distractions that keep them from pondering the biological mystery of life. Students

DNA experiments are offered to members of the Long Island Biological Association on a regular basis. Mark Bloom helps LIBA members interpret their DNA gel.

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 careers in biological research.

The restructuring of biology curricula must not be aimed merely at the academically gifted, but must be geared to the abilities of all young people. In the 1990s, a basic understanding of human genetics must be considered as important as a basic understanding of hygiene and nutrition. "Retooling Biology Education for the Gene Age," a study conducted by the DNA Learning Center of 252 high school biology teachers from 10 states confirmed this opinion; they rated genetics along with ecology as the biology topics "most important in preparing students for adult life."

Our experience with over 1000 advanced high school teachers in 24 states suggests that DNA literacy is only trickling through formal channels of science communication. Curriculum setters at the state and even national levels have done little to square teaching syllabuses with the reality of modern biology. Biology curricula have evolved over the years by simply cramming in more and more facts. So, at best, human genetics still must compete with frog biology for mention in the classroom.

High school biology teachers are hamstrung by overambitious and outdated syllabuses. Survey data show that the vast majority spend most of their class time lecturing from textbooks. Yet the textbooks they teach from are typically five to ten years out of date and fail to account for the biology that appears in the news almost daily. 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. 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 society.

DNA Science: A First Course in Recombinant DNA Technology

Molecular biology is generally construed as the culminating experience of the biology major's academic career. We believe that lab-teaching in molecular biology should be an initiating experience—introduced in general survey courses and comprehensively instituted in advanced high school and beginning college level courses. Through its Postgraduate Training Program and laboratory manual *Molecular Cloning*, Cold Spring Harbor Laboratory has played a key role in educating research biologists in molecular biological techniques. The DNA Learning Center extends this training to high school and college teachers through the DNA Science Workshop program.

The laboratory exercises developed for the workshop will be formally published as *DNA Science: A First Course in Recombinant DNA Technology* by David Micklos and Greg Freyer. A joint publication of Cold Spring Harbor Laboratory Press and Carolina Biological Supply Company, the lab/text is the first specifically written at the advanced high school and freshman college levels. In addition to ten field-tested protocols, extensive notes give the novice teacher access to technical subtleties that are the distillation of our teaching experience and research collaborations with over 1100 educators across 24 states.

A separate text, written in a semi-journalistic style, builds upon basic biological principles presented in a general survey course. Classical genetics and DNA structure are reviewed in a historical chapter that traces the development of molecular biology. An initial technique chapter explains the theory behind methods actually used in the laboratory. The last four chapters discuss topics of current interest that illustrate the use of recombinant DNA in basic and applied research, drawing examples directly from prominent research journals, including *Cell, Science,* and *Nature.*

Starting Early

A basic introduction to human genetics should, in fact, begin in elementary and middle school. These teachers, who interface with a cross section of America's youth, constitute a major conduit through which scientific literacy can flow to society. As a content area, human genetics at once builds upon the traditional health emphasis of elementary and middle-school science and offers an entrée 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 evaluation of science and its practical applications.

Children start their lives as natural scientists. Survey data tell us that the majority of elementary school students are enthusiastic about science; however, student interest decreases dramatically through the middle and high school years. Making best use of this window of opportunity during the elementary years 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.

The Challenge to Informal Science Education

Although the nation's schools are the logical place to begin building a DNA literate public, these formal channels of science education do not appear to be moving quickly to integrate human genetics into curricula at the precollege and even beginning college levels. This challenges agents of informal science education to move quickly to fill the void in public education and play an active role in preparing teachers to integrate human genetics at all levels. In this way, museums and science centers can help bootstrap biology teaching into the gene age.

In 1985, Cold Spring Harbor Laboratory instituted enrichment activities for precollege teachers and students under the title of the DNA Literacy Program. Key was the development and testing of entry-level experiments in molecular genetics. Although these laboratories were once viewed as somewhat esoteric, there is now growing conviction that they are essential to a general biology education. This sentiment has been legitimized by the Educational Testing Service, which recommended the teaching of DNA manipulation laboratories in the 1989–1990 Advanced Placement (AP) Biology syllabus. These laboratories will become compulsory for AP students in 1993–1994. Similar laboratories are included in the 1989 edition of a widely used text published by the Biological Science Curriculum Study.

As national curriculum setters, the Educational Testing Service and Biological Science Curriculum Study have, in effect, mandated DNA laboratory teaching at the high school level. Our experience in 24 states and Canada indicates that even the elite cadre of AP and honors teachers do not have the hands-on experience needed to introduce these laboratories with confidence. Thus, science centers can play a critical role in updating teachers on molecular genetic techniques, with which most have had no formal training. However, training activities are likely to affect only the upper echelon of most motivated teachers. Science centers must therefore take responsibility for the students of less-motivated teachers, who do little laboratory teaching of any sort.

The DNA Learning Center initiated a laboratory field trip program in spring of 1988, following completion of the *Bio2000* Laboratory. The program was an immediate success; every laboratory 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.

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.

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. Laboratories 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 better results, than their academically gifted peers. Success with 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* Laboratory for a Saturday laboratory program, "Fun with DNA." During two introductory sessions, the youngsters observed and categorized *Drosophila*

DNA Learning Center Director David Micklos looks over experiments performed by elementary school students.

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.

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. Saddening, because we can only wonder in how precious few of these young people the spark of science will be kept alive through the remainder of their precollege schooling.

In an era when fewer teachers have the time or equipment to offer meaningful laboratory experiences, the laboratory field trip program is a model for a cost-effective means to provide pooled laboratory resources to a local region. Since its opening, the *Bio2000* Laboratory has served 2000 students (105 classes) from March to December 1988 and 3800 students (183 classes) in all of 1989. 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 laboratory 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.

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. Through summer 1990, the *Vector* staff will have instructed nearly 1400 educators at 69 workshops across 28 states and Canada. Allied programs in North Carolina and California will have independently instructed an additional 621 teachers at 27 workshops. Recognizing the educational value of this workshop experience, the State University of New York at Stony Brook agreed to offer a credit option to *DNA Science Workshop* participants nationwide. Teachers who complete both a workshop and follow-up are eligible for three graduate credits from the Continuing Education Department. A workshop has been held at the Stony Brook campus each summer since 1987, sponsored by the University's Center for Biotechnology.

Our experience over the past four 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. 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.

Educational Collaborations

The Curriculum Study has grown to include 24 Long Island school districts, which receive numerous benefits, including lectures by scientists, reduced admission fees 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 1989, minority/rural students and teacher chaperones representing each of the Macy-sponsored programs convened for a 2-week workshop at the DNA Learning Center. 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 students sampled some New York culture, including the Metropolitan Museum, Bronx Zoo, Broadway, the New York Mets, and a whale watch off Montauk Point.

Students from New York, Connecticut, Alabama, and Arizona participated in a two-week workshop sponsored by the Josiah Macy, Jr. Foundation.

A related 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 62 schools where BioPrep teachers have instructed 2000 students.

The 1986 workshop held at the University of California at Davis prompted the creation of a state-supported instructional program. 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 California, and they have also "cloned" our Vector van approach to teaching. A minivan supplied by Genentech, Inc.—named Helix I—carries equipment to participating schools, where teachers and 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. By the end of 1989, the number of teachers trained increased to 325.

The program also makes available, on a rotating basis, eight equipment sets to help teachers begin to implement DNA laboratories. By the end of the 1989–1990 school year, 100 schools, representing two thirds of the school districts in the state, will have 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 been incorporated as a standard part of the Institute's summer program.

As the year ended, we began a collaboration with the Howard Hughes Medical Institute. Respected as the largest nongovernment contributor to medical research, Hughes is now aiding the effort to revitalize science education. So, we were pleased when the Vice President of Hughes, Joseph Perpich, asked us to help establish a DNA science program in their home area of Montgomery County, Maryland. During the next year, we will be working with Hughes to train Montgomery County educators in laboratory-based DNA science teaching.

The Evaluation Program

As of fall 1989, we have personally instructed nearly 1100 high school and college instructors in DNA science workshops. The majority have completed both a pre-survey at the beginning of the workshop and a post-survey at the end of their week-long training. In fall 1988, we began a mail survey to follow up on 252 teachers who had completed the workshop prior to 1988. The response of our "alumni" was overwhelming; 90% returned completed surveys.

We have just completed a preliminary analysis of the survey data. The findings document a number of behavioral changes that resulted from workshop participation and suggest ways to promote innovation in the science classroom.

Seven in ten teachers had presented new topics on molecular biology and attempted at least one new laboratory during the school year following the workshop. Three in ten had implemented laboratories on DNA transformation (36%) and DNA restriction analysis (28%).

Many participants carried on networking activities to educate other teaching professionals about molecular biology, including presentations (36%), lab demonstrations (24%), presentations at professional meetings (11%), and training workshops (11%).

A majority of workshop participants (54%) attempted to secure funds or equipment with which to implement new laboratories. Seven in ten of those who tried were successful, reporting a total of $189,000 in monetary support and $88,000 in equipment/reagent donations.

The highly innovative science teacher feels more respected in the community and has more positive attitudes about his/her students' parents and school administration. This finding emphasizes that the more innovative teacher is not a "lone wolf," but feels connected within a social system.

This silent background of positive attitudes about students, school system, and community allows the innovator to overcome infrastructure constraints to laboratory teaching—insufficient time, space, and equipment. The innovative teacher makes greater use of all information sources, except television, and incorporates into his/her teaching more information from primary sources—education and scientific journals.

We will have a complete set of data on 1988 participants later this fall. These new data will give us an opportunity to test a predictive model of innovative behavior. We will see if a discriminant function developed from the 1987 data set can identify innovators among the 1988 cohort.

Materials Development

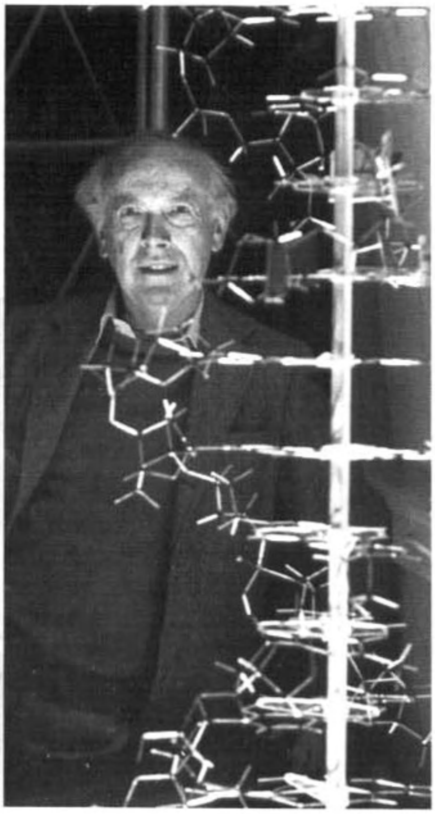
In September, we completed a $24,500 renovation of our downstairs space to create a small prep and research laboratory. Supported by a grant from the Banbury Fund, the renovation gives us much needed private space to adapt research techniques to the needs of educators. The prep lab is fitted with two small autoclaves that free us from endless trips to the Laboratory to sterilize reagents and agar plates.

Basement area before and after renovation into a research lab.

We are developing 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. Our approach is to 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 (USB) and Perkin-Elmer Cetus to develop polymerase chain reaction (PCR) for educational purposes. Of great interest is a kit that allows 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 sample of 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.

United States Biochemical, with expertise in PCR, DNA sequencing, and nonisotopic detection systems, is an ideal corporate partner to assist in the development of these second-level experiments. Furthermore, USB has expressed interest in helping us to develop instructional materials that make use of video and interactive computer software. This multimedia approach will complement laboratory-based instruction exceeding the capabilities of either used alone.



James D. Watson

Exhibit Development

A world-class museum program was established 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. The exhibit chronicles the study of heredity from Darwin to DNA and confronts the visitor with the promise and concern of genetic technology. Since its opening in September 1988, over 15,000 visitors have toured *The Search For Life*.

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 *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.

As a small institution, we can never hope to attract audiences the size of those that visit the Smithsonian or the Museum of Natural History. Therefore, we intend to extend our educational reach by "franchising" or leasing exhibits to other science museums. Several factors should encourage franchising:

Cold Spring Harbor Laboratory has an established reputation in molecular genetics, and the DNA Learning Center is the world's only museum dedicated to biotechnology education. Few museums have a staff of molecular biology interpreters or such access to expert assistance.

The cost of lease or franchise will be far less than it would be to develop an exhibit from scratch.

Modular design will enable exhibit components to be configured for almost any display area.

Exhibit elements will incorporate the latest audiovisual and computer technology. Interactive features will encourage use of a number of senses to stimulate interest and understanding.

***DNA Detective*: Variability in Human Molecular Genetics**

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. Each case module consists of three backlit 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." The third display describes the resolution of the case.

Dr. and Mrs. Richard J. Roberts at opening of the DNA Detective exhibit.

The serialization of cases and the ease of exchanging materials between one or more modules makes it cost-effective to create a rotating "gallery" of DNA fingerprint cases. The Technology Center of Silicon Valley in San Jose, California plans to install a unit for its opening in 1990, and several other museums have expressed interest. The initial cases illustrate various applications of DNA fingerprinting and, whenever possible, historical precedents in law, medicine, and society:

Ghana Immigration (1985). This case from Britain was the first to introduce DNA fingerprinting in a court of law. The data were used to prove the maternity of an English woman and her child, who wished to emigrate from Ghana. 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.

Thoroughly Bred? (1989). In this case, the paternity of a thoroughbred race horse was in doubt. DNA fingerprints showed that the foal was not sired by a famous race horse, but by his less illustrious son. Original case materials were provided by Lifecodes Corporation.

Corporate executives attending the Baring Brothers conference used a sophisticated new technique called polymerase chain reaction to perform a DNA diagnosis for sickle cell anemia.

Staff

The expanding programs of the DNA Learning Center (DNALC) are a testament to the dedication and hard work of the staff. Education manager, John LeGuyader, continues to shoulder most of the daily teaching responsibilities in the *Bio2000* Laboratory. John's research and teaching experience enabled him to quickly assume the role of senior instructor for the *DNA Science Workshop program.* His organizational skills are now being put to effective use managing our Curriculum study and Macy-school collaborations.

In January 1989, Susan Lauter (formerly Susan Zehl) left the Laboratory's Public Affairs Department to join our permanent staff as designer. 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.* Sue's first exhibit design, *DNA Detective*, is currently on display at the DNALC.

Anne Zollo has the unenviable task of overseeing the smooth running of the DNALC. Her many responsibilities include scheduling laboratory and exhibit visits, juggling travel schedules, and managing the bookstore. Perhaps most important, Anne has adapted well to the occasionally frenetic pace of activity—without losing her composure.

The teaching load was 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. Kelly has also made an important contribution to the summer workshop program, so we are very pleased that she will be helping us again this summer.

Carrie Abel began part-time work at the DNALC in June 1989, assisting Sue with artwork for the textbook. Carrie has an art degree from Syracuse University and currently teaches at C.W. Post. Her artistic and organizational talents have proven essential to the timely completion of the project.

Interns, ranging in age from high school sophomores to graduate students, provide critical assistance to our teaching staff. Deserving special mention is John

Kruper, who completed his doctorate in science education at the University of Illinois at Chicago, in October 1989. Currently a postdoctoral fellow at the University of Chicago, John has had primary responsibility for our evaluation program, which tracks the many hundreds of teachers who have participated in *DNA Science Workshops* over the years.

Chai Chen (aka "Sol,"), presently a senior at Rensselaer Polytechnic Institute, joined us for the summer 1989 *Vector* tour. Sol quickly adapted to life on the road as a DNA gypsy and kept the workshops running smoothly. Lab aide Steve Malloy, a senior at Cold Spring Harbor High School, has been joined by Steven Friedenberg and Jeff Hwang, both sophomores at Half Hollow Hills East High School. Their efforts are essential to the smooth functioning of the *Bio2000* Laboratory.

Sandy Ordway, who together with Anne Meier helped coordinate our volunteer program, is now a part-time DNALC staff member. Sandy continues to help with museum visitation while providing much needed assistance with our evaluation program. Working together, the staff are helping the DNALC continue to grow, striving to reach its potential as an "exploratorium" of DNA.

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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
	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
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
	Ohio State University, Wooster*	1989
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.

Curriculum Study Membership 1989-90

Cold Spring Harbor Central School District*
Commack Union Free School District
East Williston Union Free School District*
Great Neck Public Schools*
Oyster Bay-East Norwich Central School District*
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*
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
Plainedge Public Schools
Plainview-Old Bethpage Central School District
Port Washington Union Free School District
Portledge School
Sachem Central School District at Holbrook
South Huntington Union Free School District
Syosset Central School District*

* Founding members

DNA LEARNING CENTER

Grantor	Program/Principal Investigator	Duration of Grant	Total Award
FEDERAL GRANTS			
NATIONAL SCIENCE FOUNDATION	Teacher Enhancement Program	1987–90	415,928
NONFEDERAL GRANTS			
The Banbury Fund	Core Support	1989	30,000
Dentsu Inc.	Core Support	1989	10,010
Harweb Foundation	Core Support	1989	1,000
J.M. Foundation	Core Support	1989	25,000
The Ester A. and Joseph Klingenstein Fund, Inc.	Core Support	1989	25,000
Richard Lounsbery Foundation	Core Support	1989	50,000
Josiah Macy, Jr. Foundation	Core Support	1987–90	490,850
Teleflex Foundation	Core Support	1989	1,000
American Society for Microbiology, Michigan Branch	Vector Workshop	1989	1,539
Anne Arundel Public School, Maryland	Vector Workshop	1989	3,430
Bethany College, West Virginia	Vector Workshop	1989	10,110
Biology Teachers' Organization, Winnipeg, Canada	Vector Workshop	1989	10,870
Board of Cooperative Education Services, New York	Vector Workshop	1989	2,000
Center for Biotechnology, SUNY Stony Brook	Vector Workshop	1989	10,550
Champlain Valley High School, Vermont	Vector Workshop	1989	830
Cooperating School District of St. Louis Suburban Area, Inc.	Vector Workshop	1989	7,382
Dover-Sherborn High School, Maine	Vector Workshop	1989	373
Nassau Community College	Vector Workshop	1989	1,000
Project Share, Connecticut	Vector Workshop	1989	2,000
University of Wisconsin	Vector Workshop	1989	1,370
Commack School District	Curriculum Study	1989	500
East Williston School District	Curriculum Study	1989	500
Great Neck School District	Curriculum Study	1989	500
Half Hollow Hills School District	Curriculum Study	1989	1,500
Harborfields School District	Curriculum Study	1989	500
Herricks School District	Curriculum Study	1989	500
Huntington School District	Curriculum Study	1989	500
Island Trees School District	Curriculum Study	1989	2,000
Jericho School District	Curriculum Study	1989	500
Lawrence School District	Curriculum Study	1989	1,500
Locust Valley School District	Curriculum Study	1989	500
Manhasset School District	Curriculum Study	1989	500
Northport-East Northport School District	Curriculum Study	1989	500
North Shore School District	Curriculum Study	1989	500
Oyster Bay-East Norwich School District	Curriculum Study	1989	500

Grantor	Program/Principal Investigator	Duration of Grant	Total Award
Plainview-Old Bethpage School District	Curriculum Study	1989	500
Plainedge School District	Curriculum Study	1989	2,000
Portledge School District	Curriculum Study	1989	500
Port Washington School District	Curriculum Study	1989	500
Sachem School District	Curriculum Study	1989	500
Syosset School District	Curriculum Study	1989	500
Brunswick Appraisal Corp.	The Search for Life Exhibit	1989	100
Shogren Industries Inc.	The Search for Life Exhibit	1989	500