in their fifties and sixties; it is inconceivable that their names have not cropped up in the prize committee's discussions on many occasions in the past ten years or so. It is now some thirty years since they recognized that bacteriophage held the answer to the key question of biology, the mechanism of inheritance. The bacteriophages are the experimental material for running the genetic code to earth, and Delbrück, Luria and Hershey are the three men who, more than others, realized this and laid the foundations of molecular genetics.

Their influence on many of the younger men who have already won Nobel prizes for work in molecular biology has been subtle but none the less profound. The collected papers of Delbrück, Luria and Hershey would form only slim volumes compared with those of many of their peers; it has been not so much what they have published but what they have said in private and at meetings, especially those at Cold Spring Harbor, which has changed the face of genetics. The mythology of molecular biology and the festschrift *Phage and the Origins of Molecular Biology*, celebrating Delbrück's sixtieth birthday in 1966, abound with stories of Delbrück's insistence on rigorous evidence for any claim. When Marmur and Doty published their first paper on nucleic acid hybridization, for example, Delbrück wrote a ten page critique. And on receiving the umpteenth paper from Seymour Benzer on T-phage genetics for communication to the *Proceedings of the US National Academy of Sciences*, his comment was "Not another"; soon afterwards, Benzer took the hint and began working on the nervous system.

Max Delbrück, a postdoctoral student of Niels Bohr, left Germany in 1935 and at Caltech started work in genetics, not with *Drosophila* as a less perspicacious man would have done, but with bacteriophage. Steeped in quantum theory, a bacteriophage was as close to a quantum of genetic information as anyone could get. A bacterium infected with a bacteriophage contained all the key elements of biological self-replication but lacked all the trimmings which then and now bedevil experiments with nucleated cells.

Luria, another refugee from Europe, met Delbrück in Philadelphia in 1940 and from the meeting they emerged as a team devoted to phage genetics. In 1943 they published an epoch-making paper proving that in populations of bacteria sensitive to bacteriophage, bacterial cells resistant to the phage appear as a result of natural selection of spontaneous mutations conferring phage resistance. It was the manuscript of this paper that brought Luria and Delbrück in touch with Hershey. The three men were instrumental in establishing the American Phage Group and establishing the Cold Spring Harbor Laboratory and the symposia held there as the Mecca of molecular biology. Hershey, a retiring man poles apart from the ebullient Luria, has remained at Cold Spring Harbor ever since, sailing or gardening when the summer migrants are at their peak and returning each autumn with a new idea.

In 1945 both Hershey and Luria demonstrated spontaneous phage mutation and in 1946 Delbrück and Hershey independently showed genetic recombination in phage. Hershey's most famous experiment, however, was yet to come. In 1952, with Martha Chase, he proved that phage DNA is the only component of a phage particle injected into a bacterium on infection. Readers of *The Double Helix*—J. D. Watson was one of Luria's postgraduate students—need no reminding of the impact of the Hershey–Chase experiment on Watson and Crick in their search for the structure of DNA.

Since those pioneer days Hershey has done a series of experiments, with the analytical centrifuge as his chief tool, which have not only led to the realization that many phage and bacterial genomes are circular DNA molecules but have also set the universal standard for accuracy of measurement. When Hershey cites a fact or figure in his papers it is never challenged. As one of his closest colleagues at Cold Spring Harbor is wont to say, "Al is always right". Unlike Hershey, Delbrück and Luria have not hidden themselves away but have become heavily involved in teaching. Delbrück, for example, whenever he changes his field of research, subjects himself to the mental discipline of teaching a course on his new interest. He also spent two years in Germany trying to alter the hierarchical structure of the German university. Luria, now at MIT, finds time not only to teach large undergraduate classes but also to sculpt, collect art and play a leading part in the anti-Vietnam War movement, which has not won him friends in Washington.

All three men, however different in character, have repeatedly put modern biology on the right tracks in the past thirty years, and the Nobel Prize committee deserves credit for recognizing that.

SOCIETIES

Another Anniversary

On November 2, 1819, a Philosophical Society was founded in Cambridge "for the purpose of promoting scientific enquiries and of facilitating the communication of facts connected with the advancement of Philosophy and Natural History". This was the third attempt at organizing a scientific group among the members of the university at a time when it was far from being a centre of British intellectual progress. It was also a successful attempt, largely because enough people were convinced that something had to be done at last: it united and revived the efforts of the individual scientists, published their work and transformed the attitude of the university to advances in what was then known as the Natural Philosophy. And it is still flourishing.

From the start the Cambridge Philosophical Society concerned itself with all aspects of science—its creators were Adam Sedgwick, the geologist, and John Henslow, who became well known for his influence on Darwin. Perhaps it won greater renown on the physical side during the nineteenth century, with the mathematician Charles Babbage and the astronomer George Airy making important contributions to meetings, but it was certainly well involved with the rantings that followed the publication of Darwin's theory of evolution in 1859. Sedgwick, who was president in 1860, launched an attack on this theory which prompted the author to label him as one of "the old fogies at Cambridge".

This was fortunately not a symptom of the society's general outlook. After the establishment of the Cavendish Laboratory, it published much of the new physics that was being developed there, and this close association continued into the era of the quantum; a crucial paper by Dirac on "The Quantum Theory of

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the Electron" appeared in the *Proceedings* in 1928. In the same decade, the *Biological Reviews* were first published, and this has since become one of the society's most important enterprises.

Among Cambridge people, the Philosophical Library is probably the best known contribution to the life of the university—its provision of periodicals for all members of the university, as well as Fellows of the society, has filled a valuable service throughout its existence, and since 1967 it has been known as the Scientific Periodicals Library. It now obtains about 1,100 journals in exchange for its own publications.

Celebrations of what the society is calling its sesquicentenary are to include the presentation of honorary degrees by the university, a series of special lectures and a dinner in St Catherine's College on November 3. Some time during the festivities, new plans will be announced to expand the activities of the society. With a financial situation that is better than ever before and the continuation of widely respected meetings and publications, the next 150 years are likely to be as fruitful as the last.

RESEARCH PLANNING

What is it Worth?

THE fourth of the science policy studies produced under the aegis of the Council for Scientific Policy is the most obscure yet. The subject is *An Attempt to Quantify the Economic Benefits of Scientific Research* (HMSO, 4*s*). Professor Harry Johnson of the London School of Economics, the member of the council who has superintended the study, acknowledges in his introduction that "it is by no means the case that the sole justification for fundamental research is utilitarian". What the authors of the study, Mr I. C. R. Byatt and Dr A. V. Cohen, have done is to suggest a number of studies which could be made of the ways in which the economic success of what are called "science-based industries" might be traced back to certain discoveries in fundamental science. According to Professor Johnson, the notion that a part of this "ambitious" plan should be undertaken has been accepted by the Council for Scientific Policy, although there is as yet no news of the industries likely first of all to be favoured by the study.

The study starts with a long and somewhat wooden list of the potential benefits of what the authors call "curiosity-oriented research". Trained manpower is at one end of the scale, and culture at the other, but the study is mainly concerned to quantify the possible value of delayed industrial applications of scientific research, "the absorption into the infrastructure of science, and the subsequent industrial application, of a whole host of apparently minor discoveries", the awareness of developments in other countries which research programmes can provide and the way in which scientific research equips people to "look for the possible commercial developments of scientific discoveries". In passing, however, the study does trample on the feelings of those who argue that science is culturally important—the authors say that because the British government spends only £24 million a year on the support of the Arts, it would be "difficult to justify" the spending of more than £5 million a year on the cultural objectives of science "in view of the smaller number of people able to enjoy science as a cultural activity". Whether it will be possible to throw more light on this problem by comparing the audiences for broadcasts of musical concerts and science programmes, as the study somewhat wistfully suggests, is another matter.

The chief preoccupation of the study is to put a numerical value on the benefits of research to industry in general and individual industries in particular. Quite properly, it works entirely in terms of costs and cash benefits discounted to some standard date. The argument is that the value of the scientific discoveries underlying a particular industry can be measured by the difference between the discounted sum of world sales in the industry and the discounted sum of all the associated costs—running costs, capital investment, market research and applied research. The object of the formalism is to make it possible to write down the partial differential coefficients by means of which are calculated the marginal changes brought about by variations of the level of expenditure on scientific research, but the usefulness of the procedure is to a very large extent undermined by casual references such as that to the need for including social costs and benefits—thin ice for most people. If it is also reckoned that a properly discounted estimate of the value of scientific research is likely often to be the difference between two very large numbers, it seems most probable that the Council for Scientific Policy will have to sponsor a great many of the retrospective studies specified in outline before the Treasury would allow it to use the generalizations which emerged as argument in an annual scramble for the research budget.

ENGINEERING

Cooperation in Electronics

THE annual report of the Institution of Electronic and Radio Engineers (*Proc. IERE*, October 1969) reflects the growing cooperation between institutions and other organizations concerned to make the best use of British potential in electronic engineering.

One of the main problems is establishing common qualifications for different grades of engineer, and the Council for Engineering Institutions has succeeded in doing this for professional engineers. From next year individual institutions will stop setting their own examinations and all chartered engineers will be registered by the Council for Engineering Institutions.

The next step is to establish a register for other grades of engineers—possibly technician engineers and engineering technicians—and the CEI has a working party looking into this now.

In line with its policy of wide-ranging cooperation the IERE has joined with the Institute of Physics and the Physical Society, the Institute of Mathematics and its Applications, and the Institution of Electrical Engineers in forming a Standing Committee of Kindred Societies. Its chief function seems to be to organize common meetings and conferences and to focus attention on borderline subjects. The IERE and the IEE have been closely cooperating for some years in fields such as medical and biological engineering, computers and a project to develop a British information retrieval system. Both institutions have, however, decided firmly in favour of remaining separate organizations.

In research and development, the National Electronics Council is responsible for ensuring efficient

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