telligence, and experimental psychology are regrettably weak; and connections with clinical psychology are not yet on the horizon. Nevertheless, those connections will ultimately need to be made, and it is gratifying that recent studies of information processing are beginning to find a place for motivational variables such as gain and loss.

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NEWS AND COMMENT

1965 Nobel Laureates in Medicine or Physiology

The award of the Nobel prize for physiology or medicine to André Lwoff, Jacques Monod, and François Jacob, of the Institut Pasteur of Paris, finally ends the 30-year period during which no Nobel prize was given to a French scientist, a period that began when Frédéric and Irène Joliot-Curie received the chemistry prize in 1935. This apparent lack of highest recognition of its leading scientists had become a matter of some public concern in France, and it is not without irony that just these three men should have been chosen to break the prizeless spell. For, while Lwoff, Monod, and Jacob had long been recognized abroad as among the world's leading modern biologists, they remained virtually unknown and without influence on scientific affairs in their own country. Both the Royal Society of London and the United States National Academy of Sciences elected André Lwoff to foreign membership years ago; but the French Academy of Sciences has not yet seen fit to include him in its ranks.

The present generation of biologists generally thinks of André Lwoff in connection with the work for which he was honored by this prize: his demonstration in 1950 that lysogenic bacteria perpetuate the capacity to produce virus in the form of the noninfective *prophage* and his discovery (in collaboration with his disciples Siminovitch and Kjeldgaard) that the prophage can be induced at will to produce infective virus, by ultraviolet light. It may have been forgotten, however, that Lwoff's study of lysogenic bacteria was only the third major incident in a career which had already gained him international fame. Lwoff began study of the morphogenesis of protozoa in the 1920's, work that culminated in the discovery of extranuclear inheritance in these organisms. Those studies established Lwoff as one of the leading protozoologists of his time. In the 1930's Lwoff turned to the nutrition of protozoa and pioneered the development of chemically defined media for their growth. In the course of this work he identified vitamins as microbial growth factors and, in a famous paper published in 1936 in collaboration with his wife, Marguerite, showed that vitamins function as coenzymes. This established Lwoff as one of the great figures in the development of nutrition as a science.

In 1941 Lwoff published his classic and influential treatise *l'Évolution Physiologique*, in which he developed the "pessimistic" thesis of biochemical evolution by progressive losses of biosynthetic capacity.

While working at the Institut Pasteur in the 1930's, Lwoff became the friend of Emanuel Wollman, one of the early students of lysogenic bacteria, who was later killed in a Nazi concentration camp. After the war, Lwoff decided to carry on Wollman's work, at a time when lysogeny was held in the lowest possible esteem by the then-nascent school of modern American bacterial virologists. But Lwoff's indubitable proof that lysogenic bacteria *do* perpetuate viruses as part of their heriditary constitution not only made lysogeny once more a respectable endeavor but also changed radically the views on the natural relation of viruses to their host cells, from inexorable morbidity to facultative peaceful coexistence.

Jacques Monod began his scientific career in the 1930's, also, as it happens, by working on protozoa. It cannot be said, however, that this work gained *him* any fame. In fact, Monod then still thought of quitting science altogether and devoting himself entirely to the cello, which he still plays with professional competence. But Monod decided to give biology another try and turned his attention to bacterial growth. This work, in which Monod developed quantitative methods and principles of growth of bacterial cultures which are now standard operating procedure in all of bacterial physiology, was published in 1941 as his doctoral thesis, "Recherches sur la Croissance Bactérienne." Upon the fall of France, Monod joined the French Resistance movement and, in time, commanded one of its underground military units. After the liberation, Monod was assimilated into the regular French Army and finally wound up in the military government of occupied Germany. In 1946 he left the army and returned to Paris to join Lwoffs Department of Microbial Physiology at the Institut Pasteur, where he began study of the synthesis of the inducible bacterial enzyme β-galactosidase. Whereas at that time such men as Max Delbrück, Salvador Luria, and

Alfred Hershey in the United States were trying to understand the mechanism of replication of the genetic material, Monod embarked on solution of the problem of the formation of specific enzyme proteins. Replication and protein synthesis turned out to be the yin and yang of molecular biology. And, just as bacterial viruses seemed the best material for study of the replication process, so inducible bacterial enzymes, whose formation proceeds only upon addition of a substrate-like inducer to the cell, seemed ideally suited for studying how the cell makes its enzymes. Among the main accomplishments of Monod's first 10 years of work on this system were the demonstrations (in collaboration with his American disciple Melvin Cohn) that the induced formation of β-galactosidase actually represents the *de novo* synthesis of protein molecules, rather than the conversion of preexisting proteinaceous enzyme precursors, and that, in inducing enzyme synthesis, the inducer does not interact at all with the enzyme. In collaboration with Germaine Cohen-Bazire, Monod then also isolated *constitutive* bacterial mutants, in which enzyme synthesis proceeds in the absence of any exogenous inducer.

Nobel prize for medicine or physiology is shared this year by (from left) Lwoff, Monod, Jacob.

François Jacob was only partway through his medical studies at the outbreak of World War II and managed to escape to England on one of the last boats leaving France after its collapse. He joined De Gaulle's Free French forces and became an officer in Leclerc's division that fought its way from equatorial Africa through the Libyan Desert to the Mediterranean; it finally took part in the liberation of Paris. Jacob was seriously wounded in these campaigns and received one of the highest French decorations of the war, the Compagnon de la Libération. In 1949 Jacob joined Lwoff's department in the Institut Pasteur and soon thereafter began a collaboration with Elie Wollman, son of the elder Wollman. The original goal of Wollman and Jacob's studies was to work out the genetic basis of lysogeny, and before long they succeeded in showing that Lwoff's "prophage" is, in fact, a state of the viral genome in which it is integrated into and replicated together with the chromosome of the bacterial host cell. In the course of these studies, however, they made an even more important discovery when they found that in sexual conjugation of bacteria, a phenomenon first discovered by Lederberg and Tatum in 1946, there occurs a gradual, ordered transfer of the chromosome of the male donor bacterium to the female recipient cell. For good measure, Wollman and Jacob also discovered, by a piece of brilliant deduction, the circularity of the bacterial chromosome and recognized a new class of genetic elements, the *episomes*. In 1961 they presented a general account of their work in their definitive monograph "Sexuality and Genetics of Bacteria."

The study of the regulation of bacterial enzyme synthesis entered a new phase in 1958, when Monod and Jacob began to collaborate in a series of physiologicogenetic studies. The first important new development was the so-called "Pa-Ja-Mo" experiment (carried out together with the visiting American Arthur Pardee), in which it was demonstrated by conjugating normal male bacteria with female mutant bacteria synthesizing β-galactosidase constitutively that enzyme inducibility is dominant over constitutivity. This finding led to the notion that the role of the inducer in initiating enzyme synthesis is to neutralize a *repressor*, itself synthesized by a specific regulatory bacterial gene. After they had fashioned the repressor idea, Jacob and Monod isolated and mapped genetically, by means of very astute techniques, a variety of novel and highly revealing regulatory bacterial mutant types. They summarized their newfound insights in 1961 in the review "Genetic Regulatory Mechanisms in the Synthesis of Proteins," one of the monuments in the literature of molecular biology. In this review, Jacob and Monod proposed two great concepts: the *messenger* RNA and the *operon*. The validity of the messenger RNA concept—that is, that for expression of phenotype the nucleotide sequence of the DNA gene is transcribed to an RNA messenger molecule of limited lifetime, which combines with preexisting ribosomes and there directs the ordered copolymerization of amino acids into specific polypeptides—was proved before the review was even in print. When the review *did* appear, it immediately suggested to Marshall Nirenberg the experiments with synthetic messenger RNA by means of which, in the course of the next 2 years, Nirenberg and others were to break the genetic code. The operon concept envisages that genes pertaining to related functions reside in contiguous regions of the bacterial chromosome and form an operon by sharing a common gene of regulation: their operator. The genes of the operon function—that is, synthesize their messenger RNA—only while the operator is "open." The operator "loses" when it is engaged by the operator-specific repressor, itself the product of a second gene of regulation. The repressor can exist in active or inactive states, depending on whether it has interacted with an *effector* molecule, which, in the case of the β-galactosidase operon, is one of the galactoside inducers resembling lactose, the natural substrate of the enzyme. Not only was this regulatory circuit capable of explaining much of the bewildering mass of observations that had accumulated by then on the control of bacterial enzyme synthesis but it could account also for prophage induction, a process that had remained rather mysterious in the decade since its discovery by Lwoff. For, as an experiment by Wollman and Jacob, which was really the heuristic ancestor of the Pa-Ja-Mo experiment, had shown in 1957, the prophage elaborates a specific repressor-like *immunity substance* that holds in check expression of the remainder of its genes. Prophage induction could then be readily understood as a neutralization of the immunity repressor by effector substances, resulting in "opening" of the operators of hitherto quiescent viral operons.

The influence of the work for which Lwoff, Monod, and Jacob are being honored by this prize now far transcends the bounds of molecular biology. Probably its most important impact has been on developmental biology, a field that, in the last analysis, concerns the understanding of regulation of gene activity in ontogeny. Though it still remains quite unclear to what extent the regulatory processes discovered in bacteria actually operate in the cells of higher forms, the messenger RNA-regulator gene concept has by now altered the face of embryology. In addition to their discoveries and dialectic constructs, the three laureates made one further, enormous scientific contribution: in their laboratories they trained a phalanx of young workers (mainly American, some European, and a few French) whose work was to transform the landscape of modern biology. It is hard to imagine anyone more deserving of this prize than André Lwoff, Jacques Monod, and François Jacob.

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R&D Boom: House Report Sees Harm to Higher Education

Until about 5 or 6 years ago, perhaps the most outstanding characteristic of relations between science and government was that the federal politicians were willing to take the scientific politicians on faith. The post-Sputnik boom in research-and-development funds accelerated what has been referred to as the "nationalization" of American science, but despite the scientific community's growing—and in many instances nearly exclusive—reliance on federal funds, science was accorded a remarkable degree of sovereignty and self-government.

In a formal sense, the system of support was tied into the traditional political process of agency proposals, executive reviews, and congressional approval; but, at least as far as basic research was concerned, the working truth of the system was that the federal government turned tax funds over to the scientific community, and the community, through an elaborate apparatus for appraising and bargaining, allocated the funds among competing applicants. The system, the federal politicians were told, could not successfully operate in any other fashion, because science, to be fruitful, must be governed by scientists.

The first major assault on this proposition came in the later 1950's, when Representative L. H. Fountain (D–N.C.) attacked the National Institutes of Health for what he considered to be inadequate supervision of the use of its funds by outside researchers and an alleged decline in the quality of the work approved for support. Meanwhile, in a less conspicuous fashion, the National Science Foundation was being pressured by Congress to spread its funds to the less scientifically developed regions of the country. And then, with the research and development budget rapidly becoming a highly visible portion of overall federal expenditures, Congress in effect concluded that science was too important, or at least too rich, to be left to the scientists. As a consequence, Congress revoked the sovereignty of science on a matter that had once been left virtually entirely to the men of science—the selection of locations for major research facilities. The major culmination of this move has been, of course, the nationwide fight now raging over the location of the proposed 200-bev accelerator.

The trend toward a greater congressional presence on what was once the almost exclusive preserve of the leadership of science has now manifested itself again, this time in the form of a devastating study issued last week by the Research and Technical Programs Subcommittee of the House Committee on Government Operations. Entitled "Conflicts between the Federal Research Programs and the Nation's Goals for Higher Education,"* it forcefully assails a fundamental argument of much of the leadership of the scientific community—that federal expenditures for basic research have had a net effect of improving American science education.

In attacking this argument, the report charges that universities with large federal incomes are thriving partly at the expense of the weak; that the federal government is committing itself to major technical programs whose manpower requirements will reduce the incentives for young persons to engage in teaching of undergraduates; and that the concentration of research funds in a relatively few major institutions is not producing a proportionate increase in scientific training. Finally, in a blow at the scientific leaders who contend that NSF's science development program will help produce an increase in new centers of scientific quality, the report charges that the program will help the "rich get richer" and will not substantially improve or extend scientific education.

* 74 pages, available without charge from the Research and Technical Programs Subcommittee of the House Committee on Government Operations. Other related documents, also available from the subcommittee, are the June 1965 report, "Conflicts between the Federal Research Programs and the Nation's Goals for Higher Education, Responses from the Academic and Other Interested Communities to an Inquiry by the Research and Technical Programs Subcommittee," and Part 2 of that report, issued in August.