a bullock cartwheel for the hub, cloth and a bamboo frame for the sails, and an automobile axle for the shaft.

Present systems of energy production are for the most part massive machines, dependent on man for their fuel and active embodiments of the dominion over nature. Windmills, by contrast, are passive devices, often made with natural materials, and expressive of external forces that represent nature's dominion over man. Their ecological chic is antithetical to the materials consuming style of western economies. As that style shifts, the windmill is moving back into its rightful place in the sun.

—NICHOLAS WADE

HeLa Cells: Contaminating Cultures around the World

In February 1951, a woman named Helen Lane was being treated for cancer of the cervix at the Johns Hopkins Hospital in Baltimore. Although she ultimately died of her cancer, Helen Lane achieved an unusual measure of immortality—cells derived from her tumor are still very much alive and with us.

Helen Lane was a patient at Hopkins when an investigator named George O. Gey was also there. Gey was a pioneer in the tissue culture field that was then in its infancy. Even today, growing human cells in culture is, in many instances, as much an art as a science. In the 1950's, growing human cells in culture was a revolutionary accomplishment. Gey and his colleagues managed it. They obtained cells from Helen Lane's cervical tumor and cultured them in a blood clot. There, they thrived. Indeed, HeLa (for Helen Lane) became the first human cancer cells to proliferate well in tissue culture. And proliferate they did. For reasons that apparently are still unclear, HeLa cells are particularly vigorous. For years, they were the most standard of all human cell lines, and today they remain a staple laboratory item. HeLa cells are, for example, an excellent medium in which to grow viruses. They have played an important role in cancer research and are among the most studied of all human cell lines.

But HeLa cells, for all the use they have been to science, can also be quite a nuisance, and worse. They have so adapted to life in the laboratory that they thrive and, at times, take over, even where they are unwelcome. If a non-HeLa culture is contaminated by even a single HeLa cell, accidentally introduced through a nonsterile pipette for example, that cell culture is doomed. In no time at all, usually unnoticed, HeLa cells will proliferate and take over the culture. Unfortunately, if this happens, it is not readily apparent. The only way to detect HeLa cell contamination is to monitor cultures by chromosomal and biochemical means. Most laboratories go to great lengths to preclude contamination and many make efforts to monitor their cell lines but, apparently, it is not enough. HeLa can still take over.

According to a California biologist who has for years been responsible for "certifying" the identity of cells for the National Cancer Institute's multimillion dollar Virus Cancer Program, there are a lot more HeLa cells in the world than most scientists recognize. Walter Nelson-Rees of the cell culture laboratory at the University of California, School of Public Health, Naval Biomedical Research Laboratory, Oakland, says that many human cell cultures are not what they seem. On the basis of chromosomal analyses and other data from his laboratory, Nelson-Rees reports that many human tumor cell lines being studied here and abroad, including Russia, are misidentified. In particular, he maintains that certain cultures of human breast tumor cells, prostate tumor cells, bladder tumor cells, liposarcomas, and others are not what they are thought to be. In truth, he says, they are all HeLa cells.

If Nelson-Rees is right—and there are those who dispute his data or are, at least, not thoroughly convinced—a lot of people may have been spending a lot of time and money on misguided research. If, for example, you are studying the properties of human breast tumor cells, hoping to find features that distinguish breast cells from others, and are, all the while, dealing unknowingly with cervical tumor cells, you've got a problem.

Almost 2 years ago, American and Russian scientists entered into a collaborative exchange of information and material related to cancer research. As one of the principal items of that cooperative program, American researchers sent the Russians cell cultures containing what they suspected to be human tumor viruses and Russian investigators returned the favor in kind. American scientists received six separate cell cultures, each said to have been derived from a different human tumor and each containing what might have been a human tumor virus.

After extensive analysis of the "Russian viruses," by immunochemical and other techniques said not to be available in the Soviet Union, it was concluded that the viruses were very similar to the Mason-Pfizer monkey virus (*Science*, 6 July 1973). Previously, this virus had been found only in a rhesus monkey that had monkey mammary adenocarcinoma. The virus was isolated in 1970. Following the observation about the Russian viruses—which was reported formally by American and Russian virologists jointly earlier this year—Nelson-Rees says it became necessary to study the cells from which the viruses came to check the species of origin. Authorities with the Virus Cancer Program sent the cell cultures to California for evaluation. Nelson-Rees and his colleagues examined the cells' chromosomes by a variety of techniques including Giemsa staining, quinacrine-fluorescence analysis, and a trypsin-Giemsa banding system in which individual chromosomes show distinct, identifiable patterns. They found several marker chromosomes common to HeLa cells. They also looked at what is known in the trade as the G6PD (glucose-6-phosphate dehydrogenase) mobility pattern of the cells. A genetically determined enzyme, G6PD, is found in a form called the type A variant in Negroes and persons of part Negro ancestry. In Caucasians, it is present in the form called the type B variant. Helen Lane

was a Negro; HeLa cells contain type A G6PD. So did those human cell cultures sent to the United States by the Russians. Nelson-Rees' conclusion: the Russian cell lines are really HeLa cells. Each line may have been accidentally contaminated, ironically enough, by HeLa cells that American scientists had sent to Russian investigators long before a formal exchange program ever began.

Having reached what can only be described as embarrassing results—which, Nelson-Rees says, the Russians took with good grace—he and his associates began looking at human tumor cell lines that were being used by American cancer specialists. Many of them, some from the very "best" of laboratories are, in his opinion, HeLa cells. It is a finding that leaves many researchers noticeably uncomfortable and which has caused considerable dismay and uncertainty within the community.

Many cell lines are implicated, as is reported by Nelson-Rees in this issue of *Science* (p. 1093); the situation involving HBT-3, for human breast tumor, cells is illustrative. Robert Bassin and his colleagues at the NCI are studying RNA tumor viruses in various cell lines, among them the HBT-3 line. In addition to their own work, they distribute these cells to other laboratories across the country—to some 15 or 20 laboratories altogether. A few months ago, when Nelson-Rees informed Bassin that he thought HBT-3 cells were really HeLa cells that had not been found out, Bassin rejected the notion. But subsequently, he accepted the possibility that Nelson-Rees could be right. On 15 April, Bassin sent a letter to all the persons to whom he sends HBT-3 cells that said in part:

> Karyological data recently obtained by Dr. Walter Nelson-Rees, using trypsin banding techniques, as well as some of our own studies, are consistent with the possibility of HBT-3 cells being a HeLa contaminant. Although this has not been proven as yet, I feel that there now exists enough evidence to alert all recipients of the HBT-3 cell line to the real possibility of contamination with HeLa cells.
>
> If you have distributed this cell line to other laboratories I would appreciate your sending copies of this letter to the recipients.

Nelson-Rees says he thinks it took Bassin real guts to send a letter like that. Bassin says of the situation, "We're in a bit of a muddle." As his letter indicates, he is not ready to concede that HBT-3 cells are not human breast cells. There is evidence, for example, that HBT-3 cells contain a protein marker that is characteristic of human breast cells. There are other data, he says, that cloud the picture.

The implications of what Nelson-Rees is saying go beyond the true identity of the HBT-3 line or of any of the others whose identity he has challenged thus far. There is the matter of the extent of culture contamination. Many investigators reason that their cultures could not possibly be contaminated because there have never been any HeLa cells anywhere near their laboratories. But if it turns out that HBT-3 cells and others previously thought to be "safe" are really HeLa cells after all—well, that reasoning no longer holds.

Then, there is the matter of whether Nelson-Rees is right and whether the various techniques at hand are sufficient to identify HeLa cells beyond doubt. Bassin summed it up nicely. "If we can't tell one cell from another, we have grave problems." That would seem to be the case.

—BARBARA J. CULLITON

Weather Warfare: Pentagon Concedes 7-Year Vietnam Effort

On 20 March, several high-ranking officials of the Department of Defense (DOD) told members of the Senate Foreign Relations Committee in detail about a $21.6 million 7-year program of cloud-seeding to induce rain over the trails of Laos, North Vietnam, South Vietnam, and Cambodia. There had been persistent allegations that the military was carrying out such operations in Southeast Asia. Their briefing, therefore, constitutes the first public description of weather modification techniques as a weapon of war.* Senator Claiborne Pell (D–R.I.), who asked for the briefing, recently released the text of it, of which excerpts follow.

The use of rainmaking as a weapon of war has long been a subject of controversy among weather scientists and arms control experts. Some of the scientists have objected that military use of weather modification will inhibit international cooperation in the atmospheric sciences. Their work, they add, should be used for humanitarian ends such as increasing the world's food supply. Some arms control experts fear that weather modification indiscriminately hurts noncombatants and enemy troops; they also argue that U.S. use of it in Vietnam could lead to proliferation of this relatively simple weapon to other countries (*Science*, 16 June 1972).

In any event, the Pentagon's briefing to Pell is far and away the most complete statement DOD has made to date of its role in weather warfare. [Even former DOD Secretary Melvin Laird hedged on the issue (*Science*, 5 April)]. While it furnishes many new details, some other information is still missing. For example, there is only vague discussion of whether agencies other than DOD have engaged or are engaging in weather warfare—yet the Central Intelligence Agency (CIA) is alleged to have started Vietnam cloud-seeding with a rainmaking project over Saigon in 1963. There is some discussion of an ongoing National Security Council review of weather modification policies, but no statement of DOD's position on future military weather modification programs. Finally, the military's claim that they succeeded in inducing from 1 to 7 inches of rain in Southeast Asia is not supported with the kind of data that civilian scientists would need for verifying it. Hence the DOD's claim that weather modification is "a valuable tactical weapon" is not proven.

Most of the presentation was made by Lieutenant Colonel Ed Soyster of the Joint Chiefs of Staff. Other DOD spokesmen were: Dennis J. Doolin, Deputy Assistant Secretary of Defense (East Asia and Pacific Affairs); Major General

* *Weather Modification*, hearings before the subcommittee on Oceans and International Environment, Committee on Foreign Relations, U.S. Senate (Government Printing Office, Washington, D.C., 1974).