knew, for what was later done by the Army itself. Lessons for the future were that the nature, and even the existence, of a problem of quite serious importance could remain unrecognized until investigated by selected and highly trained scientific workers; that mixed teams are required, of compositions determined by the probable nature of the problem; that hopeful investigation depends on willingness on the part of the community to participate actively; that results, however potentially valuable, can remain disregarded until thoroughly appreciated at the topmost levels; and that for rapid solutions, simultaneous investigation in different circumstances by different teams is a very great advantage. The only danger is that, with the return of peace, the Medical Research Council might find it necessary to withdraw from social biology.

Mr. Louis Moss, director of the Government Social Survey, referred to the need for studies of both the social and industrial conditions of particular jobs, as well as of the attitudes of potential recruits, if labour were to be induced rather than compelled to particular industries.

Prof. J. D. Bernal, as the last speaker, was handicapped by the length of discussion which had already taken place, and what follows is based on the written contribution which he had intended to make. The same needs, he contended, that led to the appearance of operational research in war should now lead to the conversion of that experience to peaceful uses, since the gap between imports and exports and the impossibility of Britain feeding itself are at least as serious and immediate as any war situation. 'Operation Production' should be considered with the same urgency and common purpose as 'Operation Overlord'. The technique of operational research could be made available to find out what has to be done, to check the success of the operation and modify its conduct. It is essential that the country's very limited resources in trained man-power in engineering and science should be used in the most effective way with a scientifically determined system of priorities, weighing not only present resources, but also those which could be increased, often by very large factors, by the application of high-pressure research and development. Only a combination of economists, engineers and scientists could achieve this; but they must operate on the highest planning authority in the country. The most obvious priorities are coal, steel, building and agriculture, but others such as transport, distribution and the utilization of chemical wastes may prove equally important. Prof. Blackett's general principle of operational research should be used, to do those things which combine the greatest need with the most rapid possibility of achievement.

All these are in the nature of economic planning, but physical research is required wherever materials and techniques have to be transferred from their present use to some new one. Lively and effective research would also be necessary on the workshop and farm level, and all the ingenuity in the country would be needed to solve the thousand small problems that would arise. Thousands of scientific workers and engineers are being used in a wasteful manner or for purposes of secondary importance—a very large number in industry and probably as many in Service research. Operational research is needed to find the best distribution and to check redistribution. It would be tragic, he concluded, if this one organisational development of the War were not given the chance to show its capacity in the peace.

THE INSTITUTE OF SEAWEED RESEARCH

"HERE, Scotland has a chance. Eire, Norway, America, Japan, have all, in varying ways, exploited their seaweed resources. We are only at the beginning, and this splendid research station gives us the opportunity not only of making up on these countries, but of surpassing them." So declared the Right Hon. Joseph Westwood, Secretary of State for Scotland, when, on September 19, he officially opened the headquarters of the Scottish Seaweed Research Association—the Institute of Seaweed Research, Inveresk Gate, Musselburgh, Midlothian. Until recently a large mansion house, Inveresk Gate now contains adequate botanical, chemical, engineering and photographic laboratories, engineering workshops, a drawing office, a library, and conference and display rooms, apart from the necessary offices. The Institute stands in eleven acres of ground, and is situated sufficiently near Edinburgh, the University, and the sea to meet the Association's various needs.

The Association was formed in June 1944, and until Inveresk Gate became available the director and staff used the King's Buildings (of the University of Edinburgh) A.R.P. Control Centre as offices, as well as certain of the University's research laboratories and facilities. During the first two years of its life the Association was financed by means of a grant of £25,000 from the Development Fund. Thus was made possible a survey of Scottish seaweed resources and investigations into methods of harvesting, handling and processing these resources. Now, Government has provided over a period of five years a further sum of £90,000, and it is hoped that at least another £10,000 will be forthcoming from industry, and from public-spirited individuals.

Dr. F. N. Woodward is director of the Institute, but at the moment has been seconded to act as director of the United Kingdom Scientific Mission in the British Commonwealth Scientific Office in Washington. The acting director is Major P. Jackson. Under this joint direction the staff of the Institute operates under three divisions: botanical, chemical and engineering. The activities of these divisions may be outlined, as in the director's report, as follows:

(1) *Survey of Scottish seaweed resources.* (*a*) Development of reliable survey methods. (*b*) Quantitative survey of the Scottish coast for littoral, sublittoral and cast brown weeds. (*c*) Study of economic and ecological factors. (*d*) Determination of optimum conditions of growth by controlled culture.

(2) *Harvesting and processing investigations.* (*a*) Development of economic harvesting methods. (*b*) Determination of optimum conditions of drying, grinding and processing.

(3) *New and extended uses of seaweed and seaweed products.* (*a*) Determination of the chemical composition of Scottish seaweeds and its variation with change of species, season, age, environment, etc. (*b*) Determination of the properties and characteristics of the chemical components of seaweed and their derivatives, with the view of finding new and extended uses. (*c*) Development of methods of production of such constituents and their derivatives as are of potential technical value. (*d*) Determination of the value of seaweed as a component of animal feeding-stuffs and as a fertilizer.

Superimposed upon this programme, and as a logical outcome of its partial completion, is the new problem which arose during 1946, that of endeavouring to establish in the Outer Hebrides a ground, dried, rockweed producing unit.

At this stage it may not be out of place to outline briefly the activities of the three Divisions. Acting head of the Botanical Division is Mr. F. T. Walker. He and his assistant algologists have had to solve one of the two main problems facing the Association, namely, whether or not there is enough weed on Scottish coasts at a density sufficient to warrant commercial utilization. Accordingly, a littoral weed survey was commenced in April 1945 and concluded in December 1946. During this time, 4,250 of the 4,630 miles (92 per cent) of practical Scottish coast, exclusive of the Shetlands, were covered and more than 180,000 tons of littoral weed estimated to be present. The most prolific area apparently is in North Uist, where Loch Maddy and Loch Eport support a total of about 60,000 tons of littoral weed. On the basis of this estimation and full-scale trials now nearing completion it may be feasible to establish a harvesting and processing unit in Loch Maddy. One of the most prolific areas for sub-littoral weed is likely to be found around the Orkney Islands, where the sea-bed between one and six fathoms (low water) has been estimated to support well over 1,000,000 tons, perhaps nearly 2,000,000 tons, of seaweed of the family Laminariaceæ. The species of this family most common to the Scottish coast do not apparently grow in measurable quantities below nine fathoms (low water), and to harvest at depths below six fathoms (low water) would be quite uneconomic. A further survey of the sub-littoral seaweed growth around the Orkney Islands, and, if possible, of other rich algæ-bearing areas in Scottish waters, is part of the programme of the algologists for 1947–48, using techniques developed in the Association's laboratories. Other aspects of their researches include a survey of the cast seaweed during the winter months of 1947–48, a determination of the rates of regrowth and recolonization of the Fucaceæ of Orkney, an estimation by controlled cultural methods of the minimum requirements for successful growth and development of the British Laminariaceæ from zoospore stages, and the induction of polyploidy in the Laminariaceæ by chemical and physical means. Moreover, several extra-mural investigations are in progress. Dr. Delf and Miss Moss of Westfield College, London, are studying the concentration gradients and constitutional and physiological differences in the Fuci from areas of varying exposure, and Prof. Bennet-Clark and Mrs. Milnthorpe, of King's College, London, the metabolism of respiration of the Laminariaceæ.

Meantime, one can say with safety that the Botanical Division has shown that sufficient seaweed is available in Scotland to make the seaweed industry a commercial proposition, *if the seaweed can be harvested.*

The harvesting of the seaweed is, of course, the second of the two main tasks confronting the Association, which stands or falls by its ability to solve the problem. This is the problem of the Engineering Division headed by the deputy director of the Institute, with Mr. Wm. Mackenzie, who has been with the Association since its inception, as second in command. Seaweed growing in the littoral zones is comparatively easy to harvest, and methods of harvesting have already been devised and are being developed. Sub-littoral seaweed, growing on the rocky sea-bottom at depths of between one and seven fathoms (low water), is much more difficult to harvest. In most parts of the Scottish coastline it grows fairly close inshore and necessitates the use of powerfully engined, shallow draft, and easily manoeuvrable vessels. Therefore, before embarking on a costly series of experimental investigations, the Engineering Division has contacted upwards of thirty engineers and interested members of other professions in the universities and colleges, Government departments, Government and other research organisations and in industry with the view of obtaining as many suggestions and constructive criticisms of existing ideas as possible. As a result, the problem has been considerably clarified, and now six possible methods have been evolved which are considered worthy of full-scale investigation. Already the first two experimental units, operating on different principles, have been designed and all the necessary equipment ordered, and shortly the first trials will start off the west coast of Scotland. Meantime, during much of the past year the engineers have had to devote themselves to matters associated with the lay-out, furnishing, servicing, equipping and the adaptation of Inveresk Gate to the Association's needs.

Assuming, then, that the necessary apparatus for the harvesting of the sub-littoral seaweed will be evolved, the main object of the Scottish Seaweed Research Association will be the development of seaweed as a source of chemicals. So far, the only seaweed product that is being used commercially on a large scale is alginic acid; but for every ton of this acid which is extracted, there are three tons of potentially useful chemicals running to waste. Obviously, the Chemical Division, headed by Dr. W. A. P. Black, has a huge field for research, and many problems have been initiated. Several of these are extra-mural investigations at certain universities and research establishments, either on a contractual or on a collaborative basis. Dr. Percival, at the University of Edinburgh, has developed accurate methods for the estimation of alginic acid, laminarin and mannitol, and is also directing research on fucoidin. At the University of Manchester, under the direction of Prof. E. L. Hirst, the chemistry of alginic acid and laminarin was being investigated. Perhaps this work will now also be conducted in Edinburgh, in view of Prof. Hirst's recent appointment to the new Forbes chair of organic chemistry in this University. At the Imperial College of Science and Technology, Sir Ian Heilbron and his colleagues Dr. L. N. Owen and Dr. A. H. Cook are studying the brown seaweed lipoids and the chemistry of the algal reproductive processes. Algal sterols are being studied at King's College, London, by Prof. D. H. Hey; while at University College, Nottingham, Dr. D. O. Jordan with the late Prof. J. Masson Gulland was attempting to isolate and identify the unknown constituents of the brown seaweeds by electrophoretic methods.

During the past two years the staff of the Chemistry Division has been working on the seasonal variation in the composition of some common brown algæ. For example, in 1946, some 144 samples of littoral weeds of the family Fucaceæ, *Pelvetia canaliculata*, *Fucus spiralis*, *F. serratus*, *F. vesiculosus* and *Ascophyllum nodosum*, and of sub-littoral weeds of the family Laminariaceæ, *Laminaria digitata*, *L. saccharina* and *L. Cloustoni*, have been collected and prepared under strictly controlled conditions, and their dry weight, ash, iodine, nitrogen, mannitol and alginic acid contents determined. It is of interest to note that the results recorded for 1946 are comparable with those obtained for 1945; indicating that the results may be approximately reproducible in subsequent seasons.

Another problem of much scientific and technical importance is a study of the variation in the composition of the sub-littoral seaweeds with depth of immersion. So far, the results obtained substantiate the hypothesis that, consequent upon depth of immersion, there is a decrease in light intensity affecting the photosynthetic processes, which is reflected in the composition of the weeds.

The above programmes of research and development have been approved by the Board of Management under the chairmanship of Sir Steven Bilsland, who is also chairman of the Scottish Council (Development and Industry), as well as by the three specialist Advisory Committees, Algological, Chemical and Engineering. At the official opening of the Institute, Sir Steven emphasized that Scottish seaweed could provide an industry worth £15,000,000 per annum. Of this sum one third would go to collectors. In all, 90 per cent would be spent in Scotland and only 10 per cent outside Scotland.

Thus, for the first time, there has been sponsored in Great Britain an organisation set up to develop an industry based on waste, indigenous, natural products. It is interesting and suggestive to recall that it is now more than sixty years ago (1884) since Stanford, employed in the Scotch kelp industry, first discovered algin and some of the substances contained therein—calcium, magnesium and sodium in combination with the new alginic acid.

H. R. FLETCHER

MECHANISM OF COLOUR VISION

ALTHOUGH some references were made to visual investigations carried out for the Forces during the War, the International Conference on Colour Vision held at Cambridge during July 28–August 2 was concerned mainly with the fundamental problem of how the visual mechanism works and, in particular, with the apparatus by which differences of colour are perceived.

R. Granit (Stockholm) reviewed the outstanding new development in this field, the work which he and his school have carried out on the electrical response of single fibres of the optic nerves of experimental animals such as the frog, cat, snake, etc. The response is picked up by applying a micro-electrode to the retina of an eye from which cornea and lens have been removed. Potential spikes generated between the micro-electrode and a second electrode, placed usually at the back of the bulb, may occur only on illuminating the retina (pure on-elements), or only on cutting-off the illumination (pure off-elements), or after both these operations (on-off-elements). But in every case a spectral sensitivity curve for the element which the micro-electrode has contacted can be measured by finding the smallest energy of various wave-lengths which just suffices to elicit a minimal characteristic response. Certain signs, for example, a single spike response at the threshold, enable the experimenter to decide whether the micro-electrode is in contact with the fibre of a single ganglion cell.

The following types of spectral sensitivity curve are obtained: (*a*) *scotopic dominator*, a broad curve which by its shape and position in the spectrum and by its appearance in rod retinæ and under conditions of dark-adaptation can be attributed to ganglion cells associated with end-organs for which visual purple (or for freshwater fish, visual violet) is the photosensitive substance; (*b*) *photopic dominator*, another broad curve, obtained with light-adapted and predominantly cone retinæ, which is displaced some 60–70 mμ towards the red compared with the scotopic dominator of the same retina (when this can be recorded); (*c*) *modulator curves*, comparatively narrow curves obtained with light-adapted retinæ and located at various points of the spectrum from about 440 to 610 mμ, possibly in groups in the red, green and blue regions; (*d*) *composite curves*, which can be regarded as the 'summation' of a dominator and a modulator or of two modulators.

From replies to questions on the relative frequency with which dominator and modulator curves are obtained, it appeared that perhaps one in twenty curves (presumably for light-adapted retinæ) would be of modulator type. A new worker in this field, de Vries (Groningen) reported that he had had no difficulty in obtaining dominator curves, but had not yet observed a modulator curve.

Some criticism was expressed of Granit's second method of obtaining modulator curves, the method of selective adaptation. The modulator curve is derived by taking at each wave-length the difference between (*a*) the sensitivity (reciprocal threshold energy) of an element after strong adaptation to coloured light, and (*b*) the reduced sensitivity of the same element in the fully dark-adapted state, that is, the dark-adapted sensitivity reduced by a constant factor so chosen that the difference in question is zero at some wave-length and is nowhere negative. One of several assumptions underlying this procedure is that both rods and 'modulator receptors' are connected to the ganglion cell, the fibre of which is in contact with the micro-electrode, and that the effects of radiational quanta absorbed in rods and modulator receptors are summed at the threshold just as if they were all absorbed by a single end-organ.

Pirenne (London) and others found this latter assumption difficult to accept. Apart from the difficulty of justification, however, the procedure used leads to modulator curves for the cat's retina which are very similar to those obtained for other retinæ by the direct method.

Certain main trends relating the on-or-off character of an element with its spectral response and other properties had been observed. Thus pure on-elements were strongly predominant in pure rod retinæ, while pure off-elements were common in retinæ having no rods. Taking as standard the spectral sensitivity curve corresponding to light absorption by visual purple, Granit and Tansley (Birmingham) found that off-responses, particularly those from pure off-elements, were in general relatively red-sensitive, but on-responses, if they deviated at all, did so in the direction of blue-sensitivity. From these and similar results Granit was led to group together rods, on-effects and blue-sensitivity on one hand, cones, off-effects, inhibition and red-sensitivity on the other.

In the latest micro-electrode work, Granit and Gernandt (Stockholm) had found that if, instead of illuminating the retina, a polarizing current of about 0·1 mA. was passed through it, on-elements gave an on effect and off-elements an off effect for one