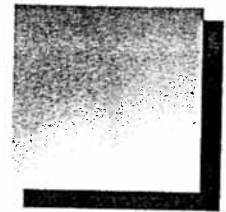
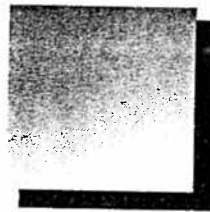
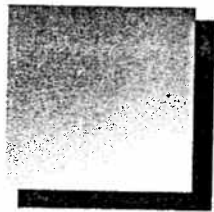
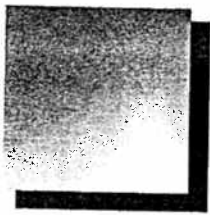


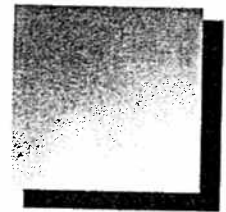
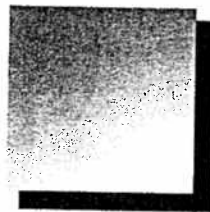
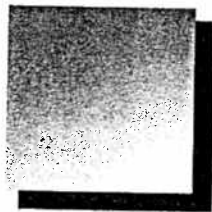
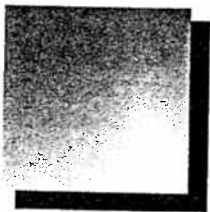
# School of Education

# REVIEW

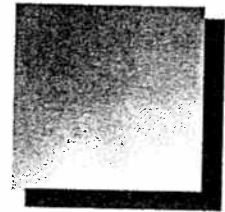
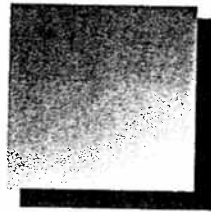
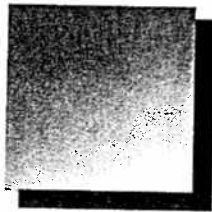
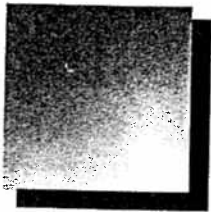
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San Francisco State University

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## San Mateo County Biotechnology/Education Partnership

Sue Black  
Kathy Liu  
Stan Ogren

*"I feel pretty important and professional using all this high-tech equipment. It's a neat experience!"*

*"I feel like a real scientist!"*

*"The part I like the best was finding out for myself. . ."*

*"I was pretty scared doing my first lab, but when I discovered that my DNA was cut, my confidence built up."*

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These are comments by students who have just spliced together antibiotic resistant genes, put them into prepared bacteria and grown the bacteria in the presence of the antibiotics. During the past two years, these students and more than 4000 of their peers in San Mateo County have done a series of high tech recombinant-DNA experiments. This technology is similar to that used by scientists in university and industrial research labs.

In the first week of labs, students learn to use equipment not usually available to high school students. Students become adept in the use of micropipets, which measure amounts as small as one microliter (1,000  $\mu$ l = 1 mL; approximately 5 mL = 1 teaspoonful) so that later they will be able to accurately aliquot the very small amounts of DNA, enzymes, and needed reagents. They master power supplies and gel boxes so they can use a process called gel electrophoresis to separate DNA fragments by length. They learn sterile techniques for handling DNA, enzymes, and bacteria so their bacteria can grow uninhibited by contaminants. (Safety is emphasized despite the fact that the bacteria used will not easily grow outside the culture medium provided.)

In the second and third weeks, students participate in a series of labs (adapted from Miklos &

Freyer, 1988) during which they:

- use enzymes to cut two different bacterial chromosomes (plasmids) into pieces;
- use gel electrophoresis to check that the DNA was actually cut;
- use another enzyme to fasten pieces of DNA to each other;
- treat bacterial cells so that they will take in DNA (make competent cells);
- introduce DNA they have recombined into receptive (competent) bacteria; and
- test bacteria for the expression of recombinant DNA by spreading the cells on nutrient agar mixed with one antibiotic, two antibiotics, or with no antibiotic.

In other experiments supported by this project, students isolate and spool DNA, simulate forensic DNA fingerprinting, and learn bacterial plating techniques.

Students react to the labs . . .

with awe: *"each procedure should be savored by the students,"*

with frustration: *"If only we could have had more time," "We went too fast,"*

and with understanding: *"There is a lot riding on one microliter," and "It is interesting to be learning about the future in the present."*

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*Sue Black, Aragon High School,  
Kathy Liu, Westmoor High School, and  
Stan Ogren, Menlo-Atherton High School,  
are science teachers in San Mateo County.*

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## A Partnership That Delivers

All of this is happening just south of San Francisco, in San Mateo County, California where we have created a partnership that delivers equipment and supplies for the above mentioned experiments to high school classrooms throughout the county. Precision micropipets, gel boxes, power supplies, prepared reagents, sterile media, enzymes, plasmid DNA, and other sophisticated equipment and reagents are delivered directly to high schools, ready to use. Detailed laboratory protocols, student worksheets and an extensive teacher resource file come with the kit.

Our students are beneficiaries of a partnership which involves an industry (Genentech), a community college (Skyline College), a county office of education (San Mateo C.O.E.), teachers from three high school districts (the authors of this article), and a university consultant (Lane Conn, Manager of the Teacher Education in Biology program (TEB) at San Francisco State University).

## How It All Began

The idea to establish a cooperative, county-wide program was conceived during a three day symposium in the summer of 1989 sponsored by San Francisco State University (SFSU), the National Science Foundation (NSF) and the California State Department of Education. As is usual at gatherings of teachers, there was a lot of "shop talk" and sharing-sharing of excitement and sharing of frustrations. The three of us had taken the exciting TEB workshop in the techniques of molecular biology and wanted our students to share our excitement. Individual department budgets could not afford the necessary equipment, and our schools do not have autoclaves with which to sterilize the reagents and supplies required for such a program. We hypothesized that a county-wide cooperative effort would be a more efficient use of resources and would have a better chance of being funded. We three teachers decided to work together to secure funding for the equipment, supplies, and support we needed to implement recombinant-DNA experiments into our classrooms.

The first step in making our dream a reality was forming the San Mateo County Biotechnology Education Steering Committee. If we were to be a county-wide project, we needed to involve the

County Office of Education. Gary Nakagiri, Math/Science Coordinator for San Mateo County, was supportive of the idea and joined the committee as the county representative. Once we applied for grant money, the county would become the fiscal agent for our project. Lane Conn, Project Manager of the TEB, joined our steering committee as a consultant.

We needed laboratory protocols and a list of equipment, materials, and supplies to support them. Using SFSU's TEB out-reach program as a model, we established a wish list of equipment, materials and supplies.

Four more major hurdles needed to be overcome. We needed:

- funds;
- a refurbishing center where someone would prepare solutions, replenish the kit between schools, and autoclave materials;
- a way of getting the kits from one school, to the refurbishing center, and back to another school; and
- scientific expertise.

The Audio-Visual Department of the County Office of Education agreed to transport our equipment in a van usually used for delivering films to county schools. (While we refer to "the kit" as a singular unit, in reality the kit consists of 26 crates of material.)

Two Genentech scientists joined our steering committee. Drs. Cori Gorman and Paul Godowsky provided considerable support to the project when it was in its infancy. They provided technical advice both over the phone and in the classroom. Dr. Gorman is now co-chair of our Bioethics Subcommittee. She continues to assist us with the procurement of competent cells and other biological materials, refinement and trouble shooting of laboratory procedures, and curriculum development.

Dr. Christine Case, Biology Professor from Skyline College, also joined the Steering Committee. She brought with her scientific expertise and the participation of Skyline College. Skyline agreed to be the refurbishing center for the kit. Our project would pay a technician to prepare reagents and media, sterilize equipment and reagents, and properly dispose of biological waste generated at school sites. Dr. Case established protocols for safely handling the materials in the kit and serves as an ad-

visor on curriculum development.

We were anxious to get started. If we could get funding in time, we would run a three-school pilot program to test equipment and procedures during March, April and May. The kit would remain at each school for approximately three weeks. Between schools, it would spend a week at Skyline.

The Steering Committee made a presentation to the Board of Directors of the Genentech Foundation for Biomedical Research. Our proposal was funded, and we were on our way. Prior planning made it possible for the program to move forward immediately upon receipt of the check. Equipment bids were finalized. Equipment and supplies were ordered. Our kit was assembled. A reception featuring student-led biotechnology experiments was held at the County Office of Education to introduce the program to county and district administrators, school principals and others invited guests.

Table 1

### Overview of Biotechnology Laboratory Experiments

#### Techniques Labs

- A. **Manipulating small volumes**  
*Skill:* Select and use the correct micropipet to accurately measure volumes from 2  $\mu$ L- 1000  $\mu$ L.  
*Concept:* Very small amounts of DNA, enzymes and buffers are used in these labs.
- B. **Electrophoresis**  
*Skill:* Safely set up and use gel box and power supply.  
*Concept:* Discover the function of each component used in electrophoresis.
- C. **Casting and loading an agarose gel**  
*Skill:* Practice casting, loading, and running an agarose gel.  
*Concept:* Electric current running through gel separates compounds put into agarose wells.
- D. **Making cells competent**  
*Skill:* Make *E. coli* cells competent to undergo transformation with exogenous DNA.  
*Concept:* The cell walls of *E. coli* must be treated in order for the cells to take up DNA from their surroundings.
- E. **Plating bacteria**  
*Skill:* Use sterile technique to streak two kinds of nutrient agar (with and without an antibiotic) with *E. coli*.  
*Concept:* Sterile technique is used to avoid bacterial contamination. Bacteria, like all living things, have different genotypes and different phenotypes.

#### Introductory Labs

##### 101. Precipitating and spooling DNA

*Skill:* Precipitate and spool DNA.

*Concept:* DNA is real. In large amounts, it can be seen and touched.

##### 102. pAmp transformation

*Skill:* Introduce DNA containing a gene for ampicillin resistance into *E. coli*.

*Concept:* Introduced DNA can change the properties of bacterial (and other) cells.

#### Recombinant DNA Labs

##### 201. Restriction enzyme digestion

*Skill:* Perform side-by-side restriction digests of plasmids containing two different antibiotic resistant genes.

*Concept:* Restriction enzymes cut DNA at locations determined by the sequence of DNA bases

##### 202. Gel electrophoresis

*Skill:* Use gel electrophoresis to determine whether DNA was cut during restriction digest.

*Concept:* Gel electrophoresis separates DNA fragments by size.

##### 203. Staining and photographing gels

*Skill:* Stain and photograph DNA in agarose gels.

*Concept:* DNA can be made visible by staining. Photographs preserve results for study.

##### 204. Ligation

*Skill:* Ligate DNA fragments obtained in Lab 201 to produce recombinant DNA.

*Concept:* Ligation enzymes catalyze the connection of DNA fragments. Some of the ligated DNA contains both of the antibiotic resistant genes (recombinant DNA).

##### 205. Transformation

*Skill:* Introduce ligated DNA into receptive *E. coli* cells.

*Concept:* Once inside bacteria, ligated DNA "transforms" the bacterial cells so that they express new traits (in this case, antibiotic resistance).

##### 206. Expression

*Skill:* Select for cells resistant to antibiotic resistant genes by plating them onto agar containing antibiotics.

*Concept:* Growth of colonies on agar containing antibiotics shows that cells are expressing their new genes.

#### Advanced Labs

##### 301. Spooling DNA from thymus glands

*Skill:* Isolate, precipitate and spool DNA from calf thymus, "sweetbreads."

*Concept:* DNA can be isolated from cells. After isolation and precipitation, it can be seen and touched.

##### 302. Effects of DNA methylation on restriction enzyme digestion

*Skill:* Use gel electrophoresis to determine whether DNA was cut during restriction digestion.

*Concept:* Methylation of DNA protects it from digestion.

##### 303. DNA fingerprinting

*Skill:* Use gel electrophoresis to visualize pieces of DNA.

*Concept:* Restriction enzymes produce unique fragment patterns of DNA from different sources.

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### Spring 1990—The Birth

The kit, temporarily dubbed "Science 2000," was delivered to Aragon High School. Just seven months after the idea of a county-wide biotech program was conceived, 165 biology students were splicing DNA. By the beginning of June, more than 700 students in 24 sections of life science, biology and advanced placement biology classes at Aragon, Menlo-Atherton, and Westmoor High Schools had participated in the pilot project. Parents, administrators, and school board members had attended three very successful open houses. The San Mateo County Biotechnology/Education Project was on its way.

### Summer 1990—A Time For Consolidation, Revision, and Planning Ahead

At an intense, one-week workshop, we reviewed program procedures, equipment and supplies. The biggest complaint from students and teachers alike was that the time was too short. Schools needed more time with the kit. Another complaint was that because Skyline did not need to refurbish every crate, moving all twenty six crates into and out of storage at Skyline was inappropriate. The crates were reorganized to consolidate the materials that needed to be replenished. Procedures were revised, sending only six of the twenty-six crates to Skyline and the rest on to the next school. This effectively gave each school an extra week with the kit.

In addition to making kit changes, we reviewed applications from potential participants, revised laboratory protocols and wrote student worksheets. Some of the labs proved extremely difficult to finish in 50 minute class periods. In some cases, changes were made in student and teacher instructions to show where the lab could be safely stopped and continued the next day. For other labs, steps were rewritten to take less class time.

### 1990-1991—Full Implementation

By September, the labs and the kit were ready for the school year. During the 1990-91 school year, the kit was in use continuously from the middle of September until the end of May. Over 1800 students of 15 teachers at eight high schools used our kit to do recombinant DNA experiments.

Summer of 1991 meant several new projects

for the SMCEBP Steering Committee: the drafting of new laboratory protocols, the production of a floppy disk to simplify the dissemination of the materials we had developed, further revision of kit logistics, the creation of a Bioethics Subcommittee, and planning for a second kit. In terms of implementation, one of the greatest frustrations we as teachers had faced was lack of time. In spite of the fact that many of the required solutions are prepared and/or sterilized by Skyline College technicians, there is still a great deal of preparation that must be done at the school site. This preparation was particularly stressful when, due to time constraints, the labs had to be scheduled on three or four consecutive days. Students, too, were overwhelmed by such schedules. The addition of a second kit during the 1991-92 school year (purchased with a generous second-year grant from the Genentech Foundation for Biomedical Research) allowed the time at each school to be extended an extra week or more, thus reducing the stress of implementation on teachers and students alike.

### The Future, Today

The addition of a second kit was just a first step in our expansion plans. As more teachers hear about and see this program in action, more want to participate. So far, we have not had to turn qualified participants away. Eventually, we would like to expand the program to include all county high schools with support for related experiments in general science, chemistry and physics as well as additional biology experiments. This will mean multiple sets of equipment, additional re-supply centers and a full time coordinator/mentor/teacher.

However, comments like these from our students show that educational partnerships like this one are worth the effort:

"At first I thought that biology was just another class."

"Letting us use the sophisticated equipment gives us the trust we deserve."

"(These labs) allowed me to believe that science is more than just reading and memorizing."

"It has made me notice that there are still things in the world to be found."

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"I know that a lot of effort went into these labs, and I really appreciate it. Thank you."

#### Partnership Participants

Partnerships such as this one take time and commitment to make them work. Ours has been successful because of the dedicated cooperation and commitment of many people. Listed below are the people and foundations who have made our program work. We join the students in thanking each one of them.

San Mateo County Office of Education  
Gary Nakagiri, Math/Science Coordinator,  
and LeRoy Finkel, Director, Media Services

Skyline College  
Christine Case, Professor, and Patricia Carter,  
Laboratory Technician

Genentech, Inc.

Cori Gorman and Paul Godowsky, Scientists

San Francisco State University

Lane Conn, Program Manager, Teacher  
Education in Biology

Genentech Foundation for Biomedical Research

Peninsula Community Foundation

#### Work Cited

Miklos, D. A., & Freyer, G. A. (1988). *DNA Science: A first laboratory course in recombinant-DNA technology*. Cold Spring Harbor, NY: Cold Spring Harbor Laboratory Press.