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(FLUID STATE PHYSICS)

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The Division has research groups working on the transport properties and thermal properties of solids and liquids both at low and high temperatures, as well as paramagnetic resonance in crystals, and on solar physics. The laboratory is chiefly responsible for the development and maintenance of physical standards in Australia; therefore good facilities exist for accurate measurement of a wide range of physical quantities, and there are instrument, electronic and optical workshops which can assist the research groups.

QUALIFICATIONS: A Ph.D. degree in physics or postgraduate research experience of equivalent standard and duration, supported by satisfactory evidence of research ability. Applicants should have active research experience in some branch of the physics of the fluid state or in some allied field, and preferably some experience of experimentation at high fluid pressures.

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Applications, quoting reference number 770/417 stating full name, place, date and year of birth, nationality, marital status, present employment, details of qualifications and experience, together with the names of not more than four persons acquainted with the applicant’s academic and professional standing, should reach:

The Chief,
Division of Physics, CSIRO,
University Grounds, City Road,
Chippendale, N.S.W. 2008. by 5th February, 1971
NOTICE TO CONTRIBUTORS

General—Manuscripts submitted for publication should take, in general, one of three forms:

An Article on matters of interest to physicists, including selected lectures given at Institute, Branch or Group meetings.

A Letter to the Editor on matters affecting physicists or on articles and letters previously published. In general, letters should not exceed 1000 words.

Notes and News may include Institute activities, announcements to members, comments and announcements by overseas Institutes of Physics and other local scientific bodies. In general, the text should not exceed 400 words. Abbreviated notices of meetings may be submitted for The Calendar.

In preparing manuscripts, contributors should follow the general style used in this journal. Manuscripts should be double space typed on one side of the paper only and with side margins one and a half inches wide. Every page, including those with tables and illustrations, should be numbered. For an Article, the author’s name should appear underneath the title, followed by the address of the laboratory. For a Letter to the Editor, the author’s name should appear at bottom right, and his address and the date at bottom left of the letter.

The original typescript and one copy should be forwarded. Original drawings should be submitted but, where possible, photographic copies, Xerox, or blueprints of the originals should also be submitted. Half-tone illustrations should only be included if essential; they should be on white glossy paper and show a full range of tones with good contrast.


References are to be cited in the text by year of publication, e.g., Brossel [1947], and are to be arranged alphabetically at the end of the article, giving author’s name and initials, followed by year of publication. For journal articles, this is followed by the title of periodic, volume, and page, thus:


Abbreviations of titles of periodicals shall conform to those used in A World List of Scientific Periodicals; please consult this.

References to books should give the author or editor, year of publication, title, number of edition, town of publication, and publisher’s name.

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PHILIPS
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PHYSICS IN MEDICINE AND BIOLOGY

D. Paix
The Prince Henry Hospital, Little Bay, New South Wales
A Report on the Tenth Conference on Physics in Medicine and Biology, Melbourne, 1970

This meeting, supported by the Australian Institute of Physics and Hospital Physicists' Association, opened at Clunies Ross House on August 24 with the vigour of the politician and the erudition of the physiologist. The first was provided by the Honourable J. Rossiter, Minister of Health in Victoria in a brief address officially opening the proceedings. The second was provided in his invited address 'Biophysics and the Brain', by Professor David Curtis, Chairman of the Australian National Committee for Biophysics.

Dominant impressions from this five day meeting would include the convenient, attractive venue; the organizers' success in covering a wide range of biophysical and medical sciences; the extensive display of relevant scientific instruments; the effective audio and visual aids completely under the lecturer's control (with a few hapless exceptions); and the making or renewing of individual contacts which should prove both personally and professionally valuable.

At the risk of offending the lecturers I have classified their contributions under a number of topics with the aim of making this review at least readable, if not readable. The arrangement of topics is alphabetical. Summaries of some of the papers are given later.

Bio-engineering papers were largely mechanical in nature. The design of an artificial elbow joint under severe constraints imposed by anatomical variations and the usual state of degeneration of the natural structures was outlined. A rig for recording continuously the centre of mass of a standing subject has been built for studies of the normal balancing mechanism by which we avoid falling over. Body sway appears typically to be parallel to the long dimension of one foot.

Work is also under way on a bed capable of detecting minor changes in body weight distribution, such as those due to redistributions of fluid. Elsewhere, a mathematical model had been set up to simulate whiplash injuries in automobile rear-end collisions. Its predictions had been compared with data from full-scale experimental crashes. Cerebral damage of an inertial nature appears to be a real possibility (c.f. the punch-drunk boxer).

Two methods of human tendon preservation (formalin immersion or gamma irradiation) were compared, mechanical properties being the criteria. The material appears to withstand both methods reasonably well. Availability of acceptable preserved tendon would allow the repair of certain common finger injuries.

Biophysics was represented by an attack on the fundamentals of cell-cell forces, e.g. why do cells suspended in a fluid attract one another? An electromagnetic theory was given indicating the dominance of infrared to microwave frequencies, peculiar to aqueous suspensions.

From across the Tasman came an account of meteorological measurements relating to the swarming of a moth having, apparently, great nuisance value. These swarms precede rain but do not correlate very well with conventional meteorological variables. Ion concentrations in the air are being recorded daily with attention to the charge ratio; moth activity is also monitored. A separate experiment exposes moth pupae to positive and negative ions in the laboratory, their emergence pattern being under observation.

We were introduced to the possibilities of electron diffraction as a complementary tool to X-ray diffraction for structural analysis of biological materials. An electron microscope is used and very small specimens may be handled.

Clinically oriented studies included ultrasonic visualization of the structures within the breast. Compound scans at 2 MHz yield cross sections with 1 to 2 mm spatial resolution, the useful image extending from the skin to the muscle overlying the ribs. A clinical comparison of this technique with X-ray mammography appears to be very desirable.

The maintenance programme followed after implantation of a cardiac pacemaker was outlined. In such patients conventional electrocardiography detects the pacemaker waveform. These measurements, regularly repeated, give warning of impending failure— for certain kinds of failure. Doubt was expressed from the audience that such observations were worthwhile. Unfortunately the speaker did not clinch his point with statistical evidence.

An afterloading system was described for radium treatment of gynaecological cancer without significant radiation to the radiotherapist.

Digital computing for nuclear medicine was represented by quantitative processing of radioisotope maps of the cerebral circulation. The numerical data thus obtained revealed deficiencies in the mapping instrument (a gamma camera of the Anger type) as well as in the technique of patient positioning. The raw maps in these circulation studies require editing to eliminate areas of non-cerebral activity; the computer itself performs
this editing more reliably than the human judgments which it replaced.

The use of a large computer to solve radiation dosimetry problems in three dimensions was demonstrated in two applications, (a) the production of iso-exposure curves around an irregular multifocal $\gamma$-ray source implanted in tissue (as in radium treatment of cancer), (b) the iso-exposure surfaces in an absorbing tissue due to photon beams of external origin, of arbitrary shape and direction. Almost all previous attacks on this problem have limited the treatment to a single plane containing the axes of all the beams.

Computer averaging techniques for repeated transients played a large part in a neurophysiology project and is referred to again below.

The fascinating game of teaching a digital computer to behave like an analogue machine was explained with reference to a number of available programmes such as MIMIC and PACTOLUS; a model of haemolytic anaemia was built and analysed.

Nuclear engineering was represented by a status report on the production of a tritium-based nuclear battery for a cardiac pacemaker. The tritium is adjacent to semiconductor junctions which generate by the electron-voltaic effect. Other batteries using a thermopile were described. These batteries would have to withstand some unusual hazards, such as pressure build-up, as the tritium decays to helium, or the cremation of the owner.

An electronic analogue for the heart and cardiovascular system was described which produces rather realistic intracardiac-pressure waveforms.

Papers relating to nuclear medicine included a survey of the developmental and routine programmes of radioisotope production at the AAEC. A few years ago medical radioisotope supplies were almost entirely imported, but the Lucas Heights radiochemists responded admirably to the challenge of short-lived radiopharmaceuticals and now provide a service which in some respects is unequalled elsewhere. A twin-headed scintillation scanner has been adapted to quantitative measurements and is performing well as a high-level whole-body counter. A review of methods of making quantitative in vivo measurements was given in which the whole problem was discussed from first principles. The twin-headed scanner was regarded as a useful and potentially accurate device for the purpose.

The possibilities of constructing a large-area, modest-resolution area scanner for a fraction of the usual cost were explored, using radiant-energy exchange theory to predict the performance of the detector.

Attainable precision in plasma-protein turnover studies performed in hospital patients was discussed.

The work of the radioactivity standardisation sections of the CKRL and of the AAEC was discussed in relation to absolute counting and radionuclide purity measurements. It was felt that users pay too little attention to calibration of their instruments against available standards. Computer assistance in work with a gamma camera has already been mentioned.

Physiology was handsomely represented by the opening address (see above) and by papers on electric-field patterns in the spinal cord, audio-frequency analysing properties of the cochlea, feed-back control in the retina, and bloodflow distribution in the lung.

The first of these set out to display the electric-field pattern across the entire spinal cord of a toad following a stimulus. Elegant sampling (with micro-electrodes) and transient-averaging (with a PDP 8) techniques were used. The result was a number of field maps across the cord at defined times following the stimulus, clearly showing current sources and sinks. This work gives a viewpoint on nervous activity in space and time after stimulation.

Equally impressive was work from the West on the site of sound-frequency analysis by the ear. The ear itself would seem to play a major part in frequency analysis, purely mechanical and relying on resonance. But this may not account fully for known frequency-discrimination powers.

Radiation-dosimetry papers ranged from the fundamental to the practical. A survey was presented of physical factors in radon and radium dosimetry, which is likely to become a standard reference. It gave the best available values of all the constants needed for computing radiation exposures due to the implanted radium or radon.

The penumbral problem with $^{60}$Co teletherapy sources had been studied experimentally. Since there is no practical prospect of eliminating penumbra by reduction of source diameter, long-distance collimation ('penumbral trimmers') should be adopted where minimum penumbra is required. Little is gained from source-diameter reduction to less than 1.7 cm.

The mean energy $W$ expended in a gas per ion pair formed, under irradiation by charged particles is the subject of an experimental study using both total energy ($W = E/I$) and differential ($W = dE/dI$) methods. Apart from its intrinsic interest, this value is needed whenever dosimetry is performed by ionization methods.

Direct dosimetry by heat measurement is currently a popular pastime in many laboratories including two in this country. At the AAEC a quasi-adiabatic microcalorimeter of aluminium is under development, and a graphite unit is planned. The University of Adelaide has an intercomparison system allowing a microcalorimeter, an ionization chamber or a container of ferrous sulphate to be irradiated under geometrically identical conditions, thus permitting the direct, the ionization, and the chemical-dosimetry methods to be intercompared. Very close agreement (order of 1 per cent.) between the three has been obtained under $^{60}$Co and 4 MV radiation beams.

Thermoluminescence dosimetry was represented by three papers, two describing a home-made and a commercial readout system. The third dealt with that marvellously woolly area, the theory of thermoluminescence in LiF. A correlation had been sought between the concentration of Mg-X units (positive-ion
vacancy units) measured by dielectric loss, and the height of the 105°C TL peak in TLD-100 (a commercial LiF containing Mg).

Radiation protection was represented by a review of transport regulations for radioisotopes. It seems likely that the comprehensive and in some respects stringent code, formulated by the IAEA, will be adopted in Australia. This may inconvenience some radiotherapists and others in whom familiarity has bred a measure of complacency.

Microwave radiation also has harmful effects, the eye being the critical organ. CXRL is working in this field. Many industrial and commercial microwave cookers are potential hazards. The hazard may well become actual if during use the oven door ceases to fit as well as originally.

Radiobiology was represented by work on the RBES of fast and slow neutrons at different stages of the life cycle of the larger cells (Chinese hamster cells). In particular, a slow-neutron RE between 10 and 20 was observed, which is greater than the recommended quality factor for radiation-protection purposes.

The instrument exhibition was watched over by the Chinees Ross mural and one felt that many trade secrets were open to that inscrutable gaze. We saw a desk-top computer drawing 3D perspectives on a plotter, a battery of electrocardiographic instrumentation, and an infrared Thermovision system. Australian competence in implantable pacemaker manufacture was demonstrated. A variety of in vivo and in vitro nuclear detectors and systems was ably demonstrated.

An interesting, well prepared tour of four sections of the CXRL deserved a larger audience. The activities presented included the whole body monitor, radiation protection activities, thermoluminescent dosimetry, and the Radiouclide Standards Section.

The most memorable address was not on the conference programme; it was given by the Chairman of the Group at the annual dinner. Its content defies abstraction for a report such as this.

To this delegate at least, attainment of our tenth year as organized Groups was fittingly marked both scientifically and socially; the organizing committee and contributors are to be congratulated.

The Committee for the Tenth Conference comprised Messrs K. H. Clarke, R. J. de Groot, F. P. J. Robotham, and J. F. Richardson. Invaluable secretarial assistance was given by Miss I. Hitchcock.

Presentation to Mr K. H. Clarke
At the close of the Tenth Conference, Mr B. W. Worthington, Chairman of the Biophysics Group, AIP, and Australian Regional Group, HPA, presented Mr K. H. Clarke with a pair of monogrammed gold cuff links in recognition of his ten years as secretary of both Groups.

SUMMARIES OF SOME OF THE PAPERS
An Electronic Analogue of the Cardiovascular System—I. S. Jenkins, D. Melley, and B. J. Shuter, St Vincent's Hospital, Sydney
Several electronic analogues presented previously have consisted of pulse generators feeding into a network of electronic components simulating the systemic and pulmonary blood circuits. Although valuable in studying vascular haemodynamics, they do not properly simulate the heart, since fixed condensers are used to simulate atrial and ventricular compliance. The pressure-volume relations of the heart chambers show that the analogues of these are not fixed condensers. In the electronic model constructed, the capacities of the four condensers used to simulate the four heart chambers vary cyclically so producing voltage and current variations analogous to pressure and flow variations, which are fed into the systemic and pulmonary circuits. In this way the model simulates a number of features of cardiovascular haemodynamics more closely than most previous models, particularly in the cardiac part of the system.

Electron Diffraction from Biological Materials—P. A. Tullock, Division of Protein Chemistry, CSIRO, Melbourne
In diffraction studies of protein structure, the amount of structural detail that can be extracted from the diffraction pattern is in general determined by the degree of crystalline order within the specimen. While in some cases it has proved possible to grow single crystals of appropriate dimensions, biological specimens for X-ray study are more typically polycrystalline or only partially ordered. The electron-diffraction technique, involving a reduction in specimen volume of
approximately $10^8$ over optimum X-ray specimen volume, is therefore potentially valuable in biological structural studies. Besides this possibility of improved structural resolution using smaller and more highly ordered specimen volumes, the recording time of seconds for electron diffraction compares with days or even weeks in the X-ray case for comparable instrumental resolution. Further, an electron micrograph of the diffracting-specimen region permits direct correlation of diffraction detail with image detail.

Previous attempts to exploit these potentialities of electron diffraction in the biological field have been unsuccessful due mainly to specimen denaturation through dehydration and electron-irradiation damage. It is now possible to report the successful application of the technique to a number of fibrous protein systems, primarily a consequence of restricting the electron irradiation to a minimum. Significantly the keratins, silks, and muscle proteins used in this study all exhibit minimal conformational change with dehydration. The anticipated improvement in resolution has already been achieved with each of these fibrous proteins, suggesting that structural studies of fibrous biopolymers in general are feasible with this technique. The prospects for its general application to globular-protein specimens, however, are far less encouraging in view of the serious effects of dehydration on this class of biopolymers.

The Physics of Biological Cell–Cell and Macromolecular Interactions—B. W. Ninhm and V. A. Paresian, Department of Applied Mathematics, University of New South Wales

Recent progress in our theoretical understanding of the forces responsible for cell adhesion and macromolecular interactions is outlined. New features of van der Waals forces in condensed media which emerge from the application of Lifshitz theory are discussed, with special reference to lipid–water systems. In particular,

1. van der Waals energies are not the sum of $1/r^6$ interactions between small elements of the interacting bodies;
2. electromagnetic fluctuations at ultraviolet frequencies, usually considered exclusively, are relatively unimportant compared with fluctuations at infrared and microwave frequencies;
3. by virtue of a strong microwave contribution peculiar to water, van der Waals forces in lipid–water mixtures increase with temperature and exhibit only weak 'retardation' effects.

Available spectral data is sufficient to make accurate calculations. Lifshitz's approach is conceptually clear, accounts for triple film 'anomalies', effects of solutes, and appears to deal naturally with hydrophobic bonding. It can be extended to develop an understanding of the way macromolecules recognize each other.

A Dynamic Analysis of the Head–Neck–Torso System During a Posterior–Anterior Acceleration Pulse—J. A. McKenzie and T. F. Williams, Department of Mechanical Engineering, University of Melbourne

A mathematical model of the head, neck, and torso system has been developed to investigate the mechanics of whiplash-induced injuries in the cervical spine. The model details the structure of the cervical spine to enable a study of the forces and bending moments acting on the spine components. Also, the kinematic behaviour of the head is studied in order that eventually, such behaviour may be related to the mechanism of whiplash-induced concussion.

A survey of medical and experimental reports pertaining to whiplash-induced injuries has shown that the major factors in a rear-end collision which influence the injuries are the seat-back rigidity and height, the collision severity, and the posture of the body before impact. It is intended to use the model to investigate the effect of these features.

Some agreement between the kinematic behaviour of the system as determined by the model and that observed experimentally has been attained. For a particular set of conditions representing a relatively mild collision situation, the response of the system to impact indicates that damage could be expected when the head is in the region of maximum extension relative to the torso. At this time the shear force and bending moment are greatest in the lower cervical region. Possible damage from such forces could be local damage of the spinal chord, tensile damage of the anterior ligament, and compression damage of the posterior aspects of the vertebral bodies.

Calorimetry—The AAEC Programme—D. F. Urquhart, AAEC Research Establishment

One of the objectives of the radiation-standards group at Lucas Heights is to set up standard instruments for the measurement of absorbed dose (in rads) for gamma rays and X-rays at energies above about 250 kV. Calorimetric methods provide the most direct way of doing this. To achieve our objective of 1 per cent. absolute accuracy at an exposure rate of 10 roentgens per minute, temperature changes in a graphite calorimeter, of the order of $10^{-6} \degree C$ per min must be measured to an accuracy better than 1 per cent. which means that changes of a few times $10^{-6} \degree C$ must be detected.

Isothermal, adiabatic, quasi-adiabatic, constant-temperature-environment, and twin-calorimeter systems have all been used by other workers in this field. Of these, the quasi-adiabatic system was judged to be the best system for our purpose.

Work is now well advanced on the construction of an experimental quasi-adiabatic aluminium calorimeter. The experience gained in the design, construction, and operation of the instrument will provide the basis for the design and construction of a standard graphite calorimeter.

Further work planned includes the construction of a graphite cavity chamber to match the calorimeter, a tissue-equivalent-plastic calorimeter, an investigation of the thermal defect in this material, and the development of a high-precision temperature-control system to enable the calorimeters to be operated adiabatically.
Design Study for a Hybrid Scanner—D. Pux, R. O. Philips, and J. A. Asgar, The Prince Henry Hospital, Little Bay

A hybrid radioisotope scanner maps an extended radioisotope distribution by a mechanical motor in one direction and electronically in the orthogonal direction; hence the designation hybrid.

We were interested in the possibility of using a long plastic scintillator with a phototube at each end in such a scanner; hence we needed a theory for the signals received by each phototube as functions of the point of detection. Although many plastic and liquid scintillators of various shapes have been built, no thorough theory of their light-collection characteristics was found in print. A suitable theory dealing with all direct and reflected light, based on flux balance between finite diffusely emitting surfaces, was worked out and the position-resolving properties of the proposed detector predicted.

This flux-balance theory is well known to heating and illumination engineers, and would be a useful tool in the hands of physicists interested in the properties of scintillation detectors.

Further work both computational and experimental, will be done on this device. At present it appears to have good prospects as a whole-body low-resolution scanner, complimentary to existing instruments, which map smaller areas at higher resolution.

Design for a Low-Radiation Nuclear Cardiac Pacemaker Battery—F. Gatt, AAE Research Establishment

The life of cardiac pacemakers is limited to 2½ years by the normal life of the chemical batteries used. Nuclear batteries using plutonium or promethium can extend the life to 10 years, however, with an associated external-radiation dose rate of 1 to 10 millirem per hour. A nuclear battery design is outlined which should give an external radiation of 0.1 millirem per hour. The proposed isotope is tritium, a low-energy (18 kev maximum) pure beta emitter. The energy-conversion principle is the electron-voltaic effect. The expected electrical output is 200 microwatt at 5 volt. Some advantages and hazards of nuclear batteries used in the body are discussed including radiation, toxicity, pressure buildup, and possible battery rupture. A short resumé of overseas work is included.


The measurement of radioisotope uptake in vivo is made difficult by the irregular configuration and incompletely known position of an organ situated in a medium which absorbs and scatters radiation.

A technique should be selected which maximizes the radiation reaching the detector from radioactivity in the organ of interest, and minimizes the radiation to the detector from radioactivity in other regions of the body or from outside the body. Radiation origina
ting in tissues anterior or posterior to the organ under study set a limit to this minimization.

In view of the errors inherent in the calibration of in vivo radioactivity measurements, it is preferable to avoid the necessity for such calibration by employing relative measurements. When calibration cannot be avoided there are three alternatives: the use of an external standard (the traditional method), the use of an internal-standard method (where the standard is administered to the patient in such a form that it is taken up to a large and accurately known extent by the organ of interest), and the use of an absolute radioactivity measurement on radioisotopes emitting photons in cascade.

Techniques based on the use of fixed detectors, wholebody systems, profile-scanning systems, or two-dimensional area-scanning methods can be advisedly used in different situations. The methods have different relative sensitivities and different accuracies. With appropriate corrections and calibrations, an accurate measurement of organ radio-isotope uptake can be satisfactorily completed in vivo.

Precision of Tracer Studies of Protein Turnover—D. Pux, The Prince Henry Hospital, Little Bay

The radioisotope data from a clinical series of plasma-protein turnover studies have been analysed by least-squares fitting to a sum-of-exponentials model, using standard numerical methods.

Such work complements the work of others with similar models, using simulated data having known statistical properties (see e.g. 9th Conference Report, Aust. Physiologist, 7: 54, April 1970).

The results were compared with those from a graphical treatment of the same data. Many such graphical treatments of results of this type appear in the medical literature, usually with no consideration of the precision of the parameter values obtained.

In this study the parameters of the model and their standard errors were both estimated; similarly the fractional transfer constants of a simple physiological system consistent with the exponential model, and their standard errors, were estimated.

The transfer constants were not estimated with equal precision. The best-defined was the transfer into the urine pool for which a 5 per cent. coefficient of variation was achieved regularly.

In some cases the fitting program failed to find the best fit to the data. Such a failure may not be obvious in any particular case. The results of fitting using an exponential model should always be regarded with caution.

Some Aspects of the Use of Radioactivity Standards—G. C. Lewenthal, AAE Research Establishment

The functions of the Radioactivity Standards Laboratory at Lucas Heights include research on the establishment of most efficient methods of disintegration-rate measurements for radio-isotopes required for all purposes; supply of sources with standardized dis-
integration rates; and accumulation of experience and data to permit advice to be given on as many radioactivity measurement problems as possible.

The demand for radioactivity standards has remained very low despite a more than tenfold rise in the use of radioactive materials over the past 5 to 6 years. This may indicate a lack of appreciation of the many difficulties besetting radioactivity measurement.

Attention was directed to errors that could affect relative measurements which are often made on the postulate of constant counting efficiency. However, effectively constant counting efficiencies, even within a ±5 per cent. tolerance, are far more difficult to realize than seems to be widely assumed. Examples of errors in radioactivity measurements were given and it was suggested that the use of sources with known disintegration rates could at least in some cases assist in the detection and minimizing of such errors.

THE REGISTER

CHANGES IN MEMBERSHIP FROM 12 OCTOBER 1970 TO 13 NOVEMBER 1970

**Fellowship**

(a) New Election

Treacy, P. B.

Australian National University, ACT

(b) Transfer

Henshaw, D. E.

CSIRO Division of Textile Industry, Vic.

**Associateship**

(a) New Elections

Graham, A. J.

Hogg, G. R.

University of Sydney, NSW

Australian Atomic Energy Commission, NSW

(b) Transfers

Bailey, I. H.

Blyth, B. M.

Western Australian Institute of Technology

Queensland Institute of Technology

(c) Resignations

Brand, G. F.

Kerrigan, G. C.

Loch, R. G.

Steele, J. G.

Stroud, D. B.

McNicol, R. W. E.

University of Sydney, NSW

Western Australian Institute of Technology

University of New England, NSW

University of Queensland

University of Melbourne, Vic.

(Qld)

(d) Deceased

Gare, L.

(SA)

(e) Removed from the Register under Clause 13 of the Articles of Association

Donelly, B. H.

(SA)

**Students**

(a) New Elections

Adams, J. G.

Bridgland, C. L.

Fazzalari, N. L.

Groves, M. R.

(B) Resignations

Michaelides, A. T.

Wood, J. W. R.

(ACT)

**Subscribers**

Resignations

Chan, K. M.

Henderson, R. J.

Meades, R. H.

(WA)

(NSW)

(NSW)
THE PHYSICAL AND MICROENVIRONMENT OF LIFE ON EARTH

C. H. B. Priestley
CSIRO Division of Meteorological Physics, Aspendale, Victoria

I. Introduction

I am honoured at being the first Pawsey lecturer invited to come down from the heavens and in from the outer atmosphere. Joe Pawsey himself would have approved of the change for he was a catholic scientist who loved to bring his gentle but immensely penetrating mind to bear and

"To talk of many things
Of shoes and ships and sealing wax",

though even he might not have foreseen a physics lecture

"Of cabbages and kings
And why the sea is boiling hot
And whether pigs have wings."

To the common man, the word 'astronomical' denotes distances or magnitudes almost impossible to conceive. As the interest shifts from one focal object to the next, from the moon to the sun, to the near stars, to the milky way, to other galaxies, even the relative or logarithmic increase in distance is hard to grasp. To the normal mind these distances are best presented on a log log scale as in figure 1, which makes astronomy an accessible subject. Another advantage may well be that it presents the various regions and disciplines more or less in proportion to their importance to mankind. Not unnaturally, my most common discussions with Joe Pawsey lay just half-way between our more specialist interests, in the burgeoning area of rain physics to which we were both occasional consultants. It was a topic and a time for asking simple questions, and trying to put numbers where none had been before; and I can best honour the memory of my old colleague by applying this simple but quantitative approach to that shallow layer of the atmosphere where man has to live, breathe, grow his food, and take his joy in his surroundings. It was an interest in meteorology, then so closely allied to astronomy, which ushered in the dawn of science and man's first manipulations of nature. A full turn of the wheel has brought back the spotlight. The declining quality of the environment and the human threat to natural habitats and communities have focused a new urgency for more detailed and quantitative study of the physical interactions between the atmosphere and the life which it sustains. The subject in its more developed form, beyond the scope of tonight's talk, becomes an exercise in classical physics, which many modern scientists regard as complex but essentially unexciting. Whilst

the glamour of quails and quadrupeds can scarcely match that of quarks and quasars I am reminded of the physicist (?) who described the countryside as 'a damp sort of place where all sorts of birds fly around uncooked'.

II. Microclimate and Energy Balance

On a fairly normal morning in March this year some measurements of temperature were taken over our open site at Aspendale. These are compared in table 1 with

![Image of a log-log graph showing distances from Earth's surface and corresponding scientific disciplines.]

Figure 1

Distances (cm) from Earth's surface and corresponding scientific disciplines.
average temperatures for March for places round Australia.

Thus the prefix in micrometeorology refers only to small distances; there is nothing small about the magnitudes of the effects. Within a few feet are experienced contrasts which, in the macroclimatic sense, would involve a journey of continental dimensions. The gradients in the vertical one are stronger than exist anywhere else in the atmosphere: they are reversed at night. A surface-dwelling insect or the tip of a seedling may experience, in a single day, a bigger range of climate than a man, standing upright, would experience in a year. A substantial part of the range can be achieved in seconds, as a cloud passes over the sun.

To derive a framework for the quantitative study of these micro-climatic factors, and of their physical interactions with individual animals and plants, consider the energy balance of the interface between the atmosphere and any body with which it is in contact. This interface will be irradiated by short-wave radiation (0.1 to 4 µm) from sun and sky at a rate \( Q_s \), of which a fraction \( r \), known as the albedo, is reflected. The surface emits long-wave radiation (4 to 1000 µm) at a rate \( Q_L \), generally close to the black-body rate, and receives long-wave radiation \( Q_A \) emitted by the atmosphere. Radiometers equally sensitive to long and short wave have been developed, in both gross and miniaturized forms, to measure directly the net effect, \( R \), of all these components.

This net incoming radiation must be balanced by the heat-disposal mechanisms of heat conduction to the air, \( H_a \), into the body, \( G \), and by \( LE \), the latent heat times rate of evaporation. The equation of heat balance is accordingly

\[
(1 - r) \ Q_s - \ Q_L + \ Q_A = R = H + G + LE
\]

Figure 2 indicates typical magnitudes of terms over grass on a clear day and night.

Where we apply the balance to a solid body, say a cow or a cucumber, instead of just an interface, we must use a slightly different form

\[
R = H + LE - M + S
\]

where \( S \) is the rate of storage of heat in the body and \( M \) its internal source of heat (metabolic heat or, negatively, energy used in photosynthesis). The metabolic heat can be large: for small insects in flight it would burn them to a cinder, if they were not able to shed the heat by their own forced convection. But for larger animals \( M \) is a relatively small term in the budget. The energy of photosynthesis in plants is only of order 1 per cent. of the total energy involved. That the biologically most relevant term is often a small residual between other larger terms requires that we must set our sights on considerable precision in assessment and measurement of the physical components.

As will be illustrated, the relative magnitudes of the major terms in (1) and (2) vary enormously, depending on three types of factors: climatic and meteorological (latitude, season, time of day, cloud, wind speed, etc.); geometrical (size and shape of body, orientation, exposure, etc.); and material or physical (conductivity, reflectivity, water content and availability, specific heat, etc.).

III. The One-Dimensional Problem

In the first instance we consider the simplest case in which everything is horizontally uniform. We are concerned solely with the Earth and sky. Equation (1) expresses the physics by which this overall climate is controlled. Let us, for example, alter one of the 'driving' terms on the left-hand side, by putting more \( CO_2 \) or dust into the atmosphere (\( CO_2 \) will affect \( Q_A \), dust also \( Q_A \)). Bydko and others have estimated that a 1 per cent. change in radiation income will evoke a change of 1 to 1.5°C in environmental temperature before the equation re-balances and this, for the Earth as a whole, is a very considerable change in climate.

If on the other hand we change the physical properties of the underlying medium, the main effect is to change the apportionment between the 'driven' terms on the right-hand side of the equation. Let \( T(z) \) denote temperature (strictly potential temperature) at height \( z \), suffix 1 denote corresponding depths \( z_1 \) in the underlying medium and 0 for interfacial values. We suppose that the turbulent air motion produces an effective 'eddy thermal diffusivity' so that the upward flux of heat is \( - \rho \ c_p \ K \partial T / \partial z \) (\( \rho \) being density, \( c_p \) specific heat at constant pressure). Strictly \( K \) will be height-dependent, but the approximation is to take the apportionment as controlled by an appropriate average through the
active layer, whence the rates of change with time $t$ are given by

$$\frac{\partial T}{\partial t} = K \frac{\partial^2 T}{\partial z^2} \tag{3}$$

$$\frac{\partial T_1}{\partial t} = k_1 \frac{\partial^2 T_1}{\partial z_1^2} \tag{4}$$

where $k_1$ is the effective thermal diffusivity of the earth or ocean. At $z = 0$, $T = T_1$, for all $t$, and it may be seen that the time and space variations of $T$ and $T_1$ will be identical provided vertical distances are scaled in proportion to $\sqrt{K}$ and $\sqrt{1/k}$ respectively, whence

$$\frac{H}{G} = \frac{\left( \rho c_p \frac{\partial T}{\partial t} \right)_0}{\left( \rho c_1 k_1 \frac{\partial T_1}{\partial z_1} \right)_0} = \frac{\rho c_p \sqrt{K}}{\rho_1 c_1 \sqrt{k_1}} \tag{5}$$

Thus a single physical quantity, $\rho c_v \sqrt{k_1}$ for each medium determines the sharing. This quantity may be called the conductive capacity and the following three rules emerge. When a plane interface between two media is heated by an external agency:

1. The heat is shared in proportion to the conductive capacities.
2. The temperature response is the same in both, provided distances are scaled in units of $\sqrt{k}$. In particular, the depth of penetration of any disturbance or periodic effect will be proportional to $\sqrt{k}$.
3. The magnitude of the temperature response is proportional to the heat supplied and inversely to the sum of the two conductive capacities.

Table 2 presents some typical values including those for air and water which, as turbulent fluids, have an effective $k$ or $K$ many times the molecular value, varying strongly with condition. From exercises with the three rules and the table it may be seen that maritime climates are more equitable than continental ones not, as is commonly taught, because water has higher specific heat than soil, but primarily because its mobility ensures much greater penetration; that the heat and cold of the desert are much enhanced by the loose dry soil condition; that rolling and watering will help to protect sensitive crops from frost; and other familiar or not-so-familiar features of near-surface climate.

More elaborate exercises in conduction are possible with multi-layered media. The atmosphere at night becomes strongly layered, since the cooling from below suppresses turbulent mixing; we can observe its pollutants, be they clouds of smoke, smog, or insects, spreading out in thin sheets which maintain high concentration. The vertical diffusing power ($K$) is subject to a total range of variation of $10^4$ or more; in some localities, this atmospheric index is used to decide how much pollution factory chimneys are allowed to put out. Snow, with its very low conductive capacity, acts as a fine winter insulator for sensitive plants. An application to human physiology lies in an explanation due to Kovarik of why darkly pigmented skin may be better adapted to hot climates. Table 2 shows that heated air is effectively a good conductor because of its mobility. It is better than human skin. Thus with absorption slightly below the surface, the top skin serves as an insulator from the air. The greater absorptivity of the darkest skins will decrease the thickness of this insulation, and so increase the conduction of heat outwards relative to that outwards to the body. Similarly it may be noted that many indigenous desert animals are black unless, for quite different (i.e. predatory) reasons, they resemble in colour the soil on which they live.

So far in this section we have considered only the apportionment between $H$ and $G$ and we must also assess, for moist surfaces, what fraction of the heat will be used in evaporation. We shall denote by $g(x)$ the specific humidity and discuss here only the case of water or of soil at field capacity where $q_x$ has the value $q_x(T_0)$ corresponding to saturation at the surface temperature $T_0$. We also approximate by ignoring the curvature of the $q_x$ versus $T_0$ curve, treating changes in $q_x$ as proportional to those in $T_0$ with a factor $\left( \frac{\partial q_x}{\partial T} \right)_0$; this is a fair approximation provided the temperature range is not too large. Turbulence has been shown to provide an effective eddy mass diffusivity close in numerical value to the eddy thermal diffusivity $K$, whence

$$\frac{LE}{H} = \frac{L \left( \rho K \frac{\partial q_x}{\partial t} \right)_0}{\left( \rho c_p k \frac{\partial T}{\partial z} \right)_0} = \frac{L}{c_p} \left( \frac{\partial q_x}{\partial T} \right)_0 \tag{6}$$

by the same type of argument as before. With these approximations, the full problem of apportionment has

| Thermal diffusivity ($k$) | 0.006 | 0.0013 | 0.004 | 0.01 | 0.1 | 0.3 | 100 | 10^3 | 10^3 |
| Conductive capacity ($\rho c_v k$) | 0.002 | 0.011 | 0.04 | 0.04 | 0.05 | 0.1 | 100 | 10 | 0.01 |

*Stable and unstable refer to cooling and heating from below respectively.

`The Australian Physicist, January 1971`
been solved. As between different climates we note a strong temperature dependence of \( \frac{LE}{H} \) (table 3). This is as important to man's water storage and irrigation schemes as to the physiology and temperature-control mechanisms of plants and animals.

Further exercises may now be carried through incorporating (6) with (5) and the three rules. For example, under conditions where a rise in temperature at or above a surface of moist soil is 20 degrees, the corresponding rise over dry sand and over a moderately stable ocean would be about 70 degrees and 1 degree respectively, taking 290 K as the central level of temperature \( T_s \) in Table 3. 70:20:1 is of course an extreme example, but the implication is clear as to what large changes we exercise on the microclimate every time we plough a field or irrigate a pasture. This is part of the science of agriculture, the artificial optimization of microclimate for specific production purposes—so agriculture is a branch of physics. And when we apply agriculture extensively, our microclimatic effects extend to the macroclimate. I emphasize this point tonight because protests about the extent to which secondary industry is changing our environment are not always made in full awareness of the extent to which primary industry has been changing it for centuries.

The figures I have calculated include allowance for differences in reflectivity. To complete the factual information, table 4 shows typical reflectivities for a selection of natural surfaces.

<table>
<thead>
<tr>
<th>Reflection coefficient (per cent.) for visible radiation</th>
<th>85</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh snow</td>
<td>45-50</td>
</tr>
<tr>
<td>Old snow, sand dunes</td>
<td>40</td>
</tr>
<tr>
<td>Clean ice</td>
<td>25</td>
</tr>
<tr>
<td>Desert</td>
<td>20</td>
</tr>
<tr>
<td>Light soil, green trees</td>
<td>10</td>
</tr>
<tr>
<td>Dark soil, pine forest</td>
<td>5</td>
</tr>
<tr>
<td>Water, high sun</td>
<td>5</td>
</tr>
<tr>
<td>Water, sun at 5° elevation</td>
<td>25</td>
</tr>
</tbody>
</table>

**IV. Water Balance**

The second basic physical consideration for many forms of life on earth, the water balance, is closely interrelated with the energy balance. It has already been discussed how water modulates the energy balance through changing the conductivity and secondly (table 3) through latent heat of evaporation. Thirdly, it may again moderate through latent heat of fusion. Frost interrupts the rate of cooling on clear nights; so we can spray water on to sensitive fruit buds, etc., to help protect them against sub-freezing temperatures.

Conversely, the energy budget may modulate the water budget, as in dew formation. On a clear night the interface is the coldest point and it follows from Equation (1) that \( |LE| < |R| \). This imposes an upper limit to dewfall which is around 1 mm per night. Such a limit applies to any large enough area and represents a rather small accretion of water, when set against daily potential evaporation rates almost ten times as large. But when the surface is inhomogeneous, dew is attracted to the coldest interfaces (lowest \( \rho c_v/k \)) at the expense of the others, so that there need be no limit to the dew deposit locally. This phenomenon of dew attraction is exploited both by nature and by man. The spiky form of desert vegetation makes it a poorer conductor than the bare soil, and hence a dew attractor, while the tendency to grow in clumps enhances the effect. Ancient civilizations in semi-arid climates supplemented urban water supplies by building stone cairns to attract (and preserve) the dew. Dew attraction preserves a green belt along parts of our North West coast, a sort of giant natural distillation scheme kept going by onshore winds.

Distillation operates in partially wet soils (as in stored grain) to move water from the warmer towards the colder parts. In bare soils, once a dry crust has formed, this process acts as a protection against further loss of moisture during the daytime heat.

**V. Proprioclimates and the Influence of Size**

We now complicate the purely one-dimensional earth-sky system by introducing the 'cow or cucumber' previously alluded to. The essential physical considerations remain the same; but the geometry of the balance as a whole is altered, while a surface of different absorbing-conduction-etc. properties is introduced which will radically alter the fields of temperature, humidity, etc., in its neighbourhood. Each individual introduces its own proprioclimate and presents the problem of its own energy balance. It is important to remember that for every warm-blooded animal there is only a narrow range of deep-body temperature in which the many delicate life processes can proceed normally; similar though not identical considerations apply to plant life.

The size of the body now assumes importance. Let us denote by \( I^{1st} \) the manner in which any heat-balance term depends on linear dimension \( l \), for a body of given shape. For radiation terms \( a = 1 \), but for terms such as \( LE \) and \( H_s \), which are governed by the air motion across the body and the progressive adjustment of the air as it moves, \( a \) is between 0 and 1 depending on the airspeed and the size of the body (strictly, on the Reynolds number). For objects the size of a leaf or a small animal \( a \) will commonly be about 0.5. One leaf 1/10th the length of another will evaporate over three times as fast per unit area, other things being equal.*

For larger natural bodies (elephants, whole trees, etc.) \( a \) is nearer to 0.7.

Bearing in mind also that heat capacity and total metabolism vary as \( I \), we see that, aside from variations of form and coat and shape, etc., different animals may have different balance patterns purely by virtue of their size. As the simplest possible exercise, consider

*Which they are not, of course: see under Parkhurst, below.
animals exposed to a day's natural radiation on a clear December day in Melbourne. Giving each a reflection coefficient of 25 per cent but no other heat disposal mechanism, the rise in average body temperature by the end of the day would be:

- elephant 4°C
- sheep 20°C
- mouse 150°C
- ant 5000°C

The sheep would be killed, the mouse boiled, the ant incinerated. Yet none of these rely on a reflex water-cooling system, such as sweating or panting, which humans and some other middle-sized animals possess. One of the earliest detailed studies of the heat-disposal mechanisms of non-water-cooled animals pertained to the sheep. What was in 1956 a surprising measurement by MacFarlane of temperatures approaching 200°F on a sheep's back led to this exercise. The calculations resulted in the apportionment of heat disposal terms as indicated in figure 3 and the wool-tip temperatures at which the calculated balance was achieved were in line with MacFarlane's measurements. Only a few per cent. of the intercepted radiation is actually conducted inwards to the body of the sheep. There emerged the clear implication that sheep grow wool in order to keep cool (aside the clothing of some Arab tribesmen). By contrast, I read of an American geneticist breeding chickens without feathers, believing that they would keep cooler in summer and so have more energy to lay eggs and put on flesh: but this experiment was reported as unsuccessful!

In figure 3, which pertains to a sheep with a 4-cm fleece and no wind blowing, the animal is primarily a radiator. Shifts in the apportionment, and changes in stress to the animal, are studied through replicated calculations incorporating other fleece lengths or changes in environmental factors, including wind and hence varying degrees of forced convection. In consequence of size alone, the baby lamb will shift the emphasis from radiation towards convection, and will balance at a lower surface temperature. Moving further down the scale, convection has become supreme, with radiation negligible, for animals as small as the cockroach or the ant, with surface-temperature-excess respectively about one quarter and one twentieth that of the sheep.

Like those of colour, texture, and size which have already been exemplified, the effects of shape and orientation on the proprioclimates are highly diversified and we must here be content with illustrations. The short squat form of the Eskimo and the long lean limbs of native African or Australian peoples are genetic reflections of the needs to conserve and dispel heat respectively. The cosine effect of a beam of radiation impinging on a surface has been fully exploited in seasonal-cum-latitude tables which are used, for example, in building design. The designer of walled gardens and even the open country farmer have used the effects empirically for centuries and it is from the minutiae of agriculture that my two actual examples are chosen. Figure 4a shows the temperature distribution at three different times of day in unplanted drills running North-South. In 4b, seedling trees in a nursery threatened with drought were planted in hollows. Plants B thrived, where the displaced clods were left to eastward providing morning shade and rather longer benefit from attracted dew, while plants A dried out early in the day without compensating benefit from the afternoon shade.

![Figure 3](image)

*Relative proportions of heat disposal terms for sheep, cockroach, and leaf.*

![Figure 4](image)

*(a) Isotherms in °F. (b) See text.)*

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VI. Plants

Since size can so significantly influence the pattern of heat balance in an exposed animal, let us see what we can similarly argue from pure physics about the size of leaves in plants. Here we have to be concerned not only with temperature regulation and moisture balance, but with the uptake of CO₂ on which growth rate will depend. As physicists we can approach this by presuming that genetic adaptation will have predisposed the plant towards optimization of some particular combination of factors, select one such combination as a working hypothesis, and then explore the implications of this optimization.

This is the method adopted by Parkhurst, choosing as his initial proposition that an ideal plant will maximize the ratio between its CO₂ intake and its water loss. A key part of the calculation, as with the animal studies, is to determine the surface temperature at which the energy equation will balance. The heat convection per unit area of leaf can be expressed as

\[ H = \frac{T_{(leaf)} - T_{(air)}}{R_l} \]

where \( R_l \) is an atmospheric boundary layer ‘resistance’. We have seen from our consideration of progressive adjustment, as the air moves over the leaf, that \( R_l \) depends roughly as the square root of the leaf dimension, and Parkhurst chose to adopt it as an index of leaf size. The total heat balance per unit area of leaf is now

\[ Q(\text{absorbed radiation}) = \frac{T_i - T_a}{R_i} + \frac{\alpha T_i^4 + L q_l - q_a}{R_i + R_a} \]

where \( R_a \) is the additional resistance encountered in the diffusion of water vapour through the stomates. Parkhurst solved numerically for \( T_i \) and next calculated the evaporation, using realistic values of the environmental quantities. In so doing he confirmed a rather remarkable result derived earlier, though not so rigorously, by Raschke. At \( Q = 0.8 \text{ cal cm}^{-2} \text{ min}^{-1} \), which is characteristic of exposure to bright sunshine, evaporation per unit area actually increased with increasing leaf size but at \( Q = 0.6 \) and below, representing a duller day or more shaded exposure, the opposite was true. Now the uptake of CO₂ encounters yet a further resistance in that the gas must diffuse beyond the stomatal cavity to the site of the chlorophyll, which absorbs the light energy for photosynthesis. So finally a diagram is reached as in figure 5, where the CO₂: H₂O ratio is indicated as a function of \( R_i \) and hence implicitly of leaf size. This is offered as an important part of the explanation for the smaller sun leaves and larger shade leaves which characterize so many of the species with which we are familiar. There are, of course, many other properties of a leaf, such as its mechanical strength, which must contribute to the final determination of shape and size.

Parkhurst has asked the question, ‘What can I infer from pure physics about how to design a leaf?’; Patridge is asking how to design a whole plant. The vegetation cover of a pasture is regarded as composed of horizontal layers. Patridge’s model calculates the heat balance layer by layer; it incorporates the interaction of higher on lower layers by the interception of radiation, protection from wind, and interference with the upward and downward transport of H₂O and CO₂ respectively. Layers of roots and their ability to extract moisture from the intensities of soil are incorporated. All these are purely physical processes, formulated to the precision which present knowledge appears to justify. The model is then based on the concept of limiting values. The local rate of photosynthesis is taken to be the lowest of the three rates as determined by the three possible restricting factors: limited local availability of radiation, or of limited local CO₂ supply, or restricted biochemical efficiency as governed by the leaf temperature at which local energy balance is achieved (restricted soil-water availability is a fourth, but is not invoked in the example shown). Finally, it is assumed that the plant can translocate its photosynthetic product and apply its total growth (the sum of the local growth rates for each layer) to whichever layer or layers will maximize its growth rate over the next time step of the calculation. This expresses a principle of natural selection, and is the final condition sufficient to close the system of equations. The model then builds up the whole growth history of the plant as determined solely by the external weather conditions (wind, radiation, temperature, and humidity) above the crop. Figure 6 shows the results of one such set of calculations.

There is obviously still far to go in improvement and verification of any such model, but an immediate dividend is to ‘tune’ the experimental programmes by indicating what growth and environmental combinations of factors should best be measured. Ultimately such models and the simpler examples which have led up
Realism of the wind, turbulence, and radiation fields, is still not in prospect in artificial experiments, even in the most sophisticated phytotrons.

VII. Conclusion

The popular naturalist Gerald Durrell has written, as it happens, in his description of his Australian tour, 'We have inherited an incredibly beautiful and complex garden, but we have not bothered to acquaint ourselves with the simplest principles of gardening'. Tonight I have simplified the complexity as far as possible by bringing forward examples to illustrate one facet at a time, and only in the last example of the total pasture has everything been thrown in at once. Further complexity must be faced in proceeding from the leaf to the tree, or with mixed stands of plants, or with studying different geometries of stomata, or with the finer details of animal propociplimates, and so on. But my endeavour has been to show you that physics has a place in the garden contributing, as physics should, in the introduction of number on which the rules of gardening must eventually be based. A paraphrase of Durrell's comment is that the problems of the environment are too important to be left to the biologists. Yet this is happening, it is happening in this country, in marine science, in the Pacific Science councils, in our own Academy. More physicists must knock on these doors, and the biologists must learn to invite them in and help to see that they work on the right problems. The subject may lack the glamour of the Pawsey-like discovery of new worlds, but there remains an interest and a challenge in trying to understand better our life on old but still unfamiliar Earth.

INSTITUTE AFFAIRS

NOTICE OF ANNUAL GENERAL MEETING

Notice is hereby given to all members that the 8th Annual General Meeting of the Australian Institute of Physics will be held at 4 p.m. on Thursday 11 February 1971 in the Physics Department of the University of New England, NSW.

J. G. CAMPBELL
Honorary Secretary

17th MEETING OF COUNCIL

The 17th Meeting of the AIP Council was held at Churles Ross House on 29-30 October 1970. All Branches except Tasmania were represented. A representative of each Group also attended and took an active part in the discussions. The President, Mr A. F. A. Harper, was in the Chair.

Finance

The Honorary Treasurer reported that, despite a budgeted deficit, a slight surplus had resulted for the year to 30 September 1970 owing to saving in expenses. The Council then went on to prepare in detail the budget for the year to 30 September 1971. This discussion remained open throughout the meeting, and when the budget was finalized it once again allowed for a deficit, this time of $690.

Membership

The Honorary Registrar reported that corporate membership stood at 1247, and total membership at

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Administration

The Honorary Secretary reported that the admission of the Solar Energy Society as a third partner in the office shared by AIP and AIRAH had resulted in reduced costs to the two original partners.

'The Australian Physicist'

Information received from the Editor had indicated that the new printers continued to provide excellent service, that the publication schedule was being accurately maintained and that costs were under control.

One unfortunate feature was the failure of most appointed Branch correspondents to supply regular information on Branch activities and other items of interest. It was hoped that Branches would take action to replace them by more effective correspondents.

Conferences, Etc.

Reports were presented on a number of activities since the previous Council Meeting, and planned for the future.

The 1970 Pawsey Memorial Lecture had been delivered in Melbourne by Dr C. H. B. Priestley on 13 October. The 1971 lecture was to be held in Western Australia.

The 1970 Summer School and Conference was held in Brisbane in May (though not strictly summer) in association with the Astronomical Society of Australia. The 1971 Summer School and Conference will be at Armidale NSW on 8-12 February.

No exhibition of scientific instruments was planned.

The Conference on Transport Properties of Solids, held in Sydney in August 1970, had been very successful.

The NSW Branch was planning a Conference on Radiation Damage in August 1971.

Groups

Group representatives reported on their activities.

The Biophysics Group reported that the tenth conference in its annual series on Physics in Medicine and Biology had been held in Melbourne in August 1970. The next such conference would also be in Melbourne, on 20-22 August 1971.

The Education Group reported that no national activity was being undertaken, but that activities continued at the state level. There was discussion as to whether the Group should be disbanded and its interests carried on by the Branches, as had already happened in WA.

The Geophysics Group was also suffering from lack of co-ordination, in that case due to the wide spread of interests represented within its membership. Once again no national activity was being undertaken.

The Vacuum Physics Group reported that their Second National Symposium and Exhibition had been held in Sydney in August 1970, in addition to technical meetings in the state sections.

Following these reports, a discussion ensued on the functions of the Groups within the Institute. It had emerged clearly that the success of a Group was closely related to the existence of a national activity. Proposals were considered by which the less successful Groups could be revived, and the alternative of disbanding them was also considered. It was decided to take no action pending further discussion within the Groups themselves.

Training and Employment of Physicists

The previous Council meeting had appointed a Committee in Victoria to investigate the implications of the results of the 1968 Survey of Physicists. That Committee however had not yet met.

The NSW Branch expressed particular interest in this project, and put forward a draft proposal to carry out a survey to collect further pertinent information. This proposal was supported by the Council, pending a firm proposal to be put to the next Council Meeting.

Benevolent Fund

The Institute's Benevolent Fund is in a position to act quickly to relieve cases of hardship which are brought to the notice of the Trustees, usually through Branch Chairmen. The Honorary Treasurer reported that one payment had been made since the previous Council Meeting.

18th Council Meeting

It was agreed that in future the attendance of every Councillor and the Editor of 'The Australian Physicist' would be supported financially for two meetings each year. The experimental 'unsupported' meeting in May 1970 was not considered successful.

It was also agreed that Group Chairmen (who are not voting members of Council) would be supported to attend at one specified meeting per year for budgeting purposes.

The next Council Meeting was scheduled for two consecutive days to be fixed in the period 17-22 May 1971.

Closure

Council expressed its thanks to Mr A. F. A. Harper, the retiring President, not only for his chairmanship of meetings over the last two years but also for his service as an Executive member continuously since the inception of the Institute and for the part he played prior to that.

Mr Harper thanked Councillors for their co-operation and declared the Meeting closed.
A.I.N.S.E.
RESEARCH FELLOWSHIPS

ANNOUNCEMENT

A.I.N.S.E. Research Fellowships are offered by the Australian Institute of Nuclear Science and Engineering for suitably qualified persons wishing to undertake research projects within the Institute's field of interest. Candidates for these awards must be nominated by an Australian University or the Australian Atomic Energy Commission. The closing dates are 28th FEBRUARY and 31st AUGUST each year, and all nominations received by the Institute after one closing date, will be considered together after the next closing date.

Research Fellowships are intended for scientists and engineers who have qualifications equivalent to the Degree of Ph.D. and are at a relatively early stage of an independent research career. Minimum tenure is two years, and the award may be extended for a third year. Emolument will be within the range of $5,850 per annum to $8,370 per annum, (Australian currency), and the Institute may contribute to the costs involved in travelling to and from Australia.

A research project within the field of nuclear science and engineering of interest to the Institute, must be proposed in the nomination after agreement between the candidate and the nominating organisation. Usually it is expected that a Research Fellow's project will require some use of the specialised facilities located within the Australian Atomic Energy Commission Research Establishment at Lucas Heights, near Sydney, N.S.W.

Further information may be obtained from—

The Executive Officer,
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