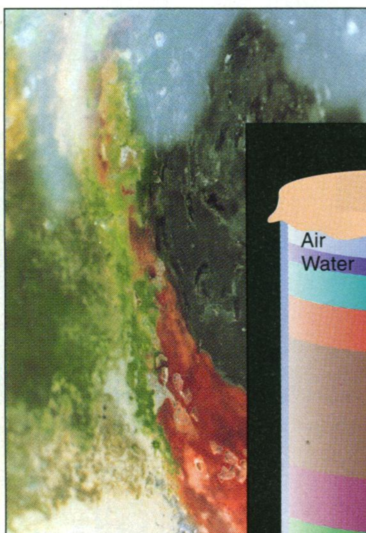
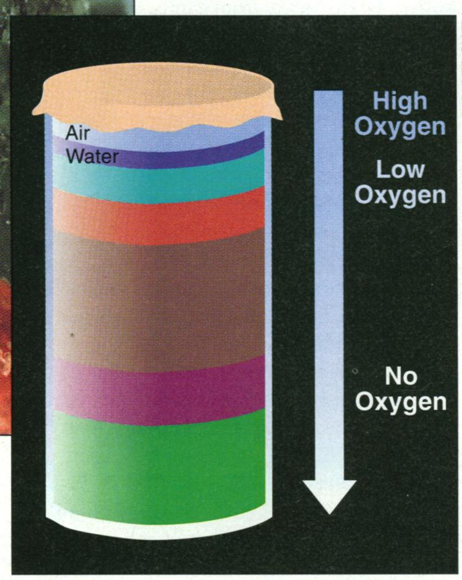
SCIENCE EDUCATION

Reading, Writing, Arithmetic ...and Microbes?

BOSTON—It seems an unlikely recipe for a good science education. First, scoop up mud from a river bank. Mix in shredded newspaper, yolks from a few hard-boiled eggs, and a bit of water. Then bottle the sludge in a tall glass container, place it under a light, and sit back and wait. In a few weeks, an earthy rainbow of greens, reds, purples, and yellows layers the muddy mixture. The reason? As they search for the perfect growing conditions, bacteria of varied types and colors separate themselves into distinct populations at different depths within the container.





Mud skyscraper. Colorful bacteria segregate themselves in the container looking for perfect growth conditions.

C. FABER SMITH

This simple visual experiment and others like it provide the foundation of an innovative science education curriculum called "Microcosmos" that is growing in popularity throughout New England and has even crossed national boundaries via teacher workshops in Canada and Spain. Named for its emphasis on using the microbial world to teach fundamental skills and encourage scientific curiosity among seventh through ninth graders, Microcosmos is the product of 5 years of development at Boston University (BU). "We're the only science education effort trying to create interest in science at the precollege level via the microbial world," claims one of the program's developers, BU education professor Douglas Zook.

While it's still too early to determine how effective Microcosmos is, it has succeeded in at least one regard. Until recently a low-budget, volunteer-driven enterprise that relied on small grants, Microcosmos went big time this spring when the National Science Foundation (NSF) lent its support to the program with a $1.1 million grant to train nearly 1600 teachers over the next 3 years. "We hope that curricula like this one, which teach good hands-on science, spread like wildfire." says David Schindel of NSF's Teacher Enhancement Program.

As Schindel's comment suggests, Microcosmos is part of a nationwide trend to give students actual experience in doing experiments, rather than relying on lectures by teachers and rote memorization. As with the many other hands-on curricula, the hope is that if Microcosmos can build the problem-solving skills and self-confidence of its young students, they will then discover that doing science is a rewarding experience—something that doesn't happen often enough now. Educational studies have shown, explains Zook, that for junior high students "science becomes a drag, a bore, a whole lot of negative things," largely because of the ineffectiveness of teaching by the lecture format. For such students, pursuing science in high school is a rare choice.

Where Microcosmos differs from other hands-on programs is in its choice of subject matter. Microorganisms such as algae, fungi, and bacteria can be excellent vehicles for educating children about both scientific principles and skills, says Zook, who first developed the concept of Microcosmos with Lynn Margulis of the University of Massachusetts, Amherst, who is best known as a fervent proponent of the controversial Gaia hypothesis, which sees the whole planet as a single organism woven from billions of interconnected life forms. At the junior high level, Zook says, students are still fascinated by the thought of alien worlds, which, in effect, the microbial universe is to most people. Microcosmos attempts to play upon that curiosity, transforming the act of science into an exploration. "It's nice because it involves things that are all around kids, but they never realized were there," says Douglas Lapp, director of the Smithsonian Institution's National Science Resource Center, which is incorporating some of Microcosmos's lessons into its elementary curriculum development.

But before students start their explorations, Zook says, it's necessary to make them feel comfortable with the world of microbes. Some children and even adults, he explains, suffer from an irrational "microphobia," a fear of microbes that he thinks dates back as far as the great plagues in history and continues today with our distaste for disease-causing "germs." To counter that phobia, teachers are trained in Microcosmos workshops, for example, to help students cook up a virtual smorgasbord of foods that rely on microorganisms: cheese and yogurt, both made with bacteria, share the menu with yeast-derived root beer, bread, and pancakes.

The heart of the program, though, is the development of the skills important in the pursuit of a scientific career, as well as for many other professions. While watching the multicolored "microbial city" develop from simple river mud and doing other simple experiments with microbes, the kids learn how to classify organisms, take measurements, keep records, and analyze results. They also learn patience, which can serve a student well no matter what his or her chosen profession. "You shouldn't be teaching content without teaching skills," says Pam Pelletier, a New Hampshire high school teacher and Microcosmos team member.

The Microcosmos approach also takes care to ease the students into the work slowly. To prepare them to use the microscope, for example, the students start with $6 microviewers that provide ample magnification to gain a new perspective on the world. Using the microviewers, the students examine patterns found in simple objects and materials, ranging from their sweaters to a piece of wood. "I find it a wonderful window into the microbial world," says Pelletier, who explains that students can sometimes be scared by the dramatic scale shift of microscopes.

And the approach to the microscope itself highlights the emphasis Microcosmos places on making traditional educational techniques fun and interactive. Just about anyone who has taken an introductory biology course has learned to use the microscope by examining a pond-water sample for the many microbes it contains. But to spice up this routine, Microcosmos-trained teachers assist students in constructing a simple fishing apparatus, made from string, a popsicle stick, and microscope slide, that they "cast" into a jar of aquarium or pond water. After letting the slide sit for a few hours, the children reel it in and use the microscope to identify the catch of the day. This simple game makes such a dramatic difference in enthusiasm, says Zook, that "students are begging to use the microscope."

With their students firmly entranced by the microscopic world and growing more confident in their abilities, teachers are then able to explore more challenging topics such as cell biology, a subject normally found in advanced placement high school biology courses. Through blowing giant bubbles, for example, students visually delve into the study of membranes, with teachers simultaneously explaining how cell membranes, like the bubbles, are made of lipid bilayers. On an even more sophisticated level, a problem-solving board game called Microsleuth introduces various organelles found in cells, such as mitochondria, lysosomes, and chloroplasts, as well as concepts like endocytosis, intracellular transport, ATP, and the production of proteins.

As with many innovative science education programs, it has been difficult to evaluate the effectiveness of Microcosmos quantitatively. The program is only a few years old and anecdotal results are the main ones currently available. But school administrators like the program because it's inexpensive and most of the lessons do not require microscopes, a luxury many schools cannot afford. And teachers, for their part, rave about the program. For instance, look at Pelletier's experience. Before attending a Microcosmos workshop in 1988, "I was kind of burning out in my classroom," says the high school teacher, who recently won New Hampshire's Presidential Award for Excellence in Science and Mathematics Teaching and spent the year giving almost 200 workshops on Microcosmos to teachers in the state.

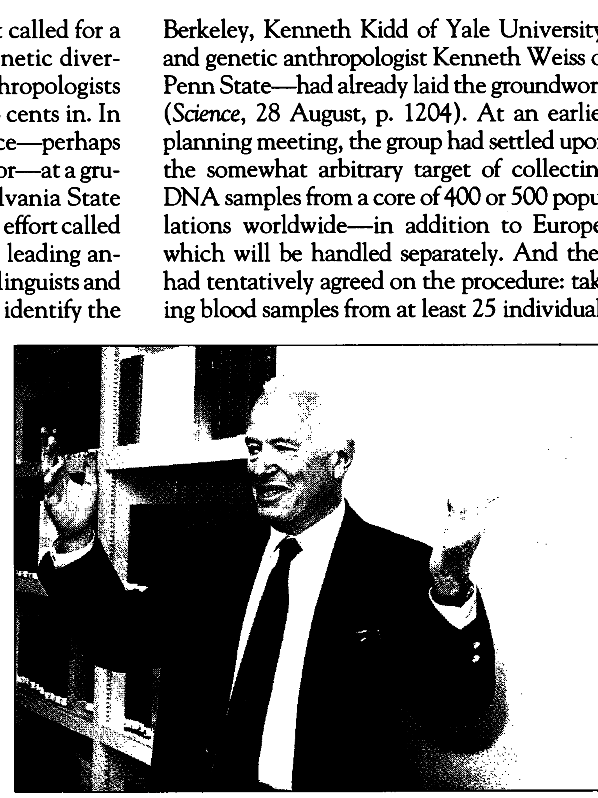
Of course, exciting students, not teachers, is the primary goal of the curriculum. In that respect, students seem to love the lessons, says Zook, but he acknowledges that a more objective academic evaluation is needed for Microcosmos in the coming years. In fact, a number of his graduate students are focusing their theses on just that task. And one of the requirements in the NSF grant is that the trained teachers provide reports on their use of the lessons.

While waiting for data to confirm their initial feedback from teachers, the Microcosmos team is confident they have hit upon a winning formula. "If the earth could speak directly to us, it's language would be microbial," begins the introduction in their curriculum guide. And by teaching that language to young students, Zook and the rest of his team hope to inspire not just more microbiologists, but rather a new generation free of microphobia, more aware of the world around them, and in love with the practice of science, whatever discipline they may choose. Only time will tell though, if lowly microbes can lead to such an optimistic future.

–John Travis

GENOME DIVERSITY PROJECT

Anthropologists Climb (Gingerly) on Board



STANFORD

Open arms to anthropology. Luca Cavalli-Sforza.

Since a group of geneticists first called for a massive survey of humanity's genetic diversity a year and a half ago, anthropologists have been dying to get their two cents in. In late October they got their chance—perhaps even more than they bargained for—at a grueling 3-day workshop at Pennsylvania State University. The organizers of this effort called together about 50 of the world's leading anthropologists, archeologists, and linguists and gave them a tough challenge: to identify the 500 or so indigenous populations most worthy of genetic study, out of the roughly 7000 believed to exist worldwide. For the assembled anthropologists, that was rather like trying to put together a sparse meal from a smorgasbord groaning with delights.

Adding to the immensity of the task before the anthropologists was the fact that the participants, selected for their expertise on specific regions of the world, came with their own perspectives, biases, loyalties, and research agendas. And then there was the tension, at least in some eyes, between the twin goals of the Human Genome Diversity Project: to get a snapshot of genetic diversity and how populations are related, and to probe human evolutionary history—human origins, migrations, and expansions. A few of the anthropologists also brought some skepticism about the design of the project and even the value of genetic data in elucidating human history.

Yet to the great surprise of nearly everyone involved, the anthropologists put aside their doubts and differences—albeit after some grumbling—and plunged in. They divided up the world into six regions, each of which was assigned to a working group. With overworked graduate students manning the word processors, the groups hammered out a several hundred page report in just 3 days, with details on some 500 populations across the globe. What pulled them together, several members of the group told *Science*, was their sense that however imperfect the survey might be, it is, as South African anthropologist Trefor Jenkins put it, "impossible to resist."

The anthropologists arrived at Penn State to find that the organizers of the project—who include geneticists Luca Cavalli-Sforza and Marcus Feldman of Stanford University, Mary-Claire King of the University of California, Berkeley, Kenneth Kidd of Yale University, and genetic anthropologist Kenneth Weiss of Penn State—had already laid the groundwork (*Science*, 28 August, p. 1204). At an earlier planning meeting, the group had settled upon the somewhat arbitrary target of collecting DNA samples from a core of 400 or 500 populations worldwide—in addition to Europe, which will be handled separately. And they had tentatively agreed on the procedure: taking blood samples from at least 25 individuals in each group. The samples will then be preserved in permanent cell lines to provide reservoirs of DNA for analysis.

The organizers had also settled on two overall criteria to guide the anthropologists' choices: to strive for a representative sample of human diversity but also to choose populations that are essential for answering major historical questions. The anthropologists were given free rein to identify the most interesting questions—for instance, how many expansions occurred across Beringia (now the Bering Strait) into the New World, or the relations among the many small populations in the Amazon. The problem, though, as the groups quickly realized, is that the two criteria don't necessarily result in the same populations.

For some populations there was no contest. Everyone agreed the highest priority should go to unique, historically vital populations that are in danger of dying out or being assimilated (see box on next page). But selecting the others was not so easy, as the deliberations of the sub-Saharan Africa group, chaired by John Yellen, archeology program director at the National Science Foundation, made clear. Most of the anthropologists in the group were much less interested in a broad