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

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.

Open arms to anthropology. Luca Cavalli-Sforza.

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

survey of genetic diversity than in designing a sample that would bring genetics to bear on specific questions such as the origins and nature of the Bantu expansion, when the first agriculturists swept across much of Africa some 2000 years ago. They quickly realized, however, that they could use up all of the 100 populations that were allotted for study in Africa on just one question if they were to probe it in detail.

In the end, after railing against the limitations, the anthropologists settled on a methodology that, as Yellen said, gave a little bit to everyone. First, they decided they had to ignore certain classes of questions altogether. Then they designed a sample to capture overall diversity and to look at some of the broadest questions in Africa, such as the origins of modern humans and the dynamics of the important population expansions—the Bantu explosion, the climate-driven migrations in and out of the Sahara, and others.

To do so they first selected isolated populations believed to be relatively unmixed descendants of ancestral populations, like the !Kung of Botswana and Namibia and the Hadza of Tanzania. Next they selected a nearest neighbor or two, to determine if these isolates are as distinct genetically as they are culturally or linguistically. Then, at Cavalli-Sforza's urging, they tried to get a representative sample of the entire continent by using the 1500 or so major language groups as a guide. Finally, the group plotted all these populations on a map to reveal geographic holes and selected 25 additional populations to fill them in.

Other groups ran through a similar exercise, but each made different calls about which questions to pursue and thus how and whom to sample. The North American group, for instance, used a scarcity of native-language speakers—a good indicator of assimilation pressure—as one criterion for selecting populations. The Indo-Pacific group selected some populations specifically to look at phenotypic adaptation. Differences aside, all of the working groups agreed on the value of sampling populations that have already been well studied, since genetic data are far less useful in a vacuum than when culture and history are understood.

After 3 exhausting days, each group ended up with a list of populations and a report describing the status of each population, why it was selected, which anthropologists to contact, who has already collected blood samples, and what ancient specimens in the region—skeletons or mummies—might be available for additional genetic study. The draft, however, is laden with caveats pointing out that it is just a first cut. In addition, the anthropologists caution, no experts were at the meeting for some regions of the world—West Africa and the Caribbean, to name just two—so any suggestions there are especially tenuous.

Weiss calls the list a "living document" that will need to be revised. "This is just 50 people trying to represent the world. We recognize this is not the Encyclopedia Humana but an abstract of what we want to do. There needs to be input from people who may disagree," says Weiss, who plans to publish the report or otherwise make it widely available to the anthropology community. Ultimately, which populations are sampled will depend on finding anthropologists who want to study them—and on funding for the project, which has received only planning money so far. In that respect, the hastily assembled Penn State report will play a key role; after refining and condensing it, the organizers plan to use it to appeal to numerous agencies here and abroad.

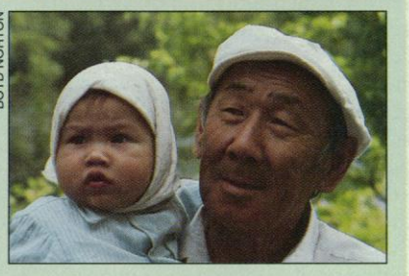
Some of the participants, though, would like another crack at the list before it is circulated. Richard Ward, a University of Utah population geneticist who chaired the South American group, for example, worries that the working groups' criteria varied so much that there is little hope of implementing the project consistently. He is pushing for another meeting of anthropologists: "I think we need to sit down and define a consistent approach to decide which should have the highest priority." But the prospects for another workshop anytime soon are dim, says Weiss; funds are limited and the program is already planning two more workshops on other topics. Still, there should be time between now and 1994, when the organizers hope to have funds to begin the project, for the anthropologists' "living document" to evolve.

–Leslie Roberts

A Few of the Chosen

When anthropologists met last month at Pennsylvania State University to draw up a list of populations for DNA sampling in a planned massive study of human genetic diversity, they faced some bewildering choices. The task of winnowing 7000 or so populations down to about 500 was only the beginning of the challenge. They also had to justify their choices, based on specific questions in human prehistory, the possibility that a group is a relatively unmixed "remnant" of a much larger ancestral population, or signs it is rapidly losing its genetic or cultural identity. Here is a sampling of the groups that made the admittedly rough first cut and the puzzles their DNA may solve.

NAIR BENEDICTO/DDB



BOYD NORTON

They made the list. Yanomami *(top)* and the Chukchi, of Siberia.

- **Hadza.** These vanishing people—about 200 are left in Tanzania—speak a language like that of the Bushmen of southern Africa thousands of miles away, but morphologically and genetically they resemble the East Africans. Who are they? Did they borrow only the Bushmen's language or do they share their genes?
- **!Kung.** About 15,000 remain in the Kalahari Desert. Genetic evidence indicates they were once far more widespread, but it is not clear who they are or where they came from.
- **Plains Apache.** A distinctive group among the Apache, they number about 1000 in Oklahoma. One of few Athabaskan-speaking groups in the Southwest—most are in Canada and Alaska—do they represent a separate migration from the North, perhaps even Siberia?
- **Yanomami.** The 20,000 individuals living along the border of Venezuela and Brazil speak an isolated language and more closely resemble Central American groups than their immediate neighbors. In addition to the mystery of their origins, the heavily studied Yanomami are a model system for tribal-scale demography.
- **Yukaghir.** Though fewer than 100 are left in Siberia, these reindeer hunters once dominated the Arctic and Sub-Arctic. Did their ancestors cross over Beringia and contribute to the peopling of the New World?
- **Chukchi.** About 10,000 of these Paleo-Asiatic speakers live in the Chukchi Peninsula of northeastern Siberia, a relatively short hop to the New World. Genetic studies of them could play a key role in reconstructing the origins of Native Americans.
- **Onge and Greater Andamanese.** These distinctive populations in the Andaman Islands off Malaysia number fewer than 100 each and are disappearing rapidly. Are they descendants of the tribes that migrated from Africa to Oceania thousands of years ago?

–L.R.