Capital Science: AAAS Meets in Washington

*While most of Washington watched nervously as events unfolded in the Persian Gulf, some 5200 attendees at this year's American Association for the Advancement of Science annual meeting on 14–19 February tried to put aside thoughts of war to focus on a panoply of scientific topics. The war was not completely forgotten: President George Bush used his keynote address to give the U.S. reaction to the first Iraqi peace proposal (*Science, *22 February, p. 869), and several sessions addressed the scientific and technical implications of modern warfare. There was also the obligatory television in the hotel lobby providing nonstop coverage from CNN. But for the most part, discussion in the hallways of the Sheraton Washington Hotel where the meeting was headquartered dealt more with brain function and ozone holes than with Scud missiles. Herewith a sampling from 5 days of scientific sessions.*

Saying So Long to Polio

Eradicate polio in the tropics? A few years ago most public health experts would have said such a goal was impossible, but according to data presented at last week's meeting, the Pan American Health Organization (PAHO) is about to do just that in the Western Hemisphere.

Even though it has been 35 years since Jonas Salk invented the first polio vaccine, and a decade since public health officials wiped out wild-type polio (as distinct from vaccine-associated polio) in the United States, the virus has been particularly tenacious in South and Central America. That's because polio vaccines generally are less effective in the tropics and in developing nations, where more children suffer from gastrointestinal tract viruses that can prevent the orally administered Sabin vaccine from working. The success rate for the vaccine is only about 60% to 80% in developing nations, compared with 90% in the United States, says Donald A. Henderson, a well-known vaccine expert who is about to become the associate director for the life sciences at the White House Office of Science and Technology Policy.

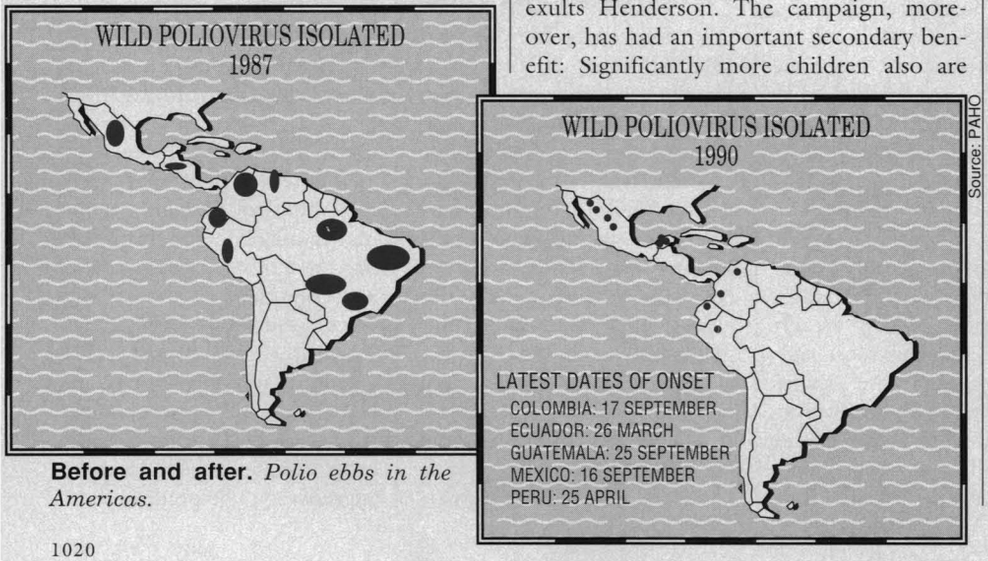
But at last week's symposium PAHO officials announced that no new cases of wild-type polio virus have been reported in the Americas since last September, and that there were only 11 cases in 1990, down from 130 in 1989 and 930 in 1986. Furthermore, more than 80% of all children under age 5 in North and South America have now been vaccinated with the Salk or Sabin vaccines—a huge improvement over 1978, when only 20% were inoculated.

These upbeat statistics are the result of a far-reaching, 4-year vaccination campaign orchestrated by PAHO that began in 1985. After spending $430 million to immunize 40 million children in 47 countries and territories in the Western Hemisphere, the campaign has wrought no less than a "miraculous transformation of the Americas," exults Henderson. The campaign, moreover, has had an important secondary benefit: Significantly more children also are being immunized against diphtheria, pertussis, tetanus (DPT), and measles.

Henderson served on a committee of public health experts that advised the PAHO Directing Council to kick off its ambitious polio eradication campaign after a small-scale effort in Brazil showed promise. The organization then set about convincing health officials in nations throughout the hemisphere to set up special vaccination days—an approach that had been successful in Brazil—and loaned them money to buy the vaccine. The nations also set up an intensive monitoring system, so that outbreaks of polio could be promptly reported and confirmed with lab tests.

As a result, PAHO officials now feel confident that they are detecting all new cases of the wild type of polio and that the decline they report is a real one. Although Henderson cautions that it will take 2 to 3 years to be certain that the disease has been eradicated—there are still a few polio hot spots that could erupt in Mexico and along the border of Ecuador and Peru—PAHO officials are ecstatic about what they have accomplished so far. "It's been a major success story," boasts Ciro A. de Quadros, an epidemiologist who is the adviser on immunization for PAHO.

The results have emboldened the World Health Organization to expand the same type of intensive campaign to other regions, particularly such hotbeds of polio as Africa, China, and India. And PAHO is deploying the new polio vaccination network in the Americas to administer other vaccines, including DPT, bacillus Calmette-Guerin (BCG), and a vaccine given to women of childbearing age to prevent neonatal tetanus. All this prompts Henderson to predict that the 1990s are "going to be the decade of vaccines." ■ ANN GIBBONS



Before and after. *Polio ebbs in the Americas.*

Using Immunity to Block Conception

Most medical approaches to preventing conception have concentrated on the sex hormones and their receptors. But for more than a decade, a number of labs have looked to the immune system rather than the endocrine system for the ideal contraceptive. Their ultimate goal is to develop a vaccine against eggs or sperm that could provide a long-acting, foolproof form of birth control. Sound like a long shot? Researchers and funding agencies have largely shared that view, but biologist John Herr of the University of Virginia never lost faith. And at a symposium he chaired on immuno-

contraception at last week's meeting, Herr predicted that such a vaccine could be a reality by the end of the decade.

The strategy favored by Herr and others who spoke at the session is to make a vaccine that would trigger the production of antibodies that bind to proteins on the surface of the egg or the sperm, making fertilization impossible. But the development of such vaccines has been hindered by difficulties in finding the right egg- and sperm-specific proteins. Then there is the problem of autoimmune reactions, often triggered when a female is immunized against her own eggs or a male against his own sperm. The most successful approach so far avoids the autoimmune problem by immunizing females against sperm. Paul Primakoff of the University of Connecticut reported that he has used sperm proteins to make female guinea pigs infertile for up to 18 months, and Herr said he will begin trials of a similar vaccine in baboons this spring. The results of the baboon trials will be available in 18 months, and Herr says that if they are successful he will seek Food and Drug Administration approval to begin human trials.

Other researchers have tackled the autoimmunity problem head on. Jurrien Dean of the National Institutes of Health reported that his group had found that carefully chosen parts of egg surface proteins may raise an antibody response in mice without activating the T cells that cause autoimmune disease, thus raising hopes for an eventual female anti-egg injection.

The researchers refer to contraceptive vaccines as "reversible" because the antibody concentrations will eventually drop to ineffective levels. Ideally this would happen after 2 to 5 years, but that time may vary in different people, and Primakoff concedes that the uncertainty may make a vaccine far more acceptable to people who never want to have children than to those who want to keep their options open. "All the other methods—barrier methods, the pill, etcetera—have the advantage that you can stop," Primakoff says.

One antipregnancy vaccine is already in human trials in Australia, according to Herr. It works by raising an immune response against a hormone made by the early embryo. Because it prevents implantation of the embryo in the uterus, that vaccine would be classified as an abortifacient, and as such would be fraught with political difficulties in the United States if it were to be tested here.

While a true contraceptive vaccine for humans may be a decade or more away, pets are likely to benefit sooner, says Bonnie Dunbar of Baylor College of Medicine. Dunbar has developed an immunization technique that ultimately kills off an animal's developing egg follicles, a process that induces more follicles to develop in a suicidal cycle that continues until all the follicles are used up, and the animal is permanently sterile. The Society for the Prevention of Cruelty to Animals is eyeing such an immunization as an alternative to surgical spaying, Dunbar says. ■ MARCIA BARINAGA

Don't Underestimate the Nose

Possibly because nosology was already taken, Annette Green, administrative director of the Fragrance Research Fund (FRF), says "aromacology" is the name for the study of odors and their effect on behavior. The new field is no joke. At a session last week scientists claimed that odors have earlier and more dramatic effects on people than has been recognized.

For the most part, FRF supports research into nice smells. Created by the perfume industry in 1982, this nonprofit agency has given away about $500,000 so far, most of it to clinical psychologists, according to Green. In one challenge to orthodoxy, FRF grantee Hilary Schmidt of the New Jersey Medical School in Newark, New Jersey, said that children 3 years old appear to be quite sensitive to odors. The assumption until recently was that olfaction begins after age 5 and is essentially learned. In a series of controlled tests, Schmidt avoided asking children whether they liked a smell, because, as she explained, they almost always say "yes." Instead, they played a game involving characters from the television program "Sesame Street" and bottles with odors ranging from spearmint to vomit. Bottles with nice smells were given to Big Bird and yucky smells to Oscar the Grouch (who likes garbage). The result: The children clearly discriminated nice from yucky, with girls being more adept than boys.

Turning to the adults, other researchers reported that a little snort of peppermint or muguet (lily of the valley) seems to be almost as good as a mild cup of coffee in relieving the tedium of a dull job. Psychologists William Dember of the University of Cincinnati and Raja Parasuraman of Catholic University in Washington, D.C., conducted these tests, which were focused on "sustained vigilance" tasks. They asked volunteers to stare at a computer screen for 40 minutes and hit the space bar whenever a pair of lines moved a small distance apart, which happened randomly throughout the test. They wore masks which intermittently released puffs of scented or unscented air. The performance of controls and subjects fell off with time, but the ones who got the scent did better. Furthermore, the scent triggered the attention focusing systems of the brain, as reflected in brain wave patterns, said Parasuraman.

Where is aromacology headed? Green could not say for sure, but she suggested the Japanese may already be going there. She noted that Shimizu, the giant construction company, recently patented the first computerized odor dispenser, a machine designed to be attached to an office air conditioning system. ■ ELIOT MARSHALL

Creating the Future for Electronic Publishing

For science librarians, pushed to the wall by sky-rocketing journal costs and crushing demands on shelf space, the words "electronic publishing" have usually been spelled "CD-ROM." That's the technical name for iridescent compact discs that look exactly like their musical cousins yet are capable of storing hundreds of thousands of digitized journal pages on a platter less than 12 centimeters across.

But CD-ROMs are only the beginning, according to the *Vision 2020* report of the American Physical Society's task force on electronic publishing. Within a generation, it says, rapidly evolving computer technology is almost certainly going to transform the nature of publishing, the nature of libraries, and the nature of scientific communication itself.

The report, which is due to be published this spring in the *Bulletin of the American Physical Society*, was discussed at a session last week on electronic publishing by task force chairman Stewart C. Loken, head of the information and computing sciences division at the Lawrence Berkeley Laboratory.

Extrapolating 30 years into the future from trends that are already obvious today, the report envisions a research environment in which computers with the processing power of today's high-resolution graphics work stations will be both plentiful and cheap.

Moreover, every one of those computers will have ready access to a worldwide network capable of piping data around at billions of bits per second. And the software controlling that network will have brought the user to the nirvana of "seamless access": All he or she will have to do is type in (or write in or speak in) a request for information, and no matter where on the network the information is actually located, it will instantly appear on the computer screen as if it had been in the machine all along.

In that kind of environment, says Loken, published documents could be far more than the static blocks of text and figures that they are today. Using sophisticated versions of the hypertext and multimedia software already available on today's personal computers, readers could view films and watch the unfolding of time-dependent data, or run computer simulations using the author's original computer code. They could each take a personalized tour of the document emphasizing the experimental details, say, or the theoretical implications. They could have access to *all* the experimental data, if they weren't satisfied with a summary. They could experiment with the data reduction algorithms to understand what the author has really done. They could even attach commentary to be seen by other readers, turning the document into an ongoing, online colloquium. "The whole document would take on the nature of a living system," says Loken.

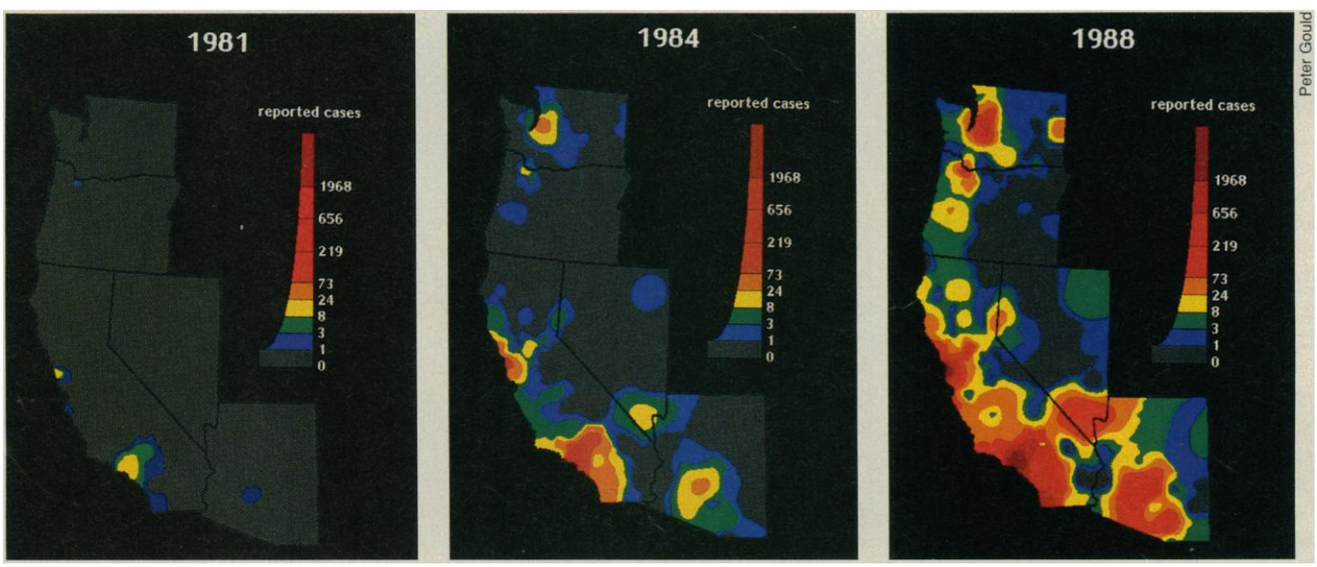
However, as Loken and every other speaker at the electronic publishing session was quick to point out, attaining such a vision is going to be a process full of imponderables. Building the hardware and the software is the least of it.

For example, what is the role of academic libraries when a keystroke can bring virtually any publication to your desktop? The libraries will certainly have plenty to store, says Loken; paper journals aren't going to disappear completely for a long time to come, if ever. But are the libraries doomed to become increasingly irrelevant as more and more of the real publication is done through the network? Or will they actually evolve into key components of the network—nodes that would each store a unique electronic collection to be shared through the network worldwide?

And what about journal publishers? Their staffers will still be editing the articles and getting them refereed, presumably. But in the electronic world publishers will no longer be able simply to mail the journal out and forget it. The company may also be expected to provide the journal's readers with advice and technical assistance, in the same way that software publishers do now. This would represent a heavy and unfamiliar burden to the academic publishers of today; some have begun to talk about forming consortia and setting up whole new divisions to handle it. Indeed, in an electronic world in which the focus is almost entirely on the individual document, it's not entirely clear what a "journal" is supposed to be—or even more important, exactly how the journal publisher is supposed to be paid by the end user. That has already generated a lot of controversy, and no one yet has a satisfactory answer. ■ M. MITCHELL WALDROP

Prion Proposal Proved?

Stanley Prusiner has spent the past decade trying to prove that prions—protein particles devoid of nucleic acids—can cause certain infectious brain diseases. Now, if results he presented at last week's meeting hold up, he just may have done it.



Spreading stain. *Geographers haven't played a big role in characterizing the AIDS epidemic, but Peter Gould and his colleagues at Pennsylvania State University aim to change that. These maps show the spread of AIDS in the western United States from 1981 to 1988. They are part of a series—one map per year—generated by Gould and his team. In a session at last week's meeting Gould showed the maps sequentially, saying they depict a "spatial-geographic logic unfolding over time." He compared the pattern to a "wine stain on the tablecloth," moving from urban centers into the suburbs and surrounding countryside. The epidemic first appeared in Los Angeles and San Francisco, followed by Las Vegas and Phoenix. By 1983 Seattle and Portland had entered the picture and the epidemic continued to intensify through the rest of the decade. In his talk, Gould lashed out at AIDS modelers and government officials for failing to take into account geographic aspects of the spread of HIV infection. "Despite millions of dollars spent on the AIDS epidemic," he said, "we have virtually no picture...[of] the geographic dimensions of this deadly virus.... All modeling and forecasting is devoted to a simplistic, and essentially useless, computation of numbers down the time line, ignoring totally the spatial...dimensions of human existence." Gould attributed this lack to "sheer ignorance, aided and abetted in too many instances by individual and bureaucratic arrogance."* ■ J.B.

Prusiner, whose lab is at the University of California, San Francisco, first made his remarkable prion proposal back in the early 1980s in an attempt to explain what causes two similar brain degenerative diseases—scrapie in sheep and Creutzfeldt-Jakob disease in humans. Although scrapie and Creutzfeldt-Jakob disease could clearly be transmitted by injecting material from the brains of infected individuals into experimental animals, years of searching had failed to produce the viruses that most researchers thought were the cause.

The Prusiner group had isolated a protein, the prion protein, which was associated with the transmission of the diseases, but despite the failure to find a conventional virus, the responses to his proposal that the protein alone could be infectious ranged from skepticism to out-and-out derision. The idea was unprecedented; bacteria, viruses, and the other known infectious agents all contained nucleic acids with the genetic instructions for reproducing themselves in the host and causing disease. How, everyone wanted to know, could something consisting only of proteins transmit diseases?

While the "how" is still murky, the evidence for a role of prions in disease has gotten much stronger. The gene encoding the prion protein has been cloned, for example, and it turns out to be widely expressed in normal brains. About 2 years ago, the Prusiner group showed that a specific mutation in the prion gene is linked to Gerstmann-Sträussler-Scheinker syndrome (GSS), a hereditary neurodegenerative condition that is pathologically very similar to Creutzfeldt-Jakob disease.

Although genetic linkage doesn't necessarily prove causality, Prusiner and his colleagues Karen Hsiao, Michael Scott, and Stephen DeArmond took a big step toward doing so late last year when they showed that they could recreate GSS in mice by using genetic engineering techniques to introduce the mutant prion gene into the animals (*Science*, 14 December 1990, pp. 1509 and 1587). "Every animal carrying the mutant transgene eventually gets sick," Prusiner says. "The big issue is, can you transmit the disease to nontransgenic animals?" If it could be passed to normal animals by injecting them with brain extracts from the transgenic mice, that would mean that the mutant transgene is all that it takes to get infectious prions. "Transmission is very crucial," agrees Dmitry Goldgaber of the State University of New York in Stony Brook, who also works on Creutzfeldt-Jakob and related brain diseases. "The ability to transmit horizontally by inoculating normal animals would prove their [prion] hypothesis."

Late last year, however, it looked as if the answer to the transmission question might be no. Prusiner and his colleagues had inoculated normal mice, hamsters, and mice with normal (not disease-causing) transgenes with brain extracts from sick transgenic animals in the spring, and the injected animals still appeared healthy in early December.

But transmission may finally have occurred. At last week's meeting, Prusiner reported that some of the inoculated animals are showing clinical signs similar to those of experimental scrapie in rodents. Overall, 15 of 93 animals have gotten sick, but the percentage is much higher in some subgroups. Prusiner stresses, however, that these results must be viewed with great caution. He does not yet know whether the brains of the sick animals harbor infectious prions. And because of the long time it took for symptoms to develop—approximately 8 months—he worries that the animals, during their extended stay in the animal colony, may have somehow been contaminated with infectious prions from other sick animals. Prusiner estimates that it will take 2 or more years of further work to establish whether transmission from the transgenic animals does indeed occur. ■ JEAN MARX

How to Regulate Environmental Releases

Gene splicing has been used in agricultural research for at least a decade, and engineered organisms have now been released in many field tests. Yet few governments have decided how to regulate this new technology, if at all. The tensions—in both U.S. and international policy—were on display last week at a symposium on biosafety organized by the U.S. Agency for International Development.

Margaret Mellon, a specialist on biotechnology policy at the National Wildlife Federation, criticized the U.S. government for what she termed a failure of leadership in controlling the risks posed by the environmental release of genetically engineered organisms. She says that guidelines for research recently issued by the Department of Agriculture (USDA) are inadequate. The rules, according to a notice published by the USDA in the *Federal Register* on 1 February, are "intended to aid researchers and institutions in the design of safe experiments," but they do not prescribe any particular

School Science Surveyed

Teachers who enthusiastically encourage their students to pursue careers in math and science will help fill the pipeline with the next generation of scientists, right? Not necessarily, according to preliminary results from the largest longitudinal study of U.S. science education ever undertaken. In both the 9th and 12th grades, the amount of encouragement teachers gave their students to choose science-related careers bore no relation to the students' proposed career choices.

The career results were the biggest surprise to come from the Longitudinal Study of American Youth (LSAY), directed by Jon Miller of Northern Illinois University. For 3 years, the study has followed the educational progress of more than 6000 junior high and high school students across the United States, analyzing more than 30 variables that might affect a child's education.

Aside from the surprising data on career choice, most of the LSAY findings were in line with expectations. For example, the study showed that parental education and the amount of encouragement a child received at home had a tremendous impact on performance, particularly in middle school. In math, for example, "parental resources"—a general index of the educational richness in the home—predicted 7th grade success better than any other single variable. And in 9th grade, children with high parental resources placed into higher courses much more often than those without. So what can be done for students who do not come from high resource homes? Miller and several of his collaborators offered two strategies at last week's meeting:

■ Make more math and science courses mandatory. Allowing lower-level kids to drop out of math and science courses in high school is doing them a big disfavor. LSAY's data suggest that simply forcing kids to take more courses will markedly enhance overall achievement.

■ Encourage more parental participation and perhaps enable parents to keep up with their childrens' coursework by publishing special guides for adults.

The study also strongly suggests that middle schools should avoid grouping children by ability. Ability grouping doesn't help the high achievers, they said, and makes low-ability students fall even farther behind their peers. Whatever method they choose, schools must find better ways to allow disadvantaged students to catch up to the others, Miller said. ■ ROBERT LANGRETH

course of action. Mellon called this a policy of "let's wing it and hope for the best." She argues that a rigorous system of monitoring tests and archiving results will be needed to put to rest concerns about bioengineered pesticides and plants.

Alvin Young, who directs biotechnology policy at USDA, defended the guidelines, which had been drawn up by his office. He says getting other agencies—including the Office of Management and Budget—to reach a consensus and endorse them was very difficult. It was the White House, he said, that insisted that the guidelines be published separately from any plan for implementing them. It is not clear at present when or by whom the plan will be prepared.

European countries don't seem to be much further along. Although the bureaucratic apparatus of the European Community in Brussels has declared its intent to impose special controls on agricultural biotechnology—including case-by-case reviews of possible socioeconomic dislocations—it has issued no rules as yet. However, John Barton, an expert in international law at the Stanford University Law School, pointed out that even developing nations are gearing up for action. The Philippines and Mexico have established guidelines to cover bioengineered organisms, and India in 1990 created a full-blown regulatory bureaucracy for this purpose.

Barton and some colleagues at the Stockholm Environment Institute have proposed an alternative to regulation, which he thinks would benefit both the technology-poor developing nations and the industrialized countries where most of the new genetic organisms are being created. His idea is to create an international ad hoc advisory committee, akin to the group of experts that has advised the National Institutes of Health on recombinant DNA activities for the last decade. As Barton envisions it, the group would operate under the aegis of the Stockholm Institute (a private, government-funded organization), serving as an adviser to all comers. It would mainly deal with issues of "hard science," Barton said, although it could also venture into broader questions of intellectual property rights and pest management. A seal of approval from this group presumably would serve as a certificate of safety for genetic engineering tests to be run anywhere in the world. One big advantage of this approach, Barton said, is that it avoids the balkanization of procedural rules and scientific data requirements that could occur if every nation enacts its own system of controls. ■ ELIOT MARSHALL

Surprise! U.S. Sometimes Beats Japan in Understanding Science

Many—perhaps most—Americans believe that Japan has one of the best science education systems in the world and that the United States lags far behind the Japanese standard. The logic is simple: Japanese students excel in virtually every international science testing program, and the Japanese dominate the world in many high-technology industries.

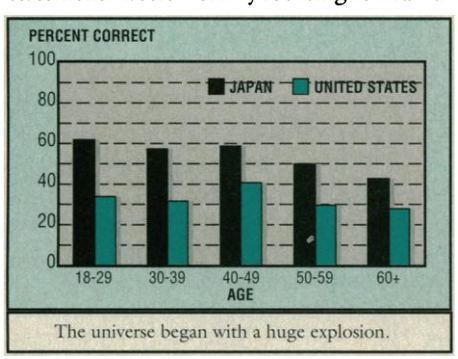
But the Japanese educational advantage may be largely imagined, if data from a new study hold up to scrutiny. In the first large-scale survey comparing public understanding of science in Japan and the United States, Jon Miller of Northern Illinois University asked 2239 Japanese and 2033 American adults of all ages to agree or disagree with seven statements about fundamental scientific principles (see chart). His results, reported at a session last week on the public understanding of science, are surprising: levels of scientific knowledge are about the same in each country. For instance, 77% of Americans and 82% of the Japanese knew that "the continents have been moving their locations for millions of years"; similarly, just about 80% of those in both countries agreed that "the center of earth is very hot."

The U.S. respondents, however, performed much better than their Japanese counterparts on the two technology-related questions—although Miller isn't sure why. Thirty percent of Americans correctly disagreed with the statement "antibiotics kill viruses as well as bacteria," while only 8% of Japanese responded appropriately. And 37% of Americans, but only 14% of the Japanese, disagreed with the statement "lasers work by focusing sound waves." On both questions, the rest of the respondents were split between agreeing with the statement, and not having sufficient knowledge to give an answer.

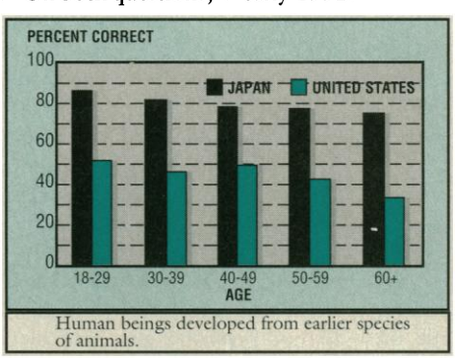
The two assertions with potential religious implications—concerning the Big Bang and evolution—demonstrate the negative impact Christian fundamentalism has on U.S. science, says Miller: Nearly twice as many Japanese answered these correctly. Seventy-nine percent of the Japanese, for example, knew that "human beings developed from earlier species of animals," but, only 45% of Americans agreed with this. "Some areas of science," Miller said, "still raise religious tensions in the United States, reducing the percentage of Americans who would qualify as scientifically literate."

On several of the questions, Americans in their forties out-performed all the other age groups, contradicting the expectation that younger respondents, fresh out of the educational system, would do better than older ones. This anomaly suggests that American science education has declined since the Sputnik era, when most of the 40-49 age group went to high school, Miller said.

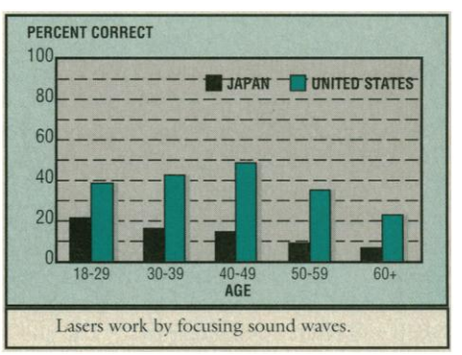
American educators shouldn't rejoice too much in the findings. It's not that Americans did well—in fact, on five of the questions, less than 50% of Americans picked the right answer—but rather, that the Japanese did amazingly poorly. The findings "don't quite compute, given the exemplary scores that the Japanese get in international testing programs," says Miller. Firmer conclusions, however, will have to wait until the Japanese National Institute of Science and Technology completes a more exhaustive study of science understanding in early 1992. ■ ROBERT LANGRETH



The universe began with a huge explosion.



Human beings developed from earlier species of animals.



Lasers work by focusing sound waves.

Monkey See, Monkey Do

For decades neurobiologists have been probing nerve cells in the brain to learn how those cells respond to the outside world. A favorite system to study is vision. There, researchers have found individual neurons that respond only to particular visual features—such as edges oriented at specific angles or objects moving in one direction. But knowing that those neurons respond to specific stimuli doesn't necessarily imply that they are involved in perception—the higher order processing of sensations into a coherent scene.

Indeed, assuming that they do requires a "vast, intuitive leap," says Stanford neurobiologist William Newsome. But now Newsome has offered some data that make the leap a little less vast. At the neuroscience seminar at last week's AAAS meeting, Newsome reported results that many neuroscientists are heralding as the first direct evidence for the role specific nerve cells actually play in perception.

Newsome, along with medical student Daniel Salzman and postdocs Kenneth Britten and Chieko Murasugi, focused on a brain region called area MT, where neurons specialize in detecting movement. The neurons in MT are grouped in columns; each column scans a part of visual space for objects moving in a certain direction.

In a test designed in collaboration with Tony Movshon of New York University, Newsome's group showed rhesus monkeys a field of randomly flashing dots. Within that visual snowstorm, a subset of the dots moved in one particular direction. The monkeys were trained to watch briefly, then signal with an eye movement to tell the experimenters which way the dots were moving. Most of the time, the choice wasn't too difficult, but when the percentage of coherently moving dots was low—around 10% of the total—the dot field looked like static on a television screen, with just a vague sense of motion up or down. Making the right choice at this level was very difficult, and the monkeys were wrong almost as often as they were right.

While the monkeys performed the task, Newsome and his colleagues recorded the electrical activity from columns of cells in area MT. When the dots in the field moved up, a column of cells sensitive to upward motion in the region where the dot field was presented would fire. The activity of these neurons mirrored the monkey's perception: When the task was made more difficult, the neurons' percentage of "right answers"—that is, firing in response to upward movement—fell along with the monkeys' performance on the judgment task.

That was an important correlation between nerve cell activity and perception. But correlation doesn't prove causation. So the group went further—and actually tried to influence what the monkeys perceived. To do that, they electrically stimulated MT neurons during the one second when the monkey was looking at the dot pattern in its most difficult mode. And they found that, indeed, if they stimulated the upward-selective neurons, the monkeys would be more likely to choose "up" as an answer, even if the dots were in fact moving down.

Sensational findings. *Chieko Murasugi and William Newsome examine their data.*

That finding "closes the loop" between neuronal responses and perception, says neurobiologist Steven Petersen of Washington University. Torsten Wiesel of Rockefeller University, who shared a Nobel Prize for mapping receptive properties of visual system neurons, agrees: "People have proposed that these cells are part of the movement-perception pathway, but that's just conjecture.... Bill's work points the way to how we should try to make the bridge between the response of cells and perception."

Newsome's experiments have also begun to shed light on a long-standing debate over how great a role a single neuron or cluster of neurons can play in perception. Some researchers, like Wiesel, have long believed localized groups of neurons do play a significant role; others take the view that neurons must work in widely flung networks to produce perception—and the input from any one location cannot be significant.

Wiesel holds his beliefs so strongly that he says he told Newsome the outcome of the experiments was obvious even before they were done. For James McIlwain of Brown University on the other hand, the results were not so predictable: "I've been in the [network] camp for a long time, which keeps me from leaping to conclusions, but this work comes as close as anything I know to showing that the discharge of a [local] group of cells has a functional significance for the animal." But that doesn't mean that Newsome's experiments rule out the network model, says Washington University's Petersen: "It only argues against the very strong statement that you'd never find a single cell with enough information to carry a perception."

Newsome points out that his group's experiments do not show that motion perception is formulated in MT, since MT neurons connect with other parts of the brain, and stimulating MT will affect those areas. But that doesn't diminish the "definitive result," says NYU's Movshon, which is to show that MT is clearly a cog in the machinery that drives perception.

A nagging question remains: What do the monkeys really see? Do the experiments change their perception of the dot motion—from down to up, say—or do they merely change the decision about how to respond? "I like to think of it in terms of what the monkey would say if he could talk," says Newsome. "Would he say, 'I saw upward motion and reported up, so why wasn't I rewarded for a correct answer?' Or would he say, 'I saw downward motion, but I reported up—I couldn't help it?' "

Newsome is considering approaching that question with a variation on the dot test. Rather than training the monkeys to answer directly whether the dots in the test field were moving up or down, he will ask them to choose which of 6 other dot fields most resembles the test field. In a matching task like this, says Newsome, "if we are influencing the monkey's perception, he may say it looks different than it does."

Newsome acknowledges that the only sure way to get the answer is to do the experiments in humans, who can tell the experimenter what they see. That is not out of the question, he says, since experiments are sometimes done with the cooperation of conscious patients undergoing brain surgery. Having pondered the issue of MT's effects on perception for so long now, Newsome says he has an ultimate wish that may be a bit more difficult to fulfill: "I do have a fantasy of someday stimulating my own MT." ■ MARCIA BARINAGA