was forced to withdraw for financial reasons, leaving a membership of ten nations. Because the IARC was also hit by inflation and the devaluation of the dollar, and because, according to Latarjet, scientific research needs an annual budget increase of 15 percent just to maintain the steady state, attempts to get more money for the center resulted in two changes in assessments from the member nations in a period of 3 years.

While the original suggestion by de Gaulle was that countries would donate 0.5 percent of their defense budgets, by the time the IARC's statute was written this had been changed to a contribution of $150,000 by each member. When attempts were made to raise this amount, however, it became apparent that it would put some of the smallest countries in the position of giving more to the IARC than to their internal research programs. Thus it was voted that additional assessments be based on what a country gave to the World Health Organization (with, however, the two nations that would be paying the most under this method, the United States and the U.S.S.R., voting against the proposal).

According to this formula, approximately 60 percent of the IARC budget came from the equal contributions and 40 percent from the nonequal. The United States subsequently introduced a new scale that would make 80 percent equally contributed and 20 percent nonequally contributed, and a compromise of 70 to 30 percent was voted.

The position of the U.S.S.R. was that no deviation from the concept of equal contributions should have been made, and the U.S.S.R. therefore sometimes made its payments late and not in full, a not insignificant factor when the budget comes from so few sources. At the meeting of the governing council in October 1972, however, the U.S.S.R. agreed to the new formula and promised full cooperation.

While the U.S. position has been consistent with its position in all international organizations—just not to pay too much—certain other countries have been a bit galled that the United States has been asking to reduce its contributions, now $336,720 and less than twice that of the smallest nations, at the same time that $1.6 billion have been allotted to the National Cancer Institute for the next 5 years. "It seemed especially ridiculous when one knew that this tremendously large amount of money—a sum too large to be spent on research—was available for cancer research in the U.S.," Latarjet said.

Frank Rauscher, head of the National Cancer Institute, has been quoted as saying that the epidemiologic approach is valuable and neglected [*Science* **176**, 386 (1972)]. Rauscher is a new member of the scientific council, and "we are putting a lot of hope on him," Latarjet said.

While grants and contracts help, Higginson is wary of too much "soft money," particularly too many contracts from one member nation, which he believes would unduly distort the work of the IARC.

If more money can be found, his priorities would include new units of immunology and metabolism (the IARC currently has units of epidemiology and biostatistics, environmental carcinogens, biologic carcinogenesis, chemical carcinogenesis, and research and training) and the restoration of the fellowship program to its previous level.

Perhaps fitting for the director of a cancer center, Higginson, who was a professor of geographical pathology at the University of Kansas medical school prior to coming to the IARC, does not favor unlimited growth for the IARC. Both he and an independent study commissioned by the governing council recommend that the center, to be most effective in respect to expenditures, be given an annual budget of $4 million to $5 million.—LYNN J. PAYER

Lynn J. Payer, a free-lance medical writer, is now living in Paris.

Salk Institute: Elitist Pursuit of Biology with a Conscience

La Jolla, California. Glamor is not a customary attribute of scientific laboratories, but it is a salient quality of the Salk Institute, a 270-man establishment devoted to biological research with a difference. Besides the magic of Salk's name, the institute glitters with a college of fellows that includes four Nobel prizewinners and a well-heeled board of trustees that probably affords the only occasion for former presidential adviser John J. McCloy and actor Gregory Peck to sit around the same table. What is the purpose of this institute, referred to by its founder as an "experiment in the sociology of science"? How does it differ from less star-studded seats of learning?

Visitors are often driven to Greek architecture to find a comparison for the Salk Institute. The building, two wings flanking a courtyard that overlooks the Pacific, is an edifice of arresting elegance. "An austere Acropolis," comments one writer; "The modern equivalent of a temple of Zeus beside the Aegean," says another. The temple is situated on the northern edge of San Diego, a conservative, naval-base city whose citizens donated 27 acres of prime land to the institute. Designed by architect Louis I. Kahn, it was constructed at a cost of $15 million, mostly contributed by the National Foundation–March of Dimes, which financed both Salk and Sabin in the development of their respective polio vaccines.

The precise purpose of the Salk Institute is not easy to pin down in practical terms. The founders' intention, states a publicity brochure, was "to create a special kind of scientific institution, dedicated to contributing, from the powerful base of modern biology, toward the advancement of the health and well-being of man." Jonas Salk, eponymous founder-in-chief, says he created the institute because "I felt there ought to be a place for biological studies but which also contained the conscience of man."

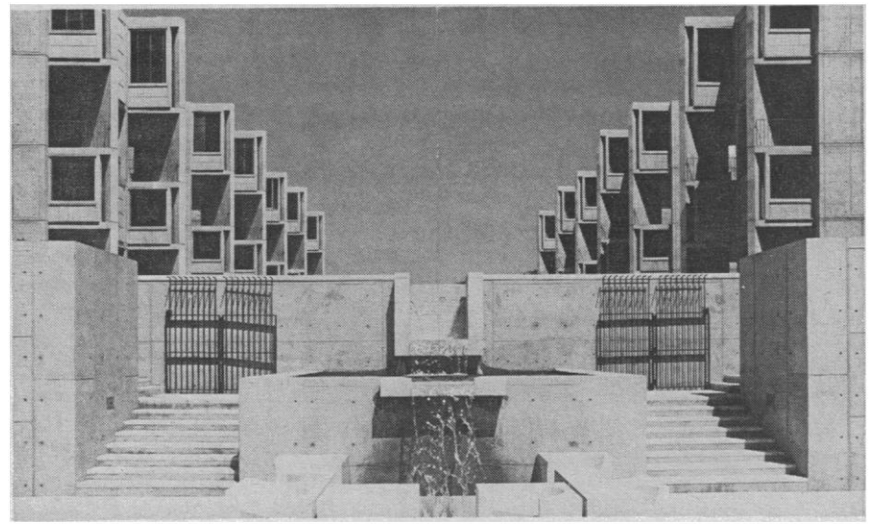
Though the younger scientists are now more independent than they used to be, the work of the Salk Institute is still centered almost exclusively around the interests of its seven resident fellows.

Occasional visits from nonresident fellows, who include Nobel prizewinners Francis H.C. Crick, Salvador E. Luria, and Jacques Monod, serve to lend an outside perspective, but the nonresidents seem now to play a considerably smaller role in affairs than they did when the institute was getting started.

The various interests of the resident fellows cover a wide range of fields, although the major emphasis, reflecting both Salk's background and the present availability of funds, is on immunology and other cancer-related fields. Three of the institute's laboratories are devoted to immunology, under the direction of fellows Melvin Cohn, Edwin Lennox, and Salk. A group under Robert W. Holley studies cell growth of both the normal and the malignant variety. Leslie Orgel and colleagues attempt to reproduce the chemical evolution of life. Roger Guillemin and his team seek to identify the hormones of the hypothalamus, which govern the pituitary gland. The seventh fellow, Jacob Bronowski, is the institute's resident humanist. In addition, there is a virology group, formerly headed by fellow Renato Dulbecco (now with the Imperial Cancer Research Fund in London), and small teams of younger members of the institute working on cancer, neurobiology, and linguistics.

Just as the institute thinks of itself as doing biology but with an extra dimension, the fellows tend to have broader than usual perspectives on science, a factor stressed in recruitment. Several gained their reputation in different fields from those they now work in. Bronowski started life as a mathematician; Holley worked on transfer RNA and, before that, on nitrogen metabolism; Lennox (who, like Cohn, came to La Jolla from the Pasteur Institute) was a nuclear physicist before he became an immunologist. The personality of the institute reflects in large measure that of its fellows, foremost among whom (although he no longer holds the post of director) is Salk.

The extraordinary place that Salk has captured in the public imagination is illustrated by a poll conducted some 5 years ago among the Overseas Press Club of New York. Asked to name the "heroes for our times," the members put Salk in fourth place, ranking below Churchill, Franklin D. Roosevelt, and John F. Kennedy, but beating Gandhi, Eleanor Roosevelt, Einstein, Pope John XXIII, and suchlike. The son of a shirtwaist factory worker, Salk was escalated to fame by his development of a killed polio vaccine, the testing of which, and the subsequent decline in polio cases, aroused intense interest in the press, public, and medical profession. Conventional wisdom at the time was that, although diphtheria toxoid, say, would protect against diphtheria, a killed virus vaccine was impossible. The "pure logic" of the situation, Salk says, led him to believe that the infectivity of polio viruses could be disassociated from their antigenicity.



Salk Institute

Whereas others might have continued on in the same field, Salk, for his next major experiment, decided in 1956 to found an institute. The motivation, he says now, was in part "a sense of responsibility for the protection of biological research and the uses to which it might be put." Salk's chief backer was Basil O'Connor, who, after his friend Roosevelt contracted polio, became president of the National Foundation–March of Dimes.

After a period of shakedown the institute is now in a period of consolidation. Salk can afford to turn his attention to other things. A philosophical work, *Man Unfolding*, was published this October, and he is preparing another on the biological foundations of ethics. With his second wife, Françoise Gilot, the painter and author of *Life with Picasso*, Salk lives in a house overlooking the ocean a mile or two below his institute. The institute is working successfully, limited but not impaired by the funding situation. It is "seen as a privileged place, which in fact it is," but the privilege does not go unearned. "The opportunities are overpowering for some," Salk says. "The absence of external pressures or teaching duties will quickly expose what an individual is good for. In this sense it's tyrannical, it's cruel."

Bronowski, who has been with the institute since it was founded in 1963, arrived by as circuitous, if less dramatic, an odyssey as Salk's. An algebraic geometer at Hull, England, he was drawn into war work in 1942 and afterward visited Japan as a member of an official mission. "My friend Penney [now Lord Penney, a principal architect of Britain's program for developing nuclear weapons] came back from Japan and decided he would make sure that Britain would have as good an atom bomb as he could manage. When I came back, I would have nothing to do with war work." The important thing is not which decision is right, but that scientists cannot abrogate the responsibility for this kind of decision, Bronowski says.

Interest in the problems of scientific responsibility was one of the two tributaries that led him to the Salk Institute. The other was his interest in human specificity, first awakened when anatomist Le Gros Clark asked him if, as a mathematician, he could help decide whether an australopithecine milk canine tooth was more human (as Clark contended) or apelike (as his opponents asserted). Bronowski was able to bring mathematics to Clark's aid. Author of works on the poet William Blake and on the philosophy of science, Bronowski worked for a decade with the British National Coal Board, where he developed a smokeless fuel (the name of which he couldn't remember at the time of interview), and also designed the plant to make it. Grow-

ing tired of the coal board, he was lunched one day by Salk and O'Connor and accepted their invitation to join the institute.

Described by Edgar Morin in his *Journal de Californie* as "le philosophe maison, petit homme possédant un extraordinaire visage d'acteur," Bronowski oversees the institute's human affairs programs, which embody Salk's desire for an extra dimension to basic research. Bronowski has recently returned from a year's sabbatical leave with the British Broadcasting Corporation, for which he prepared a television series entitled the "Ascent of Man" (the pun on Darwin is intentional). The BBC says it will do for science what Sir Kenneth Clark's "Civilisation" series did for art. Bronowski's associate in running the human affairs program is Harry Boardman, for 8 years a staff member on the collective *eminence grise* of American statecraft, the Council on Foreign Relations.

Leslie Orgel, like Bronowski, also has an English education. As an inorganic chemist working at Cambridge on ligand field theory he became interested in biology through his friendship with Crick and Sydney Brenner. Not wanting to go into any of the standard areas of molecular biology he chose prebiotic synthesis. A "terribly difficult" field, the aim of prebiotic synthesis is first to establish that the chemicals basic to life could arise on the prebiotic earth; second, to work out how they could come together in random polymers; and third, to divine how the polymers came to acquire genetically ordered biological properties.

Prebiotic chemists, Orgel says, have already achieved the first goal. Recently his group discovered that urea, a simple chemical likely to have been present on the primitive earth, can catalyze an important step in the formation of polynucleotides from individual nucleotide units. By forming urea from ammonium cyanate, Wöhler in 1828 broke the imagined barrier between inorganic and biological chemistry. Orgel finds it pleasing that the same chemical may have broken another kind of barrier between the two realms.

Orgel considers the absence of departmental disciplines an attractive feature of the Salk Institute. "One of the reasons I came here was that I didn't belong to any particular discipline; here it's possible to do things between disciplines." But he does not believe in an elitist rationale for the institute. "The idea of having a group of talented people who will inspire each other is one of those myths. I often expect that people who don't have anyone else to talk to just have to get on with their work."

Holley has probably changed fields more often than anyone else in the institute because, as he says, it's more fun to switch. Having deciphered the structure of yeast alanine transfer RNA, for which he won a Nobel prize, he turned to the problem of cell growth, an issue directly relevant to cancer, "because I wanted to do something to help people, not just pure research." Holley describes himself as "not an expert in anything—not even transfer RNA. I don't have a cataloging mind at all. What I am good at is picking up inconsistencies, seeing what are the important questions."

Holley came to the Salk Institute from Cornell because there were more people at Salk working on problems related to his own, problems such as the nature of the cell surface, the immune system, and the transformation of cells by viruses. Work in his new field is going well and leads him to believe that the availability of common nutrients may play a more important role than supposed in the growth of malignant cells. Cancer, he says, is a very interesting field to be in—people who 5 years ago thought otherwise "were not paying attention to it."

Roger Guillemin, the most recent fellow to join the institute, was trained as a physician at Lyon and worked with the French resistance during World War II. He became interested in endocrinology and right after the war seized the opportunity of a research post at Montreal. A visit from Geoffrey Harris, the pioneer Oxford student of the pituitary, turned his attention toward that gland, an interest Guillemin pursued in earnest when he moved from Montreal to the Baylor College of Medicine at Houston in 1952. His discovery that pituitary cells in culture would not secrete a particular hormone unless fragments of hypothalamus were added to the medium was an experiment, Guillemin says, that changed his life. Since 1955 he has been studying the control of the pituitary, known now to be mediated by hormones produced in the hypothalamus region of the brain. Fourteen years later he extracted from 300,000 sheep brains 1 milligram of the first such hormone to be identified, TRF or thyrotropin releasing factor. With the tools he has developed, Guillemin's team is now gleaning a harvest of knowledge about the brain's function as a gland.

"I was mesmerized by the beauty of the building. It is one of the most beautiful buildings I have seen anywhere in the world," says Guillemin in talking of the decision to move his team from Houston to the Salk Institute 2 years ago. With no teaching duties, his productivity at Salk has "increased exponentially." But he worries about the institute's financial security, which is "not in keeping with the quality of what is going on here." Guillemin's is an expensive operation, and he was caught short when the system of fellows' "estates"—an annual $110,000 given by the institute to each fellow to do with as he pleased—was in practice partially suspended for lack of funds.

The Salk Institute was to be a place from which nothing bad should ever come—"biology with a conscience regarding its significance," says Guillemin. "It is not an elitist place in a vacuum. It is an elitist place with a purpose."

Szilard-Doering Memo

The clearest definition of what the Salk Institute is meant to be—at least in two men's view—occurs in a memorandum written in 1957 by Leo Szilard and William Doering.* Szilard, the Hungarian-born physicist who played a pivotal role in the development of the atomic bomb, the postwar attempts to control it, and the physicists' invasion of molecular biology, helped also to found the Salk Institute. A salient purpose of the institute proposed in the Szilard-Doering memo was to attract "outsiders" to conventional biological problems, particularly those related to health. The outsiders, like the physicists working on wartime engineering problems, were to spot solutions the experts had missed.

In size, organization, and the background of its fellows, the Salk Institute follows quite closely the Szilard-Doering outline. The emphasis has been rather more on general basic research, rather less on specific health problems near the verge of solution, which was what Szilard envisaged. The institute has been forced more deeply into cancer research than it might have liked—a subject that Szilard in 1957 said it should avoid because of the great attention cancer was already receiving elsewhere.

"The source of all our problems is

* Bernard T. Feld and Gertrud W. Szilard, Eds., *The Collected Works of Leo Szilard: Scientific Papers* (M.I.T. Press, Cambridge, Mass., 1972), pp. 505–524.

lack of funds," says one institute scientist. The institute receives a guaranteed $1 million each year from the National Foundation for housekeeping costs but must raise the rest of its $5 million budget from public and private sources. A hiatus between resources and ambitions that became apparent some 2 years ago has left the institute unable to make more than limited progress with its humanist programs. Hopes of establishing large groups in neurobiology and aging have had to be shelved. Instead, the institute has been sucked into cancer research because that is where the money is, both from federal sources and private donors. Even so, nearly two floors of the building, containing some 40,000 feet of floor space, are still vacant.

Another result of financial uncertainty is that the institute cannot offer any tenured positions in addition to those of the existing fellows. This, and the policy of relying on the fellows to attract large grants on behalf of their group—all of whom are jeopardized if the grant fails to come through—has made it harder to keep younger people. "I think the place was slow in building up young people as independent investigators," says Holley. "One of the side benefits of the financial problems is that this will probably change."

If the Salk Institute is something of a pauper in rich man's clothing, even to have stayed financially viable is no mean achievement for a pure research organization dependent on public support. The institute seems now to have put its financial affairs on a firmer basis, and a new executive officer, Frederic de Hoffman, a physicist and former member of the San Diego business community, is trying to raise an endowment. Though tenure is a problem for some, there are others who prefer to remain at Salk than accept tenured posts elsewhere. With its unrivaled setting, and the virtual absence of teaching duties, the institute is an attractive enough place to do research, as evidenced by its ability to draw researchers such as Holley from Cornell or Guillemin from Houston.

"The institute is a useful refuge for people who in the last 3 or 4 years have found the increasing teaching burdens at university made it difficult to do research," says one scientist. And Salk himself, referring to the tendency of others to make a public figure of him, said on a CBS program some years ago, "I sometimes think that the idea of creating the institute was to create a shelter for myself." The institute may not yet have produced anything with the public impact of Salk's polio vaccine, but its continued vitality suggests that Salk's second experiment can probably be counted a success.

—NICHOLAS WADE

RESEARCH NEWS

Hydrogen: Synthetic Fuel of the Future

It may take 50 years, 100 years, or longer, but the time is approaching when gas, oil, and coal will no longer be available for use as fuels. Possibly, reserves of these fuels will be depleted by then. Probably, production will not be able to keep pace with demand (Fig. 1). But most likely, the remaining reserves will become far too valuable as feedstocks for chemical production to be simply burned for their energy content.

By that time, of course, nuclear fission and fusion—and perhaps solar energy—will almost certainly be the major energy sources and should, in theory, be capable of supplying all our energy needs. Most developmental work on these sources has emphasized the production of electricity, however, while only about 10 percent of energy end use is supplied by electricity. The remainder is supplied by the combustion of fuels to produce heat energy that is used in industry, homes, and transportation. It is likely both that electricity will play a larger role in supplying future energy demands and that heat energy from nuclear reactors will be utilized in large nuclear/industrial complexes, or nuplexes. Nonetheless, there will remain a strong demand for portable, fluid fuels, particularly for applications in transportation, and the most likely response to this demand will be vastly increased production of hydrogen.

Hydrogen, of course, is not an alternative primary energy source, because large amounts of energy will be required to produce it. Rather, it holds promise of being a highly efficient energy carrier that would prove valuable in situations where transfer of energy as electricity is inefficient, impractical, or impossible. It is this potential that has generated such widespread interest in the possibility of a "hydrogen economy."

In many ways, hydrogen is virtually an ideal fuel. When it is burned in air, the only possible pollutants are nitrogen oxides derived from the air itself, and concentrations of these are generally lower than concentrations produced by other fuels. When it is burned in pure oxygen, the only product is water and there are no pollutants at all. The ignition energy of hydrogen is about 0.02 millijoules, less than 7 percent that of natural gas, so that it can readily be used in low-temperature catalytic burners that also produce no pollutants.

The energy content of hydrogen gas is 325 British thermal units per standard cubic foot (1 Btu/scf$=2.98 \times 10^5$ joules per cubic meter), less than a third that of natural gas (about 1000 Btu/scf). The lower viscosity of hydrogen permits a threefold increase in flow capacity of a pipeline, however, and one pipe can carry nearly equal energy contents of either fuel—although hydrogen transmission requires a greater pumping capacity. The energy content per unit mass of liquid hydrogen is about 2.75 times greater than that of hydrocarbon fuels, so that the liquid form is an ideal fuel for rockets and airplanes. The volume of liquid hydrogen is much greater than that of a comparable weight of hydrocarbons, however, since its specific gravity is only 0.07.

There is some concern—often called the "*Hindenburg* syndrome"—about the safety of hydrogen, but most such fears