should attract a grant from H.M. Treasury. It is indicated that the National Central Library proposes to institute, in consultation with the National Institute of Adult Education and the other bodies concerned, an inquiry into the present provision of books for adult education classes, with the view of considering how far the type and the extent of the services require modification.

THE FILM AND THE SOCIAL SCIENCES

ALTHOUGH film processes are being increasingly used for research in the physical and biological sciences, little attention is paid to the cinema as a medium for investigating, teaching and propagating new knowledge in the social sciences (*Science and Film*, **3**, No. 2; June 1954). This may perhaps arise from an old-fashioned but not entirely played-out attitude of disdain for the place to be given, within the hierarchy of knowledge, to the study of human relations and human behaviour. An over-narrow view of the film-medium itself may also at times colour our outlook on its applications to science. The camera has, of course, special qualities for the observation of time and of mechanical movement, and the roles it can fulfil in the 'exact' sciences are obvious. But its usefulness does not end there.

The camera as an instrument of research in the social sciences has so far been little developed. Even for investigating manipulative processes, of such demonstrable value to the study of workshop skills and of industrial conditions generally, its use still remains the exception rather than the rule. For more subtle and less tractable problems of human behaviour, its use has been even less explored. Two recent examples of the use of the camera in psychological inquiry—of maternal separation and of the reactions of children to the cinema—illustrate well some of the possibilities. A rather similar, though brief, use of the motion-picture camera occurred in "Children Learning by Experience", itself a remarkable 'anthology' of children's behaviour as an aid in the training of teachers. Less normal phenomena form the subject of a pioneer Canadian series of filmed case-histories for the use of psychopathologists. Here the camera records permanently, unobtrusively and 'objectively'. To take another branch of the social sciences, no subject offers perhaps so wide a scope for the film record as does anthropology. Among many instances, Dr. Mountford's "Tjurunga" and his other films of the Australian stone-age men reflect the interest, not only scientific but also sometimes æsthetic, of such visual reports. Indeed, the trained cinematographer might well be considered an indispensable member of all field-teams engaged in anthropological or ethnological studies.

The dramatic qualities of the film medium are also available to the social scientist for explaining his purposes and methods to the general public. The cinema can illumine, too, the social relations of science; and this is perhaps one of the most important of its functions. There is need for films which will explain to the man in the street what science is, how scientists think and work, and the limits and freedoms affecting their activities. To this task the cinema as an art can bring special qualities of imagination and human warmth.

RESEARCH COUNCIL OF ALBERTA

REPORT FOR 1953

THE thirty-fourth annual report of the Research Council of Alberta, to which are appended lists of committees, staff and publications, covers the calendar year 1953* and emphasizes a shift in emphasis in coal research towards the exploration of the chemical potentialities of coal. Besides this a palæobotanical study was made of the flora and biological origin of Alberta coal measures, as well as investigations into the chemical and colloidal structure of coals. The vertical electric tube furnace for the determination of volatile matter in coal, built in 1929, was redesigned and a 14-in. rotating, self-clearing grate and ancillary control and recording equipment, installed in 1952, was used to complete an evaluation of the combustion characteristics of typical Alberta coals; a study of water retention by coal was also completed. Investigation of the trace metals in oil-sands oil and other Alberta oils suggests that occurrence of vanadium and nickel may serve as a precise correlative for crude oils and that cretaceous oils in general have a common origin. Attention is being directed to the origin of the trace-metal carriers, the porphyrins, and studies are proceeding on the properties of the heavy oils of Alberta and the viscosity of dispersions of wet oil containing mineral matter. The survey of the quality of Alberta gasoline continued, further tests were made on the storage of aviation gasoline, and work also continued on the partial oxidation of butane, in which a new reaction system was designed and built, and on the production of carbon black in a tubular furnace.

Field work by the Geological Section included detailed studies of selected areas for uranium in north-eastern Alberta, along the north shore of Lake Athabasca, and in the north-central portion of the Pre-Cambrian outcrop area in Alberta and especially north of Fidler Point and Leggo Lake, as well as a Pleistocene study in east-central Alberta. A fundamental mineralogical investigation of montmorillonite, the chief constituent of bentonite, in which forty samples of montmorillonite were subjected to X-ray and differential thermal analysis, indicates that every montmorillonite is a complex and intimate mixture. Further work under the Highway Research Project indicates that the dispersing and other properties of lignosol are important factors, as well as the viscosity effects, in preventing the migration of soil moisture to the frost line, and that sodium hexametaphosphate is equally effective in preventing frost action. Soil surveys were concentrated largely in the Peace River area, and a reconnaissance survey of the Grande Prairie sheet completed the field work on some 750,000 acres. Irrigation research was commenced on the solonetzic soils of the projected Red Deer irrigation area to determine the response to irrigation of various methods of treatment.

In the Industrial Projects Section research and testing for industry are of increasing importance. The ten-year biological cycle now appears to have reached the collapse predicted, and various publications on these extensive investigations are now being prepared. Two other investigations in animal science related to the effect of 'management factors' on the

* Thirty-fourth Annual Report of the Research Council of Alberta, 1953. Pp. 41. (Edmonton: Queen's Printer, 1954.)

percentage hatch of turkey eggs and to the nutritive value of varying types of grass silage. A committee was appointed to study the fluoridization of municipal water-supplies. Routine measurements of solar ultra-violet radiation continued.

FREE NERVE ENDINGS AS TRANSDUCERS OF THERMAL STIMULI

By H. J. V. TYRRELL
Department of Chemistry, University of Sheffield
and D. A. TAYLOR and C. M. WILLIAMS
Department of Anatomy, University of Oxford

RECENT evidence suggests that the encapsulated nerve endings postulated by von Frey to subserve specifically the sensations of warmth and cold (Ruffini corpuscles and Krause end bulbs, respectively) are not related to thermal sensibility, for, among other things, thermal sensations are as easily evoked from regions devoid of them as from regions where such encapsulated endings occur[1–3]. Moreover, it has now been shown[4] that thermal sensations can be aroused from the cornea, a tissue devoid of blood vessels and innervated solely by nerves the terminals of which are unencapsulated (free). In normal hairy skin, which is not being subjected to deformation, there is evidence which suggests that free nerve endings do not give rise to propagated action potentials under isothermal conditions; they only discharge when thermal gradients occur in the skin in which they lie[5]. In support of this, Hodgkin and Katz[6] have shown that under isothermal conditions the resting potential of the giant squid axon is practically constant (the mean value being 47 mV.) between $-1°$ C. and $20°$ C. It is also known[7,8] that a burst of propagated action potentials is evoked when a nerve trunk is heated or cooled relative to an adjacent region.

The mechanism by which a free nerve ending gives rise to a propagated disturbance when conditions are not isothermal has been compared[5] to the principle upon which a thermopile type of bolometer gives rise to an electromotive force. This analogy, though useful, must eventually be capable of expression in terms of the ionic hypothesis if the mechanism postulated is to be validated. What follows is an attempt to explain the discharge of propagated disturbances by free nerve endings under non-isothermal conditions.

A difference in temperature between the two junctions in a metallic thermocouple gives rise to a thermo-electric potential. This has two components: (1) due to the difference in potentials at the two metal–metal interfaces (Peltier e.m.f.), and (2) due to the difference in potentials in the two homogeneous metal conductors due to the temperature gradient (Thomson e.m.f.). Depending upon the metals used, the Peltier e.m.f. is ten to a hundred times greater in magnitude than the Thomson e.m.f. The free nerve terminals are less than 1 micron in diameter. Since the light microscope cannot resolve boundaries in objects so small, it is not known whether an axoplasmic filament is in fact a homogeneous medium in equilibrium with the extracellular fluid or whether it is a miniature of the axon with two interfaces, for example, extracellular fluid/membrane/axoplasm[9]. It is likely that the effects which are postulated below will occur in either case, but for the sake of brevity it is assumed that the nerve terminal can be regarded as a medium in which ions are adsorbed in equilibrium with extracellular fluid containing free ions. A phase boundary potential will exist at the interface, and if a portion of the interface is heated or cooled with reference to another portion, a potential difference consisting of the following components will be set up in the system:

(1) The difference in the interface potentials at the two temperatures. This is analogous to the Peltier e.m.f.

(2) The thermal diffusion potentials in the extracellular fluid and in the nerve terminal due to the temperature gradient. This is analogous to the Thomson e.m.f.

The effect of the thermal diffusion potential in the extracellular fluid can be estimated approximately, since the initial thermal diffusion potential in solution before the Soret equilibrium is established is given by:

$$-\sum_i \frac{t_i}{z_i}\frac{Q^*_i}{F\,T},$$

where t_i, z_i and Q^*_i are the transference number, valency and heat of transfer respectively of the ith ion and the summation is taken over all ions in the solution[10]. For extracellular fluid in the giant squid axon this potential may be calculated (on the assumption that all ionic heats of transfer are equal to 1 kilocal./mol.) to be about 40 microvolts per degree. This e.m.f. would not be enough to cause the discharge of a giant squid axon. It is known that the capacity of a nerve membrane[11] is of the order of 1 microfarad. cm.$^{-2}$. A change of potential of 1 mV. across such a capacity requires a charge transfer of 10^{-9} coulomb cm.$^{-2}$, or approximately 10^{-14} gm. equivalents cm.$^{-2}$ of a univalent ion. This is a small fraction of the amount of any diffusible ion transferred per second across the membrane (10^{-10} to 10^{-12} gm. equivalents cm.$^{-2}$, ref. 12). Clearly a local potential change of a magnitude greater than a thermal diffusion potential in a homogeneous phase would be produced across the membrane if the diffusion-rate of any one ion was affected, even to a relatively small degree, by a change in temperature. In this connexion, it is of great interest to note that Hodgkin and Keynes have recently observed that the activity of the 'sodium pump' in extruding sodium ions from the surface of the membrane of the giant squid axon has a high temperature coefficient[13]. It is therefore not unreasonable to assume that for a free nerve terminal in contact with extracellular fluid, the major contribution to the thermal e.m.f. would also arise at the interface between the phases. In this case there would be an exact analogy with a metallic thermocouple, the electrons of the latter being replaced by ions common to both phases. The existence of such a thermopotential would provide a stimulus to nerve terminals identical with that provided by the passage of a d.c. current across the nerve[14]. The sign of the potential will depend upon whether the tip of the fibre is heated or cooled with respect to the parent axon. The local ionic currents will change in direction accordingly; however, in either event, the nerve may discharge, being 'triggered' either at the tip of the fibre or near the stem axon. There is no need, therefore, to postulate different mechanisms to account for the response of free nerve endings to 'warm' and 'cold' stimuli. The