power will not come into its own until "one invents superconductors at room temperature or temperatures close to it."

Kapitsa sees a "terrific future" for such applications of low-temperature physics as the development of superconductors which will permit economical production of strong magnetic fields in accelerators or electric power systems, microwave transmitters, and magnetohydrodynamic generators. In such applications his own basic research on magnetism and low temperatures, done in the 1920's and 1930's, would be of great significance.

Nonetheless, Kapitsa did not express an expansive feeling about the development of physics. In his lecture on Rutherford, he said:

> The year that Rutherford died (1938) there disappeared forever the happy days of free scientific work which gave us such delight in our youth. Science has lost her freedom. Science has become a productive force. She has become rich but she has become enslaved and part of her is veiled in secrecy.
>
> I do not know whether Rutherford would continue nowadays to joke and laugh as he used to do.
>
> —VICTOR K. MCELHENY

Oceanography in Britain: Significant New Support

London. The British government's support for physical and biological studies of the sea has increased rapidly during the 1960's, especially for the budget year beginning 1 April 1966. These increases are responses to steady lobbying by the scientific community, although this lobbying was quieter than similar efforts in the United States.

By 1964–65 the budget for civilian marine science in Britain had risen to a total of $6 million (compared to nearly $20 million in France and $70 million in the United States); it is now nearer $10 million. The National Institute of Oceanography at Wormley in Surrey has been particularly favored. From an initial budget of about $280,000 in 1949, the institute's spending rose to $740,000 in 1962–63. In subsequent budget years the figure has risen to $1 million, $1.15 million, $1.47 million, and now $1.96 million.

Money has been provided to add a new wing to the NIO building. The increased budgets also make it unlikely that NIO's 3000-ton research vessel *Discovery*, built in the early 1960's at a cost of about $2.3 million, will have to be laid up between expeditions—as she was in 1964 after her initial cruises to the Indian Ocean.

An important factor in the recently increased support for oceanography has been the formation of a special government granting agency for the earth sciences: the Natural Environment Research Council, which was established in 1965 during the general regrouping of British government agencies supporting science and technology. Under the chairmanship of Sir Graham Sutton, retired head of the Meteorological Office, the NERC took over Nature Conservancy, the Geological Survey and Museum, the Hydrology Research Unit, the National Institute of Oceanography (previously supported in part by the Navy), and the Development Commission's responsibilities for marine and freshwater biology and fisheries research.

During the budget year ending 31 March, NERC grants for fisheries research were $1.9 million; this year they are to be $2.25 million. In the broad field of earth-sciences grants, some of them for oceanography, NERC handed out $1.4 million last year; this year, the total will be $1.7 million, an increase of more than 20 percent.

Even more encouraging than the figures has been NERC's determination to remedy two of the major defects of oceanography in Britain: lack of university programs in the field and lack of attention to manned underwater research vessels.

In both physical and biological studies of the oceans, research work had tended to concentrate outside the universities in such establishments as NIO. NIO was particularly notable for its studies of waves (important for the design of harbors), of the continental shelf off western Europe (for which a precision echo sounder was developed to study bottom sediments), and of deep currents in the open ocean (for which the famous neutrally buoyant float was developed). Biological studies were strongest in the laboratories of the Marine Biological Association at Plymouth, the Department of Agriculture and Fisheries for Scotland at Aberdeen, the Scottish Marine Biological Association at Edinburgh, and the Ministry of Agriculture, Fisheries, and Food at Lowestoft. The Edinburgh laboratory was notable for detailed surveys of plankton distribution in the North Sea.

University programs tended to be small except at the University College of North Wales (which received a $250,000 authorization for a biology-research vessel in 1962–63), the University of Liverpool (noted for its studies of tides), and the department of geodesy and geophysics at the University of Cambridge (which has concentrated on studies of the sea floor).

In 1965 the new NERC bought the 120-ft trawler *Noblesse* from the White Fish Authority for conversion to a research vessel for university departments; she is being reequipped with instruments, live-storage space for specimens, and living and working space for scientists. The refit is supervised by a committee headed by the late M. N. Hill of the department of geodesy and geophysics at Cambridge. In a letter to the London *Times* last October, Hill said he hoped that *Noblesse* would be the first of five such vessels that would cost about $5.6 million to buy and convert and about $560,000 annually to operate.

There are also plans for assisting universities to expand their graduate programs in oceanography. It is hoped that more universities will allow doctoral students to have their work supervised at NIO and other institutions.

Undersea research by men received considerable impulse in the summer of 1965 when British graduate students took part in a cooperative program of diving in an especially clear part of the Mediterranean off Malta. During the 1966–67 budget year, the White Fish Authority will rent from America a diving apparatus for fisheries research, which will be the first manned undersea craft used by the British. Scientists will be able to see how various types of fishing gear operate when they are dragged through the water, and how schools of fish react to the gear.

Criticism of Britain's earlier lack of

interest in manned undersea research vehicles has been so intense that officials responsible for oceanography have taken pains to explain their cautious approach. At a special press conference at Wormley in October 1965, when NIO was officially taken over by NERC, NIO director G. E. R. Deacon explained his institute's attitude. Since NIO's main emphasis was on physical oceanography, it was less interested in undersea craft than were fisheries researchers. Marine biologists would benefit, Deacon acknowledged, from the chance to observe the behavior of marine organisms at depth. Geologists, even more, wanted vehicles for direct examination of the sea floor. But, at NIO's budget level, even a long-range asdic device was out of the question. For the present, NIO would get more out of the continuous recordings that can now be made from the surface of the ocean—from ships or from fixed, unattended buoys.

R. J. H. Beverton, secretary to the NERC, expanded on this point of view in a recent interview. Like Deacon, he was friendly in principle to a bigger British effort in the field. The problem of operating undersea vehicles was much less complex for fisheries biologists, whose main interest is exploration in the range of visible light, than for the marine geologists who want to work on the sea floor hundreds of fathoms down, Beverton noted. Experience in the United States shows clearly that the expense, and sophistication required, of systems for manned undersea exploration rise sharply with increased depth and size, especially if scientists want a vehicle able to move about freely. Gales on the surface can blow up suddenly so that even a sizeable support ship may run into trouble. Provision for escape in case of trouble becomes much more expensive at greater depths, said Beverton. Thus work would start modestly with the towed vessel rented for the White Fish Authority.

This view was summed up eloquently last October in M. N. Hill's letter to the *Times*; he wrote:

> I agree that skin-diving can be most instructive concerning the flora, the fauna and the nature of the sea floor in inshore waters and closed seas; in these areas much will be learned thereby of commercial and academic value. The limitations of area are, however, very restricting and if it is necessary that man should directly, rather than indirectly, investigate the enormous areas of the seas and oceans unapproachable by diving, then manned submersibles must be built.
>
> Even, however, if this approach has to be used, it is a misapprehension to suppose that research and fish farming can do anything other than to alleviate very local food problems produced by a world population explosion. Increased productivity of the land is what is required for any major increase in world population. It would be wrong to suppose that oceanography is primarily concerned with productivity.
>
> What is required in this country if we are to remain in the forefront of all aspects of oceanography—physical, chemical, biological and geological—are more conventional sea-going and research facilities, more sea-going and laboratory staff and more money for apparatus. (It has, incidentally, been estimated that for each *scientific* man-year at sea, eight man-years are required ashore.)

Hill's letter placed the issue of manned submersibles in the broader context of the new NERC's thinking about oceanography. This thinking was spelled-out for British science reporters at the Wormley press conference. Both Reginald Prentice, then Minister of State for Education and Science (in charge of higher education and research), and Michael J. Lighthill, a member of NERC, stressed that the government was determined to expand support for oceanography. Lighthill, a professor at Imperial College and chairman of NERC's panel on oceanography and fisheries, said, "We are convinced that the growth must be maintained and intensified."

The panel had agreed on two immediate goals for the National Institute of Oceanography: (i) addition to the equipment aboard *Discovery* of more devices for data acquisition and data processing on board; and (ii) increase in staff to help reduce and analyze the large amount of data acquired during recent *Discovery* cruises in the Indian Ocean and the Atlantic.

Accepting the need for major expansion in oceanography, the panel was marshalling both economic and scientific arguments for a 3- to 5-year program, Lighthill said. As items in the economic argument, Lighthill mentioned design of ships, routing of ships' voyages, fisheries, mineral resources, defense, improved meteorological forecasts, and coastal engineering.

Deacon expanded on some of these items. He noted that British ports spend at least $30 million yearly on sea walls and other barriers against the sea; yet until 10 years ago there were no wave recorders to speak of in Britain. In ship design, bulbous bows are giving way to rams, although the reasons why the ram bows perform better at sea are still poorly understood. Pollution of the sea by oil and radioactive materials remains an important issue requiring research. Studies of the productivity of fishing grounds continue to produce new evidence of the link between the circulation of waters and biological productivity. Although it is true that an airplane "won't fly without a lot of science," Deacon said, the resources committed to navigation of the seas are still much larger than those committed to aviation. If oceanography could improve knowledge sufficiently to cut the bill for sea navigation by even 1 percent, the gain would be a large sum.

In general, Deacon said, Britain could not hope to compete with the United States or the Soviet Union in its oceanography effort. But, with considerably less money, Britain could remain in the front rank, "and that's what's really important. So far, we've done well enough that our people are on the whole welcome in other nations' laboratories."

In reviewing the budget increases that derived from such thinking, Beverton of the NERC stressed in a later interview that the major emphasis would be on instrumentation. "The prime need at this stage is to keep up with the rapidly developing instrumentation. Oceanography is moving toward 'big science'."

Beverton again mentioned the need for sophisticated shipboard computers to process data during a cruise, to enable the expensive vessel to react to opportunities more swiftly. Also needed, he said, is far-more-sophisticated navigation equipment for areas of the world out of reach of shore-based radio aides to navigation. The development of such equipment will require rapidly increased budgets for oceanography, even without a massive build-up of scientific personnel.

An interesting feature of these arguments is that they hardly mention the defense applications of marine science. In Britain it seems that oceanographers will have to seek continued rapid increases in government support on an almost entirely civilian basis. Arguments related to shipbuilding, navigation, or fisheries should carry added force now that Britain is increasingly aware of its perilous economic situation. Also, it must count for more than nothing that Britain was the sponsor of the *Challenger* expedition of the 1870's which many rate as the foundation of modern scientific oceanography.

—V.K.M.