# ABSTRACTS
OF
# DISSERTATIONS

*Approved for the*
PH.D., M.SC., AND M.LITT. DEGREES
*in the University of Cambridge*
*during the Academical Year*
1953–1954

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IN THE

# UNIVERSITY OF CAMBRIDGE

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# PREFACE

THE present publication comprises summaries of dissertations approved during the academical year 1953–54.

Each summary has been approved for publication by the Examiners or by the Research Student's Supervisor.

The summaries are arranged in the alphabetical order of the Faculties under whose Degree Committees the Research Students have worked. Within these main divisions they are arranged by the Department in which the author worked, as outlined in the Table of Contents which follows. Not every Research Student working in a Department is necessarily under the supervision of the Degree Committee of the Faculty to which the Department is formally assigned. Some Departments may thus appear under more than one Faculty. An index of authors' names will be found at the end of the book.

A copy of each dissertation has been deposited in the University Library where it may be consulted by all who may use the Library. Copies of dissertations may not be removed from the Library.

THE OLD SCHOOLS
CAMBRIDGE

*November 1954*

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# THE FACULTY OF AGRICULTURE

*For the* PH.D. *Degree*

## STUDIES ON GROWTH AND REPRODUCTION IN THE FEMALE RABBIT

*By* CYRIL EDWIN ADAMS

*Downing College, Cambridge, and the University of Wales*

THE long interval between successive generations of farm animals is a serious handicap to progress in live-stock improvement. The object of the present studies was to investigate some of the problems associated with the experimental shortening of the generation interval. The rabbit was selected as the experimental animal.

The first section of the dissertation is almost entirely devoted to the literature on the subject; it includes a brief review of reproduction in the female rabbit, of its sexual development and growth, of the effect of gonadotrophin treatment on immature animals, and of the subsequent fate of the ova.

Section II contains original observations on reproduction and an account of experiments on the effect of nutrition on sexual development and ovarian response to gonadotrophins.

Immature does, reared from birth according to predetermined growth curves, were treated with pituitary (AP.118.B) and chorionic gonadotrophins according to Pincus (1940).

Does from one breed (A) (average mature body weight 3500 g.) were fed *ad libitum* (high plane) from birth and treated with gonadotrophins at either 70, 84 or 98 days of age. At 70 days there was no ovarian response; at 84 and 98 days superovulation occurred.

In does from the same strain receiving restricted feeding from birth to 56 days of age and then *ad libitum* feeding, ovulation occurred at 84 days and superovulation was observed at 98 days.

In similar does with restricted feeding (low plane) throughout, very little follicular response occurred at 84 days of age.

Does from another breed (B) (average mature body weight 3650 g.), when fed *ad libitum*, showed the first follicular response at 90 days of age. Superovulation was not observed until 115 days.

Histologically, the ovaries of low- and high-plane does (breed A) were similar up to 50 days of age. Thereafter the difference in ovarian and uterine growth and development became more pronounced, an extreme condition being reached at *c.* 75 days of age, when follicular antra were present in does fed *ad libitum* from birth.

The presence or absence of oestrous behaviour was correlated with the degree of ovarian response, which was itself highly correlated with the development of the ovary at the beginning of gonadotrophin treatment.

Of thirty immature gonadotrophin-treated does (breed A) only 10 % produced young; in a further 20 % extensive foetal atrophy occurred. In the remainder it is probable that the ova were lost at, or prior to, implantation.

The inhibition of superovulation which occurred in 95 % of does primed for a second time with AP.118.B was shown to be due to antibody formation rather than to an ovarian condition.

In does receiving restricted feeding, puberty occurs later in life and at lower body weights than in does fed *ad libitum*.

Does born between 1 October and 31 December reach puberty at a significantly lower age and body weight than those born at other times of the year.

Section III contains a review of the literature and the results of experiments on ovum recovery and transplantation. The percentage ovum recovery by one method (Pincus, 1930) and an *in vivo* method (Adams, 1952) was 72 and 46 % respectively; 74 % of the ova were recovered in the first drop of fluid. No ovum was recovered from 15–20 % of the donors.

The reciprocal transfer of two-cell ova in mature (more than 180 days old) and immature (less than 120 days old) does is described; 33 % of the ova transferred from immature to mature does developed into normal young.

Only one of nine immature does which acted as recipients for ova from mature does produced young. No young resulted from ova transferred to immature does treated with progesterone in the absence of corpora lutea.

In all, 40 % of the mature recipients became pregnant, and 50 % of the ova transferred to them developed to term.

By combining gonadotrophin treatment of the immature doe (breed A) with ovum transplantation to the mature doe it is possible to shorten the generation interval to approximately 110 days.

*For the* PH.D. *Degree*

## BIOMETRICAL PROBLEMS IN REPRODUCTION

*By* RICHARD COLIN CAMPBELL, M.A.

*Gonville and Caius College, Cambridge*

THE object of the dissertation is to develop and illustrate methods of biometrical analysis that can be applied to the conception rates recorded at artificial insemination centres.

(*a*) *Development of the methods.* The simplest assumption on which to base the theory of the distribution of conception rates is that all inseminations of all cows have the same chance of success. This assumption, although mathematically simple, is too naïve to be of use to the biologist. A series of more complex assumptions is discussed, each assumption being one stage nearer to reality. A necessary and sufficient condition for conception rates to have a binomial distribution is established.

Fisher's method of iterative solution of the maximum-likelihood equations is applied, using various transformations of the conception rates, and a simple approximate method of analysis is found which compares satisfactorily with the full maximum-likelihood method.

Smaller problems investigated include the distribution of conception rates from second inseminations and the use of 'number of services per conception' instead of conception rate as a criterion of fertilizing capacity.

(*b*) *Illustration of the methods.* The conception rate is an exact measure of the economic success of the artificial insemination service and is also a valuable estimate of the fertilizing capacity of the semen used. Conception rates are therefore the standard form of result in investigations concerned with artificial

insemination. Selected examples of such investigations are described.

Three of these investigations deal with the testing of new diluents for semen or of antibiotic supplements to the diluent. One of these, a $2^4$ factorial design confounded into blocks of two, is the largest experiment of its kind that has been carried out in this country.

Other investigations deal with the conception rates of second inseminations, with the problem of herd infertility, and with the breeding records of a single herd.

*For the* M.Sc. *Degree*

## THE PARASITISM OF *ALTERNARIA SOLANI* (ELL. AND MART.) JONES AND GROUT ON CERTAIN SPECIES OF *SOLANUM*, AND THEIR USE AS SOURCES OF DISEASE RESISTANCE

*By* ALAN WEBSTER CHARLES

*Downing College, Cambridge, and the University of Sydney*

1. A review is given of the literature on the history, distribution and economic importance of early blight of potatoes, and the history, host range and nomenclature of the causal organism, *Alternaria solani*. Previous work on breeding for resistance to *A. solani* is discussed.

2. Under appropriate conditions *A. solani* spored heavily on potato dextrose agar + 1 % yeastrel, and on a powder prepared by drying potato tubers at a low temperature.

3. Problems arising from inoculation with spores from culture were considered. The period elapsing after isolation of the organism and environmental factors affected the size of the spores. Virulence declined in culture more rapidly than did the capacity for sporulation.

4. Sixty-eight *Solanum* spp.—1500 clones in all—were tested for their reactions to *A. solani*. None was immune, but clones of the wild diploid species *S. saltense* Hawkes and *S. toralapanum* Cardenas and Hawkes were highly resistant.

5. The resistance of *S. saltense* was partially broken down when conditions favoured water-soaking of the leaves, but *S. toralapanum* was unaffected.

6. Isolates of *A. solani* could be separated into physiological strains on the bases of spore size and certain cultural characteristics. Physiological specialization was not demonstrated.

7. The pathogen entered a susceptible host by penetration of the cuticle or through the stomata. It spread inter- and intra-cellularly. In *S. saltense* invasion was apparently limited by the formation of gums or tannins. In *S. toralapanum* the fungus entered via stomata only and penetrated for a short distance intercellularly.

8. In interdiploid crosses the genes for resistance from both species were recessive, and resistance to early blight was inherited in a complex manner. The genes for resistance were not the same in the two species.

9. Breeding for resistance was initiated, using *S. saltense* and *S. toralapanum* as the resistant parents. The tetraploid level was reached by interspecific hybridization and by the use of colchicine.

*For the* PH.D. *Degree*

## THE BIOLOGY AND PARASITISM OF THE BEET FLY (*PEGOMYIA BETAE* CURT.), WITH AN APPENDIX ON ITS CONTROL

*By* ROBERT ANDREW DUNNING

*Queens' College, Cambridge, and the University of Leeds*

THE results of field and laboratory work on the biology and parasitism of the beet fly are presented. The extensive literature on the subject is reviewed and the '*Pegomyia hyoscyami* complex' discussed. The techniques and results of field population studies in East Anglia are detailed; during 1949 and 1950 there was a maximum of three distinct generations in the field, the third one being only partial.

The egg, mature larval and pupal characters of *P. bicolor*, *nigritarsis*, *versicolor*, *genupuncta* and *setaria* are described, illustrated and compared with those of *P. betae*. The host range of *P. betae* was determined as far as possible.

There is a diurnal rhythm in the emergence of beet flies from puparia, peak emergence occurring between 6 and 7 a.m. each day; it is concluded that the rhythm is inborn. Approximately 5, 50 and 100 % respectively of the pupae of the three successive generations enter diapause at the time of formation of the true pupa within the puparium. Diapause may be induced by exposure of the 'forming-pupa' to low temperature, whilst pupae in diapause recommence development after exposure to low temperature. Thermal summation from formation of the pupa to emergence of the fly gave a result of approximately 250 'degree-days' C., constant within the range 10–25° C., the theoretical developmental zero of the pupae being 5° C.

The distribution and prevalence of the beet fly in England and Wales is outlined, and data are given on the parasitism of the successive generations in the field. The pupal parasite *Phygadeuon pegomyiae* and the larval parasites *Biosteres carbonarius*, *B. wesmaelii*, *Opius nitidulator* and *O. ruficeps* exerted a considerable influence in the natural control of the beet fly throughout the study, and they are considered in detail; brief notes are also given on hymenopterous and fungal parasites that occurred only rarely during the study.

The results of work done on control are given as an appendix in the form of a paper prepared for publication by the writer and F. G. W. Jones. Field and laboratory trials are detailed and recommendations made for the control of this pest.

*For the* PH.D. *Degree*

## THE HATCHING RESPONSES AND HOST RANGES OF SOME ROOT EELWORMS (*HETERODERA* SPP.)

*By* ROBERT DAVID WINSLOW

*Jesus College, Cambridge, and Queen's University, Belfast*

AN account is given of investigations on the hatching responses and host ranges of nine species or varieties of *Heterodera*, namely, the beet, cabbage, clover, *Galeopsis*, potato, carrot, hop, oat and pea-root eelworms. Techniques evolved by other workers in

this field were used, with such adaptations as were considered desirable.

It is shown that, in the case of the first seven species mentioned, marked differences occurred in hatching responses from cysts incubated in root leachings from various plants, these differences being diagnostic for the species concerned. In general, good responses to leachings from host plants occurred, whereas there was little or no response in non-host leachings; but cases of response to non-hosts and of failure to respond to hosts were encountered. In the case of the other two species no appreciable response occurred when cysts were incubated in host leachings, but there was some evidence that such a response did occur, in the case of pea eelworm, under field conditions. Promising results were obtained in diagnosis of mixtures of some of the above species.

Curves for rate of hatching of eight species and for dilution of leachings in the case of six species were investigated and found to be of the same form as the corresponding curves described by Fenwick for potato-root eelworm.

Results are given of some experiments on the effect of age of plant on the potency of the root diffusate, on the loss in potency of diffusates during storage, on the use of fungicides in hatching experiments, and on the 'hatchability' of cysts of different sizes.

In addition to the hatching responses from cysts under laboratory conditions, seasonal changes in field populations were investigated, and use was made in 'trap-cropping' experiments of non-hosts stimulating hatch.

In the host range experiments plants were grown in infected soil in the open, in plant pots, or in test-tubes, and the roots were examined at intervals. Plants with well-developed cysts attached to the roots were recorded as hosts, and no reinfection of the type host was attempted. Consequently, the resulting host-plant lists are regarded as merely provisional, pending confirmation by reinfection tests.

# THE FACULTY OF ARCHAEOLOGY AND ANTHROPOLOGY

*For the* PH.D. *Degree*

## FAMILY AND KIN AMONG THE IBAN OF SARAWAK

*By* JOHN DEREK FREEMAN

*King's College, Cambridge*

THE Iban, or Sea Dayaks, are a proto-Malay people of western Borneo. They are a riverine people with a subsistence economy based on the shifting cultivation of hill rice in the tropical rain forest. Some 190,000 of them live in the interior zone of the territory of Sarawak. The dissertation is based on intensive field research carried out among the Iban during the period January 1949 to July 1951. It is concerned, in particular, with the pre-literate and pagan Iban of the Baleh region of the Third Division of Sarawak. The object of the dissertation is to present a formal analysis of Iban social structure. The social system of the Iban is of the cognatic type, and stands in marked contrast to unilineal systems, which have a very much wider distribution. In the past little has been written of the cognatic societies of Indonesia, but there can be little doubt that when our knowledge of them is complete they will come to occupy an important place in that general typology of human societies which stands as one of the principal objectives of the science of social anthropology. In the dissertation an endeavour is made to describe some of the salient features of the cognatic social system of the Iban. Three Iban long-house communities of the Baleh region were selected for intensive investigation, and quantitative methods of analysis were used in an attempt to establish the nature of the principal regularities which characterize Iban society.

*For the* PH.D. *Degree*

# SOME NEOLITHIC POTTERY OF THE AEGEAN, WITH SPECIAL REFERENCE TO POSSIBLE CONNEXIONS IN ASIA MINOR

*By* AUDREY EVELYN FURNESS, M.A.
*Girton College, Cambridge*

IF one accepts the principle of the diffusion of Neolithic civilization from a Syrian centre, it follows that one must account for the arrival of the art of pot-making in the Greek peninsula and in the Aegean islands by presuming influence, if not an 'invasion', from the east.

A comparison between the Aegean Neolithic wares and the earliest pottery series of Syria suggests that, in so far as either painted pottery or burnished monochrome wares are concerned, there could have been no direct connexion between these two areas at so early a stage.

For the sequence of Neolithic wares at Knossos in Crete, in which four phases may be distinguished, it is difficult to find any significant parallels elsewhere; there are, however, a few surprisingly close parallels with sherds from the 'chalcolithic' mound of Büyük Güllücek in central Anatolia.

The Neolithic pottery which has been recognized at more than twenty other sites in Crete adds little to what is known from Knossos, while a study of the beginnings of Early Minoan ceramics illustrates the debt Crete owed at this later stage to foreign influence from the east, rather than any appreciable legacy from the Neolithic period.

In the east Aegean islands of Samos and Kalimnos there are series of pottery which have been described variously as 'sub-Neolithic' or Neolithic; a detailed comparative study of these, and of an unpublished series from Chios, reveals the strong likelihood of their pre-Trojan date. There are parallels, more clearly than in the case of Knossos, with Büyük Güllücek and with Beşiktepe in the Troad.

In Macedonia there are parallels both to the east Aegean island group and to the central Anatolian wares, which, together with a

particularly strong likeness between some incised wares of east Bulgaria and those of Alişar Hüyük, are sufficient to demonstrate an eastern, rather than a Thessalian or Danubian, origin for the earliest Neolithic pottery of the north Aegean seaboard.

The Thessalian and south Greek wares, although superficially different, are not so radically unlike those of Macedonia that their separate origin need be assumed.

*For the* PH.D. *Degree*

## THE APPLICATION OF MULTIVARIATE STATISTICAL ANALYSIS TO PROBLEMS OF PHYSICAL ANTHROPOLOGY, WITH SPECIAL REFERENCE TO THE PHYSICAL ANTHROPOLOGY OF CERTAIN PEOPLES OF NIGERIA

*By* HAROLD MULHALL

*King's College, Cambridge, and the University of Sydney*

THE dissertation is in three sections. The first section is introductory and is concerned with the role of statistics in physical anthropology. In particular, the special problem of the measurement of group divergence is surveyed, and a critical comparison is made of Karl Pearson's coefficient of racial likeness and P. C. Mahalanobis's generalized distance ($D^2$). Each of these coefficients was used on the same body of data, and the deficiencies of the coefficient of racial likeness, compared with the generalized distance, were demonstrated.

The second section has the subtitle 'An Examination of the Physical Types of Ibo and Neighbouring Groups', and consists of a statistical analysis of some 1700 sets of head and facial measurements of adult male Ibo, the original measurements having been taken by G. I. Jones of the Faculty of Archaeology and Anthropology in the University of Cambridge. Following a brief account of the ethnology and geography of the Ibo peoples and their habitat, the measurements are analysed in detail. The primary purpose of the second section is methodological. A complete $D^2$ analysis was carried out on a large body of data. Statistical tests

established as reasonable the hypothesis that a set of groups can have different means with a common co-variance matrix, and a reliable matrix of correlation coefficients between the pairs from a set of cephalic characters was estimated for subsequent use in the third section.

The third and major section of the study is an anthropometric survey of Nigeria, principally the Southern Provinces. The field work was carried out by the late Dr P. Amoury Talbot when he was Resident of Southern Nigeria.

The measurements are described in Chapter I and the sampling is discussed. Chapter II deals with the earlier ethnographic classification of the tribes of Southern Nigeria, with some reference also to the tribes of the Northern Provinces. Chapter III contains a preliminary statistical survey of certain subgroups. Talbot had subdivided certain tribes into clans, and the measurements were examined in an attempt to ascertain whether or not these subgroups were physically homogeneous. In Chapter IV the main statistical analysis is described, and in Chapter V a reclassification is carried out on the basis of the measurements.

The fifty-one groups included in the survey are classified into 'clusters'. The first of these, the Yoruba, is considered to represent the true Negro type. A fairly similar set of groups, the Sobo, probably represents a variation of the Yoruba type, showing some effect of influence from the north. The Ibo peoples were found to be physically heterogeneous, forming three principal clusters. One of these, a northern type, is physically akin to the Sobo. A central Ibo type includes some groups originally classified as Semi-Bantu, and there is a south-eastern type with appreciably lighter skin, physically related to the Ibibio, the dominating group of this region. Finally, there is a Bantu type with definitely lighter skin living in the neighbouring Cameroons.

It appears that the region of the survey presents a picture of the typical Sudanese Negro showing signs of contact with the Hamites to the north and the Bantu to the south-east. However, the differences in physique are not great, a situation demanding care in the collection of anthropometric data and restraint in the drawing of conclusions from the data.

*For the* PH.D. *Degree*

# SOME MESOLITHIC CULTURES OF THE IBERIAN PENINSULA

*By* MICHAEL WELMAN THOMPSON, M.A.
*Pembroke College, Cambridge*

THE first section of the dissertation describes the Azilian remains from the north of Spain. After a description of the Magdalenian harpoons from that area, the Azilian harpoons from there and from south France and the connexions of one with the other are discussed. A sequence for the harpoons in France is proposed, and from measurements of the thicknesses of the harpoons in both areas it is concluded that the change of antler was not the motive for the change in form. It is concluded that this form originated in southern France.

The second section deals with the middens at Mugem. The situation, fauna and industry of the middens are described. Some comparisons are then made between these middens and others known from western Europe, leading to an assessment of conditions at Mugem when the shells were collected. Old maps and borings in the river bed are used to show changes in the estuary in historical and remoter times.

In the third section lists of the flints found in the first, third and fourth season's excavations at La Cocina are given, and the forms appearing in St Pericot's stratigraphy are described. Then reference is made to published sites in eastern and southern Spain.

A brief account of final flint cultures in the peninsula follows. A hundred microliths from Portugal are figured and described. A brief account of the flint industry of Vila Nova de São Pedro is given. Reference is made to Vilaró's excavations and the difficulty of disentangling the simple Catalan sequence in other parts of the peninsula.

In the conclusions that follow an outline for the sequence in the peninsula as at present known is suggested.

Four appendices follow.

The first contains a list of the material used and the museums in which it is found, and a key to maps, etc., in the first section.

The second deals with a possible functional change from the Magdalenian to Azilian harpoons, and ethnographical parallels are used to find a motive for such a change.

In the third appendix an attempt is made to judge the value of climatic changes deduced from certain shells in the Atlantic middens.

The fourth appendix is larger than the three previous ones. Experiments in working in antler are described, and an account of worked antler inspected in museums in France and Spain is given. From a large number of bases a difference between the working of the reindeer and red deer antler is suggested.

*For the* M.Sc. *Degree*

## THE FAMILY AND THE NEIGHBOURHOOD IN A BRITISH COMMUNITY

*By* CONSTANCE SHIRLEY WILSON, M.A.
*Girton College, Cambridge*

THE dissertation describes the internal and external relationships of the family in a Scottish mining town and suggests how both are affected by aspects of social status.

After a preface on method, the first chapter outlines the local setting, the geography, history, and the economic, political, educational and religious organization. This is followed by a description of the status system; the differences in behaviour and values between people of higher and of lower status are described, with particular reference to the morally backed social mobility of the former. This system is territorially expressed, the town being divided into streets of varying social grade, so that families of very different status tend to be separated. The local pattern is mainly a product of the influence of the white-collar higher-status people on the siting of tenants; this influence is described, and comment is made on the concept of social balance in the light of these attempts to prevent residential mixture.

The family's local relationships are discussed in detail in the chapter on the neighbour group, normally a small, socially homogeneous unit whose internal contacts are determined by the con-

cepts of neighbourliness. These differ between people of higher and of lower status. Among the former the desire to select and restrict contacts is fundamental, so that in a heterogeneous group factors of status rather than of spatial siting as such determine the relationship pattern between neighbours.

Leisure-time contacts are also affected by the desire to prevent mixing and by the different concepts of leisure among people of different status. Associational groups and smaller cliques are shown to be established and differentiated on status lines, and a similar influence pervades the ties between relatives.

The discrimination of social contact produces a relatively isolated and self-sufficient family; the internal organization and relationships of this are described in detail and are shown to be affected by an emphasis on family solidarity—mainly during the childhood period—and on the individual responsibility to get on. In the summary it is suggested that both the cohesive and the individual elements are related to the values of the social group to which the family is affiliated, that the internal relationships mirror tendencies noted in the family's external relationships, and that the state of comparative isolation which the higher-status family has achieved is not a pathological condition but exists in response to the cultural demand of individual social mobility; it is an effective mechanism permitting this.

# THE FACULTY OF BIOLOGY 'A'

## (1) *BOTANY*

*For the* PH.D. *Degree*

## EFFECT OF LIGHT INTENSITY ON THE GROWTH AND ASSIMILATION OF TEA (*CAMELLIA SINENSIS*) SEEDLINGS

*By* DINANATH BARUA

*Fitzwilliam House, Cambridge, and the University of Calcutta*

THE relationship between the 'commercial yield' of the tea plant and the intensity of incident sunlight was recently investigated at the Tea Research Station, Assam, and shown to vary from type to type. The yield, representing only the weight of young shoots, is not a good measure of total growth. The current classification of the hybrid tea into 'positive' and 'negative' agrotypes is examined, and it is suggested that the unit leaf rate and leaf area would be better bases for analysing differences between different types and their response to light intensity.

Seedlings of one type of tea were grown under controlled temperature and humidity with intensities of illumination (from tungsten filament lamps) varying between 2·5 and 9 kilolux. Reduction in illumination reduced the rate of expansion and thickness of leaves, decreased the total dry weight, increased the water content, especially of the leaves, and affected the partition of assimilates between various parts of the plant. The area of leaves reached a maximum under intermediate light intensities.

Under identical environmental conditions and light of intensity 9 kilolux the unit leaf rate of the tea seedlings was less than half of that of sunflower seedlings.

Real assimilation was calculated by determining respiration of excised parts. It appears that this type of tea plant has, under natural conditions, a maximum real assimilation rate of about 5–6 mg. $CO_2$/dm.$^2$/hr.

The assimilatory activity develops gradually in an expanding leaf and reaches a maximum in sunflower before, and in tea after it is half expanded.

For four types of tea plant the relationship between assimilation rate of detached mature leaves and intensity of illumination (4–32 kilolux) with saturating carbon dioxide could be expressed in the form of a rectangular hyperbola. The maximal rate of assimilation, which varied from type to type, and the half-saturating light intensity, might be used for comparing and characterizing different types of tea plants.

The two positive types had the same rate of photosynthesis per unit of chlorophyll, and the same was true for the two negative types.

The usefulness of unit leaf rate and assimilation measurements in the early selection and characterization of the tea plants is indicated.

*For the* PH.D. *Degree*

## THE INHERITANCE OF *B*-CHROMOSOMES IN *ZEA MAYS*

*By* MARGARET BLACKWOOD

*Newnham College, Cambridge, and the University of Melbourne*

*B*-chromosomes are usually small chromosomes supernumerary to the regular *A*-chromosomes and present in variable number in several species of animals and plants, such as *Zea mays*. In *Z. mays* the loss of the *B*-chromosomes at any time during the life cycle, and the occurrence of non-disjunction at stages in the reproductive cycle, both of which have been observed, would lead to loss from the population. However, there is no evidence of loss of *B*-chromosomes from the population. The problem of how an equilibrium of *B*-chromosome number is maintained in the population is the subject of the dissertation.

Non-disjunction of the *B*-chromosomes occurs at two stages during the reproductive cycle, at anaphase I and at the second pollen-grain division, giving a wide range of *B*-chromosome numbers, with an excess of even over odd numbers in the male gametes, and tending to increase the relative number of gametes

with no *B*-chromosomes. Many pollen grains have male nuclei with unlike numbers of *B*-chromosomes.

The effect of double non-disjunction, producing a relatively large number of gametes without *B*-chromosomes, is countered by preferential fertilization of eggs by gametes with large numbers of *B*-chromosomes, ensuring the addition to the population of plants with larger numbers of *B*-chromosomes.

Comparison of progenies from similar crosses, in which unrelated plants were used as parents, revealed significant differences between progeny mean numbers of *B*-chromosomes and the distributions of progeny plants with different *B* numbers. Not only was there differential fertilization in different crosses, but there was a differential rate of non-disjunction also. Comparison of progenies from similar crosses in which the same pollen parent carried the *B*-chromosomes showed no significant differences between their means or distributions, indicating that the amount of preferential fertilization, determined by the pollen, and the rate of non-disjunction, are constant for a particular plant.

It is concluded that the genotype of the *A*-chromosome controls the frequency of non-disjunction, hence the distribution of *B*-chromosomes to the male gametes and the degree of preferential fertilization.

*For the* PH.D. *Degree*

## BIOLOGICAL EFFECTS OF X- AND $\gamma$-RADIATIONS

*By* KUMUD CHANDRA BORA

*Fitzwilliam House, Cambridge, and the University of Calcutta*

THE primary aim of the dissertation is to study the mechanism of chromosome breakage by radiations. The direct-action hypothesis assumes that a break is caused directly by the passage of the ionizing particle through or near the breakage locus. The indirect-action hypothesis assumes that the breakage is the result of some biochemical processes which intervene between the physical events and the appearance of the break. It has been shown by some workers that fractional X-ray doses reduce the chromosome breakage frequency and that there is no subsequent recovery, but

others have shown that the reduction is temporary and is followed by a recovery of the breakage frequency.

The present experiments started with an attempt to study the effects of fractional doses, with long time intervals, on the chromosomes of *Tradescantia* microspores, but it was later realized that it was more important to study the mechanism of breakage by using short time intervals and high radiation intensity. Attempts were also made to study the influence of temperature and developmental stages on irradiation effects.

The results suggest that the breakage is delayed and probably caused by an indirect mechanism through a series of biochemical processes. The duration of the breakage process probably depends upon radiation intensity and temperature. No recovery of the breakage frequency was observed up to a period of 32 hr. after irradiation. The mitotic inhibition effect of low temperature and X-radiation was found to be greater when the former was combined with fractional doses. The reduction in the breakage frequency by fractional doses is independent of radiation intensity and temperature. Most of the breaks reunite rapidly, but a few may remain open for many hours.

Experiments with X- and $\gamma$-rays show that in high-energy radiations in the filtered beam produced by the 30 MeV. synchrotron $\gamma$-rays of $^{192}$Ir of mean energy 0·4 MeV. are less effective than conventional 220 kVp. X-rays in inducing breaks.

The effects of the combined treatments of X-rays and tetrasodium 2-methyl-1:4-naphthohydroquinone diphosphate (Synkavit) on mitotic inhibition in the root tips of *Allium cepa* were studied. The combination treatments appear to be more effective than separate treatments.

*For the* PH.D. *Degree*

## *FUSARIUM* DISEASES OF *GLADIOLUS*

*By* ERIC WILLIAM BUXTON, M.A.
*Trinity Hall, Cambridge*

THE two major phases of the disease complex on *Gladiolus* caused by *Fusarium oxysporum* occur as premature yellowing of the leaves

of growing plants and as rotting of stored corms. The yellowing phase is new to Britain. Details of symptomatology, the host range of the pathogen, and the reactions of the host to invasion by different strains of the fungus, are studied.

Variations in the effects shown by different isolates of the *Fusarium* occur in respect of their ability both to cause yellowing and to incite corm rotting throughout different ranges of *Gladiolus* varieties. Field observations of the occurrence of yellowing were made in Britain and in Holland. Infection is specific to *Gladiolus* and to near relatives within the Iridaceae; no symptoms can be induced on host plants which succumb to other pathogenic forms of *F. oxysporum*. As a potential control method, a programme of breeding *Gladioli* for resistance to the diseases was instigated.

The fungus is studied from three main standpoints. The morphological variation in response to cultural environment leads to a reconsideration of earlier taxonomic definitions of the isolates which can cause the different disease phases. The designation *F. oxysporum* Fr. f. *gladioli* (emend Snyder and Hansen) is held to include all the British isolates. The survival capacity of the fungus extends to at least one year in soils varying in acidity and moisture content.

Genetic variation in the *Fusarium* (which has no known sexual stage) is shown to be due to some extent to the association of different nuclear types within the same mycelium (heterokaryosis). Synthesized heterokaryons show changes in nuclear ratios which depend upon the carbon or carbon/nitrogen content of the culture medium. Observations of nuclear distribution in the hyphae, anastomoses between hyphae of different types, and nuclear movements during conidium formation, reveal the basis on which the heterokaryotic system could work. Artificial biochemical mutants, produced by ultra-violet irradiations, are also shown to form heterokaryons. Work on techniques for the demonstration of mechanisms which promote recombination without sexual reproduction, in which diploid nuclei within vegetative hyphae might play a part, is in progress.

The implications of cultural variation on taxonomic difficulties and the need for an understanding of genetic variability in plant pathogens are discussed.

*For the* PH.D. *Degree*

# VARIATION IN CHIASMA FREQUENCY WITH SPECIAL REFERENCE TO THE EFFECT OF TEMPERATURE

*By* CHARLES GORDON ELLIOTT

*Trinity College, Cambridge, and the University of Tasmania*

EXPERIMENTS were carried out to determine whether there is any effect of temperature on chiasma frequency, the constant temperature being maintained throughout the whole of meiosis.

In a diploid variety of *Hyacinthus orientalis* the chiasma frequency is greatly reduced at 10°, and especially at 5°, compared with 15 and 20° C. This is due to extensive failure of chromosome pairing and to incomplete pairing within bivalents at the low temperatures. There is no evidence of a temperature effect on chiasma frequency in the parts of chromosomes which are paired.

No effect of temperature on chiasma frequency was found in *Locusta migratoria* over the range 1–37° C., nor in *Endymion non-scriptus* (*Scilla non-scripta*) over the range 1–15° C. At any one temperature there is so much variation in mean chiasma frequency between individuals that any differences between temperatures are insignificant.

Supernumerary chromosomes were found in *Locusta* which vary in number from cell to cell of the testis of the one animal. The relation of the number of supernumeraries to the chiasma frequency of the autosomes was examined.

In *Endymion non-scriptus* at 20° C. failure of pairing of chromosomes lead to a great reduction in chiasma frequency. The temperature at which meiosis occurs in nature is 5–0·5° C., the soil temperature showing very little variation over short periods.

Significant heterogeneity in the mean chiasma frequency of different individuals was found in *Locusta*, *Hyacinthus*, *Endymion*, and *Chorthippus bicolor*. A comparison was made between an outbreeding and an inbreeding grass (*Secale cereale* and *Triticum monococcum*); variation between individuals was found in both species. Evidence shows that in *Triticum* this variation is under genetic control.

The relation between chiasma frequency of the chromosome arms and their mitotic length was investigated in *Endymion nonscriptus*, and it was found that their chiasma frequency varies with length in the same way that genetical map distance is known to vary with cytological length along one chromosome. The behaviour of individual arms as the total chiasma frequency per nucleus changes was studied. Positive and negative correlations, and absence of correlation, between the chiasma frequency of different bivalents were found. The type of correlation is not related to the total chiasma frequency per nucleus, but results from the amount of internuclear variation.

*For the* PH.D. *Degree*

## A STUDY OF MUTATIONS OF *CHLAMYDOMONAS REINHARDI* DANGEARD

*By* JOHN NORMAN HARTSHORNE

*Trinity College, Cambridge, and the University of Wales*

A REVIEW of the relevant literature shows that unexpected and possibly unique genetical behaviour has been attributed to certain unicellular algae. The work concerned is largely unconfirmed, and the need for independent investigations of a similar nature has been stressed on numerous occasions. A start was made in developing fundamental genetical study of *Chlamydomonas reinhardi*, a heterothallic unicellular member of the Volvocales.

The technique for making crosses and analysing their progeny is described in detail. Experimental study of zygote germination has led to improvement in technique, and a generation may now be completed in three weeks.

Cultures were irradiated with ultra-violet light with the intention of producing mutations. It was demonstrated that, as in other micro-organisms, the lethal effects of ultra-violet light may be considerably reduced by exposure to visible light immediately after irradiation. From the progeny of irradiated cells five mutant clones were isolated and used for genetical experiments. One mutant ('eyeless') lacked the eyespot, and the other four showed

reduced growth rate. All five appeared to differ from wild-type by single gene mutations.

Reciprocal crosses between eyeless and wild-type were tested for the presence or absence of eyespot and for mating type. There was no evidence of linkage between the two loci involved. The progeny from these crosses also segregated for two factors affecting colony size, which were named 'small-colony' and 'slow-growth'. Test crosses carried out to study the inheritance of these characters support the hypothesis that the two genes concerned are both suppressed by the wild-type allele at the eyeless locus, and are expressed only in the presence of the mutant allele.

The four induced slow-growing mutants are due to mutations at four different loci. There is no evidence of linkage between any two of them, nor between any one of them and mating type.

A significant excess of four-type tetrads in certain crosses is attributed to interference, and this prevented the accurate calculation of map distances. All the loci studied, except those for the eyeless and 'slow-growth' genes, appear to be widely separated from their centromeres.

All genetical results are consistent with crossing-over at the four-strand stage.

Absence of the eyespot is not associated with complete loss of sensitivity to light, though the phototactic responses of the eyeless mutant are less rapid and less uniform than those of the wild-type. It is considered that sensitivity to light is not confined to the eyespot, and may be to some extent a property of the entire protoplasm.

*For the* PH.D. *Degree*

## STUDIES ON THE FLORA AND VEGETATION OF THE SIERRA DE CAZORLA

*By* VERNON HILTON HEYWOOD

*Pembroke College, Cambridge, and the University of Edinburgh*

THE Sierra de Cazorla consists of a complex of limestone mountains in the botanically neglected province of Jaén in south Spain.

The predominant tree vegetation is of forests of *Pinus clusiana* which, it is shown, constitute the climax formation in the greater

part of the territory. There is a lesser development of *P. halepensis* and *P. pinaster* at lower altitudes in more xerophytic regions, the latter species being found especially where the soil is decalcified. The evergreen oak, *Quercus ilex*, is the potential climax formation in the lower, more xerophytic parts of the territory, although to-day it is very scarce in tree form as a result of anthropogenic action (felling, burning, etc.) which favours replacement by *Pinus halepensis*. *Quercus lusitanica* occurs sporadically in the lower and middle parts of the territory but does not form forests.

At about the tree limit, *c.* 1600–1800 m., commences a vegetation of spiny chamaephytes and nanophanerophytes, principally *Echinospartum boissieri*, *Erinacea anthyllis* and *Ptilotrichum spinosum* (xero-acanthetum), and these, with dwarf junipers (*Juniperus communis montana* and *J. sabina humilis*), give a characteristic appearance to the upper slopes.

Floristically rich saxicolous and scree communities are found on the summit slopes of the peaks, and those of the outer part of the territory are characterized by *Pterocephalus spathulatus* and *Convolvulus nitidus*. When these communities merge into xero-acanthetum formations, an intermediate type, subxero-acanthetum, lacking a clear dominance of spiny species is formed.

The rupicolous vegetation is rich and varied, and several new communities, including those characterized by *Pinguicula vallisneriifolia*, are recorded.

The climate is remarkable for its high rainfall, the annual total ranging from 1000 to 2000 mm. in several stations. This is reflected in the predominance of *Pinus clusiana* and a strong representation of mesophytic or boreal species such as *Buxus sempervirens*, *Helleborus foetidus*, *Sorbus aria*, *Ilex aquifolium*, etc.

Three vegetational zones are delimitable in the territory: a lower one between 700 and 1300–1400 m. with *Pinus halepensis*, *Quercus ilex*, *Pistacia terebinthus* well represented (here is included the *maleza*, a wild scrub of *Quercus ilex* with *Arbutus unedo*, *Phillyrea* spp., *Erica arborea* and *Cistus* spp. in a localized humid climatic enclave); a middle zone between 1300–1400 and 1700–1800 m. characterized by a great development of *Pinus clusiana* with *P. pinaster*, *Quercus lusitanica*, *Acer* spp., *Crataegus*, *Berberis*, etc.; and an upper zone between 1700–1800 and 2000 m. with xero-acanthetum and dwarf juniper communities.

A critical catalogue is given of all species of flowering plants and ferns known to occur in the territory, based mainly on the author's own collections and those of Reverchon. A careful synonymy is given for each taxon, with reference to its place of publication. In most cases a summary of the general ecology of the species within the territory is given, and often critical notes on its taxonomy, distribution or nomenclature.

Several new taxa are described, including ***Fumana paradoxa*** Heywood, an apparent case of introgressive hybridization, and *Astragalus sempervirens* subsp. *giennensis* Heywood, which forms part of a clinal pattern of variation.

A total of about 800 species is recorded, the majority of them with a more or less Mediterranean distribution; the percentage of Spanish endemic species, 30 %, is notably high. A number of species are new for the province of Jaén, and a few have not been previously recorded in Andalucía.

*For the* PH.D. *Degree*

## STUDIES IN THE SUSCEPTIBILITY OF PLANTS TO VIRUSES

*By* JOHN HAROLD HITCHBORN

*Fitzwilliam House, Cambridge, and the University of London*

SOME factors affecting the susceptibility of plants to infection with tomato mosaic virus and tobacco necrosis virus were investigated. These include nitrogen supply, pre-inoculation darkness, decapitation of the plant, and age of leaf.

French beans (*Phaseolus vulgaris*) grown in sand and receiving no added nitrogen were less susceptible than plants receiving nitrogen at any of the levels tested. The most susceptible plants were usually those receiving nitrogen at a rate which reduced growth. Plants grown during the summer without nitrogen or with nitrogen at a low level were always more susceptible after a period of 1–4 days' darkness. The susceptibility of plants receiving the highest level of nitrogen tested was increased to a much smaller extent by similar periods of pre-inoculation darkness. This result suggests that pre-inoculation darkness increases susceptibility by

increasing the amount of organic nitrogen available in the leaf.

The effect of periods of pre-inoculation darkness on French bean plants was found to vary with season. During the summer susceptibility was increased by the treatment. At other times of the year treatment had little effect on susceptibility.

Removal of the top portion of tobacco (*Nicotiana tabacum* and *N. glutinosa*) plants at various times before inoculation with virus usually decreased the susceptibility of plants to tomato mosaic virus. The susceptibility to tobacco necrosis virus of French bean and tobacco was not affected by similar treatment. With both viruses differences in susceptibility between plants were reduced by decapitation. Defoliation was not as effective as decapitation in reducing susceptibility. Possible reasons for the effect of decapitation are discussed.

The susceptibility to tomato mosaic virus of leaves of different ages on tobacco and *N. glutinosa* plants was measured, using two methods of inoculation. The upper leaves were usually more susceptible than the lower leaves to inoculation by pricking. The reverse was true when the rubbing method was used. It is suggested that the number of lesions produced by pricking is influenced by the closeness with which the cells are packed.

The significance of these results in relation to previous work is discussed.

*For the* PH.D. *Degree*

## A TAXONOMIC REVISION AND ECOLOGICAL STUDY OF BRITISH *THYMUS*

*By* CHRISTOPHER DONALD PIGOTT, M.A.

*Emmanuel College, Cambridge*

### *Taxonomy*

1. The genus *Thymus* is represented in the British Isles by at least three taxonomic divisions (*T. drucei*, *T. pulegioides*, *T. serpyllum*). Comparative studies of natural populations and cultivated samples show that these divisions differ in growth form, leaf dimensions and hair arrangement on the stems. Stomatal size and distribution provide further differential characteristics.

2. British populations of *T. serpyllum* and *T. pulegioides* show marked genotypic homogeneity, contrasting with the wide variation of *T. drucei*. Simple biometric studies of stature and leaf dimensions suggest that *T. drucei* includes several ecotypes.

3. Comparison of *T. drucei* with central European races of *Thymus* suggests that this species is more closely related to *T. alpigenus* and *T. humifusus* (*T. praecox* agg.) than to *T. serpyllum*.

4. The following chromosome numbers were determined in British and Continental European material:

*T. serpyllum* subsp. *serpyllum*, $2n = 24$.
*T. pulegioides* subsp. *pulegioides*, $2n = 28$.
*T. pulegioides* subsp. *froelichianus*, $2n = 28$.
*T. drucei*, $2n = 52–56$.
*T. alpigenus*, $2n = 56$.

5. Internal and external barriers operate to isolate the three British species genetically. *T. serpyllum* and *T. pulegioides* show a low interfertility, but neither will apparently cross with *T. drucei*.

6. Reasons for regarding the three divisions as distinct species are discussed. It is suggested that *T. drucei* may be an allopolyploid of which *T. serpyllum* is possibly one diploid ancestor.

*Ecology*

7. *T. drucei*. Morphological features of ecological significance are described. Seed production is regular in lowland habitats throughout the British Isles. Seedlings require protection from disturbance in their early stages; radicle elongation is inhibited or retarded on 'mor' humus. *T. drucei* shows wide climatic tolerance, but requires well-drained soils with at least a low exchangeable base content; it is intolerant of shade and competition and occurs in many different communities.

8–9. *T. serpyllum* and *T. pulegioides*. A general autecological account is given. *T. serpyllum* is restricted to very 'open' communities on sandy soils. *T. pulegioides* is most frequent on the south-east English chalk and appears to be climatically limited northward and westward owing to reduced reproductive capacity.

10. Grazing and clearance are important factors in relation to the inland distribution of *Thymus*.

11. *T. drucei* is widespread throughout the British Isles. *T. pulegioides* is almost confined to England. *T. serpyllum* occurs only on the Breckland of East Anglia.

12. The probable history of the species since the last glaciation is discussed.

*For the* PH.D. *Degree*

## THE PRINCIPLES OF VEGETATIONAL CLASSIFICATION AND THE ECOLOGY OF WOODWALTON FEN

*By* MARTIN EDWARD DUNCAN POORE, B.A.
*Clare College, Cambridge*

THE first section (four-fifths of the work) is a discussion of continental methods for the description and classification of plant communities, especially those of Dr Braun-Blanquet.

These methods have been held in disrepute in this country, partly because their exponents have made untenable claims for them. The dissertation first expounds the methodology and methods of Braun-Blanquet (without criticism). Next, certain refinements of Braun-Blanquet's field technique are suggested, without departing from his principles. These are discussed in the light of other continental and British work. As it appears that the value of the Braun-Blanquet system is empirical, the methods are applied, in modified form, to plant communities in Breadalbane, Perthshire. These are described, and the problems arising in their description are discussed. This constitutes an exercise in the use of plant sociological techniques.

The results of this empirical study do not support Braun-Blanquet's hierarchical classification of vegetation, already suspect on theoretical grounds. The facts can only be explained by a multidimensional classification. But the technique is considered valuable because, by its use, well-defined units may be distinguished and named, and many ecological problems may be partially solved or, at least, accurately defined.

The second section of the dissertation deals with the ecology of Woodwalton Fen. A general description of the vegetation is given. This can be divided into two seres, the *Calamagrostis* sere and the *Molinia* sere. Data are presented to show that these differ

in their history and in the peat type on which they occur. The *Molinia* sere is thought to have continuity with the original vegetation, the *Calamagrostis* sere none. This hypothesis is supported by stratigraphical and historical data. The development of the present vegetation has also been modified by changes in water level during the last 100 years. The behaviour of the fen water table is found to differ in some respects from that at Wicken.

*For the* PH.D. *Degree*

## DEVELOPMENT OF DICOTYLEDONOUS LEAVES WITH SPECIAL REFERENCE TO THEIR VENATION

*By* BRENDA FAULKNER SLADE

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1. Clearing methods are principally used throughout this investigation.

2. A detailed account of the venation pattern of *Cercis siliquastrum* is presented under the following headings:

(i) Stem apex and origin of leaf primordia.

(ii) Origin of the lamina by marginal growth and the initiation of its embryonic layers.

(iii) Origin of main veins in midrib and lamina.

(iv) Origin of veins of higher orders, their distribution and relationship to the main vein system.

3. The ontogenetic changes of the leaf are described during the two phases of growth, namely,

(i) The meristematic phase, and

(ii) The stage of cell enlargement.

4. Similar investigation upon *Prunus serrulata* and *Acer pseudoplatanus*, although they vary in minor detail, shows a similar pattern of origin and development of leaves to that of *Cercis siliquastrum*.

5. The following problems have come to light, and appear to have escaped previous attention:

(i) The relationship of the origin of major veins and the minor venation pattern to the distribution of meristematic activity in the leaf.

(ii) The rupture of ultimate veins to form vein-endings during the phase of cell enlargement. This appears to be purely a mechanical process, and the frequency of vein endings in the mature venation patterns can be correlated with specific differences in (*a*) the average size of the embryonic islets; (*b*) the amount of leaf expansion and cell enlargement following cessation of cell divisions in the vein mesophyll layer; and (*c*) the distribution of bundle-sheath extensions. The character of the mature 'reticulum' is very largely determined by these extensions, which 'reinforce' the minor venation against mechanical breaking.

(iii) The discontinuity of the initial xylem.

(iv) The continuous thickening of the veins by incorporation of lateral files of 'vascular tissue' formed at the periphery of the embryonic islets.

6. The open *accretive* character of the dicotyledonous vascular bundle is emphasized in contrast to the *closed* bundle with limited growth in monocotyledons. Although venation patterns and leaf forms may be similar in either group, the vascular bundle construction remains distinct. The problem of cambial activity within the procambial cells of the large accretive bundle is also discussed.

7. A unified system of nomenclature for describing veins is used throughout this work. It is suggested that this or a similar system might be more widely employed for description of leaf venation.

*For the* PH.D. *Degree*

## THE SYNTHESIS OF SUCROSE BY A PLANT ENZYME SYSTEM

*By* JOHN FREDERICK TURNER

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THE aim of the investigation was to obtain a plant enzyme system capable of synthesizing sucrose.

Using extracts from various plant tissues, a search was made for a sucrose phosphorylase of the known bacterial type which would catalyse the reaction

glucose-1-phosphate + fructose $\rightleftharpoons$ sucrose + phosphate.

Crude extracts from peas were found to form sucrose and inorganic phosphate from a mixture of glucose-1-phosphate and fructose. The activity of these crude extracts was relatively labile and was not associated with particulate matter. The amounts of glucose-1-phosphate, fructose, sucrose and inorganic phosphate present during the course of the reaction showed that the system was unlikely to be a simple sucrose phosphorylase of the bacterial type. The presence of a phosphofructokinase was demonstrated in the crude preparations.

The enzyme system responsible for sucrose synthesis was partially purified by precipitation with ammonium sulphate and subsequent dialysis. The addition of a boiled pea extract was necessary to restore the activity, and the system was inactive in the absence of $Mg^{2+}$ ions. The boiled pea extract was replaceable by nucleotide fractions prepared from peas or yeast, and the coenzyme activity of these fractions was acid-labile. The boiled pea extract could also be replaced by a diphosphopyridine nucleotide preparation, and the activity of this preparation was increased by the addition of uridine monophosphate or adenosine phosphates. Fructose could not be replaced by fructose-6-phosphate, fructose-1-phosphate, or fructose-1:6-diphosphate, but glucose-1-phosphate could be replaced by fructose-6-phosphate. Mechanisms of the synthesis are discussed.

Some properties of a sample of synthetic sucrose are compared with those of an authentic specimen.

Sucrose synthesis by the partially purified enzyme preparation was inhibited in an atmosphere of nitrogen or *in vacuo*. Manometric experiments showed that the system had no oxygen uptake but that it liberated carbon dioxide. Fructose disappeared more rapidly in nitrogen than in air, and the carbon dioxide output was increased. The possible significance of these observations in relation to the Pasteur effect was considered.

*For the* PH.D. *Degree*

# STUDIES OF THE INTER-GLACIAL AND POST-GLACIAL HISTORY OF BRITISH VEGETATION

*By* DONALD WALKER, M.A.

*Clare College, Cambridge*

A REVIEW of the geology and archaeology of the Quaternary Period in Great Britain in relation to those of western Europe as a whole was attempted. Special consideration was given to the Late-glacial geology of the north of England.

An organic deposit at Cambridge was assigned to the last (Eemian) Interglacial on the evidence of pollen analyses which compare closely with those from this period from Jutland and the Netherlands.

Late-glacial and Post-glacial deposits from Seamer (near Scarborough), Skelsmergh and Kentmere (Westmorland), Moorthwaite Moss, Tarn Wadling and St Bees (Cumberland), as well as from a number of less important sites, were examined. The results obtained allowed a tentative reconstruction of the vegetational development of the north of England since the Newer Drift Glaciation and a comparison of this development with that of the rest of the British Isles and of Continental Europe. The north-west seems to have had far greater affinities with Ireland, north Jutland and South Norway than with the rest of England and Europe. The north-west, on the other hand, developed parallel with the south-east and with western Germany and the Netherlands until the Atlantic period and the flooding of the North Sea basin. Even during the Post-Atlantic period the vegetation of the north-west and that of the north-east seem to have been rather different in composition.

The early age of the Scottish Readvance Glaciation was established, and suggestions regarding the extent of glaciation during Zone III of the pollen analytical chronology in the Lake District and the western Pennines are made. The value of 'Inter-glacial peats' at St Bees as indicative of conditions between the Main Lakeland Glaciation and the Scottish Readvance was examined.

The interplay between vegetation and human activity was investigated as closely as possible. The chronological position and the ecological background of a Mesolithic settlement at Seamer are described, and data relevant to the study of the impact of farmer cultures on the vegetation of the north-west are presented.

## (2) *PARASITOLOGY*

*For the* PH.D. *Degree*

## PARASITIC PROTOZOA

### (*a*) AN *IN VITRO* STUDY OF *ENTAMOEBA INVADENS*, INCLUDING THE EFFECT OF AMOEBICIDAL DRUGS

### (*b*) STUDIES ON ANTIMALARIAL COMPOUNDS AND DRUG RESISTANCE IN AVIAN MALARIA

*By* ELSPETH WILSON MCCONNACHIE, M.A.
*Newnham College, Cambridge*

*An* in vitro *study of* Entamoeba invadens, *including the effect of amoebicidal drugs*

AN *in vitro* study of *Entamoeba invadens* was undertaken for comparison with the known characteristics of *E. histolytica*. The strains of *E. invadens* studied were growing with only two species of bacteria, and had been produced from chemically treated cysts. A monobacterial strain of *E. invadens*, growing with *Bacterium coli*, was also obtained. Data were obtained for the survival of cysts and amoebae at different temperatures and after treatment with chemicals; the amoebae were found to be adversely affected by free oxygen. The growth of amoebae and the size of cysts were found to be influenced by different media and bacteria. The effects of starch and temperature on the growth of the amoebae were also investigated. The encystation of two strains of *E. invadens* was studied in different media. Under certain conditions an increase in the production of cysts was correlated with the depletion of starch in the medium. *E. invadens* was found to be less sensitive to emetine than *E. histolytica*, but the response of the two

organisms to three quinaldines was similar. The relationship of *E. invadens* and *E. histolytica* and *E. ranarum* was discussed.

*Studies on antimalarial compounds and drug resistance in avian malaria*

The effect of prolonged treatment with sulphadiazine or proguanil upon latent infections of *Plasmodium gallinaceum* and *P. relictum* was studied for comparison with the known effects of these drugs on strains of malaria maintained as acute blood infections. Resistance failed to develop in the treated latent infections or in a strain of *P. gallinaceum* maintained as an acute blood infection in which the numbers of parasites exposed to the drug were relatively small. It was found that a strain of *P. gallinaceum* which was fully resistant to proguanil was not hypersensitive to sulphadiazine, and that a sulphadiazine-resistant strain was not cross-resistant to certain pyrimidine precursors of proguanil, nor to 3′-5′-dibromosulphanilamide. Antimalarial activity was discovered in 2:4-diamino-6:7-di*iso*propylpteridine, and the response of proguanil- and sulphadiazine-resistant strains of *P. gallinaceum* to this compound and to 2:4-diamino-6:7-diphenylpteridine was determined. Evidence was obtained that the 2:4-diaminopteridines constitute a heterogeneous group of compounds.

## (3) ZOOLOGY

*For the* PH.D. *Degree*

# OBSERVATIONS ON THE GERM CELLS OF SOME INVERTEBRATE ANIMALS

*By* MRS ANNE HIBBARD GOSS CAMERON

*Girton College, Cambridge, and Dalhousie University*

SINCE Leeuwenhoek discovered spermatozoa in the seventeenth century these cells have received a good deal of attention from cytologists. In the last 10 years the electron microscope has been increasingly used in the study of sperm morphology. As most of this recent work has been done on the sperm of vertebrates, it was decided to apply the modern cytological methods to a study of the

structure of the sperm of some invertebrate animals. Accordingly, sperm of the following species were examined: the slugs, *Deroceras reticulatum*, *Arion hortensis*, *A. ater*, *A. circumscriptus*, *Milax sowerbii* and *Testacella haliotidea*; the cockroach, *Periplaneta americana*; and the earthworm, *Lumbricus terrestris*.

Observations were made on living material by means of the phase-contrast and polarizing microscopes. Fixed and stained sections and smears were observed under the ordinary light microscope. Cytochemical tests for DNA, lipids, arginine, cholesterol and polysaccharides were carried out on the sperm of some of the species. Whole mounts and sections were examined under the electron microscope. Some of the sperm were treated with salt solutions, enzymes, acids and alkalis. These reagents brought about digestion or solution of certain structures in the sperm, thus revealing others which had been difficult to see in normal untreated material.

The morphology of the sperm as revealed by these methods is described and is compared with that reported in the literature for the sperm of the same and closely related species.

Indications of the chemical composition of some of the structures observed in the sperm are pointed out and are compared with the cytochemical reactions which have been reported for other sperm. In general, the results obtained for the sperm examined were similar to those which had been described for the sperm of vertebrates.

The morphology of the sperm examined was compared with that of vertebrate sperm which have been observed under the electron microscope. On the whole it was found to be less complicated than that of the vertebrate sperm.

The fibrils in the axial filaments of the sperm examined were found to be very similar in size, arrangement and number to the fibrils of the axial filaments of other sperm, and to the fibrils in the flagella and cilia of many organisms throughout the plant and animal kingdoms.

*For the* PH.D. *Degree*

# SOME PHARMACOLOGICALLY ACTIVE SUBSTANCES FOUND IN INSECTS

*By* MALCOLM LAURENCE CAMERON

*King's College, Cambridge, and Dalhousie University*

THE structure of the corpus cardiacum of *Periplaneta americana* and its relations to the brain are explained in detail.

The pharmacological activity of extracts of corpus cardiacum and brain of the insect on the isolated heart, gut and Malpighian tube is outlined. Extracts of corpus cardiacum increase rate, amplitude and co-ordination of contraction in these isolated tissues. Extract of brain increases rate and amplitude but not co-ordination in gut and Malpighian tubes. The effect of brain extract on the isolated heart is due to acetylcholine, to which the gut and Malpighian tubes are not sensitive. The corpus allatum does not stimulate these tissues.

These extracts are active from a threshold concentration just under 1 pair glands or 1 brain per 100 ml. of Ringer solution to an optimum concentration 10 times as great. Higher concentrations of corpus cordiacum extract cause over-stimulation; higher concentrations of brain extract have little further effect. Nerve section experiments show that the corpus cardiacum substance is produced in the gland. This substance was isolated and shown to be an orthodiphenol homologous to adrenaline. It is produced in the central body of the gland.

Evidence is presented to show that it may be identical with the chromatophorotropic hormone of the corpus cardiacum.

This corpus cardiacum substance is believed to be the insect equivalent of adrenaline.

*For the* PH.D. *Degree*

# COLD ACCLIMATIZATION IN INSECTS WITH ESPECIAL REFERENCE TO THE GERMAN COCKROACH *BLATTELLA GERMANICA* LINN.

*By* EARNEST HOWARD COLHOUN

*Christ's College, Cambridge, and the Ontario Agricultural College*

IN the voluminous literature on temperature and poikilothermal activity an occasional paper is found dealing with temperature acclimatization. The majority of work has been carried out with fish.

In respect of insects, it has been shown within recent years that their activity at low temperatures above the freezing-point of water is modified by their previous thermal history, thus indicating that insects acclimatize to temperature. Thermal acclimatization experiments were carried out with several species of insect, but particularly with the German cockroach, *Blattella germanica* Linn. The results are summarized below.

(1) A constant-temperature apparatus was constructed which made possible the acclimatization and exposure of insects to temperatures from 1° C. upwards in the laboratory.

(2) It was established that there was a relation between the temperatures at which the insects were kept and activity at low temperatures. Insects held at 15° C. were able to remain active at low temperatures at which others held at 25 and 35° C. were immobilized by cold.

(3) Insects kept at 10° C. did not show increased activity over those held at 15° C., which suggests that there is a temperature below which further acclimatization is not possible.

(4) Experiments were conducted upon the rate of acclimatization when the insects were transferred from one temperature to another. It was found that the rate of acclimatization depends upon the magnitude, position and direction of the thermal change.

(5) Data obtained from the rate of recovery from cold immobilization or chill-coma showed that there was a relation between the acclimatization temperatures, the period of exposure

to low temperatures, the temperature of exposure and the temperature of recovery.

(6) It was further established that there was a relation between acclimatization temperatures and the rate of survival at temperatures above freezing.

(7) It is concluded that *Blattella germanica* Linn. acclimatize to the temperatures at which they are kept in the laboratory, but that the degree of acclimatization is negligible in respect of the survival of the species. It is more indicative of a subtle change in physiological state, and this should be taken into consideration when conducting experiments on insects and temperature, especially where another factor, such as a toxin, is involved. The physiological mechanism of temperature acclimatization is not known, but in the light of observations in the present work and information in literature certain theories are discussed. The central nervous system appears to play a part.

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*For the* PH.D. *Degree*

## THE SEASONAL ECOLOGY OF DRAGONFLIES (ODONATA)

*By* PHILIP STEVEN CORBET

*Gonville and Caius College, Cambridge, and the University of Reading*

THE work described represents a comparative treatment of the mechanisms involved in the seasonal regulation of development and reproduction in British dragonflies. The life-histories of five species were studied under natural conditions; in two of these, diapause was investigated in the laboratory.

In *Anax imperator* Leach eggs were found to be laid from June until August and to hatch after about 3 weeks. Active larval growth occurred only between May and October. Although variation in larval size was wide, total adult emergence was restricted to 6 weeks each year. Two emergence groups were recognized: the first, comprising about 90 % of the annual adult population, emerged during the first 10 days; the second group emerged about 20 days later. The first group consisted of larvae which had entered the final larval instar in summer, 1 year after

hatching from the egg, and had then postponed emergence until the following spring. Experiments showed that this was brought about by a facultative diapause in the final instar induced by any photoperiodic regime in which daily increments were less than 2½ min. Diapause development was completed in autumn. In this way all larvae entering the final instar after 1 June embarked upon diapause and emerged the following spring. In larvae attaining the final instar before 1 June diapause was prevented; these underwent metamorphosis without delay and formed the second emergence group.

Of the remaining species studied only *Pyrrhosoma nymphula* (Silzer) was found to have a life history similar to that of *Anax imperator*. *Lestes sponsa* (Hansemann), which was univoltine, was found to have an obligate diapause in the over-wintering egg. Diapause development was completed most rapidly at 10° C., taking about 100 days. *Coenagrion mercuriale* (Charp.) was semivoltine and *Sympetrum striolatum* (Charp.) univoltine, but in neither species could a well-developed diapause stage be recognized.

The five species studied fall into two groups. *Anax imperator* and *Pyrrhosoma nymphula* have a diapause in the final larval instar and a short, well-synchronized emergence in spring. The other species lack diapause in the final instar and have an extended, poorly synchronized emergence later in the year.

Data collected for the other British dragonflies indicate that they all fall into one of these two groups. The general implications of this classification are discussed.

*For the* PH.D. *Degree*

## ON SOME TRIASSIC CYNODONTS FROM TANGANYIKA

*By* ALFRED WALTER CROMPTON

*Downing College, Cambridge, and the University of Stellenbosch*

A COLLECTION of gomphodont cynodonts obtained from the Upper Horizon (Middle Trias) of the Ruhuhu valley in Tanganyika was prepared. Two new forms, *Cricodon metabolus* and *Aleodon*

*brachyrhamphus*, are described, the former from an imperfect skeleton and the latter from a skull. The post-canine teeth of *Trirachodon angustifrons* Parrington are shown to differ sufficiently from the South African species of that genus to merit transfer to a new genus *Scalenodon*. A growth series of this form, consisting of nine upper jaws and six dentaries, is described, together with some post-cranial remains.

Two post-canine teeth in an isolated maxilla are shown to resemble those of *Gomphodontosuchus brasiliensis* F. von Huene from the Rio do Rasto Series of Brazil, and similarly the post-canine teeth of *Scalenodon angustifrons* resemble those of *Traversodon stahleckeri*, also from the Rio do Rasto Series. It is concluded that the Triassic cynodonts of the Ruhuhu valley compare more closely with those of the Brazilian Rio do Rasto Series than with those of South African deposits.

It is shown that there is evidence that the incisors and canines of *Scalenodon angustifrons* are replaced at least twice, and consequently the dental succession of this advanced cynodont cannot be considered as mammalian. The eruption of the incisor teeth appears to be distichic. It is shown that the ninth upper post-canine teeth of *Cricodon metabolus*, which are of the shearing type, are undergoing replacement by gomphodont teeth; that the ninth and tenth upper post-canine of *Scalenodon angustifrons* are apparently also being replaced in two specimens; and that the sixth upper post-canine of *Diademodon* sp.indet. is undergoing replacement. It is concluded that the use of the terms 'premolar' and 'molar' is unjustified in gomphodont cynodonts.

*For the* PH.D. *Degree*

## THE NERVES AND MUSCLES OF MEDUSAE

*By* GEORGE ADRIAN HORRIDGE, M.A.

*St John's College, Cambridge*

A CHARACTERISTIC feature of the behaviour of medusae is the symmetrical beat of the whole bell, which is co-ordinated in *Scyphozoa* by a network of motor nerve fibres. The qualities of this network imply the existence of a second conducting system re-

sponsible for activity other than the co-ordination of the contraction wave. The network of motor nerves in *Aurellia* and *Cyanea* is described, from both living and fixed preparations. It was shown that a bridge of tissue will conduct the contraction wave until the last nerve fibre running across has been cut, as seen under phase contrast. An action potential was recorded electrically from a single motor nerve fibre at each beat. A reinvestigation of the effects of continual stimulation showed that an explanation of the variation in size, frequency and distribution of contractions can be found in terms of discrete impulses which originate in the nerve net at the point of stimulation. It was also shown that in *Rhizostoma* the average refractory period of the population of striated muscle fibres shortens progressively when the muscle is repeatedly excited.

The co-ordination of Hydromedusae was also investigated, with emphasis upon the analysis of the pathways by which the excitation is transmitted about the bell. In *Aequorea* and *Geryonia* there are two kinds of excitation transmitted independently across the bell. The symmetrical beat depends upon a diffuse system which acts in a through-conducting, all-or-nothing manner. The movements of the manubrium depend on a radial conducting system which produces a maintained contraction of the manubrium. The action of the velum is analysed. The details of the nervous system are compared with the physiological pathways shown by experiment.

*For the* PH.D. *Degree*

## THE REPRODUCTION OF THE SOUTHERN ELEPHANT SEAL (*MIROUNGA LEONINA* LINN.)

*By* RICHARD MAITLAND LAWS, M.A.

*St Catharine's College, Cambridge*

THE general and reproductive behaviour of the species is described, the chronology of the annual cycle established, and the importance of fasting and the moult process discussed.

Initially formed by gregarious parturient females, the harems are maintained largely owing to the attachment between cow and pup. The bulls are concerned only with sexual gratification.

Virgin females probably mate aquatically, but mature females mate terrestrially because oestrus occurs during lactation when they remain on land.

The males attain sexual maturity in the fourth year. Rut lasts for about 3 months, from August to November, and multinucleate giant cells are present in the seminiferous tubules during the anoestrous period.

The female first mates when 2 years old. The right ovary and uterine horn are usually associated with the first pregnancy, and the function alternates in successive years. Although ovulation occurs about 19 days after parturition, implantation of the blastocyst is delayed for over 4 months, and the average duration of gestation is 50 weeks. Individual females give birth about a week later each year, so that after a number of years oestrus occurs too late to ensure impregnation. The female then undergoes a number of pseudopregnant cycles and mates early the following season.

In the annual reproductive cycle of the female there are two periods of follicular activity during pregnancy—at the beginning of the free blastocyst stage, and after implantation—but follicular maturation does not occur. From May until October follicular development is suppressed in both ovaries. The changes in the size and appearance of the corpus luteum are discussed, and descriptions of the cyclical changes in the uterine and vaginal mucosae are given. It is suggested that oestrogens are produced during oestrus and are present throughout the free blastocyst period. The corpus luteum does not produce progesterone until shortly before implantation, when the uterine mucosa shows progestational changes. The significance of delayed implantation is considered, and a connexion with the moult process is suggested.

*For the* PH.D. *Degree*

## (*a*) IONIC REGULATION AND THE FUNCTION OF THE ANTENNAL GLANDS IN SOME PALAEMONID PRAWNS

## (*b*) OSMOTIC AND IONIC REGULATION IN THE ISOPOD CRUSTACEAN, *LIGIA OCEANICA*

*By* GWYNETH DOROTHY PARRY

*Girton College, Cambridge, and the University of New Zealand*

*Ionic regulation and the function of the antennal gland in some palaemonid prawns*

PREVIOUS osmotic pressure measurements of the blood and urine of three species of prawns were confirmed. A fourth species was investigated. Blood and urine, which are isotonic, are both maintained at a relatively constant total composition when subjected to wide changes of external salinity.

Common inorganic ions were analysed in the blood and urine of the largest of these species. When the animal is in sea water, which is hypertonic to its blood, sodium, potassium and chloride are about 80 % of the outside concentration; calcium is more concentrated; magnesium and sulphate concentrations are very much lower. In the urine, chloride is a little higher than the blood, but sodium, potassium and calcium are 80–90 % of the blood concentrations. Magnesium and sulphate are present at roughly four times their blood concentrations. It is concluded that the main function of the antennal glands is to remove these two ions from the blood.

Similar analyses of fluids from animals in 50 and 120 % sea water demonstrate the absence of an osmoregulatory function of the glands, although their ion-regulating function is affected by different external concentrations.

The structure of the antennal glands and the relative merits of the theories of urine filtration or urine secretion are discussed. Estimates of the rate of urine production were made by three independent techniques. All three methods indicate a minimal

flow in isotonic conditions and an increase in hypo- and hypertonic ones.

Experiments to demonstrate ion exchanges showed that the animals are easily and quickly permeable to sodium and water (by using $^{24}Na$ and heavy water).

*Osmotic and ionic regulation in the isopod crustacean,* Ligia oceanica

The osmotic pressure of the blood of *Ligia oceanica* in its normal environment is about equivalent to 3·58 % NaCl, a little more concentrated than sea water. It is much higher than that of related terrestrial isopods or the fresh-water *Asellus*. The osmotic pressure of the blood increases during moulting, but no subsequent decrease was observed in the following 4 days.

Animals kept at low humidities lose water, and they may be desiccated until the blood is equivalent to 5·8 % NaCl. They will recover if returned to damp conditions. In well-aerated conditions of 50–100 % sea water the animals survive complete immersion without significant alteration of the blood osmotic pressure. Above and below these salinities the osmotic pressure rises and falls. Animals kept on filter paper wet with distilled water have a reduced blood osmotic pressure (2·4 % NaCl).

Analyses of the common inorganic ions in the blood show that sodium, potassium and chloride are all higher in concentration than sea water; calcium is very much higher; magnesium and sulphate are very much reduced.

*For the* PH.D. *Degree*

## THE EFFECTS AND MODE OF ACTION OF EXTERNAL FACTORS REGULATING REPRODUCTIVE CYCLES AND SPAWNING IN TELEOST FISH

*By* DAVID ERNEST SERGEANT, M.A.

*Corpus Christi College, Cambridge*

THE reproductive maturation and overt secondary sexual characters of three species of fresh-water teleosts, namely,

stickleback *Gasterosteus aculeatus* L., minnow *Phoxinus laevis* L. and bitterling *Rhodeus amarus* Bloch, were studied under different experimental conditions of daily light-dark cycle and of temperature. In stickleback males long day length brought about early development of the secondary sexual characters, but did not hasten testicular maturation. The effect was first produced in mid-winter and came about more rapidly as the natural spawning period was approached. In minnow males long day length brought about full spermatogenesis with development of spawning tubercles in late winter, a 24 hr. day being more effective than a 16 hr. day. A high temperature had the same effect, the optimum temperature being near 18° C. In minnow females high temperature and long days advanced oocyte ripening, but great individual variation among the fish obscured the optimal conditions.

In bitterling females different levels of light duration and intensity had no effect on the growth of the ovipositor at any stage of the reproductive cycle. Temperature rise caused growth which was transient only. The presence, however, of a mussel, which is the natural site of oviposition of the bitterling, brought about full ovipositor growth, even in total darkness.

The literature on maturation and spawning in teleosts is reviewed. It is shown that a threshold temperature, variable for different types of fish but with some phylogenetic constancy, is required for maturation to proceed actively. A further threshold is required for spawning to occur. Experimental work showed that a stimulus of long day length hastens maturation in some, but by no means all, teleosts. A visual stimulus of the environment elicits spawning in several species previously studied. The thesis is therefore advanced that two or more such factors—a temperature stimulus and a stimulus of diffuse light or of a perceived object—summate in nature to bring about maturation and spawning at the biologically optimal period.

The mechanism of the light stimulus was studied in the female bitterling. It was shown that blinding led to loss of the corpora lutea in the ovary and to cessation of ovipositor growth, which was, however, renewed in some individual fish. The stimulus of the mussel is regarded as part visual and part tactile.

Using growth of the bitterling ovipositor for assay, gonadotrophic activity was found in extracts of crude pituitary

but not in those of various regions of the brain taken from trout.

Neurosecretory material in the preoptic nucleus and in the neurohypophysis of bitterlings and sticklebacks was found to show a constant histological picture throughout the year, not varying with the sexual cycle of the fish.

No histologically visible connexion was found between the pars distalis of the pituitary and the hypothalamus.

The mechanism of the neural control of secretion of gonadotrophins was not, therefore, clarified by this study.

*For the* PH.D. *Degree*

## AGGREGATION IN CELLULAR SLIME MOULDS

*By* BRIAN MYER SHAFFER, B.A.
*Trinity College, Cambridge*

IN the aggregation of a population of myxamoebae that have previously moved independently and at random a few cells, the primary centres, attract the other cells towards them. There was indirect evidence that this is a chemotaxis. Experiment and theory suggested that the actives ubstance, acrasin, is highly unstable. A technique for obtaining a cell-free preparation of this substance was successfully developed, and the attraction of the cells towards an artificial source was demonstrated. Acrasin has a half-life of about a minute at room temperature, but may be stored in the cold. A cell cannot secrete it in more than a certain concentration, and the cells in a mass partially inhibit each other's production of acrasin. There are specific D- and P-acrasins that mainly act on, and are made by, the genera *Dictyostelium* and *Polysphondylium* respectively; but, at certain stages, *Polysphondylium* cells make and respond to D-acrasin too.

The myxamoebae at different stages in the life history of the mould can be classified in a series of states differing in social organization; each is characterized by a qualitatively and quantitatively different combination of the following physiological properties: motility, stickiness, polarity, sensitivity to acrasin and secretion of acrasin. An important distinction is to be made

between integrated and unintegrated states: integrated cells adhere to each other strongly, if of the same species (but hardly at all if of different genera), and usually make acrasin; unintegrated cells have a much weaker mutual stickiness and do not make acrasin. Changes of state may be spontaneous, or partly or completely dependent on external factors. Integration, with secretion of acrasin, occurs in primary centres spontaneously, and in other cells, if they are sensitive, as a result of exposure to acrasin. This 'homoiogenetic induction' of the integrated state functions as a chemotactic relay system.

During aggregation, a clump of cells may, in a few seconds, disintegrate; it stops emitting acrasin and loses the stickiness that binds it together. This is only one of the possible types of reversal of development from a higher social state to a lower one; it may be followed by a return to some higher state. The absence, at times, of any discernible spatial or temporal pattern in the cellular transformations under uniform external conditions is ascribed to the simplicity of the developmental mechanism and principally to the absence of overriding factors impelling development in one direction, so that random fluctuations in the internal balance of the cell play a part in determining the path it follows in development.

# THE FACULTY OF BIOLOGY 'B'

## (1) *ANATOMY*

*For the* PH.D. *Degree*

## OBSERVATIONS ON THE PRENATAL DEVELOPMENT OF THE SKULL OF THE SHEEP

*By* WILLIAM RONALD BURSTON

*Pembroke College, Cambridge*

THE investigation was primarily concerned with the development of the skull of the sheep up to the period representing the optimal development of the chondrocranium, i.e. before the onset of endochondrial ossification.

Considerable quantities of fresh material, ranging from 4½ to 50 mm. crown/rump length, in closely graded developmental stages, were collected for this purpose. Methods of examination included the preparation of serial histological sections, the preparation of whole cleared specimens stained for bone and for cartilage, and microdissection. Older specimens (50–125 mm.) were cut into serial sections for use as adjuncts to the present work and to form a basis for future investigations.

A wax-plate model was made of the skull of a 48 mm. embryo to demonstrate the features of a fully developed chondrocranium. This is described in detail to form a basis for the description of the other stages. In the preparation of this model certain refinements of the Born method were elaborated to secure the maximum accuracy.

Two main lines of investigation of the earlier stages leading up to that of the optimal development of the chondrocranium were employed:

(1) The main outlines of chondrocranial development were traced by the examination of a close series of van Wijhe preparations. This method was standardized by reference to the histological sections so as to furnish reliable results.

(2) The emergence of the chondrocranium from the mesodermal condensations was examined in the histological sections.

An attempt was made to trace the origin of these condensations, and to this end a limited number of early somite stages were examined in addition to the above-mentioned material. Certain appearances were noted which suggested possible correlations with findings in the experimental field.

Examination by the histological method was carried into the later stages of development of the orbito-nasal region, the hypophysial region and the visceral skeleton.

The presence of paired trabeculae cranii was established, and the fate of these structures was traced into the later stages. It was established, contrary to previous findings, that the sheep possesses a spheno-ethmoidal commissure, and that the ala temporalis is a structure originally separate from the central stem and has an independent centre of chondrification. In addition, the continuity in the mesodermal stages of the anlage of the ala temporalis with that of the first visceral arch was demonstrated.

Finally, the findings in the sheep are discussed in relation to previous findings in other species from the standpoint of some of the many problems of cranial development and morphology.

## (2) *ANIMAL PATHOLOGY*

*For the* PH.D *Degree*

## A STUDY OF VIRUS PNEUMONIA OF PIGS AND RELATED CONDITIONS

*By* ALAN OSBORN BETTS, M.A.

*Magdalene College, Cambridge*

THE term 'Virus Pneumonia of Pigs' (V.P.P.) is suggested for the disease described by Gulrajani and Beveridge in 1951 and called by them, provisionally, 'Infectious Pneumonia of Pigs'.

Evidence was produced to suggest that V.P.P. has increased considerably since the end of the war. It now appears to be by far the commonest disease affecting pigs in Britain, and is a source of very great economic loss to the pig industry.

The clinical and epidemiological features of the experimentally produced, and the natural, disease were studied. Some attention

was paid to the differential diagnosis of the condition from pulmonary ascariasis.

In spite of the high incidence of the disease and the lack of any specific diagnostic test, it was possible to build up, purely by clinical examination on a herd basis, a herd free from V.P.P. to supply healthy piglets for an experimental investigation of the disease.

Experimentally, the virus proved to be a difficult agent to work with, but techniques were evolved to permit a study of the causal agent. Attempts to adapt the virus to small laboratory animals and embryonated eggs were unsuccessful, so that in all the investigations described the natural host was used as the experimental animal. In the pig it was possible to set up pneumonia only by direct injection of the virus into the respiratory tract. Filtration studies suggested that the virus is a large one, and the agent was found to be susceptible to aureomycin and terramycin but not to penicillin or the sulpha drugs. The virus was recovered from pneumonic lesions many months after infection.

Convalescent serum and an extract of old-standing pneumonic lesions failed to protect pigs against challenge with active virus, and attempts to produce active immunity were also unsuccessful, even when living virus was injected into the peritoneal cavity and a 'pathotopic potentiating agent' was used in addition. Attempts to evolve an allergic diagnostic test did not meet with success.

A possible method, based upon epidemiological considerations, for the eradication of the disease from infected herds was evolved, and the preliminary results of a trial in the field were encouraging.

*For the* PH.D. *Degree*

## TOXAEMIA OF PREGNANCY IN SHEEP: METABOLIC STUDIES WITH SPECIAL REFERENCE TO KETOSIS

*By* PETER DAVID STORIE PUGH, M.A.

*Queens' College, Cambridge*

A CONFUSED situation exists concerning both the diagnosis and the aetiology of toxaemia of pregnancy in sheep. A critical review was made and led to the formulation of a classification of those

diseases in late pregnancy associated with hyperketonaemia. Clinical and experimental data are given which support the classification advanced.

The experimental investigations are related to the *in vivo* study of the effect of pregnancy and starvation upon alternative metabolic pathways, with special reference to ketogenesis.

The principal object of this study was to determine whether an impaired metabolic efficiency located in the stages of the tricarboxylic acid cycle is responsible for the increased level of ketone bodies in fasting ketosis. Acetate and butyrate were used as test substances for the production of ketone bodies in the sheep under three different experimental conditions:

(*a*) during the course of normal pregnancy;
(*b*) in the pregnant ewe with experimentally induced ketosis;
(*c*) in the fasting non-pregnant ewe.

During the course of normal pregnancy little or no change was found either in the rate of volatile fatty acid uptake or in the production from them of ketone bodies. This was interpreted as showing that in the non-fasted pregnant animal there is no enhanced susceptibility to ketosis.

At the same time the results are reported of experiments designed to find out to what extent the oxidation of acetate may satisfy the energetic demands of the foetus under physiological conditions. It is found that the oxidation of acetate by the sheep foetus accounts for less than 10 % of the total oxygen consumption.

In marked contrast to the results concerning volatile fatty acid metabolism during normal gestation, it was found that in the fasting hyperketonaemic ewe the uptake of acetate from the blood is greatly slowed up. Conversely, the metabolism of butyrate is only decreased to a small extent. A close relationship between this inhibition of acetate uptake and the blood level of ketone bodies is seen; it is suggested that this relationship may be fortuitous, as a similar correlation with the blood-glucose level can also be demonstrated.

In order to determine whether this inhibition of acetate metabolism is simply an effect of starvation, unrelated to pregnancy, to ketosis, or to hypoglycaemia, the effect of fasting upon the metabolism of the same two substances was investigated in the non-pregnant and non-ketonaemic sheep. It was found that, although

there is a fall in rate with fasting, this is insufficient to account for the observed fall in ketosis. It can be concluded that the starving of a sheep in pregnancy inhibits the uptake of acetate from the blood without comparably affecting the uptake of butyrate.

The experimental results suggest that the specific inhibition of acetate metabolism occasioned by fasting in pregnancy occurs at some stage outside the tricarboxylic acid cycle, possibly in the preliminary activation of acetate, whereas the non-specific effect of fasting on the metabolism of the two volatile fatty acids takes place at some stage common to both.

The general conclusion is reached that the hyperketonaemia present in the fasted pregnant ewe is not the result of an impaired efficiency of the metabolic steps of the tricarboxylic acid cycle.

Simultaneously with these studies an investigation concerning the role of oestrogens, as one of the placental hormones, in affecting fat metabolism was initiated. An action of oestrogens in increasing lipid translocation to the liver without simultaneously increasing ketone body production in the non-pregnant female rat is described.

## (3) *BIOCHEMISTRY*

*For the* PH.D. *Degree*

## THE ENZYME RELATIONSHIPS OF THE PHENOLIC CONSTITUENTS OF THE POTATO

*By* MRS PARUKUTTY BARUAH, M.A.

*Newnham College, Cambridge*

THE dissertation deals primarily with the study of the constituents of the potato tuber which affect the activity of polyphenol oxidase. A brief historical survey of the work on potato polyphenol oxidase draws attention to the fact that very few studies have been made on the activity of the enzyme with the natural phenolic substrates and the effect of other cell constituents which limit the potential activity of the enzyme *in vivo*.

Two methods for measuring the rate of enzyme activity were developed, one based on the measurement of the formation of the brown colour during the oxidation of catechol, and the other a

direct determination of the disappearance of phenolic substrates measured spectroscopically. The limiting condition for the application of the first method is examined in detail, and the effect of aeration and ionic copper is stressed. These methods are compared with those of previous workers, and some of their advantages are noted.

The effect of ascorbic acid on the activity of polyphenol oxidase was studied in detail. The addition of ascorbic acid to a substrate-enzyme system not only delays the onset of browning but decreases the rate and intensity of colour production and the oxygen uptake. The reduction in the activity of the enzyme which is shown to occur in the presence of the vitamin is not reversed by ionic copper, but the role of the metal in enzyme browning is specially stressed. The effect of other inhibitors such as glutathione and cyanide are compared, and the results are correlated with those of other workers in order to assess the possible ways in which copper is bound to the enzyme.

In the presence of $\beta$-glycosidases, the activity of the enzyme was shown to be reduced. The probable explanation of this phenomenon and its relation to the *in vivo* activity of the enzyme is discussed.

The identity of the natural substrate is important in understanding the specificity and behaviour of the enzyme, and an approach was made by the study of the oxidation of some of the phenolic compounds actually occurring in potatoes and other plant tissues. Isolation and identification of some of the natural polyphenols of potato tuber, using chromatographic techniques, and their behaviour as substrates for potato polyphenol oxidase, is described. Some indication of the significance of the presence of polyphenols as glycosides in the tissue was found, and the probable limiting structure for the monohydric phenolic compounds which are oxidized by the enzyme was reduced.

The effect of ascorbic acid on enzymic browning and the *in vivo* activity of the enzyme was briefly examined, together with other possible rate-controlling mechanisms.

*For the* PH.D. *Degree*

# THE CLOTTING OF FIBRINOGEN

*By* FRIEDRICH RAPHAEL BETTELHEIM, M.A.
*King's College, Cambridge*

THE dissertation deals with work designed to elucidate the chemical mechanism of the final stage in the clotting of blood: the conversion of soluble fibrinogen into insoluble fibrin under the influence of the enzyme thrombin. The action of thrombin was found to result in the loss from each molecule of fibrinogen of probably two residues of amino-terminal glutamic acid, and the appearance of probably four residues of amino-terminal glycine. These facts led to the discovery that peptide material is released from the protein on clotting. The amino-terminal glutamic acid represents the tips of chains which are split off, while the amino-terminal glycine represents the 'scars' left behind on the main body of the protein molecule.

Several possibilities were considered to account for the fact that the number of amino-terminal glycine residues in fibrin is greater than that of amino-terminal glutamic acid residues in fibrinogen. It was eventually found that the peptide material contains molecules of at least two types, which can be separated by electrophoresis on filter paper at pH 4·1, and are called peptides A and B respectively. Amino-terminal glutamic acid is present in peptide A only. No amino-terminal residue is detectable in peptide B, suggesting that it may contain a cyclic chain; its presence is capable of accounting for the excess of the number of glycine over glutamic acid amino-terminal residues.

Peptides A and B were prepared on a small scale, and their constituent amino-acids were identified. Their isoelectric points differ by less than one-tenth of a pH unit, and lie close to 3·2. It was discovered that they display two unusual features. First, the amino-terminal glutamic acid residues of peptide A show a tendency to disappear under mild conditions, and at the same time there appears a new electrophoretic component in which no amino-terminal residues are detectable. Secondly, the phenolic

hydroxyl groups of the tyrosine residues in peptide B appear to be chemically blocked in some way.

A discussion is given of the factors responsible for the ability of fibrin to form rigid gels at very low concentrations.

*For the* PH.D. *Degree*

## SEPARATION OF PROTEINS ON ION-EXCHANGE RESINS

*By* NORMAN KEITH BOARDMAN

*St John's College, Cambridge, and the University of Melbourne*

THE basic proteins, lysozyme and cytochrome *c*, were subjected to chromatography on columns of the ion-exchange resin, 'Amberlite' I.R.C. 50. The effects of pH and sodium-ion concentration of the buffer on the adsorption of cytochrome *c* on the resin were studied in detail, and the information gained was used to predict conditions for the separation of neutral proteins. The behaviour of a protein on the resin is markedly different from that of ampholytes of low molecular weight, such as the basic amino-acids. Lysine is desorbed as the pH falls below 5 owing to suppression of the ionization of the resin carboxyl groups, but the adsorption of protein is greatly increased under acidic conditions. It is suggested that this is caused by a large increase in secondary short-range forces.

A method was developed for the separation of closely related neutral proteins by elution chromatography on the resin, Amberlite I.R.C. 50. Sheep-foetal carbon monoxide haemoglobin was separated from bovine carbon monoxide haemoglobin and bovine carbon monoxide haemoglobin from bovine methaemoglobin. Some preliminary experiments with bovine serum albumin and $\gamma$-globulin are also reported. To obtain good yields of the haemoglobins, it was found necessary to work at a temperature near 0° C. Tests carried out on bovine carbon monoxide haemoglobin eluted from the column indicated that the protein had the properties of the original material.

Attempts were made to develop a general method for the separation of neutral proteins, using the gradient elution

technique. A differential equation is presented describing the zone shape on a chromatogram which has been fed with a fluid of constantly rising concentration of solute, and the pH gradient down a column of a weak acid resin was calculated. A new adsorbent was made by copolymerizing methacrylic acid and divinyl benzene on to the surface of celite. Successful gradient elution of cytochrome *c* was obtained, but difficulties were experienced with carbon monoxide haemoglobin and the serum proteins.

*For the* PH.D. *Degree*

## OBSERVATIONS ON MITOSIS IN CULTURES OF NEWT TISSUES

*By* JEFFREY MARK NEWMAN BOSS

*Fitzwilliam House, Cambridge, and the University of London*

CULTURES of newt tissues were used as a source of mitotic cells, which were easily observed with negligible disturbance. The methods of cultivation and observation are described in detail, and the relation of the appearances of the cells to their state in the intact body is discussed.

The study of mitosis in living and fixed cells yielded the following information:

Examination of chromosomes in early prophase indicates that the former reproduce before the onset of mitosis. In late prophase the chromosomes show a characteristic arrangement which is probably a stage in the formation of the metaphase plate. Chromosomes pair in anaphase, and this pairing differs from that reported by other workers in that the chromosomes come together so closely that each pair has the appearance of a single body.

The movement of chromosomes along the spindle and the elongation of the spindle are not simultaneous; the former precedes the latter. Cleavage and spindle elongation begin simultaneously. Cleavage may be modified by tension in cell processes.

Ribonucleoprotein in the interphase nucleus is present not only in the nucleoli but also as fine granules lying among the chromonemata. In prophase the chromosomes become coated with ribonucleoprotein, which forms a matrix for the chromatids in

metaphase and is partly shed into the equatorial region of the cell in anaphase. Disturbances of the cell surface, which are a normal feature of late anaphase in culture and *in vivo*, are probably due to a substance, which may be ribonucleoprotein, released from the chromosomes. In telophase ribonucleoprotein lies between the chromosomes within each daughter nucleus.

*For the* PH.D. *Degree*

## THE INFLUENCE OF THE ANTERIOR PITUITARY GROWTH HORMONE ON NITROGEN METABOLISM

*By* MRS BARBARA JOAN GRAY, B.A.
*Newnham College, Cambridge*

WHEN anterior pituitary growth hormone is administered to an animal, it induces either growth or diabetes, depending on the animal employed. When growth occurs, the proportion of body protein increases. The nature of the extra protein deposited and the mechanism of its deposition form the subject of the research described in the dissertation.

The nature of the extra protein was examined in two ways: by chemical analysis, and by the determination of enzyme activity. Though the proportions of the three protein fractions determined chemically do not change, the specific activity of the myofibrillar adenosinetriphosphatase diminishes.

Non-protein constituents of the tissues were also examined. The concentration of ribonucleic acid in rat muscle was shown to increase after growth hormone treatment.

Tissue slices were used to investigate the mechanism of the growth-promoting action of the hormone. In them secondary effects of other hormones are eliminated, thus providing a system less complex than the living animal, though not so far removed as isolated enzyme systems. The effect of growth hormone on nitrogen metabolism in liver slices, liver homogenates and isolated diaphragms was studied. The addition of growth hormone *in vitro* increases glycine incorporation. Insulin causes a similar increase in glycine uptake.

Growth hormone was also found to effect the uptake of glycine by the tissues of the intact adult rat. By these experiments growth hormone-induced growth is shown to result from an increased rate of synthesis of new protein, and not from decreased breakdown of old. Growth hormone appears to act both directly, on metabolic processes, and indirectly, by the stimulation of the secretion of other hormones.

The resemblance between hormone-induced and normal growth and the relation between growth hormone and the pancreas are discussed. For full growth-promoting action an adequate supply of insulin is required.

*For the* PH.D. *Degree*

## THE α-KETOGLUTARIC OXIDASE SYSTEM

*By* FRANCIS ARTHUR HOLTON, M.A.
*Trinity College, Cambridge*

THE dissertation contains four chapters. The first gives an historical account of previous investigations of α-ketoglutarate oxidation in biological systems. While extensive studies of purified enzyme preparations have indicated some of the simple reactions which together make up the complete process of aerobic oxidation, little is known about the integrated enzyme system of the cell. An aerobic α-ketoglutaric oxidase system is present in certain intracellular granules, and the remainder of the dissertation examines some properties of this system as it is found in the large granules isolated from heart muscle.

Chapter II describes investigations, carried out with E. C. Slater, into the phosphorylation reactions associated with the aerobic oxidation of α-ketoglutarate. The kinetics of both oxidation and phosphorylation reactions were studied, and particular attention was paid to an accurate measurement of the ratio between the amounts of organic phosphate synthesized and the oxygen consumed. The value obtained for this ratio disagreed with the results of some other workers. Possible reasons for this are discussed.

Chapter III describes an unusual anaerobic reaction of α-ketoglutarate which took place in the simultaneous presence of heart-muscle granules and of a factor obtained from yeast. It consisted

of a dismutation yielding succinate, carbon dioxide and L-glutamate in equal molecular amounts, and occurred in the absence of stoichiometric amounts of ammonia. The results could be best explained by the occurrence of a new type of coupled reaction involving both dehydrogenase and transaminase enzymes.

Investigations summarized in Chapter IV were concerned with the nature of the hydrogen-transferring components of the α-ketoglutaric oxidase system. Visual spectroscopic observations were supplemented by a spectrophotometric method devised specially for this problem. The reversible reduction of endogenous respiratory carriers of heart-muscle granules could be observed and measured. By this means evidence was obtained that the α-ketoglutaric oxidase system includes both cytochrome *b* and cozymase, as well as other cytochrome components.

*For the* PH.D. *Degree*

## ENZYMIC INTERCONVERSIONS OF PHOSPHORYLATED HEXOSES IN HIGHER PLANTS

*By* BRIAN CRAYFORD LOUGHMAN

*Downing College, Cambridge, and the University of Wales*

THE work presented in the dissertation is concerned with two of the enzymes involved in the glycolytic cycle of higher plants. These enzymes are:

(*a*) phosphoglucomutase, catalysing reversibly the conversion of glucose-1-phosphate to glucose-6-phosphate;

(*b*) phosphohexoisomerase, catalysing reversibly the conversion of glucose-6-phosphate to fructose-6-phosphate.

The partial purification of phosphoglucomutase and phosphohexoisomerase from extracts of green pea seeds is described. A protein fraction was obtained containing both enzymes free from interfering enzymes such as phosphatase and amylose phosphorylase. The factors involved in the preparation and purification of the enzyme system were investigated, and a standard procedure was devised.

The purified preparation was used to study the properties of the enzymes. The effect of inorganic ions and pH on the activities

of the enzymes was investigated, and the concentrations of hexose monophosphates present at equilibrium were determined. A specific inhibition of phosphoglucomutase by low concentrations of boric acid was demonstrated.

The activation of phosphoglucomutase by a co-factor (presumably glucose-1:6-diphosphate) present in a preparation of fructose-1:6-diphosphate, and the enzymic synthesis of this co-factor in crude pea extracts, were demonstrated. The mechanism of the reaction catalysed by phosphoglucomutase and the biological synthesis of glucose-1:6-diphosphate are discussed.

The properties of the plant enzymes are compared with those reported for the same enzymes obtained from animal tissues.

A modified method for the analytical determination of fructose was developed and was used throughout the work.

*For the* PH.D. *Degree*

## THE MODE OF ACTION OF POLYMYXIN ON *PSEUDOMONAS AERUGINOSA*

*By* BRUCE ANTHONY NEWTON, B.A.

*Peterhouse, Cambridge*

POLYMYXIN B, a cyclic peptide antibiotic, is rapidly bactericidal for a number of strains of *Pseudomonas aeruginosa*. The limiting inhibitory concentration of the antibiotic depends upon the size of inoculum used in growth tests. Treatment of washed cell suspensions of *Ps. aeruginosa* with a concentration of polymyxin which kills 99·9 % of a bacterial population results in less than 30 % inhibition of glucose oxidation and doubles the endogenous respiration of the cells; this concentration also causes a release of pentose, phosphate and materials which have an absorption maximum at 260 m$\mu$ from the cells.

The limiting inhibitory concentration of polymyxin is increased by the addition of non-toxic cations to the growth medium. Washed cells can be protected against the bactericidal action of polymyxin by pretreatment with certain cations, and it was shown that the cations prevent the absorption of polymyxin by competing with it for sites on the cells.

That an immediate change in cell permeability results on treatment with polymyxin was demonstrated by the use of a dye (*N*-tolyl-α-naphthylamine-8-sulphonic acid) which forms fluorescent conjugates with protein. Measurement of the rate of penetration of this dye into cells treated with polymyxin in the presence of certain cations provided data on the relative affinities of these cations for the 'polymyxin-combining groups' of the cells; the results indicate that the polymyxin-combining loci of the cells may be polyphosphates. A fluorescent derivative of the antibiotic was prepared, and the localization of this compound in a sensitive organism was studied.

Cell walls of a polymyxin-sensitive and a polymyxin-resistant strain of *Ps. aeruginosa* were prepared; the amount of polymyxin absorbed by the cell walls of the latter was less than 25 % of that absorbed by those of the sensitive strain. Certain differences in the phosphorus and lipid content of the cell walls of these two strains were found.

From the results obtained it is suggested that the bactericidal activity of polymyxin is due to its ability to combine with and disorganize a cell membrane or osmotic barrier.

*For the* PH.D. *Degree*

## OXIDATIVE CATALYSIS BY COPPER IN BIOLOGICAL SYSTEMS

*By* JOHN FLETT SCAIFE

*Emmanuel College, Cambridge, and the University of New Zealand*

A STUDY was made of the combination of copper with several amino-acids, peptides and crystallized proteins. The ability of the resulting complexes to catalyse the aerobic oxidation of ascorbic acid was also measured.

When a soluble copper salt is added to a solution of an amino-acid, it is difficult to determine the extent of combination, especially if the solution is buffered, since buffer salts often form soluble copper complexes. These difficulties were avoided by equilibrating sparingly soluble malachite with solutions of amino-acids and related compounds in bicarbonate-carbon dioxide buffers.

The solubility of malachite could be explained quantitatively by assuming it to be in equilibrium with cupric ions and a soluble complex, $CuCO_3$.

When the concentration of free copper in solution is defined, the relative avidity of the compounds can be conveniently compared. The dissociation constant of copper glycine obtained by this means agreed with values recently published; this is believed to support the postulated existence of a $CuCO_3$ complex. The relation between avidity and amino-acid or peptide structure is discussed.

At a constant concentration of free copper, the number of atoms of copper bound to a molecule of bovine plasma albumin, pepsin or lysozyme was independent of the concentration of protein over a wide range. Combination appeared to take place, therefore, at a number of independent sites. Evidence was obtained that not all of the sites had an equal avidity for copper.

The catalytic power of the amino-acid and peptide complexes varied much less amongst themselves than did the affinity of their parents for copper. Sodium chloride is known to be a powerful inhibitor of the copper-catalysed oxidation of ascorbic acid; in comparison, the catalytic power of copper glycine was found to be hardly affected. This differential effect made copper glycine a more powerful catalyst than free copper at the higher concentrations of chloride and a weaker catalyst at low concentrations.

Atom for atom of bound copper, the catalytic power of the protein complexes was less than that of the amino-acid complexes. The pepsin complex was approximately three times more powerful than the albumin complex. Compared with the other two proteins, lysozyme hardly combined with copper at all, and the complex possessed the property of strongly inhibiting the catalytic activity of free copper and copper glycine. Some evidence was obtained that the copper bound to the more reactive sites in the pepsin molecule had a greater catalytic activity than the more loosely bound copper; there was no such difference in the case of bovine plasma albumin.

*For the* PH.D. *Degree*

# BACTERIAL METABOLISM OF PEPTIDES

*By* MRS PAMELA JUDITH TALALAY, B.A.
*Girton College, Cambridge*

VARIOUS aspects of the bacterial metabolism of the tripeptide glutathione were investigated. These included studies on the estimation, synthesis and breakdown of this compound, as well as transpeptidation reactions between glutathione and amino-acids.

The glutathione content of a number of bacteria was estimated by the specific activation of dialysed yeast glyoxalase. *Escherichia coli* was found to contain more free glutathione than *Staphylococcus aureus*, but the latter contained an active glyoxalase which interfered with the estimation. The properties of staphylococcal glyoxalase were found to differ from those of the yeast or liver enzyme in that it could not readily be resolved into apo-glyoxalase and coenzyme glutathione under a variety of conditions.

Cell-free extracts of *Esch. coli* actively synthesized glutathione from glutamic acid, cysteine and glycine. Hexose diphosphate, coenzyme I, adenosine triphosphate, potassium phosphate and magnesium ions were required for the reaction.

Extracts from *Esch. coli* which synthesized glutathione did not hydrolyse this compound. Washed cell suspensions and extracts of *Proteus vulgaris*, however, broke down glutathione to its component amino-acids. Paper chromatographic investigation of the reaction products when phenylalanine and certain other amino-acids were added to glutathione and *Proteus* cells showed the formation of new materials having the properties of $\gamma$-glutamyl peptides of the added amino-acids. These reactions were studied and found to resemble the transpeptidations described in mammalian and plant tissues.

Certain antibiotics were without effect on glutathione synthesis. Breakdown and transpeptidations were inhibited only by very high concentrations of some of these compounds.

*For the* PH.D. *Degree*

# STUDIES ON THE CHEMISTRY OF CELL DIVISION

*By* MICHAEL GEORGE WEBB

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SECTION I. *The influence of magnesium on bacterial cell division*

IONIC magnesium is required specifically for the maintenance both of bacterial growth in simple chemically defined nutrient solutions and of normal cell division of the Gram-positive rods in peptone media. Thus, with the possible exception of divalent manganese, other metallic ions, of valencies and ionic radii similar to $Mg^{2+}$, are unable to replace magnesium in these processes.

In simple chemically defined media a deficiency of magnesium limits the growth of bacteria but is without effect upon cell division. The magnesium requirements for optimal growth of bacteria in such simple nutrient solutions are reduced markedly by the addition of amino-acids. In complex amino-acid solutions, as in peptone media, a reduction in the magnesium content below *c.* 10 p.p.m. leads to the formation of filaments in cultures of the Gram-positive bacilli, lactobacilli and clostridia. Under the same conditions no change is observed in the morphology of the Gram-negative rods.

Chemical analysis shows that the average amount of deoxyribonucleic acid per normal cell of a given bacterial species in the resting state is constant, whereas the deoxyribonucleic acid content of the filamentous forms of the Gram-positive rods varies with the length of the filaments. If these filaments are counted as the equivalent number of cells of normal size, a constant value is obtained for the deoxyribonucleic acid content of the 'unit cell' which is identical with that found for the normal cell of the same species.

The constant deoxyribonucleic acid content of the normal cell, or 'unit cell', is used as a standard of reference to determine changes in chemical composition associated with the growth of bacteria in magnesium-deficient peptone media. Such analyses show that growth of Gram-positive bacteria in the magnesium-deficient medium results in a decrease in both the acid-soluble

nitrogen and protein nitrogen contents of the cells, whereas growth of Gram-negative bacteria under the same conditions does not lead to significant alterations in the contents of either of these cell constituents. From these and the previous results it is concluded that the formation of filaments in cultures of the Gram-positive rods is not caused by direct inhibition of cell division by the lack of magnesium, but results from the inhibition of amino-acid assimilation.

SECTION II. *Cytochemical observations on the cell division of metazoan cells*

The May–Grunwald and Giemsa staining method stains ribonucleoproteins dark blue and deoxyribonucleoproteins purple-red. This differential staining of the nucleoproteins and the general specificity of the method are established by (i) comparison with other staining procedures, (ii) digestion experiments with ribonuclease and deoxyribonuclease, (iii) studies of the effect of the May–Grunwald and Giemsa dyes on isolated nucleic acids and nucleoproteins.

Application of this staining procedure to cultures of chick fibroblasts before and after treatment with ribo- and deoxyribonuclease reveals that the chromosomes of cells in mitosis contain significant amounts of ribonucleoprotein. This ribonucleoprotein, which accumulates on the chromosomes in prophase and which, in part, may be derived from the nucleolus, reaches its maximum concentration at metaphase. In anaphase ribonucleoprotein appears to be shed from the two groups of daughter chromosomes as they separate and to concentrate in the cytoplasmic area between them. In telophase, when the daughter nuclei form, the remaining ribonucleoprotein disappears from the chromosomes.

The possible implications of these findings are discussed.

SECTION III. *The action of mitotic inhibitors on the enzymic depolymerization of deoxyribonucleic acid and deoxyribonucleohistone*

Initial studies, which fail to reveal any inhibitory action of a number of mitotic poisons on the activity of pancreatic deoxyribonuclease on calf-thymus deoxyribonucleohistone, lead to an investigation of the intracellular distribution and properties of the deoxypentosenucleases of various tissues. A procedure is

described for the isolation and purification of these enzymes, which are found among the cytoplasmic components of the cells.

The properties of the purified deoxypentosenucleases, while closely similar among themselves, differ appreciably from those of pancrease deoxyribonuclease.

The insensitivity of the deoxypentosenucleases to a number of mitotic poisons, studied with other chemical substances as potential inhibitors of the enzymes, suggests that the biological activities of these agents are not due to their ability to inhibit deoxypentosenuclease activity.

Although the enzymes may possibly be involved in deoxyribonucleic acid metabolism, their cytoplasmic location and low pH optima suggest that they do not play a functional role in the mitotic cycle.

*For the* PH.D. *Degree*

## THE DEAMINATION AND DEPHOSPHORYLATION OF ADENINE NUCLEOTIDES IN MUSCLE

*By* HENRY LEWIS WEBSTER

*Downing College, Cambridge, and the University of Sydney*

A STUDY was made of the rate and extent of breakdown of adenosine triphosphate (ATP) by homogenates of rabbit muscle, with particular reference to the inhibition of the fibre ATP-ase by the M-B factor.

This inhibition is observed consistently in homogenates of fresh muscle, where the fibre ATP-ase is almost totally suppressed. The effect is not due to resynthesis of ATP or diversion of ATP to esterification reactions, nor is it influenced by the concentration of ATP. Removal of this inhibition occurs when the reaction is carried out at low ionic strength, and also when the final concentration of the homogenate is reduced below a critical level. The ATP-ase activity is also stimulated greatly by extremely low concentrations of Ca (0·1 mM).

A wide variation in the degree of inhibition is observed in homogenates of rigor muscle, but, where present, is removed by low concentration of Ca.

On the other hand, the ATP-ase activity of samples of washed brei does not exhibit the same response to Ca. This type of material was studied in relation to the influence of pH, degree of dilution, concentration of substrate, and of Ca and Mg on the fibre ATP-ase; and comparisons were made with similar studies on fresh homogenates. The results are discussed in relation to the mechano-chemical properties of the M-B factor observed by other workers.

It was also observed that washed muscle brei can deaminate ADP directly, with which the presence of residual myokinase interferes. The latter enzyme was shown to be suppressed by ethylene diamine tetra-acetate, but this reagent has no marked effect on either ADP- or AMP-deaminase. The accumulated inosine diphosphate was identified by paper chromatography and ionophoresis. The pH-optimum for this deamination is about 6·2, and the enzyme is dependent on sulphydryl groups for its activity. It could not be detected in preparations of washed heart muscle, nor in actin or myosin separately. The deamination of ADP is discussed in relation to the results of other investigators.

## (4) *BOTANY*

*For the* PH.D. *Degree*

## MECHANISMS CONCERNED IN THE SYNTHESIS OF STARCH IN PLANTS

*By* WILLIAM RONALD REES, B.A.
*Trinity Hall, Cambridge*

FOR convenience of presentation the account given of the investigations described in the dissertation is divided into two sections. Section I deals with the preparation of the substrates required for the enzymic work discussed in Section II.

SECTION I. A full investigation was made of the fractionation of potato starch, using pyridine as an amylose precipitant. The optimal conditions for this separation were studied in a series of small-scale experiments, and the information obtained was applied to a large-scale preparation of amylose. Some details are given

of the use of cellulose as an adsorbent in the purification of the amylopectin fraction.

The preparation and purification of the first six members of the linear maltodextrin series by the method of charcoal chromatography is described.

SECTION II. The methods described in the literature on the subject for the preparation of Q-enzyme from potatoes were compared. Reasons for the lack of reproducibility of the activities displayed by such preparations were sought. It was found that traces of lead ion are inhibitive, and that an amylose precipitant present in potato juice produces erratic results. A method for the removal of this amylose precipitant, as well as for the removal of phenolic materials which cause the darkening of potato juice, is described. A reproducible method for obtaining Q-enzyme preparations was devised.

During the course of experiments designed to investigate the possible role of maltodextrins as co-substrates for Q-enzyme action, a new enzyme system was discovered in the potato. This new enzyme, designated D-enzyme, bears a similarity to the *B. macerans* amylase and to amylomaltase in its action.

It was shown that D-enzyme is capable of effecting a redistribution of α-1 : 4-linkages in the maltodextrins, giving rise to linear products of higher and lower molecular weight than the parent dextrins. Some of the products stain a deep red with iodine. An account is given of certain characteristics of the enzyme action, including its specificity requirements. The possible role of D-enzyme in the economy of the plant cell is discussed.

Work on the Q-enzyme system was largely confined to an examination of the possibility that, under suitable conditions, the maltodextrins take part in the reaction between Q-enzyme and amylose, acting as acceptors for the short chains transferred by the enzyme from the amylose substrate and thereby becoming part of the synthetic amylopectin molecule. Evidence is presented in support of this hypothesis.

## (5) *EXPERIMENTAL PSYCHOLOGY*

*For the* PH.D. *Degree*

# THE EFFECT OF PROPAGANDA ON RECALL, RECOGNITION AND BEHAVIOUR

*By* MRS EUNICE BELBIN, M.A.
*Girton College, Cambridge*

IN some field experiments carried out on behalf of the Road Research Board, propaganda was shown to children in cinema clubs in an attempt to influence their behaviour on road crossings. This propaganda had no effect on their behaviour, although they recognized and recalled the propaganda material quite well. Children who used the crossings correctly were not always those who recognized or recalled the material best. These results are in conflict with the assumption which has hitherto been made that propaganda is likely to affect behaviour in proportion to the extent to which it can be recognized or recalled. Laboratory experiments were therefore conducted in order to discover to what degree and under what conditions recall and recognition of propaganda are related to its effects upon behaviour.

In the first experiment the extent to which adults and children recalled and recognized propaganda material was compared with the length of time they spent looking at it, how well they understood it, and how it affected their behaviour on a subsequent task. It was found that some subjects who understood the propaganda were not able to describe or recognize it, although it affected their behaviour. Others who could describe or recognize it failed to understand it and were not influenced by it.

The results of this experiment made it clear that the information which had been learned from the propaganda material could become apparent in two distinct ways: (*a*) in recall or recognition, (*b*) in subsequent behaviour.

A further series of experiments was conducted to find the circumstances which caused effect (*a*) or (*b*) to be more apparent in some subjects than in others. (*a*) was relatively less marked in people over 60. Effect (*b*) was considerably greater than (*a*) in

older people and in those who had previous behavioural experience of a relevant kind.

The ways in which information may be retained in relation to the manner in which it may be learned were examined. A hypothesis is suggested which shows how the previous learning experiences in an individual's history will determine the method by which incidental information is learned and, in consequence, the way in which it is retained.

*For the* PH.D. *Degree*

## EXPERIMENTAL STUDIES OF ADULT LEARNING

*By* HARRY KAY, M.A.
*Trinity Hall, Cambridge*

AFTER a brief assessment of what was known about the effects of ageing upon learning performances, the dissertation presents ten experiments examining some of the characteristic features of adult learning. Several of these studies were undertaken with a light-key apparatus specifically built to provide serial learning tasks of varying difficulty, but the scope of the research was widened by including experiments on the learning and remembering of different kinds of verbal material.

All studies revealed some decline in the learning performances of older subjects, but the amount varied considerably according to the difficulty of the task, the kind of material, and the different criteria for success adopted by subjects. The performance of a simple operation showed that younger subjects (the twenties) were sacrificing accuracy for speed, whereas the older group (over 55) were doing the reverse.

In no experiment did it appear from the analysis of performance that older subjects were introducing new learning features, but they were accentuating tendencies which were common enough to all age groups. In contrast to the customary emphasis upon older people's failure of memory, it was felt that their main learning deficiency was the tendency to repeat errors. In a range of tasks from rote learning to transformation problems an older

subject's difficulty was not so much the formation of a general 'scheme' but its subsequent amendment. This feature—learning involves unlearning—was applicable to all age groups: progress was rarely barred by 'blankness' but by an irrational insistence upon wrong 'solutions', and it was the inability to accept the evidence against these erroneous predilections which distinguished poorer performances, whether by older subjects or by clinical and neurosurgical patients.

In the discussion some of the difficulties and deficiencies of learning theories are brought out, and it is argued that the complexity of human adult learning precludes us, for the present, from making a satisfactory theory with unambiguous relationships between its variables. But, working within the biological framework, there is a sufficient corpus of accredited knowledge to indicate many of the more worth-while issues for study, and the present findings are regarded as a contribution to establishing that record of human behaviour without which there is little possibility of formulating a satisfactory theoretical model.

*For the* M.Sc. *Degree*

## AGE AND WORK IN AGRICULTURE

*By* HOWARD FREDERICK KING, M.A.
*Emmanuel College, Cambridge*

THE studies described form part of a programme of research into the effects of ageing upon skilled performance. The relation between age and nature of work and other features of the occupation was studied among persons engaged in agriculture and ancillary trades to see how far, and at what points, available material could be used to advance the knowledge of ageing.

Methodology is first considered, and then evidence is presented upon age distributions in the main categories of agricultural work, changes of job, labour turnover, part-time work and productivity. The relatively high proportion of older workers in agriculture is not evenly distributed over the separate categories; the nature of the work and changes in demand over the years are both important here. The other data are used in an attempt to relate the

observed differences to age factors. Features of agricultural employment favourable to older workers seem to be: the long experience of almost all such persons; the wide range of tasks, allowing selection of jobs for persons whose range of ability is restricted; and the practicability of arrangements for part-time work.

An analysis of 2000 farm accidents shows, for example, increase with age in falls and decrease in cases of self-inflicted injury. Possible explanations are examined. The nature and site of injury, and the job being done at the time, also show interesting trends with age.

Evidence from training schemes is presented and appears to indicate that although the speed of learning decreases with age, suitable adjustments of the training situation can, in some circumstances, have an ameliorative effect.

The observed changes with age can be summarized as leading to greater carefulness and slowness, but explanations of their operation or of the locus of change are not yet available. If our knowledge is to be advanced by field investigations, a co-ordinated system of recording information, although not yet available, will be essential.

*For the* PH.D. *Degree*

## SOME EXPERIMENTS ON MOTOR PERFORMANCE IN RELATION TO AGEING

*By* JAKUB SZAFRAN, M.A.
*Fitzwilliam House, Cambridge*

THE interest of many psychological studies of ageing has been restricted to establishing a relation between the subject's 'score' and his 'ability'. Experimental and clinical observations make it clear, however, that the overall response of a subject in a test is often less valuable, as an indication of his potential, than the manner in which a given task is dealt with. The experiments here described were designed to explore in detail differences associated with age in the methods used by adults to deal with simple perceptuo-motor tasks.

It was observed that:

(1) There were no differences in achievement when the relationship between visual information and a motor action was simple,

but the older approached the task with a higher level of care. When the same display and motor task stood in an unusual relationship, subjects in the fifties were less accurate. Although the achievement of the thirties and forties was comparable to that of the twenties, the methods whereby this was attained were different. The older appeared to compensate for the encountered difficulty by concentrating their effort on a more easily comprehended aspect of the task. Subsidiary experiments suggested that a reversal of display-control relationship caused more difficulty to the older individuals than to the younger when no distinct pattern for movements was provided.

(2) The thirties and older tended to look more at what they were doing than the younger. This was investigated in greater detail in further experiments which suggested that restriction of the visual peripheral field could not alone account for the observed difference.

(3) When unable to make use of vision, the older had greater difficulty in locating small items in the surrounding space and attempted to seek additional proprioceptive data. They were slower than the younger during the initiation of an action and in the waiting time between one action and another in a sequence, but the age groups did not differ in the speed of execution of the individual movements.

(4) When unable to guide their hands with vision, the older encountered greater difficulty than the younger in 'matching' a horizontal movement with a vertical misalignment. The age groups did not differ when, under the same conditions, a horizontal movement had to be 'matched' with a horizontal misalignment.

It is suggested that the observed tendencies emphasize in a general way the relatively greater importance of direct visual information in middle and later life. The experimental data indicate the possibility of a change in the perceptual organization of vision and kinaesthesis rather than of a failure within the proprioceptive or motor system.

Two incidental findings are also reported:

(*a*) A difference between civilians and servicemen in their preferred speed at a task apparently not associated with occupation. The observed difference produced spurious age correlations

and emphasized the problem of generalized occupational transfer effects in relation to studies of ageing.

(*b*) Some evidence on the relation between transfer and difficulty of initial task. Relatively more positive transfer was observed from a difficult initial task to one which was easier than from a relatively easy to a relatively difficult one.

## (6) *PATHOLOGY*

*For the* PH.D. *Degree*

## SEROLOGICAL STUDIES ON FOUR BLOOD GROUP ANTIGEN-ANTIBODY SYSTEMS OF THE RABBIT

*By* MRS DOROTHY HELEN HEARD

*Newnham College, Cambridge, and the University of London*

The dissertation describes the isolation of four of the blood group antigen-antibody systems of the rabbit. It is prefaced by an account of previous work in this field which explains how earlier in this century six of the rabbit's blood groups had been discovered, but then, as the reagents were lost during the last war, the work had to be begun again.

A difficulty encountered early in the investigation was that the red cells from individual rabbits varied markedly in their agglutinability after treatment with antisera which apparently contained only the homologous antibody. This property of the red cells was investigated, and reasons are put forward suggesting that it is due to variation in the number of available antigen sites on each red cell.

The detection of the antibodies to the four antigens by some of the common reagents and methods used in human blood grouping work is mentioned, and a note on the inheritance of the antigens is appended.

## (7) *PHYSIOLOGY*

*For the* PH.D. *Degree*

# HISTOCHEMISTRY OF NEURONES WITH SPECIAL REFERENCE TO THE RETINA

*By* FRANCIS MATHEW CHALISSERY

*Fitzwilliam House, Cambridge, and the University of Madras*

THE retina and other parts of the nervous system of vertebrates were studied histochemically to find out the chemical basis of structure in its relation to function. Certain enzymes which have a possible role in neuronal and interneuronal transmission and photochemical mechanism (in the retina) were localized. New methods were developed to localize adenosine triphosphatase and monoamine oxidase; and a modified method of Koelle was used for localizing cholinesterase, while existing methods were used to localize succinic dehydrogenase and an esterase hydrolysing higher fatty esters of choline. The histochemical findings support the view that acetylcholine may act as a mediator of transmission across certain synapses (like those between the bipolar cells and ganglion cells in the retina) and of conduction along some fibres (e.g. the ventral root fibre), and that adenosine triphosphate may mediate conduction along certain other fibres (dorsal root fibres, for example). Monoamine oxidase is found in the greatest concentration in certain cells (neurones) in the adrenal medulla, while succinic dehydrogenase is found in the ellipsoids of the photoreceptors, the ellipsoids being, probably, the seat of synthesis of visual pigments.

The different neurones can be grouped roughly into two types: large cells with coarse, discrete particles of Nissl substance, abundant glycolipids and prominent nucleoli, and small cells with finely granular or diffuse Nissl substance and very little glycolipid; intermediate forms are also seen. This division into two types is well seen in the ganglion cells of the retina. In these cells no difference is found in the nature, distribution and amount of Nissl substance between stimulated (by light) and resting (in the dark) retinae. Satellite nucleoli are present in most neurones,

and no relationship could be found between their occurrence and the sex of the animal, in contrast with the claims of some previous investigators.

Among other substances localized, the various lipids were investigated in detail in the retina with some significant results. Carbohydrates were also localized. The structural relationships of certain cells in the retina (amacrine and horizontal cells) were investigated by silver staining methods. By silver and vital staining methods the large ganglion cells (in the cat and rabbit retinae) were found to have their dendrites spread over an extensive area approximately 0·75 mm. in diameter; this is very similar in extent to the receptive fields of a single ganglion cell in these species, as determined by electrophysiological methods.

*For the* PH.D. *Degree*

## SODIUM AND POTASSIUM MOVEMENTS IN RED CELLS

*By* TREVOR IAN SHAW, B.A.

*Clare College, Cambridge*

PREVIOUS workers had established that the high concentrations of potassium and low concentrations of sodium found in the red cells of many species were not maintained by an impermeability of the cells, but were connected with metabolism. The present work sought the mechanism by which these ions penetrate red cells.

Sodium and potassium movements were studied with the aid of radioactive tracers, so that the net movement of an ion was resolved into its two component fluxes. The fluxes were measured with the cells suspended in media containing sodium and potassium in complementary concentrations. Thus the relationship between the flux and the concentration of an ion, which is governed by the mechanism of ion transport, was found.

In the presence of glucose the potassium influx increased at first rapidly, then more slowly and linearly with increasing external potassium concentrations. The outflux, however, was independent of the external potassium concentration, but was

proportional to the slope of the linearly rising potassium influx. The sodium influx, which increased rapidly at first and then more slowly with increasing external sodium concentrations, tended to rise again as the potassium of the external medium was wholly replaced by sodium. Overall movements of sodium were from the cells and were small in media of low potassium concentration.

Shaking the cells for a few hours in the absence of glucose resulted in the potassium fluxes becoming sensitive to glucose; the influx obeyed a Langmuir isotherm with respect to the external potassium concentration, and the outflux was dependent upon the composition of the suspending medium.

The results are interpreted in terms of a potassium leak and a sodium-potassium exchange pump. A mechanism for the pump is suggested.

An appendix to the dissertation describes a search for lipid soluble sodium and potassium compounds in red cell stroma.

# THE FACULTY OF CLASSICS

*For the* PH.D. *Degree*

## LATE ROMAN MILITARY ARCHITECTURE IN BRITAIN AND NORTHERN GAUL, WITH SPECIAL REFERENCE TO THE COASTAL DEFENCE SYSTEM

*By* RONALD MORLEY BUTLER, B.A.
*Peterhouse, Cambridge*

THE dissertation is a study of all the buildings erected for military purposes in Britain and northern Gaul during the period A.D. 250–400. Devastating barbarian invasions and pirate raids in the later third century led to the fortification of many previously unwalled cities, to the construction of a new frontier line, and to the creation of coastal defences. These new military works are characterized by thick and lofty defensive walls, usually containing re-used masonry from earlier monuments, and by projecting towers, generally semi-circular in plan.

In the area studied the fortifications known to archaeologists, some 250 in all, may be divided into three main groups: the forts of the Rhine frontier zone, the city walls of the interior of Gaul, and the coastal stations of Britain. The features of the individual sites in each group are first described according to a uniform system, and the general characteristics and chronology of the sites are then considered. Fuller descriptions and more numerous illustrations (twenty-five of the sixty-three plates) are devoted to the well-preserved walls of Le Mans, Jublains, Pevensey, Porchester and Richborough, considered to be key sites for the understanding of the nature of the coastal defences. The chapters on the main groups of fortresses are preceded by an introductory section in which the history of the period is summarized, features of earlier town defences are reviewed, and the relevance of the Notitia Dignitatum is discussed.

The frontier defences are seen to have been the work of several successive emperors, in particular Diocletian and Valentinian I.

The latter's building activity between the years A.D. 369 and 375, recorded by Ammianus Marcellinus, is amply attested by archaeology. The Caesar Constantius is thought to have been responsible for most of the city walls of Gaul. In the coastal districts and the north-west, however, forts and town defences of rectangular plan, showing connexions in technique with the Saxon Shore forts of Britain, may be explained as the work of Carausius. These, together with the principal coastal forts of southern England, are accordingly assigned to the period A.D. 286–293. The essay concludes with a survey of the relationship between the late Roman fortifications in the area under discussion and those elsewhere in the Empire.

*For the* PH.D. *Degree*

## A STUDY OF IMAGERY IN LATIN VERSE OF THE SILVER AGE IN THE GENRES OF EPIC, TRAGEDY, DIDACTIC VERSE AND SATIRE

*By* MICHAEL COFFEY, M.A.
*St John's College, Cambridge*

ANCIENT critics maintained that each literary genre has its own laws of propriety of style. Modern research has shown that in practice Latin poets observed such laws strictly in the choice of vocabulary. The present work is an attempt to determine how far such notions of propriety governed the choice of subject-matter and the function of imagery in the verse of the Silver age.

After an examination of the simile in the earlier Greek and Roman epic tradition, it is shown that the Silver age epic poets conform to and even limit the range of subject-matter of their predecessors, in particular in the avoidance of technical and banausic themes. The functions, too, of their similes are the same as in the previous tradition. There are a few exceptions in the work of the innovator Lucan, who seems impatient with a strict system of generic propriety.

Simile and metaphor in the tragedies of Seneca, the only extant writer of tragedies in the Silver age, approximate for the most part

to those of epic, to which the genre of tragedy in Latin is closely akin. But a certain number of the metaphors in Seneca's tragedies are alien to the language of high poetry. He uses metaphors from commercial and legal life, the function of which is to illustrate moral judgements and evaluation. This departure from the canons of high poetry is to be explained in terms of the moralizing purpose of Seneca's tragedies, in which Stoic ideas and a rhetorical presentation of irrational passion are important. A comparison of the imagery of the *Octavia* with that of the tragedies proper gives a little further support for rejecting its authenticity.

The *Aetna*, the main representative of didactic verse in the Silver age, is in the tradition of Empedocles and Lucretius, and contains elements of high poetry, but the main function of the imagery is to elucidate and explain; the subject-matter includes mechanical topics such as are not permitted in epic. The tenth book of Columella is in the tradition of the Alexandrian handbook in verse; its explanatory imagery includes the sordid.

The verse parts of Menippean satire use imagery to parody high poetry, as in the *Apocolocyntosis* and in the long verse extracts in Petronius, as part of a pastiche of epic and tragedy. Satire proper has a wide range of colloquial simile and metaphor. Persius uses the imagery of high poetry only in order to burlesque it. Juvenal's imagery contains elements of diatribe, but occasionally violates the canons of the genre of satire in that it includes epic-style similes used without parody in a serious context.

It is established that, in the four genres examined, Latin poets of the Silver age deferred to tradition in their adherence to a system of propriety in their use of simile and metaphor. Lucan's departures from the epic norm are relatively unimportant. The two writers who show a marked departure from the system of propriety are Seneca, whose purpose in writing his tragedies was was in part didactic, and Juvenal, some of whose satires have a serious moral purpose.

*For the* PH.D. *Degree*

# PROLEGOMENA TO THE STUDY OF MAGIC AND SUPERSTITION IN THE *NATURAL HISTORY* OF PLINY THE ELDER, WITH SPECIAL REFERENCE TO BOOK XXX AND ITS SOURCES

*By* PETER MORRIS GREEN, B.A.

*Trinity College, Cambridge*

THE dissertation represents initial work towards the collocation and interpretation of evidence relating to magic and superstition in Pliny's *Natural History*, with the ultimate aim of relating its conclusions to the general development of magic as a social phenomenon in Greece and Rome. It was written with the following principles in view: (*a*) that the term 'magic' differs widely, often radically, from country to country, century to century, and often between individuals in the same country and century; and (*b*) that therefore the approach must begin with the individual writer and an analysis of his personal attitude to the subject and not by the enunciation of general formulae, which can only ultimately be derived from a consideration of all the evidence.

The present study, therefore, works from the detailed analysis of a passage in the *Natural History* (Book XXX, sections 1–8) which deals specifically with the general problem of magic, and from a translation, with notes, of the further sections 9–18. The conclusions drawn from this study will ultimately be more generally applied. They are (i) that Pliny's attitude to magic can be divided sharply into two categories: his condemnation of foreign (especially Greek and Magian) rites *of all kinds*, and his unconscious acceptance of much purely Roman belief which was as superstitious as that which he condemned; (ii) that his knowledge of the subject was largely acquired at second-hand from other authors, and that his views differed in many respects from the attitude of his contemporaries and immediate predecessors.

These conclusions are supported by a study of Pliny's personal character as revealed in his own works and the testimony of

others; and this combined evidence has been utilized, in Appendix A, to provide an analytical index of every reference in the *Natural History*, both objective and opinionatory, to magic or superstition of any kind, whether it conform to modern definitions or not. It is hoped that the further development of the work described in the dissertation may provide evidence of value not only to the classical scholar, but to the sociologist and anthropologist as well.

*For the* PH.D. *Degree*

## A HISTORY OF THE ELECTRUM COINAGE OF MYTILENE

*By* JOHN FRANCIS HEALY, M.A.
*Trinity College, Cambridge*

MYTILENE, the political and commercial capital of the Greek island of Lesbos, after early experiments in silver and other metals, issued a fractional electrum coinage. The series continued from *c.* 488 B.C. until 330 B.C.

The present numismatic study is based on a corpus of all accessible, extant *hektai*; a descriptive and critical commentary relates it to the wider field of Classical civilization.

The sequence, or order of issue of the coins, which is established through close examination of die-links and die-interchanges and through stylistic comparison with other art forms, affords independent evidence for the history and economics of the East Greek world and for its artistic development.

Mytilenaean coin types and their combinations occasionally record *jalons historiques*, and they reflect generally the political relations of Lesbos with Athens, Persia and Sparta during the fifth and fourth centuries B.C.

The types also throw new light on the local cults of the main Panhellenic deities in Lesbos, in particular on those of Apollo and Dionysos.

In the field of economics the evidence indicates that the *hektai*, together with parallel issues from Kyzikos, enjoyed the privilege of federal circulation, and were thus second only to the 'Owls' minted at Athens. In the early years of the fourth century B.C.

Mytilene entered into an agreement with Phokaia to issue electrum on the same metrological standard and from an alloy of uniform quality. This treaty is confirmed by an inscription and provides an example, unique for that period, of the operation of a monetary union.

Mytilenaean *hektai*, in design sensitive and receptive to outside influences, were modern of their day, and, unlike the archaizing Attic tetradrachms, make a valuable contribution to our knowledge of the development of Greek art.

As a *parergon* the problem of the composition of the ternary electrum alloy (gold, silver, and copper) is re-examined in light of new results obtained from specific gravity measurements and X-ray diffraction analyses.

# THE FACULTY OF DIVINITY

*For the* PH.D. *Degree*

## AN INDUCTIVE APPROACH TO THE EPISTLE OF JAMES: MATERIALS FOR A FRESH STUDY

*By* JAMES ADAMSON

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THE Epistle of James has been termed the riddle of the New Testament and up till now has proved elusive in the way of research. The dissertation aims at neither a definitive study of all aspects of the problem of the Epistle nor a commentary on the text itself, but is rather, as the title suggests, an inductive approach, undertaken with the object of providing materials for future research. The inductive method first undertakes to determine from the data of the Epistle the situation which called it forth. The study begins with a discussion of 'The Economic Order', in which attention is directed towards James's use of the term πλούσιος. Such an investigation tends to confirm the belief that the Epistle reflects an economic situation dating from before A.D. 66 and probably even earlier. In the next four chapters, entitled respectively, 'The Test of Faith', 'The Law of Brotherhood', 'The Moral Fibre of Faith', and 'The Wisdom from Above', the theological and ethical teaching of the Epistle is similarly tested. All lines of evidence, both economic and religious, converge upon the conclusion that the Epistle derives from a nascent, pre-Pauline period of the early Church. Over against such evidence of the primitive content of the Epistle must be set the various arguments against its authenticity. By way of solution, it is suggested, in the final chapter, that the Epistle was originally a homily, probably delivered by James, the brother of the Lord, which was preserved and transmuted in the course of ethical instruction. An appendix, dealing with 'The Relation of the Epistle of James to the Synoptic Tradition', concludes the discussion.

*For the* PH.D. *Degree*

# THE CAREER AND INFLUENCE OF BISHOP RICHARD COX, 1547–1581

*By* GEORGE LEWIS BLACKMAN, M.A.
*Emmanuel College, Cambridge*

Cox's career falls naturally into two periods divided by the interlude of Mary's reign.

In the first period he won royal favour and gained a reputation as a teacher, scholar, administrator and reliable investigator of theological 'deviation'. The radical cast of his own theological opinions made him congenial to Cranmer and earned him a place on various commissions concerned with ecclesiastical matters.

The death of Edward VI abruptly ended these activities; and until Elizabeth's accession Cox was in exile on the Continent, where he proved an effective champion of the 1552 Prayer Book and reformation on an English, as opposed to a European model.

In the second period of his career he assisted Parker in restoring order and discipline in the disorganized Elizabethan Church, improved the efficiency of the traditional machinery of episcopal administration in the diocese of Ely, combated the disruptive agitation of papists, puritans and heretics, and fought to preserve the episcopal manors against the depredations of land-hungry courtiers.

During more than forty years in which he had a place among those who charted the course of the English Reformation three principles characterized his policy: a judicious combination of old and new in Church discipline and administration, the formation (in particular through directed study of a Bible accurately translated into simple vernacular) of a laity whose conformity might rest on intelligent and instructed consent, and the development of a body of clergy so well grounded in sound learning as to be a slave neither to the intellectually barren slogans of ecclesiastical party nor to the wayward spiritual enthusiasms of studied ignorance. He may well rank with Cranmer and Parker as one of the chief architects of the reformed Church of England.

*For the* PH.D. *Degree*

# THE PHILOSOPHY OF CLEMENT OF ALEXANDRIA

*By* ERIC FRANCIS OSBORN

*Queens' College, Cambridge, and the University of Melbourne*

CLEMENT of Alexandria expresses, in his enigmatical *Stromateis* and other works, a Christian philosophy. His thought is influenced by later classical philosophy, which was concerned with the antithesis between a transcendent One and an immanent One-Many. The difference between the One and the One-Many or between simple and complex unity is like the difference between a pinpoint and a spider's web.

Clement's answers to three questions—What is God like?, What is Goodness?, What is Truth?—are set out. His answers to these questions follow the same pattern of a transcendent simple unity and an immanent complex unity. God is the transcendent One, a simple unity. The Son of God is the immanent One-Many, a complex unity. The goodness of God is simple, transcendent and one, though manifest in an eternal scheme of providence. The goodness of men who are assimilated to God is a manifold complex unity. The unique truth of Christianity transcends all human opinions. The truths which men have known are part of a complex whole which the power of Christ can bring together. Faith is a simple act of trust, decision, acceptance or perception. Knowledge which is both logical and spiritual sees all things as one.

Clement emphasizes the antithesis between the One and the One-Many, but refuses to accept dualism. Father and Son are one God. The goodness of God is the source of all human goodness. All truth, whether the special revelation of Christianity or the truth contained in the views of the philosophers, comes from God. Faith and knowledge cannot be separated. No logical reconciliation of these antitheses was possible. Clement found in Christian experience a sense of unity with God which brought all things together. This was an earthly anticipation of heaven, the coming of the kingdom of heaven into human life.

# THE FACULTY OF ECONOMICS AND POLITICS

*For the* PH.D. *Degree*

## SOME ECONOMIC ASPECTS OF THE LAW RELATING TO OR AFFECTING THE MEASUREMENT OF THE CAPITAL AND INCOME OF BUSINESS ENTERPRISES

*By* TREVOR ROBERT JOHNSTON

*Trinity Hall, Cambridge, and the University of New Zealand*

THE dissertation attempts to cut across well-defined fields of study by analysing the economic aspects and history of certain existing legal requirements and contrasting them with what economic analysis suggests would be more appropriate. Company law is mainly discussed, and in this connexion attention is given to the 'extra-legal' source of authority, accounting 'principles'; but reference is also made to the law relating to income tax, price control, monopoly inquiries and nationalized undertakings.

Until recently the emphasis in law was on freedom of contract and on leaving those concerned with business affairs to define their own terms. But changes in social outlook and the experiences of the depression, culminating in the case of *Rex* v. *Lord Kylsant and another*, have modified the policy of the legislature, which has introduced more restrictive measures and conferred greater authority on the auditor.

These developments have been an advantage in that they have resulted in a closer definition of property rights and a more satisfactory functioning of the capital market. But, in an endeavour to attain objectivity and on the grounds that the law so provides, the accountants have selected the concept of 'money profit' as the basis of their 'principles'. It is shown, however, first, that the law has not been as definite as accountants suggest; secondly, that for most purposes the economists' concept of 'real profit' is more significant; and thirdly, that accounting 'principles' developed for company-law purposes are not necessarily satisfactory for other purposes.

A study of the comparative law of the United States, France, Germany and Sweden brings out in contrast the reliance placed on the auditor by English law and practice, and shows how these countries have developed more rigorous legal or administrative controls.

Two suggestions consistent with the traditional approach to company law—freedom of contract, and publicity—are made regarding the problems in this country arising from changes in money values. The first is that companies should be allowed to adopt the 'real profit' concept if they specially provide in their articles that a Capital Adjustment Account be credited or debited (whether in credit or not) with adjustments to depreciation charges or inventory pricing due to changes in price levels. This overcomes the main objections to the adoption of the 'new' methods of accounting: that proprietary rights would be infringed, and that existing company law presents difficulties during a period of falling prices. The second is that companies not adopting this first suggestion be required to state in their published accounts the difference that would have been made to their profit figures if depreciation and the pricing of inventories had been computed on the basis either of replacement cost or of historical cost adjusted by reference to a general or special price index. It is pointed out that this suggestion is consistent with existing statutory requirements.

The establishment of an authoritative body on accounting, linked with but independent of the accountancy profession, is also proposed.

*For the* PH.D. *Degree*

## THE EFFECT OF ECONOMIC PROGRESS ON PROFITS AND INTEREST: AN ESSAY IN THE HISTORY OF BRITISH ECONOMIC THOUGHT, 1650–1850

*By* GRAHAM SHARDALON LEE TUCKER

*Christ's College, Cambridge, and the University of Melbourne*

IN the early nineteenth century the theory that the general rate of profit on capital tends to fall in the course of economic progress

attained a position of primary importance in English political economy. The dissertation seeks to answer three main questions: How did the theory of the falling tendency of the rate of profit originate? What explanations of this tendency, and of the factors which may counteract it in practice, have been offered by different writers? How have these theories been connected with the economic conditions and practical problems of the English economy?

The survey covers a period ending *c.* 1850; it may be divided broadly into three stages. First, it is shown how seventeenth-century discussions concerning the regulation of interest by the State attracted attention to the idea that the rate of interest on loans will fall 'naturally' as a consequence of the growing wealth of a nation. This conclusion depended partly upon the observation of an historical decline of loan-interest in England since the early seventeenth century. Secondly, the dissertation deals with the attempts made by eighteenth-century writers, including Adam Smith, to explain the historical fall of interest-rates in terms of a corresponding decline of the rate of profit in trade and industry, which governed the price that producers were willing to pay for loans. The reduction of profits was in turn regarded as an effect of the accumulation of capital. Finally, it is argued that in the early nineteenth century, following the work of Adam Smith, the idea that the accumulation of capital tends, *ceteris paribus*, to depress the rate of profit was no longer subordinated to the problem of explaining changes in loan-interest. Discussion now centred on the rate of profit itself. The dissertation describes the theories outlined by Ricardo and Malthus and seeks to identify the nature and causes of the differences of opinion between these two writers. It concludes with a general review of the application and significance of the theory of the falling tendency of the rate of profit in 'classical' thought.

# THE FACULTY OF ENGINEERING

*For the* PH.D. *Degree*

## A STUDY OF MAGNETIZATION AND ITS DEPENDENCE UPON MECHANICAL STRESS

*By* HAROLD ASPDEN

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THE dissertation is a record of investigations carried out with a view to understanding the cause of the eddy-type discrepancy component of magnetization loss commonly referred to as the 'Eddy-current anomaly'.

The discrepancy is generally attributed to the effect which the non-linearity of a magnetization loop has in producing a distortion of magnetic flux wave form across a cyclically magnetized specimen. However, there has been inadequate quantitative support for this, and explanations based upon a fundamental time lag in magnetization and the effects of magnetic inhomogeneity resulting from finite domain size have been proposed in recent years.

A new experimental technique is described by means of which the discrepancy is measured in a sheet steel specimen under conditions in which there is substantially no flux wave-form distortion. The results indicate that the discrepancy is only partly attributable to flux wave-form distortion.

The effects of tensile stress upon the eddy-type discrepancy component of the coercive force of an a.c. magnetization loop were measured in samples of electrical sheet. An appreciable stress dependence was found, but no simple relationship could be formulated. A technique was developed for measuring the effect of stress upon the loss anomaly factor in a single sheet.

Experiments on thick steel specimens under conditions of appreciable skin effect showed that there was little evidence of an appreciable eddy-type discrepancy in such specimens, and that, as frequency increased, the observed discrepancy decreased.

*For the* PH.D. *Degree*

# HIGH-POWER MICRO-WAVE AMPLIFIERS

*By* GRAHAM MORLEY CLARKE, B.A.

*Pembroke College, Cambridge*

THE dissertation is divided into two sections. Section I is concerned with the general theory of the geometry of microwave valves, and is approached from the point of view of a valve consisting of three-dimensional wave-guide. The methods of possible termination of the spatial axes are limited in nature, and by permuting them together with the current flow vector a finite number of arrangements is found. These may be combined with the known electron mechanisms to yield the possible microwave valves. Many of these are of course the known types, but certain classes of them are new. Inspection of the symbols used to describe them can be used to predict group properties, and the geometry for a valve with predetermined features can be deduced.

This process is followed, taking as the aim the design of a high-power microwave amplifier. The geometry which is arrived at may be considered to be derived from the conventional cylindrical cavity magnetron oscillator by cutting along a radial line and opening out into linear form, followed by rotation about a parallel line outside the two conductors. The valve is thus in the form of a coaxial line with radial electric field, and in order to obtain the required crossed electric and magnetic fields for axial progression of the electron flow, a large current is passed down the inner conductor. A wave-slowing structure is proposed for the outer conductor consisting of a deep helical groove cut in it.

This valve, known as the axial flow magnetron amplifier, is studied theoretically and experimentally in Section II. A chapter is devoted to the production of the novel magnetic field, and the associated problems are solved. An elementary theory shows that the wave-slowing structure proposed initially is unsuitable in this application; this conclusion is supported by experiment. A second structure is proposed and considered together with the problem of transforming the wave into and out of the circuit. A satisfactory high-power junction was developed with adequate band-width.

The problem of obtaining the distribution of temperature along a rod heated by an internal current and cooled by radiation from the surface and conduction from the ends is solved in terms of general parameters.

Several experimental diodes were constructed and tested in order to establish the correct operation of the constituent parts. Tests with R.F. power were not reached owing to the need for investigation of the 'slipping stream effect', which conflicts with the desired operation of the valve. Apparatus for automatic display of electric field patterns within the valve and for the production of 3 MW. 2 $\mu$sec. pulses used in the investigation is described.

*For the* PH.D. *Degree*

## THE ANALYSIS AND MINIMUM WEIGHT DESIGN OF DUCTILE STRUCTURES

*By* JOHN DAVID PERCY FOULKES

*Gonville and Caius College, Cambridge, and the University of Oxford*

THE dissertation is concerned with the design and behaviour of plane ductile frameworks. The first six chapters examine the problem of assigning economical sections to frames which derive their strength from a bending action, and the last four chapters deal with triangulated frameworks. In the first section the theory of plastic collapse is used to predict failure. A geometrical model is used to clarify the nature of the problem and to prove five general theorems. A few methods of solution are suggested, and their relative merits are demonstrated by practical examples. The second section describes an experimental and theoretical study of the collapse behaviour of a stiff-jointed truss. A planned series of experiments is described, and the results are discussed. A numerical picture of the behaviour of these structures was obtained with the help of the electronic computer at the Mathematical Laboratory, Cambridge. The theory used assumed an idealized stress-strain relation for the material of the framework and assumed that plane sections remained plane. A reasonable agreement between experiment and theory was obtained.

*For the* PH.D. *Degree*

# THE FLOW OF WATER IN PIPES AND CHANNELS: WAVES IN A UNIFORM FLOW WATER CHANNEL

*By* JOHN CARNEGIE ORKNEY

*Trinity College, Cambridge, and the University of Glasgow*

THE dissertation gives the results of an examination into the causes of several wave systems which were found and investigated during the development of a design for a large, uniform-flow, wave-free water channel in which stationary ship models could be tested. A channel was built, 14 in. wide by 8 ft. long, and supplied from a reservoir. Velocities up to 7 ft./sec. were used. It is shown experimentally that (i) friction, or other small obstruction, in a stream, can cause the unusual Scott-Russell solitary wave; (ii) the stationary undular hydraulic jump is exactly similar to the travelling wave train, or bore; (iii) agreement is close with the accepted theory of the plain hydraulic jump, a theory hitherto believed inadequate for the undular jump; (iv) the range over which these wave trains exist, the breaking point of the leading wave, and the point of transition to the plain hydraulic jump are determinate, and can be defined in terms of the flow Froude number; (v) a previously unsuspected source of stationary waves lies in the shape of the contraction joining an open reservoir and channel; (vi) these waves are caused by the water entering the channel with a sloping surface after accelerating through the contraction; (vii) the wave-producing properties of a contraction are dependent on the speed, but not on the depth, of the channel; (viii) for each shape there is a limiting speed below which no waves form; (ix) shapes, and their properties, can be scaled up according to Froude's law of geometric similarity. The two major wave theories, due to Stokes and to Korteweg and de Vries, are compared on a similar basis for the first time. Consideration is given to capillary ripples and surface shock waves; to the outlet controls necessary to a channel at subcritical velocities; to the stilling processes in the reservoir whereby a uniform velocity profile and freedom from turbulence are obtained; to the optimum

contraction shape for wave-free flow; and finally, to the complete design of a large circulating flume. Dimensionless ratios, and particularly the flow Froude number, are used wherever appropriate.

*For the* PH.D. *Degree*

## THE PLASTIC BEHAVIOUR OF FLEXURAL MEMBERS AND CONNEXIONS UNDER COMBINED LOADING

*By* GEORGE DOUGLAS TYNDALL WRIGHT

*Trinity College, Cambridge, and the University of Toronto*

THE dissertation describes studies made in the plastic theory to determine methods of designing compressed beams and structural connexions.

Beams and flexural members subjected to axial compression are often encountered in structural frames, and the design of such members is of considerable importance. It is shown that axial compressions have an appreciable effect in reducing the ability of beams to carry transverse load, and that instability occurs in the plastic range. Formal analyses are presented for various cases, and it is shown that the behaviour of beams under combined axial and transverse load depends on a simple function of average axial stress, slenderness ratio, and Young's modulus. Alternative solutions based upon numerical methods of analysis are also presented; these may be used for problems of any degree of complexity. The numerical analyses are employed to explore the significance of the approximations used in the formal analyses, and indicate that the formal analyses are reasonably accurate for axial stresses up to at least six-tenths of the lower yield point. Experimental evidence is presented, and this appears to confirm the theory satisfactorily. The first section of the dissertation closes with a study of the effects of axial compressions on the strength and stability of portal frames.

The second section of the dissertation deals with the two most common types of rigid connexion: the knee joint, used in portal frames, and the symmetrical beam-stanchion joint, used in multi-story, multi-bay frames. From an examination of previously

published studies of knee joints, a new and apparently better method of design for square knees is derived and confirmed. For beam-stanchion connexions it is shown that the strength of joints embodying profile fillet welds can be predicted on the basis of standard weld tests, and it is also shown that this connexion type fails abruptly with no plastic deformation, indicating that, for frames designed by the plastic theory, such connexions must be adequate to develop the full plastic resistance of the beams. Methods of design for stanchion reinforcement, used to prevent crippling of the stanchion at the joint, are also presented.

# THE FACULTY OF ENGLISH

*For the* PH.D. *Degree*

## W. B. YEATS AND OCCULTISM: A STUDY OF HIS WORKS IN RELATION TO INDIAN LORE, THE CABBALA, SWEDENBORG, BOEHME AND THEOSOPHY

*By* HARBANS RAI BACHCHAN

*St Catharine's College, Cambridge, and the University of Allahabad*

THE dissertation estimates the influence of occultism on Yeats's poetry and philosophy.

Yeats was familiar with Eastern as well as Western occultism, the former coming from Indian scriptures, Mohini Chatterji, Rabindranath Tagore and Purohit Swami, and the latter from the Cabbala, Swedenborg, Boehme and Blavatsky.

The first chapter shows that Yeats's preoccupation with the occult was as much the result of his nature and upbringing as of the times in which he lived. His work also belonged to an old and reputable literary tradition.

The second chapter deals with the influence of Chatterji's mystic nihilism on Yeats's earlier poems and plays, and with his efforts to escape from it.

The third chapter traces the influence of the Cabbala, Swedenborg and Boehme on Yeats. The Cabbala saved him from oriental abstraction, gave him the secret of communicating with the World Memory, made him conscious of the antinomy in life, and provided him with certain basic principles of his philosophy and certain symbols which he used both poetically and metaphysically. Swedenborg helped him to form his conception of the afterlife and of the angelic world. Yeats also owed to him the idea of 'gyres', though the poet learnt of their contrariety from Boehme.

The fourth chapter discusses the influence of Yeats's *Upanishadic* knowledge, gained from Purohit Swami, on the 'Supernatural Songs', *The Herne's Egg* and *A Vision*. The Swami also heightened the conflict between the philosopher and the poet in

Yeats's mind, and affected his position as poet in the final phase of his life.

The fifth chapter considers the question of the sources of the central geometrical conception of *A Vision*, and finds it mainly to have been derived from Madame Blavatsky.

The sixth chapter sums up Yeats's occult philosophy, which in some respects runs counter to the Christian culture of Europe. Whatever inspiration Yeats might personally have drawn from this philosophy, it cannot be accepted as a tradition which he believed his age was in need of and which he aspired to provide.

*For the* M.LITT. *Degree*

## HENRY JAMES AND THE NATURE OF CIVILIZATION

*By* ALWYN BERLAND

*Fitzwilliam House, Cambridge, and the University of Chicago*

THIS is a study of Henry James's major theme: the search for, and the defence of, an ideal conception of civilization. James held civilization to be a positive good, and found in it many of the sanctions we traditionally think of as religious. Through civilization's complex forms, and through its art, man's nature finds its highest fulfilment. His conception of character stresses the moral, but the particular Jamesian essence is in the joining of the moral with the aesthetic and intellectual. His practice represents a liberation from the limitations of Puritanism on the one hand and from mere 'aestheticism' on the other, and favours a conception of the 'Whole Man', whose pursuit of beauty does not displace or conflict with his moral integrity, but constitutes instead its highest expression.

Related to the theme of civilization is James's frequently sounded note of renunciation. Similarly, his major theme determines or establishes a frame for his famous treatment of the 'international', which has been too literally, though endlessly, interpreted by his critics. James sought an ideal synthesis of 'national' qualities, which, as he found them in America and in Europe, were fragmentary and limited.

The dissertation centres on the novels most pertinent to this theme, and it is significant that they include most of James's major works. Although the traditions from which his views spring are examined, the centre of interest is in the fiction itself rather than in the philosophical validity or the historical and biographical relevance of James's ideas. The works discussed at length in the light of James's major theme include *Roderick Hudson*, *The American*, *The Portrait of a Lady*, *The Bostonians*, *The Princess Casamassima*, *The Tragic Muse*, *The Ambassadors*, *The Golden Bowl* and *The Ivory Tower*. Other novels and stories are adduced in support, or in clarification, of the major argument.

*For the* PH.D. *Degree*

## SHAKESPEARE'S HISTORICAL MYTH: A STUDY OF SHAKESPEARE'S ADAPTATIONS OF HIS SOURCES IN MAKING THE PLAYS OF *HENRY VI* AND *RICHARD III*

*By* JOHN PHILIP BROCKBANK, B.A.
*Trinity College, Cambridge*

A REVIEW of the evidence leads to the conclusion that Shakespeare was responsible for the three plays of *Henry VI*, that he read two chronicle accounts and glanced at others in the course of preparing them, and that he was the first Elizabethan playwright to take seriously his obligations as a historian.

An analysis of the effects of the source adaptations in the first tetralogy shows that he not only expounded and clarified, but tested the official historical and political myths in an effort to give them dramatic life. At the same time he tested the conventions and rhetoric of contemporary drama in stage situations contrived from the chronicles.

While treating political themes of urgent interest to his audience, Shakespeare tried to make his historical pattern of cause and effect aesthetically and ethically valid, and developed an analogy between the world and the stage which required that the relationship between character and action in the drama should express that between individuals and historical processes in the

chronicles. Inequalities in the first three plays are therefore explained as the outcome of his attempt to come to terms with the facts, theories and values of the chronicles without betraying his integrity as a dramatic artist. In *Richard III*, however, he shaped a tragi-comic form fit to convey the equivocal political theology of Hall and More; the tragic-religious solution to civil disorder (evil in the realm purged by blood sacrifice) and the Machiavellian one (stability imposed by strength) are temporarily, and ironically, reconciled.

It is hoped that a synthetic critical method yields a result of interest to the dramatic critic, the producer, and the student of Elizabethan historiography.

*For the* PH.D. *Degree*

## THE DEVELOPMENT OF THE POETIC IMAGINATION IN TENNYSON, WITH PARTICULAR REFERENCE TO THE JUVENILIA AND TO THE INFLUENCE OF ARTHUR HALLAM

*By* JOYCE MOLLY GREEN

*Newnham College, Cambridge, and the University of Bristol*

IT is erroneous to regard Tennyson as a lyrical poet encumbered by a spurious Victorian 'message'. His juvenilia show, on the contrary, that during an adolescence overshadowed by his father's surrender to neurosis he had already found that his lyrical inspiration was dominated by an essentially negative and treacherous nostalgia, or 'Passion of the Past', which was, however, unfailingly seductive. He was concerned from the first to write from a more positive impulse, and some of his recently published juvenilia reflect an intense mystical capacity which promises integration.

At Cambridge the renewed emotional security provided by his friendship with Arthur Hallam and the Apostles led at first to the triumphant, but static, lyricism of the 1830 volume. When this security was destroyed, from various causes, during the next year, Hallam exerted his influence to persuade Tennyson that he could

achieve integration without condemning or mistrusting the 'Passion of the Past', if he wrote under the aegis of a combative Christian faith. The 1832 volume was consequently an experiment towards a simultaneously ethical and magical poetry, and Tennyson was planning a more confident experiment when Hallam's death in 1833 shattered this attempt at synthesis.

He was left to face unpopularity aroused not only by the faults of the 1832 poems, which Hallam's enthusiasm had hurried into print, but also by the Apostles' indiscreet partisanship and 'cockney' journalism. This challenge to all that his relationship with Hallam and with them had seemed to signify was met, during the 'Ten Years' Silence', partly by the successful struggle for reunion with Hallam recorded in *In Memoriam*, and partly by an approximation to the common interests of the time which sought to carry out the spirit of this friendship and particularly to apply Hallam's doctrine of integration through a law of love.

The limitations of the resultant vision do not arise from the presence of a 'message', but from the fact that it was sometimes rebelliously or narrowly conceived. Nevertheless, Tennyson's work possesses a peculiar richness of texture, resulting from its blend of personal and general reference, which is the surest safeguard of his future reputation.

*For the* M.LITT. *Degree*

## DICKENS'S NOVELS AS THEY RELATE TO HIS CULTURE

*By* STEVEN PAUL MARCUS

*Pembroke College, Cambridge, and the University of Columbia*

THE dissertation attempts to present a coherent view of the evolution of Dickens's mind. The central fact of this evolution is the maturing of Dickens's intelligence and skill as a novelist; the general concern of the dissertation is with the nature and direction of this maturing process. It shows how Dickens began with a rather simple, yet distinct, relation to literature and to his culture, and came in time to maintain a complex relation to them both. It elucidates several ideas about life and society which seem to be

inherent in Dickens's writing from the outset of his career, and demonstrates how, though their substance persisted, they, too, became transformed and complicated. Special attention is paid to the sequence of this process, to the differences between one novel and the next, and to the essentially organic relation that exists between any one of the novels and those which precede or follow it. The alterations and transitions recorded in the dissertation are often subtle and almost always partial; though a general direction may be discerned in them, they do not finally comprise any simple or symmetrical abstract pattern. The dissertation also considers those notions of Dickens's which seem not to have undergone notable changes, and demonstrates their relation to the changing, growing mind of the novelist.

The term 'culture' as used in the title of the dissertation implies several things. It refers to the literary culture and tradition that Dickens belongs to, and which, in the course of his career, he extended. It alludes to the general culture of Dickens's class and age, and to the social and political circumstances and events which are most relevant to the understanding of his work, though the latter are referred to only as they impinge on the central issues of the novels. It comprehends, further, the culture of Christianity, to which Dickens maintained a complex and central relation. The evolution of Dickens's understanding of his culture and of his own position in it is part of the primary concern of this study.

*For the* M.LITT. *Degree*

## THE POETRY OF RICHARD CRASHAW

*By* LAURA DOMENICA HENRIETTA PETTOELLO, B.A.
*Newnham College, Cambridge*

THE dissertation seeks to solve certain problems which arise from the study of Crashaw's poetry.

The first problem is: Does Crashaw's style owe more, as many critics assert, to the influence of Latin and Italian poetry (in particular Marino's) than to that of English poetry? In Chapter I Crashaw's style is carefully fitted into the context of English seventeenth-century poetry, which includes the school of Spenser,

the Metaphysicals, and the 'transitional' poets of the middle of the century. Chapter II attempts to disprove the current assumption that Marino's influence was responsible for the extravagance of Crashaw's style, which is shown to be of an indigenous and not of an exotic nature. This involves an examination of Marino's poetry in its Italian setting.

The second problem is: What exactly are the Baroque qualities of Crashaw's style, which are not so much defined as taken for granted? Chapters III and IV attempt to find a precise definition by showing, with the help of numerous reproductions, how certain qualities in seventeenth-century Baroque art can be paralleled in Crashaw's poetry. The Baroque in Crashaw is thrown into relief by being related to the Baroque in the Italian poet, Marino, and the English poets, Giles and Phineas Fletcher, Donne, Marvell and Milton.

The final problem is: Does the sensuous element in Crashaw's religious poetry clash with the spiritual element, and to what extent can his unconscious sexuality be said to invalidate his religious sentiments? In the last chapter his sensuous imagery is shown to have traditional symbolic overtones which, with certain exceptions, counter-balance its sensuousness. Similarly, his sexual imagery is considered in terms of its intended symbolism as well as of Freudian psychology.

*For the* M.LITT. *Degree*

## CONTEMPORARY CRITICISM OF HARDY, GISSING AND 'MARK RUTHERFORD' AS NOVELISTS, 1870–1900

*By* ROY THEODORE HUGH STEVENS, M.A.
*Christ's College, Cambridge*

THE first purpose of the dissertation is to provide a history of Hardy criticism in England during the nineteenth century. Its second purpose is to construct a background to Hardy criticism by relating Hardy's reviewers to movements in critical taste, and these, in turn, to the thought of late-Victorian England. The work of Gissing and 'Mark Rutherford', and of their reviewers,

is introduced in this connexion; first, for purposes of comparison with Hardy, in that they support the writer's main thesis concerning the marked isolation and individuality of Hardy during his second phase as a novelist; secondly, as contributions to the study of these novelists in their own right.

The following conclusions are submitted. As revealed by the critics, Hardy's relations with the Victorian world fell into two sharply defined phases. In the first he was in no sense a literary rebel, but conformed to conventionalized attitudes of disillusionment and escape. At this point current fashions in minor fiction worked in his favour and facilitated the swift acceptance of his early stories.

In the second phase Hardy's position suffered a radical change, since after 1880 his writing assumed an individual quality which divided him from majority opinion. At this stage it is difficult to align his work with other contemporary developments in fiction, and current movements in minor fiction had an adverse effect upon the reception of *Jude the Obscure*.

The individuality of Gissing's position resembles that of Hardy, but is modified by an approach which is, in effect, a concession to taste; the neutral tone of much Gissing criticism reflects this attempt at compromise. The method of 'Mark Rutherford' represents a more successful marriage of subject-matter not unlike Hardy's with the mood of the time; accordingly he is reviewed with indulgence.

As a group, these novelists and their critics provide a key to the pace at which Victorian values were modified and to those values which were most enduring.

# THE FACULTY OF GEOGRAPHY AND GEOLOGY

## (1) *GEODESY AND GEOPHYSICS*

*For the* PH.D. *Degree*

## THE INTERPRETATION OF GRAVITY ANOMALIES IN THE EASTERN MEDITERRANEAN

*By* JOHN CHRISTOPHER HARRISON, B.A.

*Clare College, Cambridge*

THE results of the 1950 British Submarine Gravity Survey in the eastern Mediterranean are submitted in a paper of which the writer is a joint author. The dissertation contains an interpretation of these results and of others obtained in that area.

Four specific problems are considered. The variations of anomaly near Malta are mainly caused by the surface geology and, together with seismic results obtained by H.M.S. *Challenger*, they allow the construction of a geological profile. Very large positive anomalies on Cyprus indicate the presence of a considerable mass of dense rock near the surface. Possible forms of this mass and its relation to the surface geology are discussed. The forces required to lift the dense rocks from their source beneath the Mohorovicic discontinuity are considered in relation to the tectonic history of the area.

The Crete island arc is recognized as a line of crustal fracture under compressional forces, the Aegean overriding the eastern Mediterranean along a northwards-dipping shear fault. The vertical displacements of the crust caused by this fracture are responsible for the large anomalies on either side of the arc. The mechanics of this type of fracture and its possible relation to the origin of geosynclines are discussed.

Thick sediments on the Nile delta are associated with positive anomalies. The distribution of the sediments and the depression of the crust caused by their weight are determined from the anomalies combined with topographical considerations.

Calculations of deflexions of the vertical on Cyprus and an account of an investigation of the effects of external temperature changes on a Worden gravimeter are contained in appendices.

*For the* PH.D. *Degree*

## SOME EXPERIMENTS ON THERMAL CONVECTION IN A ROTATING LIQUID

*By* RAYMOND HIDE

*Gonville and Caius College, Cambridge, and the University of Manchester*

ALTHOUGH the problem of the origin of the earth's main magnetic field is still unsolved, it is now generally accepted that the mechanism sought involves hydrodynamical motion in the earth's liquid core. Bullard has shown that this motion is likely, although not completely certain, to be thermally driven, perhaps by radioactive heating, and, in so far as our knowledge of the earth's internal condition permits the appropriate considerations to be made, the motion would be strongly influenced by the dynamical effects arising from the earth's rotation. Hence an understanding of the hydrodynamics of thermal convection in a rotating liquid might be a necessary step in providing an adequate theory of the earth's magnetism.

There have been some previous theoretical and experimental studies of thermal convection in a rotating fluid, most of which were concerned with the hydrodynamics of the general circulation of the earth's atmosphere. The theoretical difficulties are great, and the experimental work was spasmodic, unconnected and mainly qualitative.

The present experiments were originally designed to contribute to the subject of geomagnetism, but the perspective of the work was unexpectedly changed when it was discovered that they might have some bearing on meteorology.

Thermal convection in water contained between two concentric cylinders (radii $a$ and $b$ cm; $b > a$) maintained at temperatures $T_b$ and $T_a$ respectively, and which rotated about their (vertical) axis at $\omega$ rad.sec.$^{-1}$, was studied. Two fundamentally different

types of flow occur according as a certain non-dimensional parameter

$$\Theta \gtrless 1{\cdot}58 \pm 0{\cdot}05 = \Theta_{\text{crit.}},$$

where

$$\Theta = \left\{\left(\frac{gd}{\frac{1}{2}\omega^2(b^2-a^2)}\right)\left(\left|\frac{\rho(T_b)-\rho(T_a)}{\rho}\right|\right)\left(\frac{1}{2}\frac{b+a}{b-a}\right)\right\},$$

$d$ being the vertical depth of water, $\rho(T)$ the density of water at temperature $T$, $\rho$ the mean density (taken as unity), and $g$ the acceleration of gravity.

The flow when $\Theta < \Theta_{\text{crit.}}$ resembles the baroclinic wave flow of a rotating fluid, which has been the subject of some recent theoretical work by dynamical meteorologists in their attempt to understand the atmospheric circulation in middle and high latitudes. When $\Theta > \Theta_{\text{crit.}}$ the flow is not unlike the atmospheric circulation near the equator.

A description of an experimental study of the baroclinic wave flow is given. From this work the importance of the parameter $\Theta$ emerges. A tentative interpretation is put on $\Theta$. It is equivalent to a Rossby number, the importance of which has been demonstrated by previous workers on the hydrodynamics of rotating liquids of uniform density. $\Theta$ is also equivalent to a Richardson number, a parameter which is important for specifying the properties of shearing flow in the presence of a stable density gradient.

The problems of the earth's magnetism and the atmospheric circulation are briefly discussed in the light of the experiments.

*For the* PH.D. *Degree*

## THE ELECTRIC CONDUCTIVITY OF THE EARTH'S INTERIOR

*By* HARRY HUGHES

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THE physics of excited solids is used to account for the conductivity distribution in the earth's mantle. The rapidly increasing conductivity in the earth derived from the induced effects of external magnetic fields is analysed, and it is shown to be caused by semi-conduction and an increasing temperature. The constants

for the process are determined. Extrapolation gives the conductivities at greater depths, and these are also deduced from the screening of the geomagnetic secular variation, which is estimated from the form of the spectrum (amplitude against period) for variations of widely different frequencies. The conductivity is large enough for the irregular fluctuations in the westward drift of the magnetic field, the length of the day and the latitude to be caused by electromagnetic torques between core and mantle, and it is suggested that currents induced in the mantle by the secular variation cause the changes.

Conductivity measurements up to 1500° C. and measurements of ionic transport, polarization, thermoelectromotive forces, optical absorption and photoconductivity show that olivines and pyroxenes are semi-conductors, with ions, electrons and impurities all contributing. The changes caused by temperature and pressure are estimated from the shift of the absorption edge and other indirect methods, but they are still rather uncertain. It appears likely that the conductivities in the mantle are due to mobile metallic ions, and that the temperature gradient there is about 1° C./km. Iron-rich silicates would give too high a conductivity near the surface. Excitation does not appreciably change the thermal conductivity but may affect the elasticity. The electronic conduction band is much lower than required by Ramsey in his theory of a pressure-ionized core of silicates. A conductivity depth distribution compatible with the observational and laboratory evidence is suggested.

*For the* PH.D. *Degree*

## THE GLACIAL SHORELINE OF SOUTH-WEST ENGLAND

*By* PETER BALLANTYNE MCFARLANE

*Gonville and Caius College, Cambridge, and the University of St Andrews*

THE aim of the work was to determine, both from experimental and theoretical studies, the relative position of sea-level in south-west England during the last maximum of the Pleistocene glaciations.

The field evidence of a relatively lower sea-level during such a glacial maximum is to be found below present sea-level, and was obtained partly by carrying out seismic refraction shooting in the estuaries of the River Erme in south Devon and of the Rivers Taw and Torridge in north Devon. These seismic experiments showed that the thickness of recent sediment in the drowned valleys is of the order of 100 ft., rock bottom being at −90 ft. O.D. in the Erme Mouth, and at −100 ft. O.D. in the Taw and Torridge at the low-water mark of ordinary tides. The mean gradients of the buried channels are in both cases consistent with a relative lowering of sea-level of about 150 ft. (46 m.) below its present level.

Results of a survey by echo-sounding and sampling of the sea bed suggest that the rivers of Plymouth graded to the foot of a discontinuity at about −144 ft. (−44 m.) O.D.

The first section of the dissertation concludes with an analysis of the soundings on Admiralty Charts. Graphs of area of sea bed against depth suggest that in some parts of the south-west peninsula a discontinuity in seaward slope of the sea bed exists at about −44 m. O.D.

In the second section the transition of a shoreline in the neighbourhood of a shaped ice cap of angular radius 12° is worked out. The earth is treated as an elastic spherical shell enclosing incompressible fluid, and the effects of compressibility are neglected initially. According to the theory the glacial shoreline of south-west England should now lie at −78 m. O.D. if the eustatic change of level at the maximum was 100 m.

*For the* PH.D. *Degree*

## THE THEORY AND PRACTICE OF GRAVIMETER OBSERVATIONS APPLIED TO CERTAIN GEOLOGICAL PROBLEMS IN THE BRITISH ISLES

*By* HENRY IVISON SHIPLEY THIRLAWAY

*Emmanuel College, Cambridge, and the University of Durham*

SECTION I. The principles and problems attending the design of gravimeters are discussed before an account is given of the physical

properties, field operations and performance of the Askania (Graf) gravimeter. Treatment of the field observations in order to determine gravity differences and instrumental and observational errors is also described, and possible sources of error and their elimination are discussed. The great majority of over 1500 independent observations have an accuracy greater than $\frac{1}{4}$ mgal.

SECTION II. The method of reducing gravity values to Bouguer anomalies leads to a consideration of the importance and problems of rock-density estimation. Results of experimental work using conventional laboratory methods, gravity observations over erosion features, and gravity observations down mine shafts, are given.

SECTION III. Interpretation of gravity anomalies along the Malvern Line, over certain areas in Ireland, and along a traverse between Aberystwyth and Waxham (Norfolk), leads to the following major conclusions:

(*a*) The Malvern Line is bounded on its eastern side by major fault structures with eastward downthrows of between 1500 and 8000 ft. stretching from the Bridgnorth to the Bath districts. These faults form the western boundary of a graben filled with Trias sediments. They were initiated in pre-Trias times and probably continued moving during Trias deposition, and little movement has occurred since the close of the Trias.

(*b*) Assuming that Wales and Ireland are in isostatic equilibrium, the anomalies confirm the estimated depth of the Welsh geosyncline and suggest a maximum of 40,000 ft. of Lower Palaeozoic rocks at Aberystwyth, which thin out against a geanticline of pre-Cambrian rocks under the Irish Channel. By analogy, the anomalies suggest that a similar thickness of Lower Palaeozoic rock exists under Arklow, Ireland.

(*c*) The Leinster granite is in the form of a laccolith, the source of the intrusion being under the Carlow district, where a thickness of 20,000 ft. of granite is estimated.

Results confirming or modifying previous work are also presented. Geological and, where possible, seismic evidence supporting or modifying the interpretation of the gravity anomalies is discussed in detail.

## (2) *GEOGRAPHY*

*For the* PH.D. *Degree*

# THE DENUDATION CHRONOLOGY OF SOUTH-WEST YORKSHIRE

*By* JOHN BRIAN SISSONS, M.A.

*St Catharine's College, Cambridge*

VARIOUS methods of cartographical analysis of relief, including a new statistical method, were applied to some 900 square miles of the eastern slopes of the central Pennines lying largely in south-west Yorkshire, and suggested the presence of erosion surfaces at a number of heights. Confirmation of the existence of such surfaces cut across the inclined and much-faulted strata was obtained by systematic fieldwork, during which the surfaces were mapped and their heights determined by aneroid measurements.

The principal surfaces occur at about 1800–1600, 1350–1250, 1070–970, 705–590, 530–390, and 260–190 ft. O.D., the last two being clearly subdivisible. The surfaces above about 450 ft. are believed to have been cut principally by marine erosion during periods of approximately constant sea-level at heights of about 1800, 1350–1300, 1070, 705, 530 and 495 ft., and those below about 450 ft. are believed to have been formed by fluvial erosion when the sea-level stood at about or a little below heights of 425–400, 245–225 and 200–190 ft. The evidence and arguments leading to this interpretation are set out, and the unsatisfactory nature of previous interpretations of the morphology of the area is indicated.

No direct evidence bearing on the age of the surfaces is available in the area, but a tentative correlation of the 1350–1250 ft. surface, which appears to be widely developed in northern England, with the Pliocene surface at a similar height recognized by Baulig over large parts of France suggests a Pliocene date for the 1350–1250 ft. surface.

The drainage system is closely related to the erosion surfaces and is considered to have evolved from consequent streams initiated upon, and extended across, the marine erosion surfaces as they were successively cut and exposed by an intermittently falling

sea. The wind-gaps that now mark the former courses of many of these consequent streams point to the rapid development of subsequent streams and make possible the construction of a series of maps illustrating the drainage system at successive stages in the emergence of the area. In the lowest parts of the area a series of drainage anomalies is believed to have been caused by superimposition from a cover of glacial drift.

## (3) *GEOLOGY*

*For the* PH.D. *Degree*

## PART I. THE DEEP STRUCTURE OF NORTHUMBERLAND AND CO. DURHAM
## PART II. A GEOPHYSICAL STUDY OF THE GRANITES IN RELATION TO CRUSTAL STRUCTURE

*By* MARTIN HAROLD PHILLIPS BOTT, B.A.
*Magdalene College, Cambridge*

### PART I

CERTAIN outstanding structural problems in Northumberland and Co. Durham emerge from a review of the structural geology of north England. These seem best approached by geophysical methods. Gravity and magnetic surveys, planned with this in view, are described in some detail.

The main feature of the gravity survey is a large negative gravity anomaly over the Alston Block. It is interpreted as resulting from an unexposed granite which is less dense than the basement rocks it intrudes. A negative magnetic anomaly over the same area supports this interpretation and suggests remanent magnetism in the country rocks. The gravity fields across the margins of the Alston Block are studied, and the general structure and tectonic history of the Block is related to the presence of granite below.

A negative gravity anomaly over the Cheviot Granite is irreconcilable with laccolithic form, and repeated uplift of this region is attributed to isostatic effects caused by the granite mass deficiency.

A magnetic anomaly with east-north-east strike crosses Northumberland and may represent a change of basement lithology. In conclusion the preliminary results of outlying surveys are briefly described.

PART II

Negative gravity anomalies over various granite masses and orogenic belts are discussed and, where necessary, reinterpreted. It is found that the gravity anomalies over granites arise because granite is less dense than the rock intruded, and that part of the mass deficiency of some orogenic belts exists as granite.

A more detailed analysis of the anomalies favours an origin for post-tectonic granites by magmatic stoping. A definite granitic layer, chemically distinct from the overlying metasediments, which are of bulk intermediate composition, seems the probable source of granite magma. Certain recent seismic results also support this modified model of upper crustal structure.

Doming around granites is adequately explained as isostatic uplift. Isostatic hypotheses are adapted to include near-surface compensation in the form of granite.

*For the* M.Sc. *Degree*

## THE FOSSIL PLANTS OF THE PERMIAN BEDS OF ENGLAND

*By* HILDA MARY MARGARET COX

*Newnham College, Cambridge, and the University of London*

THE dissertation is a monograph of the fossil plants found in the Permian beds of England, based on collections preserved in seventeen museums, on material collected from Westmorland, Nottinghamshire and Durham, and on cores from a number of borings in the underground coalfield of Nottinghamshire and Yorkshire. An account of the fossil flora of the Enville or Corley Group of Warwickshire is included, as this has close affinities with that of the Autunian or Lower Rotliegende of the European continent. The Middle Permian (Saxonian) period is not represented by fossiliferous deposits in this country, and the greater

part of the dissertation deals with the fossil plants of the Upper Permian (Thuringian) beds.

Seven species from the Corley Group are described, and the Upper Permian beds yielded twenty-seven plant species with describable macroscopic remains, from many of which cuticle preparations were made, which are also described and illustrated. Representative of two new genera are included. Among several Algae described are new species of the genera *Piaea* and *Calathella*, founded on forms from the German Zechstein. It is shown that the important index fossil of the Upper Magnesian Limestone, hitherto known as '*Filograna*' *permiana* King, is identical with a German species upon which a genus *Tubulites*, supposed to belong to the Algae, has been founded. Although closely related to that of the German Zechstein, the English Upper Permian flora includes the two important species *Psygmophyllum cuneifolium* (Kutorga) and *Cordaites aequalis* (Göppert), which have not been found in Germany. Several problematical fossils once regarded as plant remains are also discussed. Some aspects of the study of fossil plant cuticles are considered.

The dissertation includes a historical review of work on English Permian plants and an account of the localities at which they have been obtained. Details of some of the chief existing sections of plant beds are based on observations by the author.

*For the* PH.D. *Degree*

## THE PERMO-CARBONIFEROUS PALAEONTOLOGY AND STRATIGRAPHY OF CENTRAL VESTSPITSBERGEN

*By* COLIN LACHLAN FORBES, M.A.

*Clare College, Cambridge*

AN account is given of a study of the fossil collection of the Cambridge Spitsbergen Expedition, 1949 (of which the author was a member), and of the smaller fossil collections of some other recent expeditions to Svalbard.

Monographic description of the Rugose Corals, most of which belong to the families Caniniidae and Lonsdaliidae, and of the

Fusulinid Foraminifera, is undertaken. The remainder of the collection, of which a preliminary study has been made, comprises Foraminifera (mostly Textulariidae and *Bradyina* spp.), Tabulate Corals, Bryozoa, Brachiopods and plants; with rare Lamellibranchs, Gasteropods, Trilobites and Elasmobranch teeth.

Distribution of species at different horizons, except the Culm at the base of the sequence, is considered and is used to subdivide and date the strata, which have hitherto been divided only into a sequence of formations based chiefly on lithology.

The correlation of the remaining strata is summarized below:

(1) The Lower Gypsiferous Series (so far as it is fossiliferous), Passage Beds and Black Crag are of Moscovian age.

(2) The Wordiekammen Limestones, from the top of the Black Crag to the 'Foraminiferensapropelit' of Staff and Wedekind, are equivalent to the *Triticites* Zone of Russia.

(3) The upper Wordiekammen Limestones and Upper Gypsiferous Series (so far as it is fossiliferous) are equivalent to the Sakmarian of Russia.

(4) The Brachiopod Cherts are of Artinskian, and perhaps in their upper part of Kungurian, age. The top of this formation is not reached in any of the sections studied.

A short account is also given of the detailed stratigraphy and structure of an area mapped by the author in 1949.

*For the* PH.D. *Degree*

## TERTIARY ECHINODERMA FROM BRITISH SOMALILAND

*By* PORTER MARTIN KIER

*Emmanuel College, Cambridge, and the University of Michigan*

A LARGE collection of Tertiary echinoids from British Somaliland is described. These echinoids were collected by C. Barrington Brown and W. A. Macfadyen from the Auradu Series, the Anhydrite Series, the Karkar Series and one species from the Miocene.

The echinoids from the Lower Auradu Series comprise nine species, seven of them new, and two of them referred to new

genera. This fauna is probably Palaeocene, as it has affinities with both the Cretaceous and Eocene, and two of the species are very similar to Palaeocene species from India. This fauna shows no affinity with that of the Lower Libyan Series of Egypt, which is accordingly held to be of Lower Eocene rather than Palaeocene age as has been suggested. From the Upper Auradu Series eleven species were collected, one of them new and representing a new genus. This fauna is, with little doubt, Lower Eocene, as many of its species also occur in the Lower Eocene of Egypt. From the Anhydrite Series came thousands of specimens of a new species of *Echinocyamus*. Because of the large number of specimens and the wide vertical distribution of the species, a statistical study of the variation of the species was made. It was found that the specimens from the higher beds are narrower than the specimens from the lower beds, and that their periprocts are nearer the peristome.

From the Karkar Series nineteen species were collected, one of them new. These species are Middle Eocene, as the fauna is again very similar to that of the Egyptian Middle Eocene. In this fauna there are a large number of specimens of *Echinolampas fraasi* P. de Loriol, varying in size from 4·4 to 95·0 mm. in length. A study of the ontogeny of this species was therefore made, and its growth changes were found to be very similar to those found in the modern *E. depressa* as described by A. Agassiz. Also in the collection there are several tetramerous variants, which are discussed.

A study was made of the occurrences and significance of the separation of interambulacral columns from the apical system in these Somaliland specimens and others.

Finally, several Palaeozoic echinoids from Britain and Canada are described.

*For the* M.Sc. *Degree*

## PLANT MICRO-FOSSILS FROM THE KARROO BEDS OF NATAL

*By* MICHAEL HENRY PLANT RILETT

*Magdalene College, Cambridge, and the University of South Africa*

THE geology of the coalfield in the northern portion of Natal is discussed, and the sediments belonging to the Ecca and the lower

portion of the Beaufort stages are described. Specimens from the two major coal seams, the iron ore band in the Middle Ecca, and a carbonaceous shale horizon in the Lower Beaufort were macerated and the included spores isolated. As these sediments have been metamorphosed by the injection of dolerite sills, it proved necessary to develop a slight variation of the normal maceration procedure in order to isolate the spores. Thirty-three species of spores from these beds are described. It was thought advisable to defer the naming of these species until an opportunity arose of comparing them with the type material from other parts of 'Gondwanaland'. These spores were assigned to eleven form genera. Although it was found unnecessary to erect any new genera, it proved impossible to avoid emending the existing genera, mainly because the size ranges as defined in the existing generic diagnoses are not large enough to include all the known South African specimens. As no work has been published on the spores from the coal seams of the Wankie Colliery, it proved desirable to macerate a run of mine sample from this source in order to compare the Natal spores with the Rhodesian. Two species of so far unknown spores from Natal, which were isolated from the Wankie coal, are described. The spores from the Karroo beds of Natal were compared with the forms described in literature. The evidence as to the age of the beds derived from such a study is inconclusive, and the spore flora appears to have affinities with the spore floras of both the Carboniferous and Permian Systems. A general correlation was attempted.

## (4) *MINERALOGY AND PETROLOGY*

*For the* PH.D. *Degree*

## (*a*) THE PETROLOGY OF THE EILDON HILLS

## (*b*) THE PETROLOGY OF THE GLAUCOPHANE-BEARING ROCKS AND ECLOGITE AT KNOCKORMAL, NEAR LENDALFOOT, AYRSHIRE

*By* JOHN BARRY ALLEN

*St Catharine's College, Cambridge, and the University of London*

### *The petrology of the Eildon Hills*

THE following rock types in the igneous complex of the Eildon Hills are described: sanidine-trachyte, fayalite-trachyte, riebeckite-trachyte, biotite-felsite, porphyritic and non-porphyritic basalts. The structure of the intrusion is largely concordant. Powder photograph methods are applied to investigate the feldspars in these trachytes and in related Scottish intrusions of the Calciferous Sandstone period. The composition of the alkali-feldspar, as determined from ($\bar{2}01$) spacing, is essentially that of the normative feldspar composition of the rock in those trachytes where a single feldspar phase is present. A Berwickshire felsite, which is similar to the Wester Eildon felsite, contains phenocrysts of high-temperature albite and sanidine of composition

$$Or_{64}\,(Ab+An)_{36}.$$

A comparison with contemporaneous Scottish igneous rocks favours an origin by crystallization differentiation. The Harker variation diagram for rocks of this series resembles that of the Tertiary Mull Alkaline Magma Series. Spectrographic analyses also suggest that the analysed rocks are late differentiates, and support the view that hydrothermal activity has modified the Wester Eildon felsite.

*The petrology of the glaucophane-bearing rocks and eclogite at Knockormal, near Lendalfoot, Ayrshire*

Glaucophane-bearing rocks and eclogite occur in a gabbro-serpentine mass which is believed to intrude the Arenig country rocks at Knockormal. A garnetiferous glaucophane-schist is associated with a glaucophane-amphibolite, and it is considered that these metamorphic rocks have been produced during the shearing of altered gabbros accompanied by metasomatism. The status of glaucophane-bearing rocks in the facies classification of metamorphic rocks is discussed.

The eclogite contains hornblende, pyroxene, garnet and spinel as primary minerals and is interbanded with the Ballantrae serpentine. The formation of this unusual rock appears unconnected with the production of glaucophane in the adjacent gabbro.

Chemical and spectrographic analyses are given for the various rock types and important minerals.

*For the* PH.D. *Degree*

## THE PETROLOGY OF SOME IGNEOUS ROCKS OF NORTHERN NORTH AUCKLAND, NEW ZEALAND

*By* MAURICE HUGH BATTEY

*St John's College, Cambridge, and the University of New Zealand*

THE spilitic series of North Auckland falls into two groups, spilites and keratophyres, erupted alternately. The series shows continuous regular variation of chemical constituents, except for the alkalis, which show a break in continuity at the division of the series. The variation may be matched by that in the tholeiitic series. Analogies between spilites and tholeiites, and the existence of intermediate types, suggest that the two may be genetically connected.

Mineralogical and textual features of the spilites indicate a low temperature of final consolidation. The divergence between them and the tholeiites may be explained on the assumption that the volatile constituents of the original magma, which normally escape from the consolidating rock, were retained at low temperatures

and reacted with the high-temperature mineral phases to produce a low-temperature assemblage, whereas pyroxene, which began crystallizing early, persisted and continued to form as a metastable phase. The lime-rich nature of the pyroxene distinguishes it from that of tholeiites and accounts for much of the lime appearing as anorthite in tholeiites.

The inferred composition of the original magma could be attained by slight differentiation along the well-recognized alkaline trend from parental tholeiitic magma, and no special spilitic magma need be postulated.

Large movements of constituents through extensive rock masses are not indicated, but there is evidence for migration of iron, magnesia and potash over short distances to form selvedges of extreme composition.

The low temperature of final consolidation is favoured by injection into geosynclinal sediments or by submarine extrusion, but favouring conditions may develop to varying degrees in different environments.

The keratophyres are connected with the spilites by a process of fractional crystallization and separation of an acid residuum with an alkali ratio near unity. Subsequent transport of alkalis within the cooling flows, or by later movements of pore fluids, has caused local segregation of soda and potash, replacement of the one by the other, and resulting rapid variations in alkali ratio in a single body of rock. The process has been widespread in old rhyolites, but affects more recent types also. Deep burial may facilitate it, but exact dating of the alkali movements is not possible.

*For the* PH.D. *Degree*

## THE METAMORPHIC HISTORY OF THE CARN CHUINNEAG-INCHBAE MASSIF AND ITS ENVIRONMENT

*By* ROBERT IAN HARKER, B.A.

*St John's College, Cambridge*

THE rocks of the Moine series round the Carn Chuinneag-Inchbae complex of Ross-shire have suffered two separate and

distinct kinds of metamorphism. This fact was recognized by the Officers of the Geological Survey when the region was originally mapped and described by them. Two large masses of orthogneiss are surrounded by schists in which relics of hornfelses are found constituting what remains, after subsequent regional metamorphism, of the thermal aureole round the pre-tectonic intrusive rocks. The main difference between the hornfelses and the surrounding schists is one of texture, but, though mineralogically similar, the hornfelses often contain kyanite (and rarely staurolite), whereas the schists, whether derived directly from pelites or from hornfelses, do not. It is concluded that the kyanite has formed metastably from andalusite and cordierite, and a number of contributing factors which may have caused its development are considered. Garnet occurs in the schists and the hornfelses; it is essentially almandine in the latter, and its status is discussed. Calc-silicate bands occur in the schists and in the hornfelses; when in the latter they may contain pyroxene, and, where they are in contact with the acid rocks, scapolite occurs.

The orthogneisses of the complex are mostly granite gneisses which can be subdivided by inspection in the field and amphibolites which are non-garnetiferous and contain biotite. The more basic rocks have been disrupted by the later acid magma, and effects of hybridization can be recognized. As in other acid orthogneisses, some of those of the Carn Chuinneag-Inchbae complex contain both orthoclase and microcline. It is concluded that much of the orthoclase has inverted to microcline on regional metamorphism, and the optical relationships between the two polymorphs were studied. The granite gneisses vein and contain xenoliths of the country rock, and obvious contamination effects are very localized. A riebeckite gneiss and a garnetiferous albite gneiss are confined to the immediate vicinity of Carn Chuinneag, and some further petrographic and chemical work was carried out on them.

More detailed mapping was completed within the granitic gneisses which contain large augen of felspar, and it was possible to subdivide them into the Inchbae rock and the Lochan a' Chairn rock. The stratigraphy of some of the pelitic rocks close to the acid gneisses on the south-east side of the complex was studied, and, with the aid of current bedding, it was possible to

verify that the pelitic rocks here become stratigraphically younger towards the granitic rocks. Less current bedding was seen on the north and west sides of the complex, but that which was examined appears to throw doubt on the hypothesis that the complex is a simple laccolith.

*For the* PH.D. *Degree*

## PALAEOMAGNETIC STUDIES OF ICELANDIC ROCKS

*By* JAN HOSPERS

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THE direction and intensity of the permanent magnetization of Icelandic lava flows, ranging in age from 1947–8 (the latest eruption of Mt Hekla) to Miocene times (approximately $20 \times 10^6$ years ago), were investigated, as well as those of sediments of corresponding ages. It is shown that the permanent magnetization of these lava flows is of thermo-remanent origin, that is, it originated when they cooled down for the first time after their formation. A similar conclusion is drawn for the permanent magnetization of the sediments; their permanent magnetization was acquired when they were deposited.

All historic, Post-glacial and Late Quaternary flows and sediments are magnetized approximately in the direction of the present field. It is shown that the mean direction of magnetization agrees significantly better with the theoretical dipole field (i.e. the field caused by a magnetic dipole situated at the centre of the earth and directed along its axis) than with the present field. Consequently it is concluded that over a period of several thousands of years the magnetic poles have centred on the geographic poles. Older Quaternary lava flows and sediments are magnetized in a direction approximately opposite to the present field. Similarly, it is found that in the Tertiary series of plateau basalts alternating zones of normally and reversely magnetized lava flows occur.

The various possible explanations (mostly based on recent work in antiferromagnetism) advanced to explain this reversed magnetization were tested by field and laboratory investigations, and it

is shown that the observations are best accounted for by assuming that the earth's magnetic polarity has repeatedly been reversed. It is therefore concluded that the main geomagnetic field has repeatedly been reversed, that the phenomenon is periodic, and that a period of normal or reversed field occupies 250,000–500,000 years. The actual reversal of the direction of the field is thought to take less than about one-fiftieth of that time, but it is not yet known exactly how this change takes place.

Finally, the application of the study of rock magnetism to problems of geological correlation and dating and to the problems of polar wandering and continental drift is discussed. It is shown that Iceland has not suffered appreciable rotation or changes in geographical latitude for the last $20 \times 10^6$ years, and that the position of the geographic pole in Miocene times as suggested by advocates of the theory of polar wandering is outside the range of possible positions derived from these measurements. The theory of polar wandering is therefore not supported.

*For the* PH.D. *Degree*

## PART I. THE PETROLOGY OF SOME CARBONIFEROUS SEDIMENTARY ROCKS FROM CENTRAL VESTSPITSBERGEN

## PART II. THE LOWER NEW RED SANDSTONE OF CENTRAL DEVON

*By* PHILIP FRANK HUTCHINS, M.A.

*St John's College, Cambridge*

### PART I

THE petrology of twenty-five specimens of Carboniferous detrital sedimentary rocks collected in central Vestspitsbergen by the Cambridge Expeditions of 1949 and 1951 is described.

The rocks show evidence of several low-temperature authigenic mineral changes, including the crystallization of apatite and quartz and the replacement of quartz and felspar by calcite and dolomite. A new mineral related to chalcedony also occurs.

The detrital mineral suites suggest that the Lower Carboniferous basin of sedimentation was formed by gentle downwarping of the pre-Carboniferous peneplain, sedimentation keeping pace with depression.

## Part II

The geology of the Lower New Red Sandstone ('Permian') deposits of the Crediton Valley is described. This narrow strip of red pebble-beds (breccio-conglomerates) and sandstones, resting unconformably on the Culm Measures, extends westwards, from near Exeter, for about 25 miles.

The succession is divided into four facies on the basis of the pebble and mineral suites. The sediments were laid down in an east-west basin, and the later facies overlap the older beds on to the eroded surface of the underlying Culm Measures. Soon after deposition the almost flat-lying deposits were folded into a shallow east-west syncline. Folding then took place on several north-south axes combined with some east-west faulting. Subsequently the whole was tilted to the south-east—possibly during the Tertiary.

The possible conditions of deposition are reviewed, and it is concluded that the beds were laid down as piedmont gravels in a wide depression between upland areas on the present-day sites of Exmoor and Dartmoor. The climate was warm, with a heavy seasonal rainfall favouring the formation of laterites.

Most of the detritus in the New Red Sandstone was derived from the adjacent Dartmoor area, but pebbles from Exmoor occur in the lowest facies. From the succession of pebble and mineral suites the geography and geology of the north Dartmoor area was reconstructed for various periods during 'Permian' times. The eastern part of the Dartmoor granite was covered by tourmalinized lavas and sediments which were intruded by acid dykes. The granite was very probably exposed in the west, near Okehampton.

The petrography of the pebbles and the mineralogy of the sandy fraction are briefly described. New detail is given about an optically dispersed biotite, outgrowths on sedimentary zircon, detrital sphalerite and the etching of detrital staurolite and topaz.

Finally, the relation of the area to the rest of the New Red Sandstone in south-west England is briefly discussed.

*For the* PH.D. *Degree*

# THE BORROWDALE VOLCANIC AND ASSOCIATED ROCKS OF THE SCAFELL AREA, LAKE DISTRICT (ENGLAND)

*By* ROBIN LANGFORD OLIVER

*Fitzwilliam House, Cambridge, and the University of New Zealand*

THIRTY-FIVE square miles of lavas and tuffs are folded, essentially, into a broad east-north-east-plunging syncline, modified by subsidiary wrinkles. North-west- and north-north-east-trending faults form a conspicuous pattern. The relationship of cleavage and jointing to the larger tectonic features is discussed. The stratigraphic sequence is, from bottom to top: aphanitic basaltic andesites; porphyritic pyroxene andesites; garnetiferous flows and welded tuffs of dacitic, rhyodactic, and rhyolitic composition, with local bedded tuffs and an andesite flow; bedded andesitic and rhyolitic tuffs, with small rhyolite flow; welded rhyolitic tuffs; tuffaceous hornstone. Thickness is 9160–10,210 ft. Intrusive rocks consist of granite; granite porphyry; garnetiferous biotite quartz porphyry; hybrid(?) 'porphyry and porphyrite', with garnets; dolerite and other basic rocks. The granite is probably connected to the neighbouring Eskdale Granite, to which most of the other intrusions may be genetically related. Secondary alteration in the volcanics is the result mainly of contact metamorphism and metasomatism. A detailed petrographic description of the lavas, tuffs and intrusive rocks is given, and sixteen complete (trace elements by Dr S. R. Nockolds), and four partial, rock analyses were made. The chemical relationships of the lavas and welded tuffs resemble those of a calc-alkali series. Three partial and eight complete (trace elements on six) garnet analyses were made, and formulae were calculated. Fe/Mg and Mn/Fe ratios increase in the garnets (70–80 % almandine) from basic to acid rocks, which latter, in the area mapped by the writer, are from lower to higher levels respectively in the stratigraphic succession. A corresponding trend is exhibited by the cell size and refractive index of the garnets concerned. A method is outlined, involving

the use of five simultaneous equations, for evaluation from physical properties and partial chemical analysis of complete garnet composition in mol. %. Field, microscopic and chemical evidence suggests, on balance, that the Lake District garnets are pyrogenetic.

# THE FACULTY OF HISTORY

*For the* PH.D. *Degree*

## WHITE KENNETT (1660–1728), BISHOP OF PETERBOROUGH: A STUDY IN THE POLITICAL AND ECCLESIASTICAL HISTORY OF THE EARLY EIGHTEENTH CENTURY

*By* GARETH VAUGHAN BENNETT, B.A.
*Christ's College, Cambridge*

IN his early years an ardent supporter of Charles II, White Kennett conformed with some difficulty at the Revolution of 1688. However, in 1700 he entered into the Convocation controversy on the side of the 'Moderate' bishops supporting William III's Junto Whig Ministry. In historical works and popular pamphlets he strove to prevent the 'High-Church' opposition from gaining an unfettered use of the Convocation as a propaganda weapon against the Ministers. In Queen Anne's reign, as Archbishop Tenison's special representative in the Lower House of the Assembly, he acted to thwart the introduction there of any device striking at the Godolphin Administration.

As a public figure, Kennett's outspoken sermons and controversial historical writings made him the object of bitter personal attack as a representative 'Moderate' divine. Although branded by Dr Sacheverell as a 'False Brother', he kept up a damaging campaign against the Harley Ministry in sermon and pamphlet. In the Convocation he successfully repelled any attempts to overturn the Revolution Settlement.

Although neglected by the Hanoverians after great efforts for their succession, Kennett continued in conflict with High Tories and Non-jurors. Made a bishop in 1718, he became a foremost ministerial supporter in the House of Lords, but failure to recognize Walpole's rise led to his exclusion from influence and preferment under Bishop Gibson's ecclesiastical regime.

As a historian, Kennett contributed to knowledge of the medieval constitution by his pioneer work on parish history and by research into the origins of Parliament and Convocation. Although his attempts to write recent history were fiercely attacked, he was anxious to avoid any schematization of the subject for political purposes. He tried to formulate new standards of impartiality and use of source material.

Experience as a London incumbent prompted Kennett to devote considerable effort to organizing and advocating the Charity School and American missionary movements. He proved an exacting administrator as both Dean and Bishop of Peterborough, although in the lax conditions of the time it was certain that his keen attention to his episcopal duties would meet with intense opposition.

*For the* M.LITT. *Degree*

## THE INFLUENCE OF WESTERN THOUGHT ON THE SOCIAL, EDUCATIONAL, POLITICAL AND CULTURAL DEVELOPMENT OF INDIA, 1818–1840

*By* VISHWANATH DATTA

*Fitzwilliam House, Cambridge, and the University of the Punjab*

IT is important for the better understanding of British rule in India to trace the influence of Western thought on the formation of Indian policy. In the study of cultural history an Indian historian, lacking the foreign historian's detachment, tends to confine his attention to the local situation and pass by with indifference the external forces of thought; whereas a foreign historian, deficient in the native historian's quality of instinctive understanding, is liable to construct his story from external knowledge, to the neglect of the local situation. In the dissertation an attempt is made for the first time to strike a balance between the two types of attitude: to study from manuscripts and contemporary printed works the changes in thought and policy in India against the background of Western ideas, to record the contents of Western ideas pertinent to Indian policy, to examine the way those ideas were transmitted to India and the effect they produced

on the social, educational, political and cultural development of India.

This is not a study of the origin and subsequent development of Western thought, but of the Western attitude towards India; only those movements of Western ideas are described that influenced the formation of Indian policy in the period under study. From India's viewpoint, an attempt is made to show the nature of the response she offered to new ideas. The importance of the period under study does not lie mainly in the important changes that occurred, but rather in the influence of Western ideas upon an ancient society.

The first chapter, on 'Social Development', deals with suttee, slavery, thuggee and infanticide; the next chapter describes in stages the development of the 'Educational Policy'; the third chapter, on 'Political Development', is concerned with the ideals of the British rule which the Government had in view; in the fourth chapter are discussed the conflict of ideas and the emergence of a new Indian élite. A separate chapter covers the response of Ram Mohan Roy to the West and his cultural influence. The last chapter summarizes the arguments put forward in the preceding chapters.

*For the* PH.D. *Degree*

## THE WEALTH OF SOME NORTHAMPTONSHIRE FAMILIES, 1540–1640

*By* MARY ELIZABETH FINCH, M.A.

*Newnham College, Cambridge*

SOME of the ways to wealth in Northamptonshire in the hundred years under review are examined in studies of five landowning families; the Ishams of Lamport, Spencers of Althorp, Treshams of Rushton, Fitzwilliams of Milton and Brudenells of Deene. Although the wealth of only the Spencers originated in farming profits, for all these families landownership was more than a method of holding wealth acquired in other ways.

Their opportunities and difficulties were determined by contemporary economic conditions, in particular by the price revolution and by the nature of credit facilities. High wool prices and

the suitability of the region for pasture induced all to become sheep-farmers. In the first half of the sixteenth century the Brudenells found it worth producing wool even under conditions which were not ideal; in the second half of the century, however, they let their pastures. Other families continued to prosper from sheep-farming, but by 1640 the fall in cloth exports had resulted in the creation of leaseholds on most pastures. Rising prices dictated improvement of estates by the enclosure of demesnes and by raising tenants' payments. Lord Brudenell completed the transition to a modern economy by schemes for farming in severalty and enclosure of his tenant holdings. Land which was wisely selected and carefully improved was a sound long-term investment. Nevertheless, absence of long-term credit facilities until about 1620 meant that it was not easy for a landowning family of small resources to advance in wealth, and put a premium on frugality in landowners. A landowner who had not the profits of state office was obliged to meet any capital outlay from savings alone; only thus could he provide for his children safely and adequately. The development of the equity of redemption transformed the mortgage into a long-term security which strengthened the position of these families. They now had a convenient alternative investment; they could safely borrow to develop their estates; and they could keep their lands intact under a much heavier burden of debt than before.

*For the* PH.D. *Degree*

## THE WORK OF THE REVEREND THOMAS TREGENNA BIDDULPH, WITH SPECIAL REFERENCE TO HIS INFLUENCE ON THE EVANGELICAL MOVEMENT IN THE WEST OF ENGLAND

*By* LESLIE PAMELA FOX

*Girton College, Cambridge, and the University of McGill*

THE dissertation aims at enlarging the historical knowledge at present available of the Evangelical Movement of the late eighteenth and early nineteenth centuries in England. Its approach is biographical, although it is not a biography. The life of

the Reverend Thomas Tregenna Biddulph is studied with the object of shedding light on the beliefs and actions of the Evangelicals.

The work begins with a history of the west of England—and, particularly, of Bristol—in the eighteenth century. Naturally, the emphasis is upon the religious life of the times, with special consideration of those groups, within or without the Established Church, which moulded the Evangelical Movement. This is background material only, but it is relevant because Bristol was the scene of Biddulph's main labours.

Then follows a biographical sketch, including a summary of the Biddulph family and the work of Thomas Tregenna's father, Thomas Biddulph, the eminent Evangelical vicar of Padstow. Biddulph's own life, up to the time of his entering upon his Bristol incumbency, is studied in detail.

Chapters III and IV are the most important. The former is a study of Biddulph's religious, social and political views, and the latter is an attempt to show how they worked in practice. Here, inevitably, the question of whether or not the Evangelicals were Calvinists is raised. They are commonly so designated, but analytical study demands that this view should be modified. 'Moderate Calvinism' is admittedly a contradiction in terms, but the Evangelicals were essentially inconsistent. This is the central theme of the dissertation.

The following chapters are studies of Biddulph's views in practice, whether in his own parish, in missionary activity, or in philanthropy generally. The final chapter contains an account of Biddulph's last years, and closes with a summary of his contribution to the Evangelical Movement.

*For the* M.LITT. *Degree*

## ART AND SOCIETY IN MID-NINETEENTH CENTURY FRANCE

*By* JOHN REGINALD GILLING, M.A.
*Downing College, Cambridge*

THE dissertation discusses the history of the organization of the art world in France in the mid-nineteenth century from the rule

of the school of David to the advent of realism, covering the period 1830–65.

The romantics of the generation of 1830 attempted to overthrow the established régime of the school of David, which controlled, through the Académie des Beaux-Arts, the system of art education. The Orleanist government, while pursuing the policy of encouraging a national-historical art, acted as a mediator between the school of David, headed by Ingres, and the innovators, headed by Delacroix. The Académie gained the control over entry to the Salon, the only great vent for contemporary art, and used this power to refuse works of art by the romantic innovators. The latter, however, were given valuable help by the critics of the time, especially by Planche, Thoré, and Baudelaire, who created a new criticism to justify the new school.

The revolution of 1848 destroyed for a time the reign of the Académie. The government, through Ledru-Rollin and Charles Blanc, tried to create a 'social' art and to support the landscape painters by state patronage. The attempt failed; Courbet and Daumier were left without state support.

The Napoleonic régime, though lavish, had no clear policy in aesthetic matters, and so a popular version of the academic style was accepted as 'official' art. Attempts to reform art education led to a government decree which put the state in control. Painters of merit, encouraged by aestheticians stressing the value of originality, rejected 'social' art, or 'historical' art, for easel-painting and individualism.

*For the* PH.D. *Degree*

## THE GENERAL ELECTION OF 1868: A STUDY IN THE BASES OF MID-VICTORIAN POLITICS

*By* HAROLD JOHN HANHAM

*Selwyn College, Cambridge, and the University of New Zealand*

THE dissertation attempts, within the framework of the general election of 1868, to examine the main outlines of the English political system immediately after the Reform Act of 1867. The Reform Act was not the outcome of economic or social changes,

but of an intellectual movement and of party exigencies, so that its effects were extremely limited. Outside the great popular constituencies the stability of society and the absence of a thoroughgoing measure of redistribution determined that influence should remain as important as opinion, and that nomination and corruption should survive alongside manhood suffrage. The force of public opinion, although of increasing importance, was weakened by its lack of integration. Regional and local political trends, exemplified by Conservative victories in Lancashire in 1868, were often only indirectly related to national ones.

Even in the larger constituencies the working classes remained politically subservient, and working-class politics were confined to a comparatively small, although widely dispersed, group. The majority were Radicals, but there was a substantial Conservative majority outside London. The Reform League attempted to unite the majority of working-class Radicals from 1865 to 1868, but, because the trade unions held aloof, there was no adequate financial basis for such a large-scale movement.

The development of party organization receives consideration in some detail, because it demonstrates the slender bonds of party. It, too, was handicapped by lack of money, and Gladstone's reforming zeal was directed to the electorate, not to party organization or to the party in parliament. His isolation from his followers gave free rein to pressure groups such as the Liberation Society or the United Kingdom Alliance, but did nothing to strengthen the ties between the discordant elements which formed the Liberal Party. Initiative was left to Disraeli.

*For the* PH.D. *Degree*

## BRITISH AND DUTCH POLICY IN BORNEO, 1809–1888

*By* GRAHAM WILKIE IRWIN, M.A.

*Clare College, Cambridge*

THE evacuation of Borneo by the Dutch in 1809 left the island free from any connexion with a European power. Two years later British forces conquered Java. Owing largely to the enthusiasm

of Stamford Raffles (Lieutenant-Governor of Java, 1811–16), a British settlement was quickly established at Bandjermasin on the south coast of Borneo and British protection extended to the principal native states on the west. The English East India Company, however, had no desire to win permanent dominion in the island. Raffles's expansionist policy was denounced, and the Dutch regained possession of the south and west coasts in 1817–18.

For the next two decades the government of the Netherlands' Indies was content with nominal sovereignty over western and southern Borneo and made no attempt to extend the area of its effective rule. But the advent in 1839 of James Brooke, the future 'White Raja of Sarawak', quickened the tempo of European expansion. Brooke's remarkable success as the English ruler of an independent and increasingly powerful Malay state had two main results: it not only drew official British attention to Borneo once again, leading to the suppression of piracy along the north-west coast and to the founding of a Crown Colony at Labuan, but it also obliged the Dutch to look more carefully to the security of their neglected Bornean possessions, causing them successively to occupy the east coast, crush the independent Chinese mining kongsis in the west, and bring the Sultanate of Bandjermasin under their direct rule.

By 1862 this flurry of activity was over, and during the next fifteen years the political map of Borneo showed little change. But the negotiation of the Dent–Overbeck concessions in 1877 provoked a second scramble for territory. While the Dutch hastily extended their rule along the north-east coast, Sarawak and the new state of North Borneo competed for possession of the remnant of the Sultanate of Brunei. Mounting confusion in Brunei and the fear of interference in this area by other European powers, particularly by Bismarck's Germany, induced the British government to declare a Protectorate over the whole of northern Borneo in 1888, and the island, now finally partitioned between Dutch and British, entered upon its modern period of development.

*For the* PH.D. *Degree*

# ROBERT SPENCER, EARL OF SUNDERLAND, 1641–1702

*By* JOHN PHILIPPS KENYON

*Christ's College, Cambridge, and the University of Sheffield*

THE public career of Robert Spencer, Earl of Sunderland, was to a great extent governed by the precarious state of his personal finances. His capital sapped by unrestrained extravagance, the decline in the value of his estates accelerated by mismanagement, he was driven to seek office at Court, where his preoccupation with public business made the supervision of his own financial affairs more difficult, and impoverished him still further. This vicious circle was established as early as 1673, and it was never completely broken. However, it was not until the dissolution of the Long Parliament in 1679 that he succeeded Williamson as Secretary of State, and his first term of office coincided almost exactly with the period of the Exclusion Crisis. He betrayed his immaturity and weakness by his reliance on the support of others and his inability to decide between conflicting policies, and after a disastrous first year in office he found himself alone in the King's counsels with Hyde and Godolphin—two men even less experienced than he. Profiting by his mistakes, however, he then formulated a coherent external and internal policy which achieved its most notable success with the signature of the Spanish Treaty in June 1680. He trusted that the attitude of Parliament would be governed by the issue of foreign policy, and, when he discovered that the precise opposite was the case, he at once decided to push his policy to its logical conclusion by giving his support to the Exclusion Bill. The reaction of the King, the utter disaster which enveloped his whole policy, and his absolute disgrace in 1681 taught him a lasting lesson. Obliged by financial necessity to come to terms with his enemies, he returned to Court in 1682 bitterly determined to out-Herod Herod in his enthusiastic, almost fanatic, support for the francophile despotism erected by Charles and fortified by James. After a brief period of consolidation, moreover, he threw himself into a vicious, cynical and exhausting

struggle for power within the administration. But the accession of James was in many ways a severe setback, and in his efforts to remove Rochester he was compelled to identify himself more closely with the King's Catholic policy than a circumspect minister would have deemed advisable. As a result he never enjoyed in comfort the supreme power for which he had laboured so assiduously, and after the fall of the Hydes his remaining period of office was notable for the brilliant improvisations by which he sought to rescue himself from the ambiguous position in which his own rashness had placed him. Restricted as he was by James's incompetent megalomania, and hampered by the visionary ambitions of the Catholic extremists, he gambled on the birth of a Catholic heir. In June 1688 he was in sight of success, but the crisis of the Seven Bishops, coinciding with the premature *accouchement* of the Queen, threw his plans into a confusion from which they never quite recovered. His failure to recognize the danger from Holland until it was too late to secure French assistance wrecked his reputation for perspicuity, and his subsequent nervous breakdown made his dismissal inevitable.

On Sunderland's death his enemies fell incontinently on his reputation, and he has suffered more than any other seventeenth-century statesman from Jacobite calumny and distortion. This has not only served to conceal the very real ability and statesmanship he displayed prior to 1688, but has also distracted attention from the solid contribution he made to William's eventual success. His was the major part in the political education of an alien monarch who was summoned to England to preside over a change in constitutional emphasis the more difficult to effect in that it defied precise definition. He was in fact the first, and not the least important, link between Stuart despotism and Hanoverian constitutionalism. Returning from exile in 1690, he remained at Althorp for two years; but in the winter of 1692–3 William called upon his ability and experience to solve the problems posed by an unprecedented combination of full-scale war and continuous parliamentary government. The measures he enforced did not in themselves provide a long-term solution, but they set the King and his ministers on the right path and gave them a necessary respite until the tide of war began to turn in 1695. But this latter year was the high-water mark of Sunderland's

career. Although his influence over the King if anything increased, his political effectiveness declined before the rising power of the Whigs, who regarded him with hostility and suspicion. After his precipitate resignation of the Lord Chamberlainship in 1697 he found it impossible to regain his former position, and with the advent of old age the desire to do so became less urgent. While William lived his influence was still strong and was often exerted to good effect, but after 1700 he did not intervene again in an active capacity. After William's death he abandoned all such pretensions and spent the last months of his life in an effort to put his own house in order. He died at Althorp on 28 September 1702, at the beginning of his sixty-second year.

*For the* PH.D. *Degree*

## '*THE EQUATORIE OF THE PLANETIS*', EDITED FROM PETERHOUSE MS. 75. 1

*By* DEREK JOHN PRICE

*Christ's College, Cambridge, and the University of London*

THE work is intended as a full, critical edition of the Middle English text and astronomical tables contained in the cited manuscript. The text deals with the construction and use of a large instrument for calculating planetary positions, and the edition therefore includes chapters on medieval planetary theory and on the history of such calculating devices. A full set of textual notes provides a commentary on the content of the text, and the astronomical tables are subjected to a similar analysis. The text is also rendered into modern English for the convenience of those not primarily interested in the linguistic problems.

Reasons are advanced for thinking that the text might be a holograph draft by Chaucer of a work intended as a complement to his *Treatise on the Astrolabe*, and for this reason the bibliographical description of the text and the problems of its ascription are given special prominence.

In addition to a full transcript of the text, an account is given of the general palaeography and of the solution of certain notes written in a secret cipher. A number of other medieval scientific

texts are included in the appendices so as to provide some material for a comparative study of *The Equatorie of the Planetis*.

*For the* PH.D. *Degree*

## RAMSEY ABBEY ESTATES: A STUDY IN ECONOMIC GROWTH AND ORGANIZATION

*By* JAMES AMBROSE RAFTIS

*Peterhouse, Cambridge, and the University of Toronto*

THE dissertation is a detailed investigation of agrarian economic conditions in medieval England within the social and legal framework of a large abbatial barony. Legal problems as such, however, are given a minor role, being treated only in subordination to questions of tenure. Descriptions of administration at the abbey itself are likewise largely introductory to the main theme, though some major attention is given to the abbey for the period of 'high farming' over the thirteenth century.

Although the chronological scope ranges from the foundation of the abbey in the tenth century to the Dissolution, paucity of documents permitted only a limited survey of the first and last centuries of this period. Twelfth-century sources are still exiguous; but the manorial extents made possible a substantial reconstruction of manorial tenemental conditions, and a comparative picture of prices and rents for nearly every generation of this century was drawn from the numerous charters.

The bulk of the study is derived from about six hundred manorial account rolls of the thirteenth and fourteenth centuries which relate to a solid block of twelve Huntingdon manors. In order to avoid tedious interruption from numerous pages of statistical tabulation, three chapters are set aside for a simple description and presentation of manorial statistics; namely, (i) livestock—plough-teams, cattle, sheep, hogs; (ii) corn production—gross amounts sown and harvested, liveries to the abbey, yields; (iii) wages and prices.

Against this statistical background further chapters survey and analyse the fluctuations in manorial returns from the thirteenth to the fifteenth centuries as they become reflected in manorial

organization. The position and the ethos of the several social groups are traced through their interdependent relation with the whole. For example, the causes and effects of capital stringency at the abbey are treated together with the various impacts upon the welfare of the tenants and wage earners during the fall of manorial revenues in the late thirteenth century.

*For the* PH.D. *Degree*

## SIR JAMES FITZJAMES STEPHEN: A STUDY OF HIS THOUGHT AND LIFE

*By* JOHN PETER CHARLES ROACH, M.A.
*Corpus Christi College, Cambridge*

THE thought of Sir James Fitzjames Stephen (1829–94) covered a wide range of subjects, and his ideas provide some interesting illustrations of the legal, political and religious problems confronting the thinkers of his day. The primary purpose of the dissertation is to study his contribution to these subjects of speculation.

His career may be divided into four parts. The first ended in 1869, when he went to India as Legal Member of Council. The second covered his years in India (1869–72). The third extended from 1872 to his appointment as a Judge of the High Court in 1879. The fourth lasted from 1879 to his death, he having resigned from the Bench in 1891 because of ill-health. The first period saw his choice of the Bar as a profession and his marriage, in 1855, to Mary Cunningham. During this period he was both a lawyer and an active journalist. His early writings express a coherent philosophy of life, though rather implicitly than explicitly, for he never worked out his philosophy in full. He was a Utilitarian, who, in all fields of speculation, appealed to the evidence of facts. His stay in India was the most fruitful period of his life. He did important work in codifying and consolidating Indian law. His Indian experience also made him appreciate more fully the need for discipline and organization in political affairs. In 1873 he published *Liberty, Equality, Fraternity*, which is a criticism of J. S. Mill's political ideas.

After his return from India he strove to promote the codification of English law, but his schemes, though they made some progress, were finally unsuccessful. However, one fruit of them was his *Digests* of the Law of Evidence and of the Criminal Law, and his *History of the Criminal Law*. He was also very interested in theological problems and was, during the seventies, a member of the Metaphysical Society. He had been brought up in the Evangelical tradition, but finally renounced Christianity altogether, though he never fully reconciled himself to the lack of a positive religious creed.

The appendices contain fuller information about Stephen's family background and early years.

*For the* PH.D. *Degree*

## PRACTICAL MATHEMATICS IN ELIZABETHAN ENGLAND: A SURVEY OF THE LITERATURE OF SCIENCE

*By* DONALD PETER JOHN WOOD, M.A.

*Fitzwilliam House, Cambridge*

LITTLE enthusiasm was shown for mathematics at the beginning of Elizabeth's reign; yet, when she died, the foundations had been laid for the great English contributions to mathematics of the seventeenth century. The dissertation tries to show, mainly from contemporary printed books, how the propositions of elementary mathematics were used to meet some of the practical needs of the Elizabethan age. An attempt is made to explain the debt English practical mathematicians owed to the Continent.

A survey is made, first of all, of the flourishing state of mathematics on the Continent, especially in Germany and Italy, during the first half of the sixteenth century, and this is contrasted with English backwardness. The second chapter shows the cosmological and utilitarian arguments used by Elizabethan mathematicians to justify their studies in face of the suspicion and scorn of their opponents. This is followed by an explanation of Elizabethan arithmetic and how its methods were used in commerce. In the fourth chapter the transformation of the art of

navigation into a science whose practice was recognizably modern is discussed. On land the most significant applications of elementary mathematics were in surveying and military affairs—especially in range-finding and in ordnance problems. These are considered in the fifth chapter. The dissertation ends with a short account of the few attempts made to organize the teaching of practical mathematics in Elizabethan England.

# THE FACULTY OF LAW

*For the* PH.D. *Degree*

## TAXATION IN INTERNATIONAL LAW

*By* ARTHUR ROBERT ALBRECHT

*Trinity College, Cambridge, and the University of Princeton*

TAXATION is a vital function of the state which is generally considered to be within the exclusive province of municipal law but which has gradually become subject to a body of international rules and practices constituting what may be called international tax law. Although such law tends to be particular rather than general, several broad principles emerge from it.

A basic proposition of international tax law is that the right to tax is an inherent attribute of the sovereign state, but the right is not necessarily limited to sovereign states. The extent of the right is determined chiefly by principles of personal and territorial jurisdiction which are inadequate to cope with the problems caused by competing tax claims upon international property and business interests. Although many treaties have been concluded to settle these problems, formidable difficulties remain, particularly those concerning the clarification of the terminology used in the treaties.

Immunities from taxation are granted under international law to international organizations, to states, and to their respective representatives. While state immunities cannot easily be justified, there is better reason for extending fiscal immunities to international organizations and their representatives. Other limitations upon the tax power have developed in respect of the taxation of aliens, which is based under international law upon the two principles of the equality of sovereign states in fiscal matters and the need for minimum standards for the fiscal protection of aliens.

An examination of the tax power in relations between states, as distinguished from the relations between the taxing state and its actual or potential taxpayers, reveals the variety of forms into which the tax power may be fashioned in order to serve particular purposes in different circumstances. International fiscal

co-operation for the promotion of economic and social interests has resulted in a great network of treaty provisions regulating taxes, granting exemptions from them, and assisting in their enforcement. The volume and scope of these provisions and the possibilities for further international co-operation along the same and other lines more than justify the study and progressive development of international tax law.

*For the* PH.D. *Degree*

## THE PRIMACY OF INTERNATIONAL LAW

*By* FELICE MORGENSTERN, M.A.

*Newnham College, Cambridge*

THE non-observance of rules of international law involves, in principle, individual or collective responsibility. The enforcement of municipal law in violation of international law is an illegality from the point of view of international tribunals. Similarly, failure to enforce the rules of international law owing to a general denial of its enforceability gives rise to an international cause of action. That being so, states have been concerned not to appear as law-breakers before the world.

For the enforcement of international law in the municipal sphere two types of machinery have been employed; they have been characterized by reference to 'Dualist' and 'Monist' theories respectively. Two significant facts emerge from a study of these two methods. In the first instance, the 'Monist' theory, which permits the direct enforcement of international law in the municipal sphere, is increasingly displacing the 'Dualist', with its requirement of 'transformation' of rules of international law into municipal law. Secondly, even under the latter method states have seen that rules of international law are, in fact, transformed and, accordingly, applicable in municipal courts. The circumstance that the enforcement of international law in the municipal sphere is wholly dependent on municipal machinery has admittedly involved certain limitations on the operation of international law. For municipal courts are bound to implement the will of the state as expressed by its legislative organs, or, in

certain circumstances, as manifested by executive acts. However, courts have refused to recognize that a violation of international law was intended unless such an intention was clearly expressed. Moreover, in some countries constitutional provisions have now been enacted which are intended to ensure the supremacy of international law over conflicting provisions of municipal legislation.

Moreover, there are exceptional circumstances in which municipal organs act fully as agents of the international community in the enforcement of its law. This is so in the case of the review of the acts of a foreign state by municipal courts with a view to determining the enforceability of these acts within the state of the forum; it is so, in particular, in the case of the review of the acts of a belligerent occupant by the organs of the occupied territory.

# THE FACULTY OF MATHEMATICS

*For the* PH.D. *Degree*

## SOME RESULTS IN THE GEOMETRY OF NUMBERS

*By* LIONEL EDWARD CLARKE, M.A.

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*The critical lattices of a star-shaped octagon*

LET $\mathscr{R}$ be the region formed by the boundary and interior of the star-shaped octagon whose sides are the lines

$$x = \pm l(y \pm 1), \quad y = \pm l(x \pm 1),$$

where $l > 1$, and whose vertices are

$$(\pm 1, 0), \quad (0, \pm 1), \quad \left(\pm \frac{l}{l-1}, \pm \frac{l}{l-1}\right).$$

Then for $l \geqslant 2+\sqrt{3}$ the critical lattices of $\mathscr{R}$ have been found by Mordell. Similar methods are applied in Chapter I to find the critical lattices for $\sqrt{3} \leqslant l \leqslant 2+\sqrt{3}$. In this range of values of $l$ it is shown that there are essentially three different types of critical lattice according as $\sqrt{3} \leqslant l \leqslant l_0$, $l_0 \leqslant l \leqslant 1+\sqrt{2}$, or $1+\sqrt{2} \leqslant l \leqslant 2+\sqrt{3}$ where $l_0$ is the root greater than unity of

$$3l^6 + 4l^5 - 7l^4 - 24l^3 - 7l^2 + 4l + 3 = 0.$$

*On products of non-homogeneous linear forms*

Let $\omega_1, \omega_2, \omega_3$ be an integral basis of a totally real cubic field of discriminant $d$, and let $\omega_1', \omega_2', \omega_3'$ and $\omega_1'', \omega_2'', \omega_3''$ be the corresponding bases of the two conjugate fields. Let

$$\xi = \omega_1 x + \omega_2 y + \omega_3 z, \quad \eta = \omega_1' x + \omega_2' y + \omega_3' z,$$
$$\zeta = \omega_1'' x + \omega_2'' y + \omega_3'' z.$$

Then for the two cyclic cubic fields with least discriminants Davenport has solved the problem of finding the best possible value of $\mathscr{M}$ having the property that, corresponding to any real numbers $a, b, c$, there exist rational integers $x, y, z$ for which

$$|(\xi - a)(\eta - b)(\zeta - c)| \leqslant \mathscr{M}\sqrt{d}.$$

In Chapter II it is shown by similar methods that when $d=148$, i.e. when the field is the totally real *non-cyclic* cubic field of least discriminant, the best possible value of $\mathscr{M}$ is $(4\sqrt{37})^{-1}$.

Let $\theta$ be an algebraic number of degree $n$ with conjugates $\theta^{(1)}$, ..., $\theta^{(n)}$. Let $\theta^{(1)}$, ..., $\theta^{(r)}$ be real and the others complex, and let $\theta^{(j)}$, $\theta^{(j+s)}$ be complex conjugates for $j=r+1$, ..., $r+s$, where $r+2s=n$. Let $\omega_1$, ..., $\omega_n$ be an integral basis of the field $\mathscr{R}(\theta)$ and, for $j=1$, ..., $n$, let $\omega_1^{(j)}$, ..., $\omega_n^{(j)}$ be the corresponding basis of the field $\mathscr{R}(\theta^{(j)})$. Let $L_j=\omega_1^{(j)}x_1+\ldots+\omega_n^{(j)}x_n$ $(j=1, \ldots, n)$, and let $a_1$, ..., $a_n$ be any $n$ numbers for which $a_1$, ..., $a_r$ are real and $a_j$, $a_{j+s}$ are complex conjugates for $j=r+1$, ..., $r+s$. Then Chapter III deals with the problem of finding constants $\mu$, $\nu$ such that, corresponding to the numbers $a_1$, ..., $a_n$, there exist rational integers $x_1$, ..., $x_n$ for which

$$|(L_1-a_1)\ldots(L_n-a_n)| \leqslant \mu |d|^{\nu}, \qquad (1)$$

where $d$ is the discriminant of $\mathscr{R}(\theta)$.

It is shown that (i) there exists a constant $\mu=\mu(n)$ such that (1) holds with $\nu=\frac{1}{2}n$; (ii) if, further, $n$ is a prime greater than 2 then the exponent $\frac{1}{2}n$ may be replaced by $\frac{1}{2}n-\dfrac{n-2}{n-1}$; (iii) if $\theta=m^{\frac{1}{3}}$, where $m$ is a rational integer, square-free and congruent to 0 (mod 3) or $\pm 2$, $\pm 4$ (mod 9), then (1) holds with $\mu=\frac{1}{9}$, $\nu=\frac{2}{3}$, and no lesser value of $\nu$ is permissible.

*For the* PH.D. *Degree*

## ACCESSIBILITY OF PLANE SETS AND DIFFERENTIATION OF FUNCTIONS OF TWO VARIABLES

*By* ROY OSBORNE DAVIES, M.A.

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MOST results of Chapters I, II and III have already been published (*Proc. Camb. Phil. Soc.* 48 (1952), 215–32).

In Chapter I the following lemma is proved (the basis for most of the remainder of the dissertation): Any bounded closed plane set $E$ can be covered by a finite number of arbitrarily long

parallelograms, with diagonals arbitrarily near to a prescribed direction, whose union meets every line not passing near $E$ in a set of small linear measure.

In Chapter II a plane set $M$ of full measure is constructed having every point accessible, that is, lying on some straight line (infinite in both directions) which contains no other points of $M$—extending Nikodym's result (*Fundam. Math.* 10 (1927), 116–68). Another result proved is that any plane set can be covered by straight lines whose union has the same measure.

In Chapter III the following are constructed: (i) a measurable function of two variables p.p. approximately derivable in two (variable) directions but not approximately (plane) differentiable, (ii) a continuous function with similar properties.

In Chapter IV a construction is given—different from Mossaheb's (*Proc. Camb. Phil. Soc.* 46 (1950), 28–45)—of a continuous function of two variables such that p.p. the directions in which it is derivable form a set of positive but not full measure.

It is shown in Chapter V that the accessible points of a closed plane set need not form a Borel set, and that those of a measurable set need not form a measurable set—results given originally by Nikodym and Sierpinski respectively.

Results are proved in Chapter VI concerning (i) plane sets at every point of which the directions of lines of accessibility form a set of positive measure (for example, such sets can be of full outer measure), and (ii) plane sets whose different points are accessible along disjoint segments (for example, such sets cannot be measurable and of positive measure).

*For the* M.Sc. *Degree*

## SOME PROBLEMS IN SEQUENTIAL ANALYSIS

*By* KODIKARA MUNIDASA CHANDRASOMA DE SILVA

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IN the first chapter a sequential sampling procedure for deciding between a finite number of terminal decisions, where experimentation is carried in a finite number of stages, is considered. At

each stage experimentation is carried one stage further, or a terminal decision is reached. The treatment of the problem is similar to that given in a recent paper by Lindley. A method is given of decomposing the sample space, using the unlikelihood criteria. It was not possible to prove the closed and convex property rigorously, so this was assumed, and the final results are subject to this extra assumption, which is probably unnecessary.

In the second chapter some binomial sequential sampling problems are considered. It is shown that the estimators proposed by Girshick, Mosteller and Savage tend to a limit, and this estimator is numerically compared with other simple estimators that have been proposed. The properties of a 'truncated inverse binomial' scheme are also derived.

A double sampling scheme for testing the mean of a normal distribution with known variance, where the size of the second sample is a given function of the estimate of the mean from the first sample, is obtained in Chapter III.

In the last two chapters two special problems are considered. The first is a problem of one-dimensional search; given the distribution of the position of the unknown point, an optimum procedure for finding it is obtained. The second is a problem in the theory of queues where there are two types of customers having different distributions of service time. The mean waiting time when (*a*) one type of customer has priority, and (*b*) customers are served in order of arrival, is obtained.

*For the* PH.D. *Degree*

## SOME COMPUTATIONS IN THEORETICAL PHYSICS

*By* ALEXANDER SHAFTO DOUGLAS, M.A.
*Trinity College, Cambridge*

THE dissertation is primarily concerned with the application of high-speed computing machines to theoretical physics, the particular machine used being the EDSAC at the Mathematical Laboratory, Cambridge. A description of this machine is given in the introductory chapter, together with a brief discussion of

the subject-matter of the dissertation. Three important physical problems are considered, two in extranuclear atomic theory and one in crystallography. In Chapter II a method is reported for determining the term to represent the polarization potential in the equation for the series electron of an atomic structure consisting of closed shells of electrons and a single additional electron. A new approach to the solution of Schrödinger's equation for the helium atom is discussed in Chapter III, and it is concluded that it is possible to solve the equation as accurately as we please. Chapter IV describes the techniques used in Chapter II for solving the Hartree–Slater–Fock equations; these techniques are similar to those used in hand computation, but certain important modifications are desirable when using the EDSAC. Improved wave functions for various states of $Si^{+3}$, $Ca^{+}$, $S^{+}$ and $Tl^{+}$ are given in appendices.

The third physical problem considered, namely, the determination of crystal structures, is fully discussed in Chapters VI, VII and VIII. Of these chapters, Chapter VI is introductory, Chapter VII discusses the problem from a physical standpoint, and Chapter VIII is concerned with the mathematical techniques used. The latter are themselves of considerable interest, involving an unusual use of the theory of congruences. In developing the organization necessary for this latter problem, an excursion was made into the theory of games, and Chapter V describes the application of the machine to the playing of noughts and crosses. The concluding chapter is a general review of the selection of the order code for a machine. This has an important bearing on the construction of future machines and is based on the experience gained in the operation of the machine on the problems described above.

*For the* PH.D. *Degree*

## SOME PROBLEMS IN THE THEORY OF ATOMIC AND MOLECULAR STRUCTURE

*By* LEONARD ALAN GEOFFREY DRESEL, M.A.

*Peterhouse, Cambridge*

THE main section of the dissertation is concerned with methods of obtaining approximate solutions of Schrödinger's wave equation

for atoms. After discussion of Hylleraas's work on helium, and the more generally applicable method of the Hartree–Fock equations of the self-consistent field, an account is given of the method developed recently by Boys.

The heavy computations involved lead to the use of modern electronic computing machines, of which the EDSAC at Cambridge provides a good example. A discussion is given of the difficulties that had to be overcome in performing on the EDSAC a four-suffix transformation of the two-electron integrals. A feature of the method adopted is the calculation of additional results by the EDSAC so as to provide an easy check on its correct operation.

With the help of the EDSAC approximate energies and wave functions for the ground-state and the first four excited states of the helium atom are calculated by the superposition of up to twenty configurations in the method of Boys. The energy obtained for the ground-state is within 0·2 % of the experimental value. A satisfactory value is obtained for the magnetic susceptibility, and two transition probabilities are calculated. Comparisons are made with results published by other authors, with special reference to the effect on the calculated ground-state energy of the inclusion of higher spherical harmonics in the wave function.

The last chapter is concerned with molecules. The equations of the self-consistent field for molecules have recently been developed by Lennard-Jones. Second-order perturbation theory is applied to these equations in an attempt to study the force constants in molecular vibrations. Some interesting algebraic formulae are obtained, but in their present form they do not appear suited to numerical applications.

*For the* PH.D. *Degree*

## A NEW APPROACH TO THE THEORY OF RENORMALIZED FIELDS

*By* SAMUEL FREDERICK EDWARDS, B.A.

*Gonville and Caius College, Cambridge*

THE formulation of quantum electrodynamics in the form of closed coupled functional integro-differential equations, which

has been presented by Schwinger, is here extended to the case interactions between mesons, nucleons and photons. The equ tions are set up and renormalized, thus constituting a simplifi approach to the renormalization theorem. The formalism can extended to the case of many fields, provided their interactions a of the renormalizable types, and the general result that t number of renormalization coefficients is equal to the number fields plus coupling constants is demonstrated.

The functional integro-differential equation for electi dynamics is taken and simplified by neglecting certain high order terms. The integral equation remaining is singular a unbounded, but can be solved, without recourse to perturbati theory, for an arbitrarily large coupling constant. The solution interpreted as expressing the effective non-locality of the electr in closed form, and the 'shape' of the electron is discussed. T results are extended to meson theory, though the derivation (r the solution after derivation) does not have so much validi The divergences hitherto present in the theory appear in tl formulation as a consequence of inadequate mathematical tre: ment, and finite values can be obtained for self-energy effects.

The possibility of improvement and application of the result discussed.

*For the* PH.D. *Degree*

## ATOMIC TRANSITIONS IN ASTROPHYSICS

*By* ROY HENRY GARSTANG, M.A.

*Gonville and Caius College, Cambridge*

KNOWLEDGE of the transition probabilities of a large number spectral lines is an essential preliminary to many astrophysic investigations.

Section I of the dissertation describes a study of the effect spin-other-orbit and spin-spin interactions on the energy levels $p^n$ configurations. The energies are affected by small, but n negligible, amounts. The agreement of the theoretical Lan intervals with observation is substantially improved. Previc work of Araki on spin-spin interactions is shown to be fallacio The transition probabilities do not, in general, differ greatly fr

the results of previous investigators. The results of this work are applied to the problem of the identification of highly ionized calcium in the solar corona. The presence of Ca XV cannot be confirmed from the data available at present. The intensities of the O II and S II doublets are compared with observational values from studies of planetary nebulae.

Section II consists of a series of calculations of intermediate coupling strengths of permitted lines. Computations are performed for the $3s$–$3p$ and $3p$–$3d$ arrays of O II and Ne II and for the $4s$–$4p$ arrays in S II and A II. The parameters in the theory are estimated by fitting to spectroscopic energy levels. Improved theoretical values of the Landé $g$-factors are computed for a large number of lines. Comparison of these $g$-factors with experimental values provides an additional check on the calculations. The absolute strengths of the arrays are discussed. A curve of growth is constructed for Gamma Pegasi, using both Russell–Saunders and intermediate coupling line strengths for the $3p$–$3d$ array in O II. The residual scatter about the mean curve is appreciably lessened. For some reason, not yet understood, the theoretical and observed curves cannot be fitted together satisfactorily. A further application of intermediate coupling theory is made to compute transition probabilities for some lines of neutral carbon.

Appendix I describes the calculation of atomic wave functions for Ne III and Ne II.

Appendices II and III contain two supplementary investigations, not connected with transition probabilities. Appendix II deals with charge transfer for protons in helium. Appendix III gives a preliminary survey of the spectrum of the star Zeta Capricorni, in which certain new peculiarities have been found.

*For the* PH.D. *Degree*

# A CONTRIBUTION TO THE THEORY OF COMMUTATORS IN GROUPS AND ASSOCIATIVE RINGS

*By* KARL WALTER GRÜNBERG, B.A.

*Trinity College, Cambridge*

A STUDY is made of various topics in the commutation theory groups and associative rings. The first result provides a free of generators of the Cartesian subgroup of a free product (t Cartesian subgroup being the kernel of the natural hon morphism on to the direct product). When each free factor cyclic, the Cartesian subgroup coincides with the derived su group, and, in this special case, there is an alternative free set generators of the Cartesian subgroup consisting of certain simp basic commutators. The former result leads to the following t theorems: If $p$ is any given prime number and $G\sim p$ is interpret to mean that, in the group $G$, the identity is the intersection of normal subgroups having index some power of $p$, then (i) $S\sim$ where $S$ is a free soluble group, and (ii) $G\sim p$, where $G=A_1{}^*\ldots{}^*$ and each $A_i\sim p$. The next topic is concerned with groups in whi the repeated forming of commutators with a fixed element alwa eventually leads to the identity. Such groups are called En groups, and it is proved that every soluble Engel group (i) locally nilpotent, but (ii) not necessarily nilpotent. The l two chapters deal with associative rings. First, a minimal set ideal generators is found for the lower central factors of a fi associative ring (as defined by S. A. Jennings), and then con tions are investigated under which the enveloping ring of a r potent Lie ring shall be of finite class. The results obtained a used to study Engel rings—i.e. rings in which the repeat forming of (additive) commutators with a fixed element alwa eventually leads to zero—and enable one to show that an En ring is locally of finite class if it (i) satisfies the maximal conditi on subrings, or (ii) satisfies the minimal condition on right idea or (iii) is an algebra over a field of non-zero characteristic.

*For the* PH.D. *Degree*

# THEORETICAL IONOSPHERIC RADIO PROPAGATION

*By* JOHN HEADING, M.A.
*St Catharine's College, Cambridge*

THE propagation of plane electromagnetic waves in a horizontally stratified ionosphere is investigated by means of the solution of the appropriate differential equations for the electric field components of the wave. The differential equations are formulated first vectorally, and then in a specific co-ordinate system, in terms of the properties of the ionosphere. These consist of the free electron density (as a function of height alone), the collision frequency (generally constant) of the free electrons with heavier particles, and the earth's magnetic field. Various profiles of the electron density as a function of height are considered which render the differential equations capable of analytical solution in such a manner that the reflexion and transmission coefficients of the model ionosphere may be stated explicitly in functional form. The numerical values of the reflexion coefficients for the anisotropic models solved are briefly compared with experimental data.

When the functional form (or numerical value) of the electric field is known throughout the ionosphere, the reflecting and absorbing properties of any individual arbitrary volume of ionization can be studied as a re-radiation process. This leads to a clear insight into the quantitative processes involved in the ionosphere as an incident wave is partially reflected, partially absorbed and partially transmitted. The actual parts of the ionosphere responsible for the bulk of these processes are be found quantitatively. Formulae showing these effects are derived for the general anisotropic model, and many illustrations are given using the analytical solutions previously found. In the light of this theory the subject of the height of reflexion is also discussed.

A fundamental chapter on phase integral methods gives a critical account of the historical development of the subject; this is then developed on a new and more satisfactory basis. It is a

method for solving the isotropic equations for the field asymptotically, but it also gives an insight into the nature of reflexion regarded as quite a different process from the re-radiation theory previously developed. The theory is finally extended to the solution of the general anisotropic equations, introducing the concept of coupling between the characteristic waves.

*For the* PH.D. *Degree*

## TWO TOPICS IN ABSTRACT ALGEBRA

*By* PHILIP JOHN HIGGINS, B.A.
*Trinity College, Cambridge*

*Composition series and radicals in Ω-groups*

AN Ω-group is a new type of algebraic system consisting of a group $G$ together with a set $\Omega$ of operators acting on $G$. The operators allowed are more general than the group endomorphisms considered in the conventional group-with-operators and, by specializing the set $\Omega$, arbitrary groups, rings (not necessarily associative), clusters and Lie and Jordan triple systems can be displayed as Ω-groups. Appropriate axioms are laid down which hold in all these special cases and are sufficient to imply the usual homomorphism theorems in their simplest form.

The theory of composition series, which has hitherto been obtained separately for groups and rings, is developed in detail for arbitrary Ω-groups, and the relations between composition factors in different composition series, given by the Jordan–Holder theorem, are formulated more exactly. Various results are then obtained concerning the order and interchangeability of composition factors, special attention being given to the distinction between two types of composition factors which correspond in groups to the Abelian and non-Abelian factors.

As an application of these methods a theory of radicals in Ω-groups is developed. A theorem of A. A. Albert on the radical of a non-associative algebra is obtained as a consequence of well-known theorems of complete reducibility and is thus easily proved in a more general form. An examination of the Wedderburn structure theorems in this larger context leads to a series of results

on various newly defined radicals, giving a possible basis for a general structure theory of non-associative algebras.

*Lie rings satisfying the Engel condition*

A Lie ring is said to satisfy the $n$th Engel condition if, for every pair $x$, $y$ of its elements, the product $(\ldots(xy)y\ldots)y$ vanishes. M. Zorn has shown that this condition implies nilpotence whenever the Lie ring also satisfies the maximum condition on subrings. The question considered here is whether the $n$th Engel condition implies nilpotence when the maximum condition is not assumed.

The results proved are that a Lie ring satisfying the $n$th Engel condition must be nilpotent in each of the following cases:

(i) if it is soluble and has characteristic prime to $n!$,

(ii) if $n=2$,

(iii) if $n=3$ and the ring has characteristic prime to 2 and 5,

(iv) if $n=4$ and the ring has characteristic prime to 2, 3, 5, and 7.

*For the* PH.D. *Degree*

## STUDIES IN MAGNETO-HYDRODYNAMICS

*By* COLIN OSWALD HINES

*Fitzwilliam House, Cambridge, and the University of Toronto*

*Generalized magneto-hydrodynamic formulae*

THE formulae for current and force which were employed in some of the initial work on magneto-hydrodynamic theory are not valid over the whole range of phenomena which the subject itself embraces. Generalized formulae suitable for wider application are derived by an extension of the magneto-ionic approach, and are applied to the simple case of plane-wave propagation in the direction of a primary magnetic field. The dispersion equation which results and the basic current and force formulae are reduced by approximations in a variety of limiting circumstances. Some earlier results are thereby regained, and in particular the region of known validity of Alfvén's propagation relation is extended.

*Magneto-hydrodynamic waves in the ionosphere*

The observational background of this section of the dissertation concerns certain ionospheric irregularities which appear to retain

a semi-permanent pattern while travelling uniformly in a horizontal direction. Their uniform motion can be accounted for in terms of winds or waves, but various physical considerations suggest the latter as the more probable agent.

Electromagnetic and hydrodynamic oscillations on the same scale as these disturbances can generally be propagated almost independently in the ionosphere, though a small magneto-hydrodynamic coupling does exist. Under special conditions of resonance this coupling leads to the generation of relatively large oscillations of one type from an initial disturbance of the other. Order of magnitude estimates indicate that in these circumstances an initial hydrodynamic oscillation will be accompanied by unusually large electron motions, and that they can therefore be more easily detected by radio methods. Further arguments can be introduced to specify more closely the conditions under which the resonant effects will be most pronounced, and these conditions supply formulae for comparison with the mean or modal values obtained observationally.

It appears that the resonant disturbance can be associated with one of the types which were observed, though the estimates which are thereby provided for the atmospheric scale height ($\sim 20$ km.) and specific heat ratio ($\sim 1{\cdot}1$) in the $F$ layer are somewhat smaller than would be expected from other considerations. The two other types of disturbance which were detected are less amenable to a similar interpretation and may have to be explained on some other basis.

Another type of resonance, in which the electrons themselves are set into a resonant motion, results from the effects of electron partial pressures. It may be possible to explain the remaining observations on such a basis or to improve the correspondence already obtained in the first set; in any case this electron resonance should be investigated.

Other aspects of the problem which remain for future consideration include the effects of inhomogeneities, especially in the sense of boundary conditions, and the calculation of actual electron motions and density variations.

*For the* PH.D. *Degree*

# SOME PROBLEMS IN ANALYSIS

*By* FRANK RICHARD KEOGH

*Emmanuel College, Cambridge, and the University of Manchester*

THE dissertation is concerned with a number of problems in the theory of schlicht functions and typically real functions.

Let $w(z)$, $z=re^{i\theta}$, be a function regular and schlicht in the unit circle $\gamma$, or $|z|<1$, mapping $\gamma$ conformally on a domain $D$ in the $w$-plane. Let $C_r$ denote the image in $D$ of the circle $|z|=r<1$. Proofs are given that, if $D$ is convex and normalized so that $w(0)=0$, $w'(0)=1$, then the maximum radius of curvature of $C_r$ is at most $\frac{r}{1-r^2}$ and the length of $C_r$ is at most $\frac{2\pi r^2}{1-r^2}$. These results are best possible, being attained when $w(z)=\frac{z}{1-z}$. Analogous results are stated for the class of normalized domains star-shaped with respect to the origin. The first chapter ends with some applications to convex domains of theorems due to R. M. Gabriel.

Next, a gegenbeispiel is given to the author's conjecture that, if $D$ is bounded by an analytic curve the curvature of which vanishes at two distinct points only, then the curvature of each $C_r$ vanishes at two distinct points at most.

Let $l(\rho)$ denote the length of the image in $D$ of the radius $(0, \rho)$ in $\gamma$. Then, if $D$ is bounded, $l(\rho)=o\left(\left(\log\frac{1}{1-\rho}\right)^{\frac{1}{2}}\right)$. A proof is given that, in a certain sense, this relation is best possible.

Suppose $w(z)=u(z)+iv(z)$, $z=\rho e^{i\theta}$, is regular in $\gamma$ and typically real, i.e. $v(z)=0$ if and only if $z$ is real. Let $\sum_{n=1}^{\infty}a_nz^n$ be the Taylor expansion of $w(z)$ at $z=0$ and let $\sigma_n^{\alpha}$ be the $\alpha$th Cesàro mean of the coefficients $a_n$. A number of theorems are given relating the behaviour of $(1-\rho)u(\rho)$ as $\rho\to 1$ to the behaviour of $\sigma_n^{\alpha}/n$ as $n\to\infty$ (mainly for $\alpha=0$).

*For the* M.Sc. *Degree*

# RIESZ POTENTIAL IN FIELD THEORY

*By* LAXMAN SINGH KOTHARI

*Fitzwilliam House, Cambridge, and the University of Delhi*

STARTING with the modified definition of Riesz potential for the electromagnetic field introduced by Auluck and Kothari (*Proc. Camb. Phil. Soc.* 47 (1951), 436) it is shown in the beginning of Chapter I that this definition refers to a field with continuous mass spectrum, and not only photons of rest mass zero remain when finally analytic continuation to $\alpha = 0$ is carried out, $\alpha$ being the parameter characteristic of Riesz potential. This property is later utilized to eliminate certain divergences occurring in electrodynamics, and, with suitable modifications, also in meson theory. The rest of Chapter I is devoted to the quantization of Riesz potential and the elimination of longitudinal waves from the electromagnetic potential. The divergence resulting from the point nature of charge that normally arises in this problem is avoided. In the second chapter finite and physically significant results are obtained for (i) the second-order electron self-energy, (ii) the correction to the scattering of a free electron in an external potential from a third-order vertex graph (a fifth-order irreducible vertex graph is also briefly discussed), and (iii) an electron self-energy graph with a vertex part insertion at one of its vertices. In the treatment of the above problems one has not to introduce any auxiliary fields or cut off factors.

In the next chapter modified Riesz potential for neutral vector meson field is introduced and discussed in a little detail. Apart from the usual expression, an extra term is obtained for the potential on the world line of a nucleon. In the last section self-energy of a nucleon in the field of neutral vector mesons is derived. The fourth chapter deals with a generalization of the solution of the Dirac equation in the '$\beta$' plane and the photon self-energy problem.

In the last chapter, using an extension of Fremberg's original definition for Riesz potential, the potential and field tensors at points outside as well as on the world line of an arbitrarily moving

point particle, interacting with a meson field of any integral spin, are evaluated. A few remarks regarding a particle in uniform motion are also included.

Some calculations, based on Fermi's theory, on the production of 'heavy' mesons in nucleon-nucleon collisions and also on meson-nucleon collisions are presented at the end in the form of an appendix.

*For the* PH.D. *Degree*

## THE HYDRODYNAMIC STABILITY OF THE FLOW IN THE LAMINAR BOUNDARY LAYER BETWEEN PARALLEL STREAMS

*By* ROBERT CHRISTOPHER LOCK, M.A.

*Gonville and Caius College, Cambridge*

A THEORY is given of the stability of small two-dimensional sinusoidal disturbances in the double laminar boundary layer which is formed when a uniform horizontal stream of incompressible fluid moves over a parallel stream of different density and viscosity.

The first section of the dissertation is concerned with steady motion. A method is given of solving the boundary-layer equations, and it is shown that the solutions depend only on the ratio $U_2/U_1$ of the velocities of the two streams and on the product $\rho\mu$ of the corresponding density and viscosity ratios. Numerical results are given, in the case when the lower fluid is at rest, for four values of $\rho\mu$, and also, when $\rho\mu = 1$, for one non-zero value of the velocity ratio.

In the second section the stability of this steady motion is investigated, with particular reference to the flow of air over water at rest. Suitable solutions of the Orr–Sommerfeld equations are developed from those of Heisenberg, and when used in conjunction with the appropriate boundary conditions they yield a characteristic equation from which the wave velocity and amplification of a disturbance of given wave-length can theoretically be calculated at given values of the velocity of the air stream and the horizontal distance from the point at which the air is supposed to come into contact with the water.

It is shown that there are two fundamental types of wave motion of the system, in one of which the motion is largely confined to the air, so that only the second type is likely to lead to the development of genuine water waves. Detailed calculations were made for neutral waves, and curves are given showing the conditions for neutral stability for both types of wave over a range of wind speeds from 100 to 300 cm./sec.

*For the* PH.D. *Degree*

## CONTINUOUS INSPECTION SCHEMES AND MONTE CARLO METHODS

*By* EWAN STAFFORD PAGE, M.A.
*Christ's College, Cambridge*

THE dissertation is in two sections entitled 'Continuous inspection schemes' and 'Monte Carlo methods'.

In the first section schemes for controlling the quality of the output from a continuous production process are considered. The best choice of the sample size and position of the control limits for control chart schemes using one sample is discussed. Some new schemes for process inspection using repeatedly applied linear sequential tests are suggested, and their properties are evaluated. The special cases for controlling the means of binomial and normal populations are examined, and some numerical comparisons with the control chart method are made. For the normal case the comparisons involve the numerical solution of linear Fredholm integral equations of the second kind, and a method of solution suitable for an automatic computor is developed. The process inspection schemes are extended to yield rules for deferred sentencing and rectifying inspection. A storage problem related to a process inspection scheme is described.

The first chapter of the second section deals with the problems of performing Monte Carlo methods and artificial sampling experiments on an automatic computor, with particular reference to the EDSAC. Methods for the solution by Monte Carlo procedures of the Fredholm integral equation are developed, and estimators for the solution are proposed which are based on the

sample path of a particle performing a linear random walk between absorbing barriers; some numerical examples are given. Finally, some sampling experiments on process inspection schemes and a non-parametric test are described.

*For the* PH.D. *Degree*

## PROBLEMS IN THE THEORY OF REAL VARIABLES

*By* JEROME RAYMOND RAVETZ

*Trinity College, Cambridge, and Swarthmore College, U.S.A.*

THE first section of the dissertation consists mainly of methods for determining the fractional-dimensional measure of linear perfect sets from the rules of construction of the sets. Applications of these results are made in the theory of the differential properties of continuous functions of a single real variable and in the theory of Diophantine approximation.

In the second section continuous real-valued functions of two real variables are studied in respect of their tangential properties. Here the analysis is from a descriptive, rather than from a metric, approach; in the statement of overall properties sets of the first category rather than sets of measure zero are considered as 'negligible'.

*For the* PH.D. *Degree*

## SUMMATION AND INTEGRATION IN LINEAR TOPOLOGICAL SPACES

*By* ALEXANDER PROVAN ROBERTSON, B.A.

*St John's College, Cambridge*

IN the dissertation the theories of unconditional convergence of series and of integration of vector-valued functions are generalized from a Banach space to a linear topological space.

The theory of summation, the natural generalization of unconditional convergence, is developed in Chapter II. Various conditions for the summability of a family of elements of a linear

topological space are established, including the fact that a family is summable if, and only if, the set of its finite partial sums is precompact (totally bounded). Most of the Banach space results appear as special cases of the theorems proved in this chapter. As an application of the theory, the general forms of certain types of linear operators are obtained.

The integration of functions defined on a general measure space and taking values in a linear topological space is the subject of Chapter III. This chapter begins with a discussion of the weak (Pettis–Gelfand) integral, and vector-valued additive set-functions are then considered. A 'topological' integral is defined by topologizing the space of weakly integrable functions and calling a function integrable if it belongs to the closure under this topology of the subspace of simple functions. This integral has the usual desirable properties, and is simpler and more comprehensive than the integral previously defined by Phillips. The chapter closes with a partial extension of the Radon–Nikodym theorem.

Those parts of the general theory of linear topological spaces required in the two main chapters are collected together in Chapter I. This is in two parts. In the first a brief résumé of existing theory is given, and the second contains a proof that a semi-norm bounded on compact sets is bounded on bounded sets, and a study of the topology on the conjugate space of uniform convergence on precompact subsets of the space.

*For the* PH.D. *Degree*

## RECURSIVE SETS

*By* NORMAN ARTHUR ROUTLEDGE, M.A.
*King's College, Cambridge*

AFTER setting out the principal results (particularly those of Pétér and Kleene) in the theory of primitive and general recursive functions, the dissertation studies ordinal recursion (a notion derived from Ackermann), and proves that all general recursive functions can be obtained using no ordinals higher than $\omega$. It then studies the notion of oracle machines (due to Turing) and proves some results about the nature of sets derivable by them

from given sets. After this the effect of the elementary arithmetic operations (addition, multiplication, etc.) on infinite binary decimals is treated from a recursive standpoint, and it is shown, for instance, that whereas the sum of two computable numbers is certain to be one of a given infinite list of computable numbers, there can be no effective way of indicating which of this infinite list it is. The theory of constructive, and realizably constructive, ordinals is then erected (using ideas found in the work of Kleene and Nelson), and this is used to extend into the transfinite the systems of 'definable sets' of Kleene and Mostowski. It is shown that, so long as they are restricted to the realizably constructive transfinite ordinals, their main properties remain. It is conjectured that it is impossible to name, in any manner, a set of integers which is not one of the extended definable sets. In appendices are studied satisfiability (including a problem about the satisfiability of expressions in the predicate calculus with equality, over finite sets); an inequality in Hilbert space; a paradox of Zeno; and a decision method for the propositional calculus, adapted for use with binary electronic calculating machines.

*For the* PH.D. *Degree*

## DISCONTINUITIES IN DISPLACEMENT IN ELASTIC CONTINUA

*By* CECIL MARIN SEGEDIN

*Pembroke College, Cambridge, and the University of New Zealand*

DISLOCATIONS provide one instance in which there are discontinuities in displacement across a surface in an elastic continuum. Another is when in a cavity in an elastic medium is fitted an elastic plug of (slightly) different size and shape. In these cases there is a discontinuous displacement across the interface, the stresses acting across this interface being continuous. The Griffith crack provides a third instance; the discontinuity in displacement is now not assigned in advance, and the stress across the crack achieves continuity by vanishing.

The question of Volterra dislocations is considered for a two-dimensional medium with two circular holes, and solutions are

investigated in terms of bipolar co-ordinates for all possible Volterra dislocations.

Methods involving the use of the complex variable are found to be suitable for handling these problems in two dimensions. When the discontinuities are assigned, each of the two complex potentials can be found separately, and the strain-energy can often be calculated with little trouble. Methods are developed to treat the case where the discontinuities are across a line, circle, ellipse and rectangle, and as an illustration the case is considered where the unstrained shape of the plug is that obtained from that of the cavity by simple shear.

Previously solved problems of a Griffith crack in a medium subject to tension, shear and bending are solved in terms of complex potentials. A related problem, in which there is a rigid plaque to which the material is firmly bonded, is solved; in this case the displacements are continuous, but the stresses are not.

Three-dimensional problems in which there are discontinuities across a sphere and a disk are also considered.

Many of the problems discussed have been suggested by metal physics, but there are other applications, such as the calculation of thermal stresses, which are of use elsewhere.

*For the* PH.D. *Degree*

## SOME TOPICS IN THE THEORY OF NON-LINEAR DIFFERENTIAL EQUATIONS

*By* RUSSELL ALEXANDER SMITH, B.A.

*St John's College, Cambridge*

CHAPTERS I–V are concerned with the equation

$$y''+y'f(y)+g(y)=P(x),$$

where $P(x)$ is an analytic function of $x$ and $f(y)$ and $g(y)$ are polynomials in $y$ having degrees $n$ and $m$ respectively. It is regarded as an equation in complex variables, and the object is to determine what types of singularity a solution can possess at a point $x*$ at which $P(x)$ is regular. When $m<n$ only two types of singularity are possible, namely, algebraic critical points and

non-isolated singularities which are limit points of algebraic critical points. When $n \leqslant m < 2n+1$, algebraic critical points are possible if a certain polynomial equation in the coefficients of $f(y)$ and $g(y)$ is satisfied. If this condition is not satisfied, there is a family of solutions having branch points of infinite multiplicity at $x*$. These branch points of infinite multiplicity can be non-isolated singularities; indeed, they can be limit points of similar branch points of infinite multiplicity. When $m > 2n+1$, there is a similar condition which determines whether or not algebraic critical points can occur, and when it is not satisfied there are branch points of infinite multiplicity. It is also shown that, if $P(x)$ is a polynomial and $m \neq n+1$, then every solution has at least one singularity in the finite $x$ plane (except possibly for some polynomial solutions).

Chapter VI deals with an entirely different problem. It is a real variable discussion of the equation

$$\ddot{x} + k\dot{x}f(x) + x = pk\lambda \cos \lambda t,$$

where $f(x)$ is a function whose graph is roughly U-shaped and $f(0) < 0$. The amplitudes and stability of the periodic solutions are determined by the Cartwright–Littlewood method, supposing $k$ small and $\lambda \doteqdot 1$. The equation is important in the theory of triode oscillations, and the special case $f(x) = x^2 - 1$ has already been discussed by earlier writers (van der Pol, etc.). In practice, the graph of $f(x)$ has a much flatter bottom than in this special case, and the writer examines how much flattening can be tolerated without the amplitude-detuning diagram losing significant properties which it possesses in the special case.

*For the* PH.D. *Degree*

## STOCHASTIC SEQUENCES OF EVENTS

*By* WALTER LAWS SMITH, M.A.

*Pembroke College, Cambridge*

A SEQUENCE of non-negative random variables $\{\mathbf{X}_i\}$ is called a *renewal process*, and, if the $\mathbf{X}_i$ may only take values on some sequence $\{n\tilde{\omega}\}$ $(\tilde{\omega} > 0)$, it is termed a *discrete renewal process*. The greatest $k$

such that $\mathbf{X}_1+\ldots+\mathbf{X}_k \gtrless x$ is a random variable $\mathbf{N}^{(x)}$ and theorems concerning $\mathbf{N}^{(x)}$ are *renewal theorems*. Section I of the dissertation (Chapters I–V) deals with renewal theory and certain allied topics. Section II (Chapters VI and VII) deals with congestion theory and with applications of renewal theory thereto.

In Chapter I frequency-function versions of the central limit theorem are proved for identically and for non-identically distributed random variables. Let $H(x)=\mathscr{E}\{\mathbf{N}^{(x)}\}$; and when $\{\mathbf{X}_i\}$ are absolutely continuous write $h(x)=H'(x)$ for the *renewal density*. In Chapter II the results of Chapter I are used to find conditions under which $(*)\,h(x)\to 1/\mathscr{E}\{\mathbf{X}_i\}$, as $x\to\infty$, when the $\mathbf{X}_i$ are identically distributed, and to show that $(*)$ is still true under certain general conditions even when the $\mathbf{X}_i$ are non-identically distributed. Chapter III is concerned with the superposition of renewal processes: a local randomness property is demonstrated, and the behaviour of Var $\{\mathbf{N}^{(x+y)}-\mathbf{N}^{(x)}\}$ as $x, y\to\infty$ is discussed. Chapter IV concerns the superposition of several strictly periodic sequences of 'events': a local randomness property is again demonstrated, and the analysis of experimental results is discussed in relation to the work of Chapters III and IV. Let $K(x)$ be the distribution function of any non-negative random variable with mean $\kappa>0$. In Chapter V we assume the $\mathbf{X}_i$ to be identically distributed and prove a general renewal theorem

$$(**)\quad \lim_{x\to\infty}\left\{H(x)-\int_0^x K(x-z)\,dH(z)\right\}=\kappa/\mathscr{E}\{\mathbf{X}_i\}.$$

When the process is discrete, $(**)$ is to be slightly modified. From $(**)$ a number of renewal theorems are proved concerning $H(x)$, $h(x)$ and Var $\{\mathbf{N}^{(x)}\}$, some of which extend theorems known to be true for the discrete process from Feller's theory of recurrent events. An ergodic result of Doob's concerning $x-(\mathbf{X}_1+\ldots+\mathbf{X}_{\mathbf{N}^{(x)}})$ is improved.

Chapter VI deals with the equilibrium distribution of queueing time, and the parallel with storage theory is demonstrated. Certain general theorems are proved, but from a practical point of view the general formulae would not be easy to compute. However, it is shown that some queues have simple properties. Let $\phi_s$, $\phi_t$ be the characteristic functions of service time, total waiting time. It is proved that if $\phi_s^{-1}$ is a polynomial of degree $r$ then so is $\phi_t^{-1}$.

In Chapter VII the theory of Section I is applied to the congestion process to prove ergodic results and to appraise the rapidity of convergence of the process towards its equilibrium condition.

*For the* PH.D. *Degree*

## ON THE THEORY OF HAUSDORFF MEASURES

*By* SAMUEL JAMES TAYLOR

*Peterhouse, Cambridge, and the Queen's University, Belfast*

IN the dissertation the theory of Hausdorff measures is not developed as an end in itself. Each advance was suggested by problems in other fields, though often the result led to more far-reaching applications than those anticipated.

For sets of points a short account is first given of the connexion between the concepts 'vector sum', 'sets of translation', 'distance sets' and 'product sets'. For a linear set $E$ of zero Hausdorff $\phi$-measure (for any measure function $\phi(s)$), it is shown that there exists a perfect set $P$ such that the Cartesian product set $E \times P$, and the set obtained by translating $E$ through distances given by elements of $P$, each have zero $\phi$-measure.

By means of examples the relationship between the measures of a linear set $E$ and its distance set $D(E)$ is obtained. A 'gegenbeispiel' is given to show that the Steinhaus theorem about distance sets does not extend to linearly measurable subsets of a rectifiable curve in a general metric space.

An extremal problem is now considered. The three dimensions of the topological image of a cube may be defined as the lower bound of the lengths of paths joining opposite 'faces' which lie completely inside the set. The methods of measure theory are used to prove that the volume of such a topological cube is at least the product of its dimensions.

In the last two chapters the probable dimensional number and Hausdorff measure of certain sets defined stochastically in terms of Brownian paths are considered. It is proved that, with probability 1, the graph of a one-dimensional Gaussian process has dimension $\frac{3}{2}$ and zero $\frac{3}{2}$-measure, while Brownian paths in $n$-space

($n \geqslant 2$) have dimension 2 and zero 2-measure. For linear closed sets it is shown that the rate at which the lengths of complementary intervals decrease to zero gives an upper bound for the Hausdorff measures. This is used to examine the set of zeros of a Gaussian process.

*For the* PH.D. *Degree*

## THE SYLOW SUBGROUPS OF THE SYMMETRIC AND OF THE CLASSICAL GROUPS

*By* ALAN JOHN WEIR, M.A.

*Jesus College, Cambridge*

THE Sylow $p$-subgroups $S_n$ of the symmetric group on $p^n$ symbols are defined inductively by the complemented extension

$$S_{n+1} \cong A^{(n)} S_n,$$

where $A^{(n)}$ is elementary Abelian of order $p^{p^n}$. The series

$$A^{(n)} > (A^{(n)}, S_n) > (A^{(n)}, S_n, S_n) > \dots$$

is written

$$A_0^{(n)} > A_1^{(n)} > A_2^{(n)} > \dots$$

and has factors of order $p$. The subgroups

$$A_{i_0}^{(0)} A_{i_1}^{(1)} A_{i_2}^{(2)} \dots A_{i_n}^{(n)}$$

are called partition subgroups. The normal partition subgroups of $S_n$ are the characteristic subgroups of $S_n$.

The classical groups are defined over the finite field $GF(q)$. If $(p, q) = 1$ their Sylow $p$-subgroups are all direct products of special Sylow $p$-subgroups $\bar{S}_n$ which are defined as complemented extensions $\bar{S}_{n+1} \cong \bar{A}^{(n)} S_n$, where $\bar{A}^{(n)}$ is Abelian of type

$$(p^r, p^r, \dots, p^r).$$

When $p \mid q$ the Sylow $p$-subgroups $G_n$ of $GL_n(q)$ are groups of $(n \times n)$ matrices with 1's in the leading diagonal and zeros below the diagonal. The set of all $1_n + ae_{ij}$, $a \in GF(q)$, is a group $P_{ij}$. The subgroups generated by these $P_{ij}$ are called partition subgroups. The maximal Abelian normal subgroups are determined and used to show that the characteristic subgroups are the normal

partition subgroups which are symmetric about the second diagonal.

The Sylow $p$-subgroups $C_n$ of the symplectic groups of degree $2n$ are subgroups of $G_{2n}$ and are expressed as complemented extensions $C_n = BA$, where $B \cong G_n$ and $A$ is elementary Abelian of order $q^{\frac{1}{2}n(n+1)}$.

The Sylow $p$-subgroup $\mathcal{Z}_n$ of the unitary group of degree $n$ is a subgroup of $G_n(q^2)$ of the same order as $G_n(q)$. Partition subgroups are again introduced and the characteristic subgroups are normal partition subgroups. The maximal Abelian normal subgroups are used to show that $\mathcal{Z}_n$ and $G_n$ are not isomorphic when $n > 3$.

The Sylow subgroups of the orthogonal groups of odd degree and the easier subgroups of the orthogonal groups of even degree are subgroups of $\mathcal{Z}_n$ and are described by the same partition diagrams, except that in this case the squares in the second diagonal are empty.

*For the* PH.D. *Degree*

## SERIAL PROGRAMMING FOR REAL AND IDEALIZED DIGITAL CALCULATING MACHINES

*By* BEATRICE HELEN WORSLEY

*Newnham College, Cambridge, and the Massachusetts Institute of Technology*

IN attempting to solve a given problem numerically the modern mathematician might avail himself of one of a class of machines known as automatic universal digital calculators. In adapting himself to its inevitable limitations, however, he finds that those lying in the realm of logical design can be as serious as those of speed and capacity.

The dissertation defines this broad class of machines and sets out idealized representations. Descriptions are given of three existing machines with which work was done in the course of the study. Brief examples serve to compare the use of their order codes. Descriptions are given of three large-scale computations carried out on the EDSAC.

The first computation represents a determination of the second-order correction to be applied to the value of gravity from pendulum measurements made at sea. The problem was well suited to the EDSAC because of its magnitude and requirement of many solutions of similar basic forms. The second problem is an automatic rendition of the Hartree self-consistent field method for the solution of atomic wave equations with exchange. These extensive calculations were programmed in a form which could be used to solve any atom within a wide range. Since an extensive application of this programme would require several months, it is shown to be better suited to a machine equipped with a permanent auxiliary internal store. The third problem illustrates the way in which an automatic calculator may be used to explore the merits of a method together with its variations. The Liebmann one-dimensional process compares unfavourably with step-by-step and adjustment methods.

Finally, from experience gained in using existing machines, an empirical theory of axiomatic programming is evolved. It is hoped that this will be a guide to the design of order codes and libraries. It is based on the proposal of an optimum basic automatic universal digital machine.

# THE FACULTY OF MEDICINE

*For the* PH.D. *Degree*

## THE DEVELOPMENT OF THE REGULATION OF THE VOLUME AND pH OF THE EXTRACELLULAR FLUID

*By* JOSEPH HENRY CORT

*Clare College, Cambridge, and Yale University*

A STUDY was made of the development of renal mechanisms controlling the volume and pH of the extracellular fluid. The experimental subjects were puppies, adult dogs and human infants. Acidosis was induced by the administration of ammonium chloride and ammonium sulphate. The volume of the extracellular fluid was altered by placing colloid in the peritoneal cavity. Finally, the two techniques were combined in order to investigate their interaction.

It was found that:

(1) In acidosis, infants can concentrate hydrogen ions in the distal tubular urine to produce the same minimum urinary pH as adults. The rapidity of the infantile response was less than that of the adult, possibly owing to a lower glomerular filtration rate, but the hydrogen-ion exchange mechanism was active from birth.

(2) Infants display renal tubular 'immaturity' in that they fail to increase ammonia excretion during acidosis. This may be correlated with low kidney slice glutaminase activity found in this age group. Simultaneous extracellular fluid volume depletion and acidosis also failed to elicit an increase in ammonia production.

(3) Phosphate excretion in infants seems related to maturity and, possibly, to the availability of phosphate for growth. Human infants and puppies showed a low base-line excretion and low phosphate clearance, and did not increase phosphate excretion in response to acidosis. With increasing age both base-line values and increases of excretion during acidosis approached those of adults.

(4) When subjected to ammonium chloride acidosis, puppies achieved adult levels of renal sodium conservation. Puppies also

responded actively to the depletion of extracellular fluid volume by increasing renal tubular reabsorption of sodium. During acidosis induced by ammonium sulphate, newborn puppies lost excessive sodium into the urine, but this may have been caused as much by the osmotic effects of sulphate in the renal tubules as by acidosis. This sodium 'wastage' was much less marked in older puppies.

(5) Puppies excreted more potassium during ammonium chloride and ammonium sulphate acidoses than adults. It is interesting to note that, during sulphate acidosis, urinary potassium losses were not simultaneous with sodium losses, which is in agreement with the concept of sodium-potassium exchange in the renal tubule.

(6) Chloride excretion in ammonium chloride acidosis was lower in puppies than in adults.

(7) Puppies showed a well-marked increase in sodium reabsorption under conditions of dehydration or depletion of extracellular fluid volume, though not to the same extent as adults. Under such conditions animals responded to acidosis with earlier and more effective development of compensatory renal mechanisms than normal animals.

(8) Water diuresis in puppies was inhibited during depletion of extracellular fluid volume.

When given acid-forming salts, the newborn animal responds to some extent by excreting hydrogen ions and conserving sodium. It remains acidotic for a longer period than the adults because it is unable to excrete hydrogen ions in buffer form as ammonium ion and dihydrogenphosphate. These deficiencies are due to 'immaturity' in renal function, and they may also be due in part to the function of the infant kidney in promoting growth by the reabsorption of intracellular materials (e.g. phosphate).

Mechanisms for the control of extracellular fluid volume and pH interact, since both are concerned with sodium reabsorption by the renal tubules. When conditions of dehydration or depletion of extracellular fluid volume were induced simultaneously with acidosis, the rate of sodium reabsorption in puppies and adults was enhanced, and, in adults, the rate of urinary acid excretion was increased. Simultaneous depletion of extracellular fluid volume also impeded sodium excretion in alkalosis induced by

sodium bicarbonate. In contrast to their behaviour during acidosis, puppies differed only quantitatively from adults in their responses to extracellular fluid volume depletion.

The possible extrarenal mechanisms concerned in the control of pH and volume of the extracellular fluid are discussed.

*For the* M.Sc. *Degree*

## A STUDY OF MYELINATION AND DEMYELINATION BY THE USE OF HISTOLOGICAL AND HISTOCHEMICAL TECHNIQUES

*By* JAMES BERT RYAL COSGROVE

*Downing College, Cambridge, and the University of Manitoba*

IN this investigation a summary was made of the present state of knowledge concerning the structure of the neurone, the histogenesis of myelin, and the chemistry of the processes of myelination and demyelination.

Three histochemical techniques for the demonstration of alkaline phosphatase, acid phosphatase, and cholinesterase in tissue sections were adapted for application to formalin-fixed nervous tissue. The specificity and reliability of these techniques were discussed with reference to the relevant literature. In addition, an examination was made of several histochemical techniques for the demonstration of certain lipoids in tissue sections.

These histochemical procedures were applied in a study of the process of myelination in the developing spinal cord of the chicken embryo and in foetal and adult nervous tissue of the human. The process of demyelination was studied in transected sciatic nerves of the adult rabbit.

Although acid and alkaline phosphatase were demonstrated in the spinal cord of the chicken embryo, no relationship was established between these enzymes and the formation of myelin sheaths. During the process of myelination occasional groups of neurones stained positive for phospholipines. This staining did not occur prior to the appearance of myelin sheaths nor after myelination was completed. Some evidence was obtained also that the

oligodendroglia are associated with the appearance of myelin sheaths and undergo some change in their functional activity at this time.

Acid and alkaline phosphatase were demonstrated in nuclei of neurones and neuroglia cells of human nerve tissue. In addition, acid phosphatase was present in the cytoplasm and axones of neurones. No difference in distribution of these enzymes in foetal and adult nervous tissue of the human was observed.

During Wallerian degeneration a marked rise in acid phosphatase was demonstrated in the peripheral segments of transected nerves. Alkaline phosphatase was demonstrated in nuclei of the peripheral segment but not in the central segment nor in normal peripheral nerves of the rabbit. Evidence was obtained that the lipoids which were identified in this study disappear together during demyelination.

Certain observations were made concerning the distribution of lipoids in nervous tissue. It was demonstrated that phospholipine occured in the neuro-keratin network of the myelin sheath. Cholesterol, and possibly cerebroside, was localized in the spaces enclosed by this network. The unsaturated phospholipines, lecithin and cephalin, were observed to be present in the nuclei of neuroglia cells and in the cytoplasm and axones of neurones.

*For the* PH.D. *Degree*

## A STUDY OF URBAN NEIGHBOURHOOD

*By* TERENCE RICHARD LEE, M.A.
*Magdalene College, Cambridge*

THE 'neighbourhood unit' principle has a central place in the the contemporary theory and practice of town planning. While the physical planning advantages of this policy are widely accepted, it has been questioned whether its social objectives—the establishment of local communities—are realistic for modern urban life, which is characterized by 'mobility' and 'anonymity'.

An attempt is made to evaluate these considerations by investigating neighbourhood in existing conditions. The approach is made through the individual, for preliminary work led to the

hypothesis that perception and behaviour within the social and physical environment surrounding the home results in a consistent orientation pattern which can be conceptualized and measured as an attitude.

The development of field-work methods for studying neighbourhoods are described, and data from a systematic sample are analysed. The main data are derived from maps drawn by subjects of their particular neighbourhood.

Each neighbourhood was found to be unique, and is regarded as the result of interaction between a particular individual and a particular environment.

The mean area or range of neighbourhoods is not affected by wide differences in the environment, but their size in terms of number of houses, shops, etc., is therefore a direct function of the locality. This information is used to derive a scale of the neighbourhood attitude, which expresses the size and pattern of the neighbourhood independent of environmental influence.

The neighbourhood attitude predisposes, by definition, to behaviour in the locality, and criteria of this behaviour, the number of local social relationships and the use of local institutions (which represent behaviour on a continuum from 'involved' to 'non-involved' in respect of the locality), are used to validate the scale. A clear relationship is found between the large neighbourhood and involved behaviour in the locality.

A number of individual variables, length of residence, age, location of work, social class, etc., are examined for their influence upon the neighbourhood attitude.

Such an approach permits some generalization to be made to the kind and extent of locally orientated behaviour to be expected in various circumstances, and points to some conditions and dimensions which require to be observed in the planning of residential neighbourhoods.

# THE FACULTY OF MODERN AND MEDIEVAL LANGUAGES

## (1) *FRENCH*

*For the* PH.D. *Degree*

## A CRITICAL EDITION OF *THE LIFE OF ST JOHN THE ALMONER* ACCORDING TO THE MS. R.3.46 OF TRINITY COLLEGE, CAMBRIDGE

*By* GERALD STEPHEN CAFFREY, M.A.
*St Catharine's College, Cambridge*

THE object of the research was to provide the first complete critical edition of the thirteenth-century Anglo-Norman *Life of St John the Almoner*, a poem of 7702 lines in octosyllabic couplets, preserved in the unique MS. R.3.46 of Trinity College, Cambridge.

A notable feature of the MS. is the relatively systematic use of accents, and the possible principles of their employment are suggested.

The source of the poem is clearly the Latin *Life* by Anastasius the Librarian (Bollandists, 23 January), and comparison of the two versions shows almost exact correspondence. As literature the work differs little from the generality of Anglo-Norman Lives of Saints, although the occasional comments of the author are refreshingly personal. The poem appears to have had no literary influence, and this applies particularly to the Anglo-Norman *Manuel des Pechiez*, which carries three episodes from the *Life of St John*. The detail of comparison with the work of Anastasius and with the relevant sections of the *Manuel* is set out in the edition in appendices.

Linguistically the work is interesting since it is written in an Anglo-Norman of the early thirteenth century which contains more than the usual proportion of western and central French features. In this respect it shows a marked similarity to the

language of Frère Angier, who was probably a native of western France (Pope, M. K., Étude sur la langue de Frère Angier, diss., Paris, 1903). Comparison with the work of Angier and with the Anglo-Norman *Gui de Warewic* suggests composition about the second decade of the thirteenth century.

Study of the syntax reveals a few interesting parallels with the Anglo-Norman *Life of St Modwenna*, dated *c.* 1230.

The versification of the poem shows some irregularity, but less than might be expected in an Anglo-Norman work, especially when allowance has been made for the poet's treatment of elision, etc. Almost all the irregular lines may be rectified by slight adjustments, which, out of deference to the single MS., are not incorporated in the text but are suggested in footnotes.

Notes and a glossary are provided, together with an index of proper names, an index of biblical references, and a bibliography.

*For the* PH.D. *Degree*

## ALAIN-FOURNIER AND *LE GRAND MEAULNES*: THE GENESIS OF THE NOVEL

*By* ROBERT RONALD DAVIDSON GIBSON

*Magdalene College, Cambridge, and the University of London*

THE dissertation is divided into three main sections: the account of the genesis of *Le Grand Meaulnes*, all the documents on which this account is based, and a full bibliography.

The account of the genesis begins with a detailed biography of Alain-Fournier, particular attention being paid to any event or phase in the author's life which affected his writing of the novel. The genesis of the novel is then described in broad outline, from the earliest stages, when it took the form of vague poetic-prose fragments, through the semi-mystical and markedly religious phases, to the final elaboration of the story as it now stands.

The genesis of various aspects of the novel is next considered in detail: the growth of the characters, the construction of the settings, the selection and rejection of episodes, and the broad developments in style. Finally, the most important criticisms of

*Le Grand Meaulnes* are examined, and a general appreciation and evaluation of the work is made.

The main appendix includes all the published and unpublished documents of Alain-Fournier which have a bearing on *Le Grand Meaulnes*, collected and classified for the first time.

## (2) *GERMAN*

*For the* PH.D. *Degree*

# THE POETIC STRUCTURE OF WOLFRAM VON ESCHENBACH'S *PARZIVAL*: A STUDY OF THE NATURAL SETTING

*By* MRS MARIANNE WYNN

*Girton College, Cambridge, and the University of Melbourne*

COMMENTARY on Wolfram von Eschenbach's *Parzival* has been almost exclusively concerned with the elucidation of the content of the work. The problem of the poet's narrative technique has so far not formed the subject of a detailed analysis. In this dissertation Wolfram's poetic technique is examined in relation to his treatment of the background in *Parzival*. His description of the scenery is throughout brief, incidental and frequently merely implicit. The beginnings of a later descriptive technique are discernible in Wolfram's occasional attempts to link sentiment with the natural scene, to create atmosphere, and to connect events with the natural background. In its most important aspects, however, Wolfram's treatment of the natural scene shows no connexions with post-medieval literary technique. As the most significant features the following emerge: the scenery is conceived as the background to a travel-history; it is represented as a geographical scheme which embraces the known world together with that of fiction, the latter appearing in the form of two topographical patterns of continuous landscape; it is divided into two distinct parts—the background to the Parzival story and the natural setting of the Gâwân narrative.

The brevity of Wolfram's descriptive technique is thus compensated by elaborate structural arrangements, and the natural

background derives its meaning largely from the various patterns into which it is cast. In detail they appear as the travel histories of Gahmuret, Trevrizent, Parzival and Gâwân, the movements of Arthur's court, the schemes of gradation in the travels of Parzival and Gâwân, the partial congruence of their chivalrous journeys, the topographical schemes and their separation, the framework of actual geography surrounding a nucleus of fabulous countries and places, and the division of the landscape by the preponderance of motifs in contrast. These patterns into which the scenery is disciplined are evolved through its connexion with other layers of the narrative. The parallelism of Parzival and Gâwân, the Arthurian setting and the themes associated with the Grail play a decisive part in their formation. The logical coherence of these structural arrangements, their careful motivation and their interdependence generally and in detail reveal Wolfram's characteristic manner of composition, whose principal aim is unity of form, while analysis of the differences between the patterns associated with Parzival and Gâwân respectively throws an important light on the intentions of the poet in the portrayal of these characters.

## (3) *SLAVONIC STUDIES*

*For the* PH.D. *Degree*

### THE POETRY OF ALEXANDER BLOK: A CRITICAL ANALYSIS

*By* JOHN ANDREW HORVAT, M.A.
*Fitzwilliam House, Cambridge*

THE dissertation deals with the published verse of Alexander Blok. In the introduction an account is given of the scholarly attempts made in the last thirty years both in the Soviet Union and the West to settle the significance of Blok's poetry.

The aim behind the method employed in the exposition is, in the first place, a critically evaluative one, in so far as artistic sensibility and the intellect have been brought to bear on the poems with a view to establishing their value as realized experience; in the second place, for expository purposes formalist

procedure is used whenever it is considered to facilitate evaluation, i.e. metric, rhythmic, and intonational structures, as well as sound patterns, such as cadences and internal rhymes, assonances and consonances, and finally, the strophic organization of verse are singled out, first, so as to make possible the examination of their functional relationship to each other, and, secondly, so as to establish the degree of their support of—or clash with—the semantic aspect of a poem; finally, relevant biographical data are adduced for poems of representative status whose meaning would have remained obscure without the additional biographical elucidation.

In the appendix the mind of Alexander Blok, to the extent to which it is reflected in his poetry, is considered on phenomenological lines—from a mass of historical and psychological data a selective choice is made, including only those facts which reflect changes in the mode of being of an essential (eidetic) character. Broad conclusions are resisted, but are implicit in the argument unfolded there.

In the twenty-four chapters the sets and cycles of poems are taken piecemeal and considered empirically. Value-judgements are passed on single poems, as well as on cycles as a whole.

Only a relatively small part of the poems are found to qualify as authentic poetry, self-induced rhetoric and sentimentality being the principal failings of the bulk of poems; that is to say that, regardless of whether it is self-induced or unself-conscious, the underlying intention on the part of the poet is found to be directed towards the rousing of sentiment—an intention disassociated, or partly disassociated, from the content that the poem is ostensibly seeking to convey. Sentimentality is here regarded as an artistic misuse of language, for instead of the meaning carrying sentiment implicitly, vague meaning, or gestures towards meaning, are presented so that a release of sentiment in the poet and the reader may follow. Broadly speaking, Blok can be said to have attained to an authentic voice whenever the predicament of intellectual and moral nihilism is being faced by him without a residue of self-pity. But even then, as in some of the poems of the cycle 'The Terrible World', in the poem 'The Commander's Footfalls', in the last chapter of the epic fragment 'Retribution', and 'The Twelve', the limitations of the Symbolist apprehension of the world are noted and outlined.

The results of the systematic analysis of the bulk of Blok's poetry, and the inquiry (in the appendix) into the essential structure of his mind are complementary, and are found to bear each other out.

## (4) *SPANISH*

*For the* PH.D. *Degree*

## THE STAGING OF SECULAR DRAMA IN SPAIN, 1550–1700

*By* NORMAN DAVID SHERGOLD, M.A.
*Trinity Hall, Cambridge*

THE study attempts a reconstruction of the stage of the public theatres and at court between 1550 and 1700 and gives an account of the resources at the disposal of sixteenth- and seventeenth-century stage managers for the purpose of staging secular plays. It is based on an analysis of the texts of the plays themselves, on accounts of festivities contained in ephemera of the period, references to the theatre in contemporary writings of Spaniards and of foreign travellers in Spain, newsletters, documents published in books and periodicals, and finally on original and unpublished papers found in various libraries and archives. The first five chapters deal with the commercial theatre and discuss the development and characteristics of the platform or 'apron' stage from the time of Lope de Rueda to the death of Lope de Vega. Chapter VI traces the evolution of the court theatre to 1635, showing that its roots are to be found in medieval and sixteenth-century pageantry. Chapters VII and VIII are concerned with the history of the court theatre between 1635 and 1700. The introduction of Italian methods of staging into Spain by Italian scene designers is discussed, and an account is given of the methods by which plays were staged in the theatre at Buen Retiro and in other royal palaces. In Chapter IX the history of the platform stage is carried to 1700 by means of a further analysis of texts, but it is argued that there were few new developments after the death of Lope. In the last chapter a reconstruction of the *corrales* of Madrid after 1630 is made, based on documents. Conclusions are

drawn, and there are eight appendices, seven of which consist of copies of documents and the eighth of a description of the theatre in Cádiz taken from the writings of a late seventeenth-century traveller. A bibliography of texts and general works consulted is given at the end.

*For the* PH.D. *Degree*

## THE ORIGINS AND CHARACTER OF GONGORISM: A STUDY IN THE PRACTICE AND ASPIRATIONS OF THE POETRY OF THE SPANISH RENAISSANCE

*By* CHRISTOPHER COLIN SMITH, B.A.
*St Catharine's College, Cambridge*

THE dissertation seeks to explain why and how the poet Luis de Góngora (1561–1627) created the extravagant, latinized style which bears his name.

An introduction records the changes of critical attitudes to Góngora down to the present day and outlines the methods of research here followed.

After a preliminary discussion of the revival of the classical tradition in Spain, particular attention is given to the literary and linguistic aspects of that tradition, to the idea that because Spanish was 'corrupted Latin' the vernacular should be restored to its classical magnificence, and to the policy of creating within the vernacular a separate literary and poetic language. The practical effects of these theories (leading logically, although not inevitably, to Gongorism) are then studied in fifteenth and sixteenth century poetry. Vocabulary and syntax are especially considered, and an original attempt is made to define the poetic language at its various levels, and to assess the contributions made to it not only by Garcilaso and Herrera, but by Aldana, Ercilla, and other writers. Emphasis is laid upon the importance of tradition and authority to the Renaissance poets. After this study of origins, there is an evaluation of the derivative and original elements in Gongorism.

In like manner, the theoretical basis and practical aspects of Gongorism itself are then discussed in the light of the interpretations

provided by the poet's contemporaries. The style was held at the time to represent the final stage of 'illustration and enrichment', to be the fittingly elevated poetic language, and to be the erudite and even obscure manner which was alone worthy of the attention of the humanists. In particular, the style of the longer poems of 1612–17 was said to obey, in complexity and extravagance, the dictates of the rhetoricians upon the 'high' or 'sublime' style, extended in the later Renaissance to embrace not only epic but also mythological and pastoral poems. The practical implications of these ideas in terms of vocabulary (especially cultisms) and syntax (especially latinized constructions) are then worked out, again in the light of contemporary views. A final chapter deals briefly with the development of the style by Góngora's followers.

In the conclusion it is emphasized that Góngora's mannerisms often succeed brilliantly in fulfilling at the same time a poetic and a pedantic purpose.

The appendices contain a chronologically-ordered summary of the controversy on Góngora's style (1613–64) with notes on some of the writers concerned; the great value of some unpublished commentaries and defences, e.g. those of Pedro Díaz de Rivas, is indicated.

## (5) *OTHER LANGUAGES*

*For the* PH.D. *Degree*

## THE HISTORY OF THE ALBANIANS (AŁUANK') ATTRIBUTED TO MOVSĒS KAŁANKATUAÇI

*By* CHARLES JAMES FRANK DOWSETT, B.A.
*Peterhouse, Cambridge*

THE aim of the dissertation is to render the *History* traditionally attributed to Movsēs Kałankatuaçi, the principal source for the study of the Albanians of the Caucasus (Ałuank'), more readily available to Western scholarship. The dissertation is divided into two sections. Section I consists of an introduction to the text of the *History* in which the various available manuscripts are examined

and co-ordinated and found to fall into two main groups. The question who was or were the author or authors of the *History* is discussed in a chapter which examines the views of previous Armenian scholars and concludes that the historian was in all probability a Movsēs of Dasxurēn rather than Movsēs of Kałankatuk' or Uti, and lived in the tenth century. The plan and methods of the historian, his own sources and borrowings from his work by other Armenian historians, and the historical reliability of the *History* form the subject of inquiry of the remainder of the chapters of Section I; it is shown that, although caution is necessary in handling Movsēs's information, it is always worthy of serious consideration.

Section II consists of a translation into English of the principal historical chapters of Books Two and Three; that is to say, certain chapters which have been taken by the historian directly from other known histories and other chapters which are of a purely hagiographical nature are omitted. The most important variant readings are included, and an attempt is made to explain the unfamiliar words and phrases in the Armenian text. An important passage missing from the majority of the manuscripts and from both editions of the text is translated and explained (III, 20, pp. 406–8). Among the main questions treated in this section are the Byzantine-Persian War between Heraclius and Chosroes II and the role played therein by the Khazars, the Mihrakan dynasty of Albania (seventh to ninth centuries), and the relations between the Albanians and the Arabs (seventh to tenth centuries). The information given by Movsēs is examined and, where possible, confronted with that of other historians, Armenian, Byzantine and Arab.

# THE FACULTY OF MORAL SCIENCE

*For the* M.LITT. *Degree*

## PSYCHOLOGICAL CONTRIBUTIONS TO A STUDY OF LITERARY EVALUATION

*By* FLORENCE ELISABETH MCCAW BROWN

*Girton College, Cambridge, and the University of Aberdeen*

THE dissertation is divided into three sections. In the first are discussed various theoretical and practical approaches to the problems of aesthetics. The attempts which have been made to bring aesthetic material under scientific investigation are considered under three headings—studies of the artist, of the audience, and of the aesthetic material itself. This historical survey indicates the fields in which worth-while experimentation has yet to be done.

The starting point of the experiments described in the second section was suggested by the historical survey made in the first section. Literary material was used for presentation because the emphasis in previous experiments had tended to fall on the pictorial. A preliminary study showed that literary preferences were quickly stated and reasons produced to support them, although memory of the subject-matter was slight. The reasons given by separate individuals for likes and dislikes showed a certain consistency. Further experiments were made to discover what influence methods of teaching in school had on the type of reasons produced. It was desired to find whether individual consistency was retained, and whether a further consistency could be found among the members of a school class who had been taught together. The material is presented in this section and analysed, and the nature of the consistency of the reasons given is illustrated.

The third section discusses in detail the conclusions which may be drawn from the results, with special reference to questions which were raised in the first section. The most important conclusions are these:

(1) That the school pupil appears to adopt a method of critical approach which determines to some extent the type of reason

given for preferences, rather than to adopt opinions or ready-made reasons from the teacher.

(2) That two types of approach are distinguishable and bear a relation to the method of teaching. These are the personal and impersonal evaluative attitudes. The difference between these attitudes is explained, and their implications are discussed.

*For the* PH.D. *Degree*

## CAUSATION

*By* ALLAN CAMERON JACKSON

*Trinity College, Cambridge, and the University of Melbourne*

THE purpose of the dissertation is to show the sense in which Hume was right in maintaining that no occurrence entails another, and that it is not intuitively self-evident that every occurrence must have a sufficient condition for it. An attempt is made to clear out of the way what seem to the writer misleading objections to the theory and misleading ways of maintaining the theory.

A comparison of 'What has shape has size' with 'Metals expand when heated' is made. There follows an examination of the argument that the fact that it is possible to imagine the contradictory of any proposition asserting the connexion of two items does not in itself prove lack of necessary connexion. Something is said about imagining: it is maintained (1) that it is not a species of sensing, and (2) that it is not an inappropriate instrument for testing the status of a connexion, since it is not an instrument.

It is then argued (1) that the claim that experience does not occur in 'discrete drops' is, so far as it is intelligible, true, but (2) that this truth does not refute the original hypothesis. Some discussion of knowing what is before one is given.

A discussion of inductive reasons follows. Lack of necessary connexion does not entail the proposition that there is no good reason for expecting given events; it does entail the proposition that the question 'Why should a good reason continue to be a good reason?' is no question. That there are true statements about the future does not entail the proposition that the future is

determined, since statements about the future are neither true nor false already, nor do they become true or false. Some discussion of what it is for something to be 'going to happen' is given.

G. F. Stout's view that the world shows active tendency is then considered: it is held that a sense can sometimes, but not always, be given to this assertion, and that correlation tests are more basic.

A consideration of some of the misleading things involved both in asserting and in denying that 'to cause' equals 'to constantly accompany' follows. The notion of producing is considered, and it is held that nothing may be produced in a sense of 'produced' which is anterior to 'caused' as defined here.

A consideration of mechanisms and of explanations of the form 'How *X* came to be in such and such a state' is given; there is a short discussion of the role of explanatory mechanisms: it is maintained that to ask whether these are constructs out of sense-data is wrong since if there be sense-data every physical thing is such a construct.

The status of voluntary movement and of calling up an image as possible examples of genuine producing is considered: it is held that, in so far as there is a case for describing, for example, calling up an image in strictly 'producing' terms, there is no case for describing it in 'causing' terms.

It is maintained that the logical status of causal and natural laws is this: it is the case that they cannot be stated in the form '*A* accompanies *B*', but it is misleading to claim that the alternative is that '*A* necessitates *B*': 'If anything were *A* it would be *B*' necessitates 'Had anything been *A* it would have been *B*' but does not necessitate that if something had been *A* it would have been *B*; for 'If anything were *A* it would be *B*' may not in a given case have been instantiated. And this is the enormous good in Hume's theory.

*For the* PH.D. *Degree*

# ON THE LOGIC OF NORMATIVE SYSTEMS

*By* KNUT ERIK TRANÖY

*Christ's College, Cambridge, and the University of Oslo*

THE dissertation consists of four sections.

Section I is an attempt to analyse certain aspects of the relations between truth, validity, acceptability and meaning. It is suggested that the confirmation procedures of the empirical sciences have been given a somewhat unfair monopoly on 'generating' meaningfulness. The notion of validity to be used in the dissertation is linked not with any particular notion of meaning, but with the notion of acceptability in consequence of an intersubjective test procedure, empirical or non-empirical.

Section II argues that the methodology of the empirical sciences can be analysed from a normative point of view and that, in consequence of such analysis, an important analogy between ethics and methodology may be brought to light. The examination of this analogy, and especially the analysis of the concepts of validity and validation in connexion with rules of methodology, yield conclusions which seem to be of interest for the analysis of moral normative systems.

Sections III and IV attempt a systematic and partly formal approach to the analysis of morality. The two main features of the discussion could be described as follows.

The attainment of certain basic goals is assumed a *necessary* but insufficient condition of 'normal human life'. Non-attainment of these goals is then *sufficient* to make such life impossible. *Permission* to seek these goals is assumed a normative minimum requirement. Other normative demands can be related to this minimum requirement. For another norm to be *valid* it is a *necessary* but insufficient condition that it should be *compatible* with these basic permissions. For another norm to be *invalid* it is a *sufficient* condition that it is *incompatible* with these basic permissions. This is the basic logic of a suggested primitive test procedure for moral norms.

These basic permissions can be regarded as *rights*. It is assumed that if a person *X* has a right to do the action *A*, then it is *forbidden* for another person to *prevent X* from doing *A*, and it is *forbidden* for another person to *force X* to do *A* against his will. This is called the *principle of the logic of permission*. By means of this principle it is shown how moral codes can be analysed as *normative systems* where categorical norms (obligations and prohibitions) can be formally derived from underlying sets of rights. The logical relations between various types of norms within normative systems are analysed. A conception of an *open normative system* is developed: a normative system is called *open* when it terminates in a set of permissions which are controlled (as to acceptability) in terms of norms relating to a basic set of rights.

The second important feature of the dissertation is the analysis, against this background, of various central ethical concepts such as 'rights', 'ideals', 'tolerance', 'freedom', 'commitment', 'promise', 'right', 'wrong', 'justice', etc. This analysis takes as its point of departure the three normative categories (permission, obligation, prohibition), and especially the category of permission. The relationship between the axiological predicates 'good' and 'evil' and the normative categories is discussed more briefly. It is argued that the concept of permission is of vital importance for morals and ethics, and that many important moral concepts depend, for their meaningfulness, on the concept of permission. Certain epistemological and formal logical problems concerning normative injunctions are discussed in greater detail, and finally the concept of validity in ethics is discussed in a systematic context.

The leading idea of the inquiry may perhaps be said to be this: It is methodologically sounder, in ethics and in science alike, to proceed by way of elimination and rejection of the undesirable than to proceed by direct attempts to attain 'absolute truth' and the 'highest good'.

# THE FACULTY OF MUSIC

*For the* PH.D. *Degree*

## ITALIAN SECULAR SONG FROM 1600 TO 1635: THE ORIGINS AND DEVELOPMENT OF ACCOMPANIED MONODY

*By* NIGEL CAMERON FORTUNE

*Gonville and Caius College, Cambridge, and the University of Birmingham*

THE most important fact emerging from this study is that the usual definition of monody—rather uninteresting recitative accompanied by a very sluggish bass—refers, broadly speaking, to only a small number of songs published shortly after 1600. On the whole, the most interesting songs, and those most important for the future, are those with aria-like melodies.

The opening chapters include an account of the rudimentary solo songs of sixteenth-century Italy and a discussion of the theories and practical activities of the Florentine Camerata—the group of humanists, poets and musicians who, at the end of the century, helped to introduce the new conception of monody. Succeeding chapters sketch in the background against which the thousands of monodies were composed; they show, among other things, how the tastes of certain enlightened rulers influenced the quality and the quantity of the songs composed by the musicians in their service; how political conditions made the songs composed in different parts of Italy different from each other; and how the kind of life a musician led affected the songs he wrote. An exhaustive discussion of how, as far as we know, the songs were and should be performed leads to the main section of the dissertation, in which the texts and the different kinds of song are analysed. This analysis treats the songs from the point of view of form, style, melody, harmony and rhythm, and it shows how between 1600 and 1635 old vocal forms—notably the solo madrigal—became obsolete and new forms—notably the cantata—came into being and prepared the way for still more new forms which flourished after 1635. A concluding chapter gives a short account of Italian

song in the years immediately after 1635 and of the influence of monody on the music of other countries. The appendices include a representative anthology of songs, detailed inventories of song-books and manuscripts, and biographies of all the composers who wrote monodies.

# THE FACULTY OF ORIENTAL LANGUAGES

*For the* PH.D. *Degree*

## THE *NIPPON EITAI-GURA* AND CHŌNIN IDEOLOGY IN THE SEVENTEENTH CENTURY

*By* GEOFFREY WILLIS SARGENT, M.A.

*Christ's College, Cambridge*

THE dissertation is an investigation into the ideological background to the *Nippon Eitai-gura* (1688) of Ihara Saikaku, serving as an introduction to a translation of the complete text. By approaching the *Eitai-gura* through a study of the morality and practical philosophy of Chōnin society as revealed in certain documents of the earlier seventeenth century, it is hoped to clarify Saikaku's attitude towards this philosophy and to contribute towards a better understanding of the purpose of the *Eitai-gura*.

Section II is devoted to an analysis of three works in the 'Chōja-kyō' tradition—a tradition to which Saikaku makes special reference in his subtitle: 'Daifuku Shin Chōja-kyō.' The works taken as representative of this group are *Tsure-zure-gusa*, 217 (1329–36), *Chōja-kyō* (1627), and *Iguchi Monogatari* (1662). Each work reaches its distinctive conclusion, but there is observed to be a basic identity of structural pattern—the form of a debate in which materialist and Buddhist viewpoints are contrasted. It is noted that the same structural pattern reappears in the opening section of the *Eitai-gura*, and that the attitude of the *Eitai-gura* is essentially that adopted by the *Chōja-kyō* of 1627. The whole of the first story is found to be modelled in detail upon the *Chōja-kyō*. It is concluded, however, that the direct, imitative relationship is largely confined to the opening story. The identity of attitude derives from common roots in a seventeenth-century tradition of Chōnin thought.

Section III deals with the relationship of *Eitai-gura* ideology with that expressed in *The Seventeen Injunctions* (1610) of the

Hakata merchant Shimai Sōshitsu. Close similarities of detailed advice and underlying theory are observed between this document, the *Chōja-kyō*, sections of *Iguchi Monogatari*, VI, 16, and the *Eitai-gura*. The keynote of Shimai's injunctions is extreme caution and economy. Saikaku's expressed sympathy with more enterprising, risky methods is noted, and it is suggested that when Saikaku incorporates the Shimai type of advice into the *Eitai-gura* it is, more often than not, parody. It is emphasized that Saikaku could have had little direct experience of business management. His attitude is that of an intelligent and sophisticated observer, and he has not always complete sympathy with the ideology of merchant society.

Section IV is concerned with indications within the *Eitai-gura* which foreshadow the change from the positive individualism of seventeenth-century Chōnin thought to the more doctrinaire conception of the place of Chōnin in the State which Chōnin society adopted in the succeeding centuries of the Tokugawa Era.

Section V is a complete translation of the *Eitai-gura*, with notes.

# THE FACULTY OF PHYSICS AND CHEMISTRY

## (1) *COLLOID SCIENCE*

*For the* PH.D. *Degree*

## THE PROTEINS OF THE PEA (*PISUM SATIVUM*)

*By* BORIS PETER BRAND, M.A.
*St John's College, Cambridge*

ALTHOUGH the work described in the dissertation covers the three proteins of the pea, namely, legumin, vicilin and legumelin, the main work was done with legumin.

The preparation of legumin given by Danielsson (1949) was modified by the introduction of a fractional precipitation step to give a purer preparation. In general, legumin appears to be a stable molecule. Its sedimentation constant, when corrected to the viscosity and density of water at 20° C., is dependent on the ionic strength ($I$) of the buffer, decreasing with increase in $I$. An attempt was made to explain this decrease on the basis of changes in the partial specific volume of the protein and hydration. On the basis of these results it is suggested that the correct sedimentation constant to substitute in the Svedberg equation to determine the molecular weight is that obtained on extrapolating the curve to high $I$. The molecular weight of legumin indicated by sedimentation and diffusion data is now given as 385,000. Light scattering measurements support this value.

The interaction of sodium dodecyl sulphate (SDS) with legumin was also studied. Addition of SDS to the protein causes precipitation at first, the precipitate dispersing on the addition of further detergent. The effect of time and heat on the rate of reaction of the detergent with the protein was studied in the ultracentrifuge and by electrophoresis. The studies show that heating the protein-SDS mixtures at $45{\cdot}0 \pm 0{\cdot}5°$ C. accelerates considerably the reaction, which is complete after 6 hr. heating. Control light

scattering and electrophoresis experiments indicated the absence of any effect on molecular weight and electrophoretic mobility of legumin alone. The SDS breaks the protein down into sixths and forms a complex containing 588 molecules SDS per molecule of legumin. Further additions of SDS join the complex, thus raising its electrophoretic mobility, which approaches that of pure detergent. Dialysis of the complex against saline buffer partially removes the SDS, and such material gives one peak of reduced electrophoretic mobility. The ultracentrifuge shows that the broken-down protein has aggregated to give a polydisperse protein of mean molecular weight *c.* 310,000.

A preliminary investigation into the properties of vicilin and legumelin supports generally the findings of Danielsson (1951 *a*, *b*) that vicilin is broken down by a proteolytic enzyme which is associated with legumelin. The breakdown is accompanied by denaturation of the protein.

DANIELSSON (1949). *Biochem. J.* **44**, 387.
DANIELSSON (1951*a*). *Acta chem. scand.* **5**, 541.
DANIELSSON (1951*b*). *Acta chem. scand.* **5**, 792.

*For the* PH.D. *Degree*

## THE SURFACE CHEMISTRY OF CERTAIN ANTIBIOTICS

*By* ALAN VICTOR FEW
*Trinity Hall, Cambridge, and the University of London*

THE work described is concerned with the surface chemistry of several antibiotics and with the application of surface chemical techniques to the detailed investigation of the mode of antibacterial action of one of the antibiotics.

Monolayers of four closely related cationic polypeptide antibiotics of the polymyxin group (polymyxins A, B, D, and E) were studied. The results showed that the four polypeptides can be classified into two groups; the highly nephrotoxic polymyxins A and D form one group, and the non-toxic polymyxins B and E comprise the other group. With the use of a highly sensitive surface balance, monolayer measurements were carried out at

very low surface pressures, and the molecular weights of the polypeptides were calculated from a two-dimensional gas-law equation. These results indicated that there was no significant difference in the molecular weights of the four polypeptides.

Using the surface balance technique as an assay method for the polymyxins, polymyxin E absorption isotherms were determined with a range of sensitive and resistant bacteria and bacterial cell walls derived from the intact bacteria by mechanical disruption using small glass beads. The results showed that loss of viability is associated with the absorption by sensitive bacteria of amounts of polymyxin E sufficient to form a monolayer within the bacterial cell wall. This absorption causes a disturbance of the osmotic balance of the organisms and a consequent rapid release of cell solutes into the suspension medium. Cell-wall damage caused by the absorption of polymyxin E was observed directly in the electron microscope.

Measurements were carried out on the surface activity of sodium penicillin G. These results showed that aqueous solutions of highly purified sodium penicillin G are only slightly surface active, although a decrease of the pH of the solutions causes an increase in the surface activity. Penicillin G-lipid monolayer interactions were investigated with several lipids, and the biological implications of these reactions and of penicillin surface activity are discussed.

*For the* PH.D. *Degree*

## THE VELOCITY OF RAPID CHEMICAL AND BIOCHEMICAL REACTIONS

*By* WALDIE WILLIAM FORREST

*Trinity Hall, Cambridge, and the University of Adelaide*

THE main purpose of the investigation was to study the kinetics of carbonic anhydrase at physiological concentrations of the enzyme. The rates of hydration of carbon dioxide and dehydration of carbonic acid catalysed by the enzyme were followed by a rapid-flow optical technique, using a pH indicator and measuring optical density changes caused by change of pH in a buffer solution. To carry out measurements under the special conditions

of the system, considerable modification of a rapid-flow apparatus was necessary.

In preliminary work to test the apparatus the rate-constant $k\mathrm{CO_2}.\mathrm{OH}$ of the reaction $\mathrm{CO_2}+\mathrm{OH'}\rightarrow\mathrm{HCO_3'}$ was determined at 20° C., again by measuring pH change with an indicator. The value obtained for the rate constant was about 30 % lower than that found by other methods. This discrepancy was found to result from a systematic error in the 'stopped-flow' technique of observation used. A device for removing the cause of the error by rapidly stopping the moving reactants was fitted to the apparatus.

The enzyme activity was found to be strictly linear with enzyme concentration till a limit is reached at high enzyme concentration, when further additions of enzyme produce no further increase in the catalysed rate. This limiting rate occurs with both the hydration and dehydration reactions, and is not predicted by the Michaelis theory of enzyme action. At concentrations of enzyme below that at which the limit is reached the Michaelis theory is obeyed, and a value of the Michaelis constant was found. Measurements were made with both crude and purified enzyme preparations, and no significant difference, except in activity, appeared between the different preparations.

The inhibition of carbonic anhydrase by sulphonamides was studied, using purified enzyme preparations. The inhibition was found to be competitive. The order $n$ of the reaction $E+nI=EI_n$ was found to be 1 for sulphanilamide. The more active inhibitor 2-acetylamino-1:3:4-thiadiazole-5-sulphonamide showed an apparent increase in order as the inhibitor concentration was increased. An explanation is proposed for this effect.

The dissociation constants for the enzyme-inhibitor complexes were determined over a range of pH for both these sulphonamides.

*For the* PH.D. *Degree*

# LIGHT SCATTERING OF PROTEIN SOLUTIONS

*By* DAVID ARTHUR INGHAM GORING

*Emmanuel College, Cambridge, and the University of McGill*

A LIGHT-SCATTERING apparatus was designed and constructed and a critical experimental study of the light scattering of protein solutions was carried out. The most suitable liquid for calibration was found to be a solution of turnip yellow virus, which did not absorb at the wave-length used for light scattering (5461 Å.). An ultrafiltration technique based on the nitrocellulose ultrafilters of Elford and the osmometer membranes of Adair proved to be the simplest and most effective way of removing aggregated material from protein solutions. Even after ultrafiltration preparations of seed globulins showed small amounts of heavy material in the ultracentrifuge. A correction for this effect was devised.

Molecular weight determinations were made on samples of serum albumin, edestin, arachin, legumin and turnip yellow virus. The values obtained agreed well with values reported by other workers using different methods.

In phosphate buffers of ionic strength 0·05 and 0·1 and pH of 6·4 turnip yellow virus showed no intermolecular interference. Similarly, for the seed globulins edestin, arachin and legumin, in phosphate buffers of ionic strength 0·5–1·0 and pH 7·5, no intermolecular interference was noted. In phosphate buffer of ionic strength 0·1 and pH 7·7 only a slight interference effect was noted for serum albumin.

Theoretically, the proteins studied should show no dissymmetry of scatter. Dissymmetries ($I_{60}/I_{120}$) of 1·05–1·10 were observed, and these were attributed to traces of aggregated material not removed.

A preliminary investigation of the hempseed extract was made in order to study the suitability of edestin as a light-scattering standard. A simple fractionation technique gave pure monodisperse edestin. In the hempseed extract there were two heavier components which were less soluble than edestin. There was also

a light component which was precipitated by $(NH_4)_2SO_4$ at 70 % saturation and which aggregated in phosphate buffer of ionic strength 0·5 and pH of 7·5.

A study was made of the pH range of stability of serum albumin, arachin and edestin. Arachin and edestin broke down into smaller subunits on increase of pH. At pH 12·4 the subunits of edestin aggregated. With serum albumin no breakdown in alkali was noted, but at pH 12·4 a similar aggregation occurred. With edestin and arachin a large increase in molecular weight occurred when the pH was lowered. The molecular weight of serum albumin remained constant through its isoelectric point, but a marked aggregation was noted at pH 3·5. The aggregation, in its gross features, was almost wholly reversible on neutralization of the solution.

*For the* PH.D. *Degree*

## METHAEMOGLOBIN REACTIONS: KINETIC AND EQUILIBRIUM STUDIES

*By* GEORGE ISSA HABIB HANANIA

*Christ's College, Cambridge, and the University of Beirut*

THE main object of the investigations was to study the mechanisms of simple reactions of methaemoglobin and metmyoglobin with a view to elucidating some of the more complicated reactions of haemoproteins. Kinetic and thermodynamic data were obtained, where possible, for three types of such reaction: acid-base equilibria, complex formation and reversible cell reactions. The results were correlated with those of other iron compounds, particularly ionic iron.

A spectrophotometric study of ionizations in acidic methaemoglobin and acidic metmyoglobin provided the fundamental thermodynamic data which were required for further studies of the reactions of these two haemoproteins. These data comprise ionization constants under given conditions of pH, ionic strength and temperature, and values for $\Delta H^0$ and $\Delta S^0$. An examination of the results revealed that in the pH range 8–9 the behaviour of methaemoglobin is similar in many respects to that of metmyoglobin, notably in the nature of the effect of neutral salts on their

ionization constants. Outside this range minor differences of behaviour could be attributed to haem-linked effects.

Mechanisms for the reactions of metmyoglobin with fluoride and cyanide were considered on the basis of kinetic and equilibrium studies of both the formation and dissociation of these complexes over a range of pH, ionic strength and temperature. Thermodynamic constants were also obtained for the various reactions, and the effect of pH on the charge type of metmyoglobin was investigated and correlated with the other studies.

The reversible oxidation-reduction potential of the cell reaction $Fe^{III} + \frac{1}{2}H_2 = Fe^{II} + H^+$ was measured potentiometrically at pH 6, ionic strength 0·25, and over a temperature range. It was particularly interesting to find the haemoglobin titration curve symmetrical and the value of $n$ about unity, that is, without haem-haem interaction effects. The cell reaction was highly exothermic, with the consequence that the ionization potential of $Fe^{II}$, in both haemoglobin and myoglobin, turned out to be remarkably close to the corresponding value for inorganic ferrous ions in aqueous solution.

*For the* PH.D. *Degree*

## INDUCED PERMEABILITY OF MEMBRANES

*By* COLIN STANLEY HOCKING

*Trinity College, Cambridge, and the University of Adelaide*

THE research described in the dissertation was designed to elucidate certain aspects of membrane function in intestine and nerve tissues. On the one hand the factors controlling transport of emulsion particles through porous membranes are considered in the light of fat absorption in the intestine, and on the other hand factors controlling membrane potentials in artificial systems are discussed in relation to nerve-action potentials.

The role of the zeta potentials at the interfaces of the systems studied is shown to be very important, and the first chapter of the dissertation is concerned with the theory of zeta potentials and experimental techniques for measuring them.

Because of their possible significance in biological membrane structure, some studies of proteins and long-chain hydrocarbon compounds (detergents) were made. By application of an electrophoresis technique, evidence for stoichiometric complex formation between bovine-serum albumin and sodium dodecyl sulphate was obtained. This topic is dealt with in Chapter II. The demonstration that complexes of this nature can be formed gives weight to the idea that biological membranes are composed of lipoprotein complexes.

In Chapter III the question of emulsion transport through membranes is considered. Studies were made of the migration of paraffin emulsions stabilized with sodium dodecyl sulphate and with cetyl trimethyl ammonium bromide to give negatively and positively charged emulsions respectively. The zeta potentials were measured, as were the membrane potentials operating while the emulsions were migrating into various electrolytes. It was established that the amount of colloidal material which migrates across a porous filter-paper membrane is proportional to the product of the membrane and zeta potentials. It is shown that these same factors are very likely to operate in the intestine during fat absorption.

The topic of nerve potentials is considered in Chapter IV. Models of biological membranes were made by employing amyl alcohol as the membrane phase and controlling its properties by the addition of detergents. The resulting effects on the membrane potentials after the addition of detergents were measured, and the zeta potentials at the membrane interfaces were also determined. It is shown that the membrane interfacial charge is of prime concern in controlling the membrane potential, and both cation and anion permeable membranes were made by the addition of sodium dodecyl sulphate and cetyl trimethyl ammonium bromide respectively. The effects of other agents such as lecithin and the potassium reagent hexa-nitro-diphenylamine were also studied, and the observed properties are discussed in relation to the surface properties of the membranes. An hypothesis based on the conception of an asymmetric membrane is advanced to explain the spike pattern of a nerve-action potential.

*For the* PH.D. *Degree*

# THE INFRA-RED PROPERTIES OF METALLIC FILMS

*By* JOHN NOEL HODGSON

*St John's College, Cambridge, and the University of London*

THE infra-red properties of metallic films, which are not appreciably transparent to infra-red radiation, can be measured by a reflexion method. Two new methods of finding $n$, the refractive index, and $k$, the absorption coefficient, by reflexion measurements were devised for use in the infra-red spectrum. An apparatus was set up for making measurements of $n$ and $k$ by these reflexion methods at wave-lengths between 1 and 13$\mu$. The apparatus included two selenium film polarizers and a double rock-salt prism spectrometer with a thermocouple radiation receiver. Experimental values of $n$ and $k$ for wave-lengths between 1 and 13$\mu$, found by a reflexion method, are given for films of gold, silver, copper, aluminium, zinc, tin and nickel.

The experimental results are compared with the predictions of Drude's electron theory of the optical constants of metals. The variation of the experimental values of $n$ and $k$ with wave-length, for sufficiently long wave-lengths, is in agreement with Drude's theory. The parameters $\sigma_0$, the electrical conductivity, and $n_0$, the number of free electrons per atom, are calculated from the infra-red values of $n$ and $k$. The values of $\sigma_0$ are from 2 to 7 times less than the electrically measured values. The values of $n_0$ agree with predictions of the theory of metals and values given by measurements of the anomalous skin effect.

The values of $n$ and $k$ for films of selenium, tellurium, germanium and bismuth were calculated from infra-red transmission measurements. The infra-red properties of films of bismuth are shown to be intermediate between those of the metallic and semiconducting elements. The possibility of a Fabry–Perot etalon as a high resolution filter of near infra-red radiation is discussed. The amount of absorption in thin films of silver excludes their use with an etalon for the infra-red. A multi-layer film with germanium for the high index layers is suggested as a suitable alternative.

*For the* PH.D. *Degree*

# A HIGHER OXIDATION STATE OF METMYOGLOBIN

*By* DENNIS HORACE IRVINE

*Christ's College, Cambridge, and the University of Leeds*

IT has long been known that, when methaemoglobin or metmyoglobin, ferriprotoporphyrin derivatives which may be represented as $Fe_p^{3+}$, react with hydrogen peroxide and alkyl hydroperoxides, a red compound is formed with characteristic bands in the visible and Soret spectral regions. This compound was generally thought to be a complex in which the peroxide molecule or its anion was bonded to the iron atom in the porphyrin ring, and its formation was considered to follow an equilibrium of the type

$$\text{Enzyme} + \text{substrate} \rightleftharpoons \text{enzyme} - \text{substrate}.$$

The present work shows that the metmyoglobin compound is formed in an irreversible process and not according to the above mechanism. The compound is reducible to metmyoglobin, and titration with potassium ferrocyanide and other reducing agents shows it to be one oxidizing equivalent above metmyoglobin. It may thus be considered as a compound with iron in the effective oxidation state of +4, represented formally as $Fe_p^{IV}$.

If a reducing agent is added to the metmyoglobin before adding the peroxide, the former is used up during the formation of the compound and no reduction is observed. This indicates the production of a highly reactive intermediate in the system, which may be the OH radical. A mechanism for the formation of the $Fe_p^{IV}$ compound is proposed in which this intermediate is involved in competitive reactions.

Analysis of the kinetics of the formation of the $Fe_p^{IV}$ compound by hydrogen peroxide shows that both the acid and alkaline forms of metmyoglobin are involved. The effect of temperature and ionic strength on this reaction was investigated. Independent studies of the reduction of the $Fe_p^{IV}$ compound and its formation in the presence of an excess of reducing agent gave values of velocity constants for the reduction and formation which are in good agreement.

The formation of the compound by oxidizing agents other than peroxides supports the view that it is not an enzyme-substrate type of complex, and in the case of one-electron-transfer oxidizing agents, such as potassium chloriridate, confirms that it is one oxidation state above metmyoglobin. The reactions with the electron transfer reagents are extremely rapid. The effect of pH on the formation of the compound by these reagents leads to an approximate value of the oxidation-reduction potential of the $Fe_p^{3+}/Fe_p^{IV}$ couple.

A study was made of the pH changes produced in the formation of the compound as well as in its reduction to metmyoglobin, and an interpretation of these and the above results is put forward in terms of possible structures of the higher oxidation state.

*For the* PH.D. *Degree*

## METAL ION-MONOLAYER INTERACTION AT THE AIR-WATER INTERFACE

*By* JAMES GERAINT NICHOLAS THOMAS

*Trinity College, Cambridge, and the University of London*

THE interaction between monolayers of the fatty acids, alcohols and long-chain alkyl sulphates at the air-water interface and polyvalent metal ions in the substrate was studied by surface pressure and potential measurements. It was found that metal ion-monolayer dipole and metal ion-monolayer ion interactions have little effect on the film properties. The marked changes which metal ions can produce in monolayers of the fatty acids and long-chain alkyl sulphates are shown to be caused by the formation of undissociated metal soaps. When complex metal ions containing hydroxyl groups are present, these are concentrated in the monolayers through hydrogen bonding which stabilizes the complex metal soap and gives solid films of high area per molecule. The effect of cupric salts in carbonate buffer solutions was shown to be caused by complex cupric carbonate ions. Chemical analysis of myristic acid films removed from cupric salt solutions revealed that several copper atoms can be associated with each fatty acid molecule.

New effects were observed in the interaction of uranyl nitrate with myristic acid. With increasing pH the transition pressure is raised and condensed liquid films are obtained. This behaviour is consistent with the special structure of the uranyl ion and its hydrolysis products.

Monolayers of sodium cetyl sulphate were studied on substrates of varying ionic strength and pH in the absence of polyvalent metal ions, and their properties are discussed. Solidification of cetyl sulphate monolayers was found to be induced only by complex metal ions which can hydrogen-bond in the monolayer, and compared with myristic acid the pH ranges of solid film formation are narrower, indicating that the solidification process in sulphate monolayers is more difficult on account of the greater dissociation of the soaps.

## (2) *MATHEMATICAL LABORATORY*

*For the* PH.D. *Degree*

## THE PREVENTION, DETECTION AND LOCATION OF FAULTS IN DIGITAL COMPUTERS

*By* MONTGOMERY PHISTER

*Trinity College, Cambridge, and Stanford University*

As man's machines and tools become more and more complex in function, they tend to be subject to a greater and greater number of failures during their expected lives. Electronic digital computers are among the most complicated of the machines in use to-day, and in most of them the rate at which failures occur is high enough to exert considerable influence on their design and use. The dissertation describes how failures are dealt with in EDSAC I, a computer which has been in use for about three years, and how they will be dealt with in a new machine called EDSAC II.

The number of failures appearing per unit time in a computer is largely determined by its initial design, and details are given of the fundamental circuits of EDSAC II. These circuits are designed

so they will continue to function even when circuit parameters vary over a wide range. However, if the failure rate is high despite careful circuit design, it becomes worthwhile to employ preventive maintenance to reduce the number of faults which occur while the machine is in use. A form of preventive maintenance known as marginal checking was added to EDSAC I and is described and evaluated. It was found useful not only in preventing faults, but also in locating them after they had occurred.

When a fault does occur, it must be detected and then located and repaired as quickly as possible. The detection of faults on EDSAC I is done with the help of test programmes, and certain programmes are described which are useful in detecting and locating intermittent faults, by far the most difficult kind encountered. For EDSAC II a built-in test, called a 'microtest', is described, which has the advantage that it will isolate store, arithmetic unit and control for test purposes. Finally, a method is developed for choosing the best sequence of tests necessary to detect and locate a fault in a machine composed of many small parts. The method is applicable to any kind of machine, though certain restrictions limit its usefulness with respect to present-day digital computers.

## (3) *METALLURGY*

*For the* PH.D. *Degree*

## INTERACTIONS BETWEEN SOLID AND LIQUID METALS AND ALLOYS

*By* VERNON WALTER ELDRED, M.A.

*St Catharine's College, Cambridge*

THE dissertation comprises a broad survey of the phenomena involved in the attack of liquid metals on solid metals and alloys.

A technique for carrying out long-term corrosion tests is described. It was applied to the investigation of over forty systems involving pure metals in contact with liquid bismuth, cadmium lead, mercury, potassium, sodium, tin and zinc at

temperatures up to 550° C. for periods of contact up to 300 hr. A series of ferrous and non-ferrous alloys in contact with the same liquid metals was also investigated under similar conditions. The types of attack observed are described and discussed.

Criteria for the classification of combinations of solid and liquid metals and alloys according to their corrosive behaviour are put forward and applied to the systems investigated.

The factors controlling the rate of solution of a solid metal in a liquid metal under various conditions are discussed theoretically in the light of the experimental results.

The knowledge at present available about metals and alloys manifesting a high corrosion resistance to liquid metals is considered, and the characteristics of such systems are discussed. A method of predicting further systems of a similar character is suggested.

*For the* PH.D. *Degree*

## THE LOAD-EXTENSION RELATIONSHIPS OF METAL WIRES OVER A RANGE OF TEMPERATURES, WITH SPECIAL REFERENCE TO INTERNAL OXIDATION

*By* ERIC GREGORY, M.A.

*St John's College, Cambridge*

SHORT-TIME tensile tests were carried out at elevated temperatures on a nickel-chromium alloy, and on silver alloys which could be internally oxidized.

It was found that much useful information on high-temperature properties could be obtained by recording the load-extension curves during the short-time tensile tests. The effects of temperature, strain rate and grain size, etc., on the general shape of the curves were noted.

The effect of a second or 'dispersed' phase on high-temperature properties was investigated by tests carried out on internally oxidized silver alloys. During the preparation of these materials many new observations on the factors effecting internal oxidation were made, and many of the formerly observed phenomena were confirmed.

The effects of the second phase both uniformly dispersed and concentrated in the grain boundaries were shown by the load-elongation curves of the silver-silicon and silver-aluminium materials. There was a considerable increase in the stress at which marked plastic deformation started and also in the ultimate tensile stress, but there was a very marked decrease in the ductility, owing to grain-boundary brittleness. The result of the addition of a second phase on the effect of grain size on high-temperature deformation was also investigated.

An attempt was made to establish a quantitative relationship between the structure of the material containing a disperse phase and the strength characteristics. The data obtained from a silver-silicon alloy were used to test various theories on the effect of hard dispersions on plastic properties. Although the data were insufficient for any one theory to be definitely established, the indications were that agreement was obtained with the Orowan theory that the yield stress is inversely proportional to the spacing between the particles. A constant had to be introduced to account for the strength of the matrix.

*For the* PH.D. *Degree*

## THE MECHANISM AND KINETICS OF THE ACTION OF PICKLING INHIBITORS FOR IRON AND STEEL

*By* ROBIN DAVID HOLLIDAY, B.A.

*St Catharine's College, Cambridge*

IN the research described, two classes of organic pickling inhibitor that will reduce the rate of attack of mild steel by sulphuric acid were studied: namely, derivatives of thiourea, characterized by a polar sulphur atom, and of quinolines, with polar nitrogen.

The relation between displacement of the polarization curves for the electrolytic reactions and the dissolution of steel is discussed; it is shown that polarization probably results from reduction by physical adsorption of the surface available for the electrode reactions, and Langmuir's isotherm approximately describes the

relation between inhibitor concentration and the apparent reduction of area effective in the electrode processes. It is shown that in such processes the rate of attack of steel in a particular concentration of inhibitor may be calculated from the solution potential without recourse to weight-loss determinations. The anode effect probably results from formation of a surface monolayer; the cathode effect, having a negative heat of adsorption, is considered to arise from build-up of a second layer above the first. For the quinolines polarization of the anode reaction decreases with temperature; the cathode effect is smaller, but has a positive temperature coefficient.

Inhibition by thioureas is primarily a cathodic phenomenon in which it is likely that specific active sites are neutralized. These sites probably participate in the formation of molecular hydrogen from atoms liberated in the cathode reaction, which appears to be no longer limited kinetically by the electrode potential at 70° C. Such inhibition is regarded as chemical, akin to the poisoning of catalysts.

Thiourea derivatives in very low concentrations increase the rate of attack of pure iron by uninhibited sulphuric acid. Such effects can be simulated by additions of sulphur dioxide to uninhibited acid. In such solutions inhibition of the attack of pure iron by larger concentrations of thioureas progresses normally as for mild steel.

Variations of rate of attack of pure iron are thought to be caused by differences of conditions of the surface, particularly grain size. Mapping of surface potentials of specially large-grained specimens of carbonyl iron shows that grain-boundary resistances are negligible, and poly-grained specimens assume a uniform potential, which becomes more noble as time of exposure to acid increases. Individual grains exposed separately assume different potentials, which become less noble with time.

*For the* PH.D. *Degree*

# THE TEMPERING OF STEEL

*By* ELMER DONALD HYAM, M.A.
*Downing College, Cambridge*

THE dissertation is an account of an investigation into the tempering of steel. Throughout the investigation use was freely made of the advantages of the electron microscope and of the dry-stripped Formvar replica technique for metallographic examinations. The dissertation is presented for convenience in two sections.

Section I describes an attempt to establish the fidelity of the dry-stripped Formvar replica technique in reproducing detail on the surface of etched metallurgical specimens. A technique was devised by which optical and electron micrographs of the same area of specimen surface could, for the first time, be systematically obtained and compared. The results show the Formvar replica to represent reproducibly and faithfully detail greater than 2000 Å. in size. Replicas of structures finer than this require a different standard of comparison, and an attempt was made to employ for this purpose a technique of electrolytic extraction, followed by direct electron microscopic examination, of the finely-dispersed carbide phase in a tempered steel.

Section II of the dissertation describes the investigation into the tempering of steel, which was carried out with the aid of this replica technique. By tempering four plain carbon steels and one alloy steel, with differing conditions of time and temperature, a range of microstructures was produced which showed marked and progressive variations in the amount of and in the degree of dispersion of the carbide phase. Electron metallographic examination of these microstructures provided data not hitherto available on the changes in ferrite grain-size and in particle size-frequency distribution which enabled the changes during tempering in dimensions of individual particles of different initial sizes to be estimated and a mechanism of particle solution and growth to be described in detail.

The parameters of these particle size-frequency distributions were calculated and used in conjunction with measurements of

the Vickers and Meyer hardness of the specimens to study quantitatively the relation between the microstructure and mechanical properties of these two-phase structures. The comprehensive data yielded by the wide range of structures examined enabled recent theories concerning this relationship to be critically investigated and illustrated the inadequacy of the simple models upon which these theories have so far been based.

A study was also made of the effect of prior cold-work and of stress at the tempering temperatures on the rate of tempering. In evaluating the data obtained in this investigation, it was necessary to transform the size-frequency distribution of particles observed on a plane of section through a specimen to the true size-frequency distribution of particles existing in a volume of the steel. The existing method for carrying out such a transformation and the modifications to it which were developed here for application to etched metallographic specimens are described in Appendix A, and a worked example is given in Appendix B. The errors which may be introduced in the particle-size analysis are critically discussed, and a method developed for the estimation of their possible effects is described.

*For the* PH.D. *Degree*

## THE EFFECT OF NON-METALLIC DISPERSED PHASES ON THE MECHANICAL PROPERTIES OF METALS AND ALLOYS

*By* JOHN WILSON MARTIN, M.A.
*St John's College, Cambridge*

POLYCRYSTAL and single-crystal specimens of copper containing dispersed non-metallic phases were prepared by the technique of internal oxidation, and some mechanical properties of these specimens were investigated.

The greatest part of the investigation was concerned with the behaviour of the metals in fatigue in alternating torsion, a constant-strain machine designed by Chevenard being used. This machine enables changes in the damping capacity and dynamic rigidity modulus of the specimen at the stress level of the test to be measured during fatigue tests.

Measurements of the damping capacity of annealed and internally oxidized specimens were also made, using a machine recording the decay of torsional vibrations in the elastic range. The changes in this value during a fatigue test were investigated and correlated with those observed at the higher stress level.

It was found that a reduced fatigue life, with inter-granular fracture, characterizes the polycrystal internally oxidized specimens. Single-crystal specimens, either oxidized or unoxidized, are stronger than the oxidized polycrystals. Under certain conditions the oxidized single crystals may be stronger than the unoxidized polycrystals.

Metallographic changes in various specimens during a fatigue test were also followed.

Tensile tests were performed on unoxidized and oxidized alloys. Intercrystalline fracture again characterized the oxidized polycrystalline material owing to the concentration of particles in the grain boundaries. Oxidized single-crystal specimens were recrystallized, and the tensile properties of this material were compared with the previous structures.

Using a Chevenard 'T.R.' constant-load machine, the effect of oxide dispersions on creep properties was examined, using single-crystal and polycrystal specimens.

Using a dialysing technique for extraction, particle-size analyses were carried out, the electron microscope being used for purposes of measurement. These results are discussed in terms of the general relationship between microstructure and mechanical properties in internally oxidized systems.

*For the* PH.D. *Degree*

## THE EFFECT OF STRESS ON INTERACTIONS BETWEEN SOLID AND LIQUID METALS AND ALLOYS

*By* WILLIAM AUSTIN MORGAN

*St Catharine's College, Cambridge, and the University of Wales*

METALLOGRAPHIC examination of specimens of copper immersed in molten bismuth and lead revealed the formation of

grain boundary grooves but no penetration of liquid metal between the grains. The specimens immersed in bismuth, when deformed, cracked along an intercrystalline path. Lead-immersed specimens showed no embrittlement.

The diffusion of bismuth into unstressed copper was investigated, and it was shown that the degree of embrittlement could be correlated with the rate of diffusion. The activation energy for the process was found to be 18,000 cals./g.atom. Variation of the composition of the molten metal increased the embrittlement with increasing bismuth content. The dihedral angle of the grain-boundary groove was measured for alloys of bismuth and lead. It was found that the value of 90° for lead decreased to 87° at 30 % bismuth and finally 20° at pure bismuth.

An applied stress increased the rate of diffusion and decreased the activation energy. At about 4 tons/sq.in. the value was 5000 cals./g.atom. Variation of the composition of the molten metal increased the depth of embrittlement. There was a greater change at 40 % bismuth than in the unstressed tests.

Tensile tests were carried out at temperatures in the range 300–500° C. in air, bismuth, lead and lead/bismuth alloys. A large fall in the mechanical properties was evident at 40 % bismuth for specimens of 0·025 and 0·055 mm. grain size, the decrease being more marked for the larger grain size. A slower strain-rate gave lower mechanical properties. It was considered that the embrittlement was due to the concentration of stress at a groove of low dihedral angle giving a rapid diffusion rate.

Experiments were carried out on bi-crystal specimens possessing grain boundaries at various inclinations to the axis of the specimen. It was found that the fracture stress increased as the angle of inclination increased, and that the effective component of stress in producing embrittlement was the maximum normal stress.

Bi-crystal test-pieces of low and high orientation difference were produced by controlled solidification from the melt. Tensile tests on these showed that the low orientation difference specimens fractured in a ductile manner.

The effect of zinc content of the embrittlement of copper/zinc alloys in mercury was determined. The embrittlement increased with increasing percentage of zinc, and this was compared with published values of dihedral angle measurements on brass.

Finally, a discussion and summary of the work is given, and future work is outlined.

*For the* PH.D. *Degree*

## THE MECHANISM OF WATER-LINE CORROSION

*By* ARTHUR MACKENZIE PEERS

*King's College, Cambridge*

WHEN mild steel and many other metals are partially immersed in certain corrosive liquids, preferential attack takes place in the region of the meniscus. The behaviour of mild steel in particular was studied in neutral and alkaline solutions containing a mixture of an inhibitive and a corrosive salt. The rate and distribution of corrosion were studied as functions of various factors, such as (*a*) the composition of the solution, (*b*) the angle at which the steel specimen cuts the surface of the solution and (*c*) the area of metal submerged in relation to the length of the three-phase boundary.

The distribution of attack was studied in the absence of complicating effects caused by the presence of oxygen by passing current from an external source through a mild steel anode in oxygen-free solutions. Under such conditions, as in the case of corrosion in the presence of air, the anode is shown to dissolve preferentially at the water line when the concentration of inhibitor is sufficiently high compared with that of the corrosive salt. It is also shown that preferential dissolution at the water line may be observed in oxygen-free sodium chloride solutions containing no inhibitive salt when the preformed oxide film on the anode is sufficiently thick, and that the distribution of attack at the anode depends on the ratio (chloride concentration)/(oxide-film thickness).

The proposed ('hindered-diffusion') mechanism requires that the values of $n/i$ (where $n$ is the anodic overpotential and $i$ is the current density), which are characteristic of the greater part of the anode surface, be appreciable compared with the resistance of the solution, and that the changes in composition of the solution at the surface of the anode which accompany the passage of current tend to diminish the anodic overpotential. Thus the current

density at the anode will be greater where the concentration changes are magnified by hindered diffusion.

A survey of the available data indicates that the systems which commonly exhibit crevice (or 'contact') corrosion are those which satisfy the conditions necessary for the operation of the hindered-diffusion mechanism.

The phenomenon of anodic 'activation' by chlorides is discussed, and it is concluded that the activation mechanism probably involves effects associated with preferential adsorption of the chloride ion.

*For the* PH.D. *Degree*

## THE MECHANISM OF SOME METHODS OF PREVENTING CORROSION BY AIR-DRIED COATINGS

*By* DANIEL VAN ROOYEN

*St Catharine's College, Cambridge, and the University of South Africa*

LINSEED oil, pigmented with basic pigments such as red lead, yields coatings which protect iron against corrosion. The protective nature of such paints is known to be associated with the formation of metal linoleates, which give rise to soluble inhibitors.

The object of the research was to identify these water-soluble inhibitors and to establish the mechanism of inhibition. The possibility of protecting iron cathodically by means of aluminium paints was also examined.

The inhibitive properties of aqueous extracts of lead, zinc, calcium, barium and magnesium linoleates in the pH range 4·6–6·0 were confirmed. It was found that lead linoleate was not sufficiently soluble in distilled water to render it non-corrosive in the absence of oxygen, but that atmospheric oxidation of the soap gave rise to inhibitors, which consisted of degradation products.

The free organic acids obtained from lead and calcium linoleate extracts were analysed; analytical methods included chromatography, quantitative steam distillation, infra-red absorption and determination of melting-points of the isolated acids and their derivatives. The following were the main components of the mixtures: formic, acetic, propionic, butyric, azelaic, suberic acids;

some unsaturated mono-basic hydroxy-acids were also found, the major constituent of which was derived from pelargonic acid.

Immersion tests on solutions of the lead and calcium salts of the steam-volatile acids showed that they were aggressive in the pH range 4·6–6·0, but the corrosion of iron was stopped by salts of higher di-basic and mono-basic acids. The lead salts were effective at lower concentrations than the calcium salts. Mixtures made according to the analytical results showed inhibitive properties similar to those of the aqueous extracts of lead and calcium linoleates.

A mechanism of inhibition is suggested which depends on (*a*) the formation of insoluble basic ferrous salts and their subsequent hydrolysis and oxidation, and (*b*) the catalytic effect of metal cations on the rate of oxidation of the insoluble ferrous compounds.

Sprayed aluminium coatings were found to be anodic to iron under severely corrosive conditions, but not in mildly aggressive solutions like tap water. Polystyrene paints, richly pigmented with aluminium, were bad conductors of electricity and failed to confer cathodic protection on mild steel. Some methods of improving the electrical conductivity were examined.

It is concluded that aluminium would be a suitable pigment for the protection of iron under aggressive conditions, provided that electrical contact could be improved.

## (4) *ORGANIC AND INORGANIC CHEMISTRY*

*For the* PH.D. *Degree*

## KINETIC STUDIES ON PERFLUOROALKYL RADICALS

*By* PETER BRIAN AYSCOUGH, M.A.

*St Catharine's College, Cambridge*

THE kinetics of the thermal decomposition of trimethyl arsine, *tris*-trifluoromethyl arsine, *tris*-pentafluoroethyl arsine and *tris*-trifluoromethyl stibine in a static system were studied, thus making possible a comparison of certain elementary reactions of fluoroalkyl and alkyl radicals. The nature of the products, the specific

rate constants, and the activation energy, were determined in each case, and possible mechanisms are discussed for each reaction.

The pyrolysis of trimethyl arsine is closely analogous to the decomposition of other alkyl-metallic compounds in the same temperature range, the rate-determining step being the production of methyl radicals and the principal volatile product methane.

Similarly, the primary step in the decomposition of *tris*-trifluoromethyl arsine is the formation of trifluoromethyl radicals, but in this case the main product is hexafluoroethane. Further, the nature of the by-products is fundamentally different, indicating important differences in the behaviour of the two types of radical. Reaction with the surface of the reaction vessel takes place to a greater or lesser extent, depending on the nature of the surface, with a consequent increase in the complexity of the products.

The behaviour of pentafluoroethyl radicals formed by the pyrolysis of *tris*-pentafluoroethyl arsine is very similar, but it is found that the decomposition of *tris*-trifluoromethyl stibine takes a different course, the main products being unsaturated and polymeric fluorocarbons, which appear to be derived from difluoromethylene radicals rather than from trifluoromethyl radicals.

In a broader discussion of the properties of fluoroalkyl radicals this work is related to earlier observations and extended by the description of a number of high-speed flow experiments which give an indication of the relative stability of fluoroalkyl and alkyl radicals at low pressures.

*For the* PH.D. *Degree*

## THE OXIDATION OF PHENOLS BY PEROXIDASE SYSTEMS

*By* HAROLD BOOTH, M.A.

*Selwyn College, Cambridge*

THE first section of the dissertation consists of a historical survey. In the first part of this section the preparation and properties of

the enzyme peroxidase are described from the historical aspect. The second part summarizes the results obtained up to 1949 from the oxidation of organic compounds by peroxidase and hydrogen peroxide. This is followed by a passage reviewing the literature concerning the oxidation of phenols by non-enzymatic systems.

In the second section of the dissertation the present experiments are described in detail. The principal aim in the investigation was to characterize the compounds produced by the oxidation of phenols by peroxidase and hydrogen peroxide. The oxidation of three phenols—mesitol, guaiacol, and durenol—was examined thoroughly. Mesitol yielded 4-hydroxy-3:5-dimethylbenzyl alcohol, 4-hydroxy-3:5-dimethylbenzaldehyde, and 2:6-dimethylbenzoquinone. It was proved that the course of the oxidation may be represented by the following scheme:

mesitol → 'alcohol' → 'aldehyde' → 'quinone'.

Guaiacol yielded a complex brownish-red mixture from which 2:2′-dihydroxy-3:3′-dimethoxydiphenyl was isolated in small yield. Reductive acetylation of the mixture gave a white solid, from which a crystalline compound, probably 3:3′-dimethoxy-4:4′-diacetoxydiphenyl, was isolated in small yield. Durenol yielded principally 4:4′-dihydroxy-2:3:5:6:2′:3′:5′:6′-octamethyldiphenyl, with a trace of duroquinone.

The second section of the dissertation also contains a passage in which these results are discussed in relation to a suggested theory of the mechanism of the oxidation of phenols. It is shown that a theory depending on the initial formation of phenoxy radicals is adequate to explain nearly all types of products isolated from the oxidation of phenols by oxidizing systems. The view is expressed that most systems differ only in the mode of formation of the phenoxy radical by dehydrogenation.

The appendix outlines some work performed by the author which is superficially unconnected with the work described in the principal part of the dissertation but which, in fact, arose directly from that work. It was found that the so-called 'Iodoform Reaction' was given by many compounds which did not contain the chemical groupings for which the reaction was usually regarded as specific.

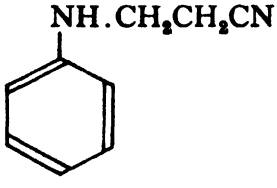
*For the* PH.D. *Degree*

# THE CHEMISTRY OF COMPOUNDS CONTAINING THE 2-CYANOETHYL GROUP

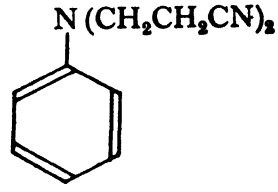
*By* JOHN THEODORE BRAUNHOLTZ, B.A.
*Trinity College, Cambridge*

THE work described in the dissertation may be regarded as the development of a series of synthetic methods leading to the preparation of new heterocyclic compounds containing two or more nitrogen atoms. Certain features of the intermediate products were also investigated.

A convenient and efficient route is described for the conversion of aromatic primary amines into their mono- and bis-2′-cyanoethyl derivatives, e.g. (I) and (II). The course of the reaction was found to depend upon the basic strength of the amine and the extent to which nuclear substituents exert an unfavourable steric influence. Certain inorganic salts, notably cuprous chloride, possess marked catalytic activity; the tetracyanoethylation of *p*-phenylenediamine, however, is effected very easily in the absence of any catalyst.




(I)

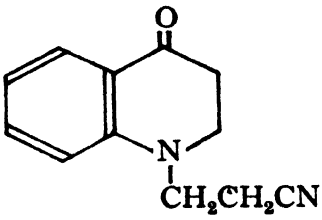



(II)

The dinitriles (II) are very weak bases, although the *para*-position has the high reactivity usually associated with such tertiary amines. The presence of the reactive terminal —C≡N groups renders these compounds of considerable potential value as synthetic intermediates.

*N*-2′-Cyanoethyl-1:2:3:4-tetrahydro-4-oxoquinolines (III) and 1:6-dioxojulolidines (IV) are prepared by cyclization of the dinitriles with aluminium chloride; either type of compound, or a mixture of both, may be obtained. The critical conditions under

which *N*-2′-cyanoethyl-*N*-methylaniline is converted into 1:2:3:4-tetrahydro-1-methyl-4-oxoquinoline (V) were also elucidated.

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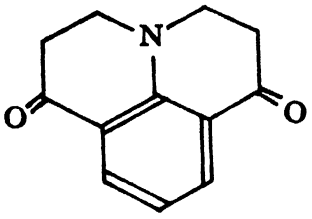


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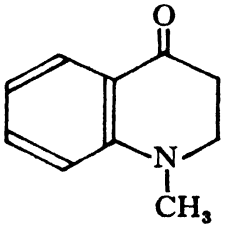
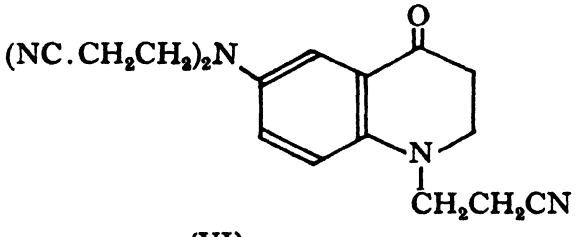



(V)

A number of attempts were made to prepare the corresponding tetraketone from *NN′N′*-tetrakis-2′-cyanoethyl-*p*-phenylenediamine; although these were not successful, the mono- and di-cyclized compounds (VI), (VII), and (VIII), were obtained.

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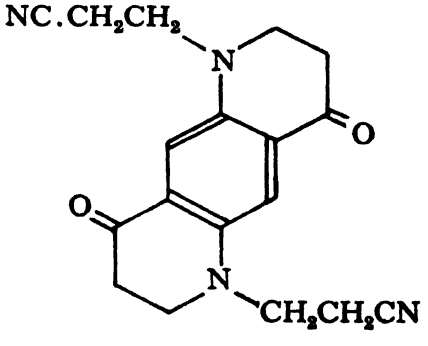


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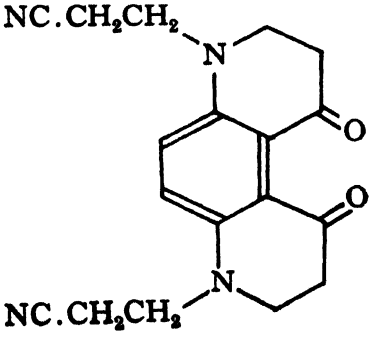
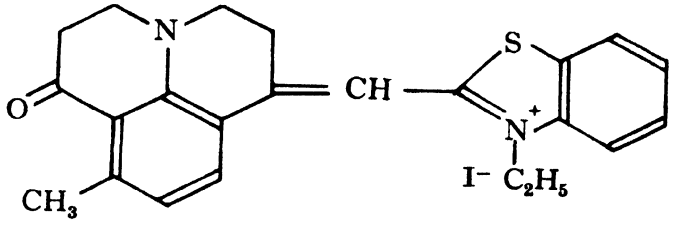



(VII)

It appears that the ketonic groups of (IV) are not sufficiently reactive to condense with 2-methylbenzthiazole ethiodide to give a trinuclear cyanine, but the closely related binuclear compound (IX) was prepared, in addition to two trinuclear merocyanines. None of these compounds has appreciable photosensitizing activity.

A part of the dissertation is devoted to attempts to decarboxylate acids of structure (X) obtained directly from the nitriles (VI). The *N*-ethyl ketones were not obtained, but a number of unexpected decompositions were elucidated. *N*-2′-Carboxyethyl-1:2:3:4-tetrahydro-5:6-benzoquinoline (XI) gives rise to four different products according to the conditions employed.

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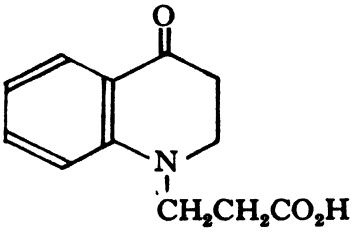


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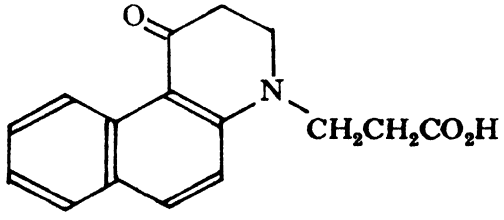
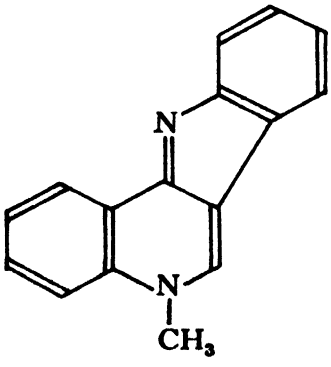



(XI)

A number of polycyclic indolo- and quinolino-derivatives of

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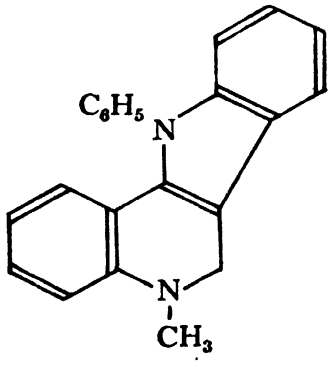
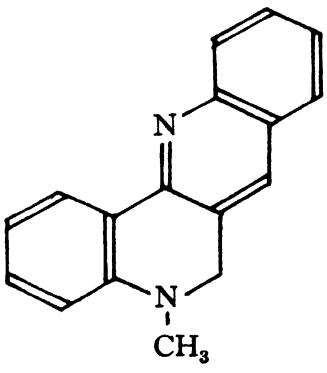



(XIII)

1:2:3:4-tetrahydro-1-methyl-4-oxoquinoline were prepared by the Fischer and Pfitzinger methods. The former (e.g. XII and XIII) are closely related to the γ-carbolines, and it might be of interest to investigate their physiological properties.

Particular interest is attached to the fact that the quinolinoquinoline bases (XIV) and (XV) afford the second recorded instance of individually stable systems of this type which are interconvertible by an allylic rearrangement; the change (XIV → XV) occurs via the salts of the bases and is reversed when the second base is sublimed *in vacuo*.

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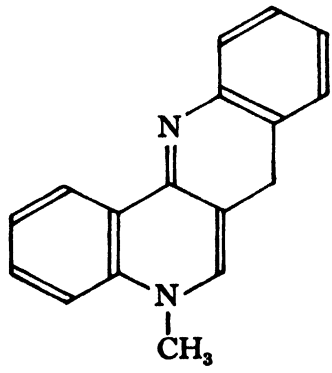



(XV)

The investigation is now being extended to the di-indolo and di-quinolino derivatives, which should be capable of preparation, by analogous methods, from 1:6-dioxojulolidine.

*For the* PH.D. *Degree*

## STRUCTURAL STUDIES IN THE VITAMIN $B_{12}$ GROUP

*By* JACK RICHARD CANNON

*Emmanuel College, Cambridge, and the University of Sydney*

COBALT-CONTAINING pigment mixtures were obtained from hydrolyses of vitamin $B_{12}$ under a wide variety of acid and alkaline conditions. Analysis of these mixtures by paper electrophoresis showed that the pigments fall into two classes, which correspond to a series of mono-, di- and tribasic acids that retain

the 5:6-dimethylbenziminazole nucleotide, and a series of pigments that do not contain the nucleotide and range from a neutral substance to one which behaves as a heptabasic acid.

The interpretation of the electrophoretic behaviour of these substances and the course of hydrolytic degradation of vitamin $B_{12}$ are discussed. Hydrolysis of the three amide groups present in the vitamin $B_{12}$ molecule can occur under either mild acid or alkaline conditions. Under more vigorous conditions hydrolysis of these groups is accompanied by, or preceded by, the fission of the nucleotide, and then D$_g$-1-amino-2-propanol is liberated. The courses taken by acid and by alkaline degradation of vitamin $B_{12}$ are very similar under mild conditions, but on more vigorous hydrolysis other changes, the nature of which is not yet understood, occur and lead to the formation of mixtures of pigments.

A simple apparatus and technique for preparative paper electrophoresis was developed, and quantities of the above pigment mixtures were separated in this manner.

It was confirmed that vigorous acid hydrolysis leads to the liberation of six moles of ammonia and only one mole of D$_g$-1-amino-2-propanol per mole of vitamin $B_{12}$. It is suggested that in the vitamin $B_{12}$ molecule the hydroxyl group of the amino-alcohol is esterified by the phosphoric acid residue of the nucleotide, and that the amino group is linked to the core of the molecule as an amide.

The oxidation of several benziminazole derivatives, of vitamin $B_{12}$, and of an esterified pigment mixture with hydrogen peroxide was studied. Oxamic acid was isolated from the products of vigorous oxidation of the esterified pigment mixture.

Evidence is presented which suggests that vitamin $B_{12}$ does not contain a porphyrin nucleus.

*For the* PH.D. *Degree*

# THE SYNTHESIS AND PROPERTIES OF SOME ACYLPEPTIDES

*By* DAVID WALTON CLAYTON, B.A.
*Christ's College, Cambridge*

THE synthesis of peptides using anhydrides of acylamino-acids with sulphuric acid (Kenner and Stedman, *J. Chem. Soc.* 1952, p. 2069) was studied. This method depends upon the reaction of a water-soluble acylaminoacyl sulphate with an amino-acid or peptide in an aqueous medium. A technique was developed which enables the pH to be maintained constant during this rapid reaction. Graphs were prepared showing the relation between pH and yield in the reaction between toluene-*p*-sulphonylglycyl sulphate and either phenylalanine or phenylalanylglycine. The optimum yields are: toluene-*p*-sulphonylglycylphenylalanine, 86% at pH 9·0; toluene-*p*-sulphonylglycylphenylalanylglycine, 92% at pH 8·7. These results are qualitatively in agreement with theoretical considerations.

DL-Phenylalanylglycine was prepared from its phthalyl derivative, and optimum conditions were determined for the removal of the phthalyl group by the method of Schumann and Boissonas (*Nature, Lond.*, 1952, **169**, 154).

It was found that the methyl ester of an acylamino-acid is formed when a dimethylformamide solution of its phenyltrimethylammonium salt is evaporated at 55° and 20 mm. Phthalylamino-acids are especially subject to this reaction, and it is necessary to use potassium methoxide for the preparation of anhydrous solutions of their salts by the method of Kenner and Stedman (1952).

An attempt was made to develop the use of an amide as 'protection' for the $\gamma$-carboxyl group in glutamic acid during the synthesis of $\alpha$-glutamyl-peptides. Carbobenzyloxy-$\alpha$-L-glutaminyl-L-glutamic acid is, however, converted into carbobenzyloxy-$\alpha$-L-glutamyl-L-glutamic acid in poor yield, and it is therefore more satisfactory to base the synthesis of $\alpha$-glutamyl-peptides upon the use of $\gamma$-benzyl-L-glutamate.

Using this γ-benzyl ester as an intermediate, toluene-*p*-sulphonylglycyl-L-phenylalanyl-α-L-glutamylglycyl*cyclo*hexylamide was prepared as a model substance for experiments on the degradation of α-glutamyl-peptides. This tetrapeptide derivative can be converted into a heterocyclic compound by loss of the elements of water between the free γ-carboxyl group and a neighbouring peptide link. Hydrolysis of the heterocyclic ring in the adduct yields an acid which is isomeric with the original tetrapeptide derivative. Evidence is adduced which suggests that this new acid is toluene-*p*-sulphonylglycyl-L-phenylalanyl-γ-L-glutamylglycyl*cyclo*hexylamide. The series of reactions thus constitutes a method for converting an α-glutamyl-peptide derivative into its γ-isomer.

In conclusion, suggestions are made which show how the heterocyclic derivative of an α-glutamyl-peptide could be used as an intermediate in a scheme for splitting a peptide chain selectively at the α-glutamyl residues.

*For the* PH.D. *Degree*

## SOME ASPECTS OF THE CHEMISTRY OF MELANIN AND OF RELATED HYDROXYINDOLE DERIVATIVES

*By* RONALD IAN TALBOT CROMARTIE, B.A.
*Clare College, Cambridge*

IN order to elucidate the changes involved in the oxidative polymerization of 5:6-dihydroxyindole to melanin and to assess the contributions of different modes of linkage to the resulting polymer, the progress of the autoxidation of 5:6-dihydroxyindole and a series of seven of its methyl- and dimethyl-derivatives was followed spectroscopically under strictly comparable conditions. In the light of these experiments the structure of melanin is discussed: it is considered that the linkage is primarily between the carbon atom in the 3-position of one monomer unit and those in the 4- and 7-positions of the next. Support for the theory that the unstable indole-5:6-quinone is an intermediate in melanogenesis is provided by the properties of its 2:3-dimethyl-derivative, which was found to be stable in solution.

The syntheses of 4-methyl-, 7-methyl-, and 4:7-dimethyl-dihydroxyindoles were carried out to complete the series of methylated 5:6-dihydroxyindoles required; for this purpose variations of Harley-Mason's new general method of preparing hydroxyindoles by oxidative cyclization of dihydroxyphenylalanines and related dihydroxyphenylethylamines in dilute aqueous solution at room temperature were employed. A new synthesis of the same type of the previously inaccessible 7-hydroxyindole was also developed. In the light of this experience taken in conjunction with published observations a mechanism is proposed for the unusual rearrangement involved in these reactions.

Since 2-methyl- and 5-methyl-3:4-dihydroxyphenylalanines had been prepared and oxidized in the course of this work, the remaining isomer, the 6-methyl-derivative, was also prepared together with the related phenylethylamine; a preliminary study of their behaviour on oxidation was made.

*For the* PH.D. *Degree*

## STUDIES IN THE SYNTHESIS OF NUCLEOTIDES

*By* ROSS HULME HALL

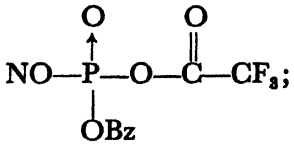
*Christ's College, Cambridge, and the University of Toronto*

THE research described in the dissertation was directed towards two main goals: first, establishment of general preparative methods for dinucleoside phosphates, and secondly, synthesis of uridine-5′ pyrophosphate.

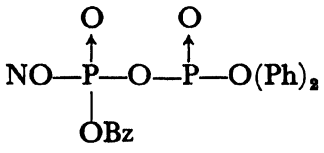
*Dinucleoside phosphates*

Current investigations of the structure of nucleic acids have been concerned with the nature of internucleotide linkages. In this respect, enzymatic and chemical degradation combined with synthesis of mononucleotide degradation products have elucidated the main features. It was desirable that, in furtherance of these studies, nucleotides containing various internucleotide linkages should be synthesized by unequivocal means. The simplest such nucleotides are dinucleoside phosphates, and, accordingly, the following methods of their preparation were worked

out: direct phosphorylation of a suitably blocked nucleoside by a nucleoside benzyl phosphorochloridate; reaction of a sodium salt of a nucleoside with a nucleoside benzyl phosphorochloridate; phosphorylation of a suitably blocked nucleoside by the 'mixed anhydride' formed between a nucleoside benzyl phosphate and trifluoroacetic acid (NOH = nucleoside, Bz = benzyl):



phosphorylation of a suitably blocked nucleoside by the unsymmetrical pyrophosphate formed between nucleoside benzyl phosphate and diphenyl phosphate (NOH = nucleoside, Bz = benzyl, Ph = phenyl):

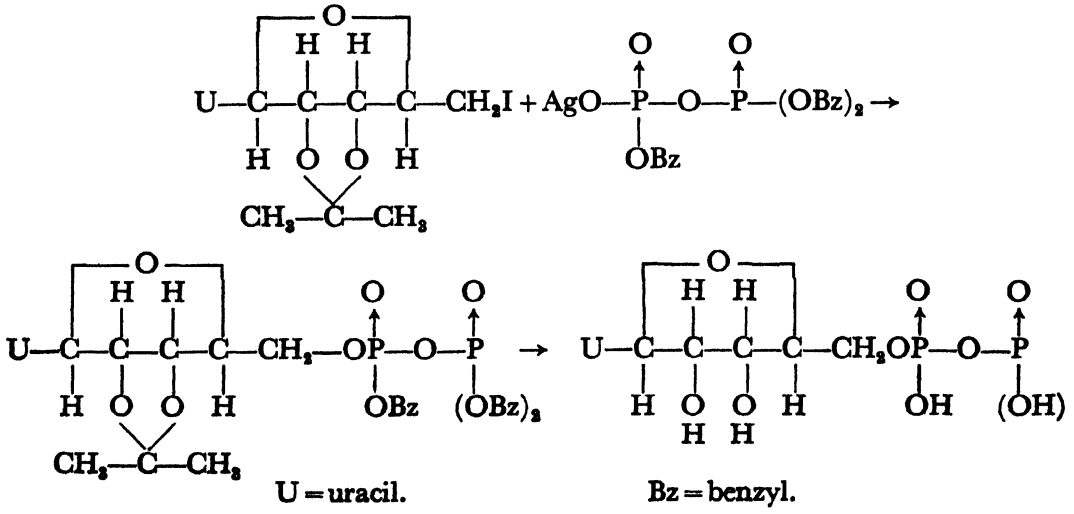


The latter two methods are perfectly general. They afford $C_{(5')}$—$C_{(5')}$ linked derivatives in good yields, but for $C_{(5')}$—$C_{(3')}$ ($C_{(2')}$) linked ribonucleotides yields are poor and results anomalous because of the vicinal hydroxyl group.

*Uridine-5′ pyrophosphate*

Leloir and co-workers have isolated a co-enzyme tentatively identified as uridine-5′-glucose-1′ pyrophosphate. For more conclusive proof synthesis of the major degradation product, uridine-5′ pyrophosphate, was undertaken.

Synthesis is as follows:



U = uracil. Bz = benzyl.

*For the* PH.D. *Degree*

# CHEMICAL STUDIES ON THE POTATO EELWORM HATCHING FACTOR

*By* JOHN KENNETH HEYES

*Emmanuel College, Cambridge, and the University of New Zealand*

THE prime object of the study was to isolate the biologically active potato eelworm hatching factor as a single chemical entity. The crude material, absorbed on charcoal, was received from the Department of Horticulture, Reading University, where it was obtained from the root diffusate of tomato and potato plants. A number of extraction techniques were tested, and a method was developed which gives consistent, though relatively poor, recovery of the activity present in the root diffusate.

The stability of the crude eluate under temperature and pH changes was reinvestigated, enabling unnecessary precautionary measures to be eliminated. Methods of separation were chosen with a view to effecting a purification with the minimum chance of chemical change occurring. Previous methods using a preliminary ether extraction of the crude concentrates after acidification and involving the precipitation of a silver salt were checked and found unreliable, as was the use of precipitation with alcohol from concentrated aqueous solution.

A preliminary separation based on the solubility of the bulk of the inactive contaminants in ethylacetate–alcohol mixtures, using a column of powdered cellulose as a supporting medium, led to further work using chromatography on cellulose. Although a partial separation of the four or five acids present in the semi-purified material was achieved, activity could not be correlated with any one acid. One of these acids was isolated as its de-activated ammonium salt by chromatography on cellulose, and infra-red spectroscopy indicated that it was a hydroxy-acid, possibly unsaturated and lactonic in nature.

Counter-current methods gave no purification unless the pH of the aqueous phase was controlled by the use of buffers, when experimental difficulties and the lack of knowledge about the actual state of the active material in the crude eluate rendered it an unsuitable practical method.

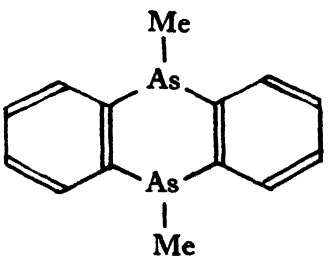
A preliminary phenol extraction of the acidified crude concentrates followed by fractionation using an anion exchange column gave two active fractions, one acidic and one apparently non-acidic. The acidic material obtained in this consisted largely of an acid of the same $R_F$ as that isolated as the inactive ammonium salt by cellulose chromatography, and a number of physical and chemical studies were carried out on it, though it was only obtained in relatively low yield: 0·05 % of the crude eluate. It was shown to be a carboxylic acid of equivalent weight about 240 and to be optically inactive. Found, C, 49·78 %; H, 6·40 %. Periodate oxidation showed an uptake of 1 mol. of periodate in a molecular weight of about 500, while alkali-treated material took up slightly more than 1 mol. Quantitative acetylation indicated the presence of at least one hydroxy group in a similar molecular weight, while hydrogenation showed there to be one double bond in a molecular weight of 490. Oxidation of the remainder with ammoniacal hydrogen peroxide indicated the formation of oxalic, malonic, and acetic acids, although the acidic products were not isolated. These results are discussed in the light of past work, with which they are largely in agreement.

*For the* PH.D. *Degree*

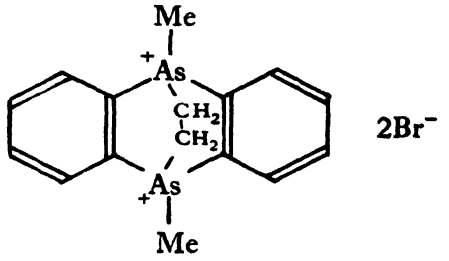
## SOME CYCLIC DERIVATIVES OF ARSENIC

*By* EMRYS ROBERT HORSEMAN JONES, B.A.
*Trinity College, Cambridge*

5:10-Dimethyl-5:10-dihydroarsanthren (I) undergoes diquaternization with ethylene and trimethylene dibromides to form the 'birdcage' type molecules of ethylenedi-*o*-phenylenediarsine dimethobromide (II) and the corresponding trimethylene-di-*o*-phenylenediarsine dimethobromide.



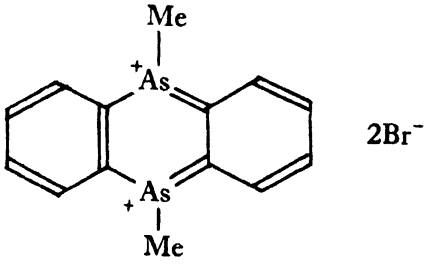

(I)



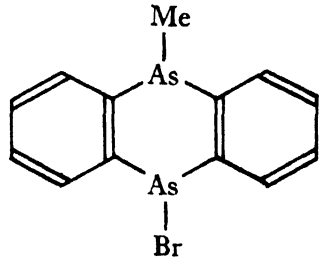

(II)

Thermal decomposition of the diarsonium salts leads in each case to the regeneration of (I).

Under certain conditions the reaction of (I) with ethylene dibromide leads to the elimination of ethylene and the formation of arsanthren dimethobromide (III), which is also formed by the action of elementary bromine on (I) in methanol. Thermal decomposition of (III) yields 5-methyl-10-bromo-5:10-dihydroarsanthren (IV) from which (III) can be regenerated by the action of methyl bromide.

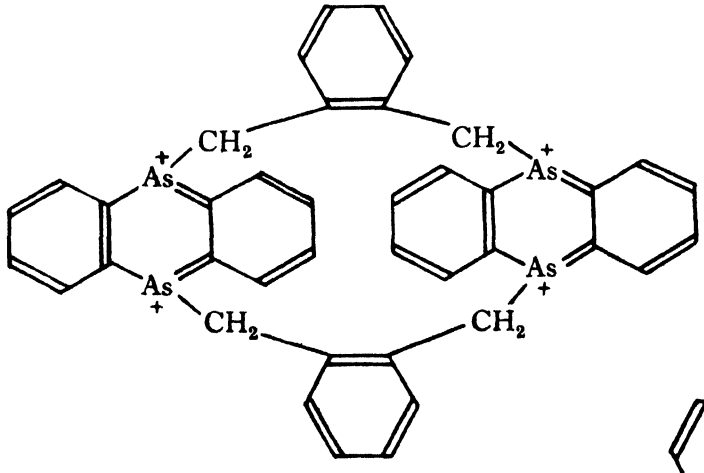



(III)

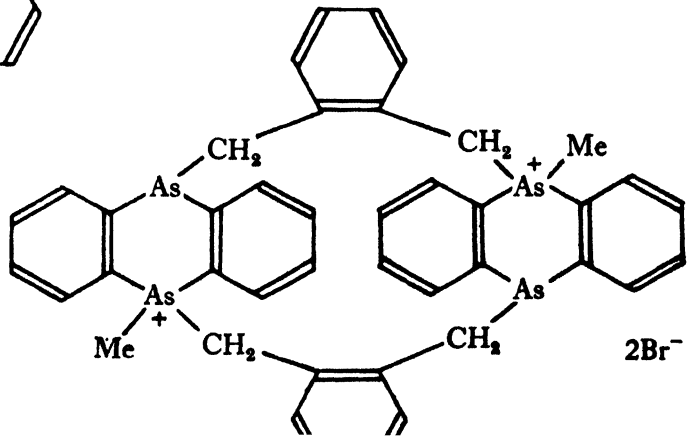



(IV)

The action of *o*-xylylene dibromide on (I) is to form both 5:5′:10:10′-bis-*o*-xylylylbisarsanthronium tetrabromide (V) and

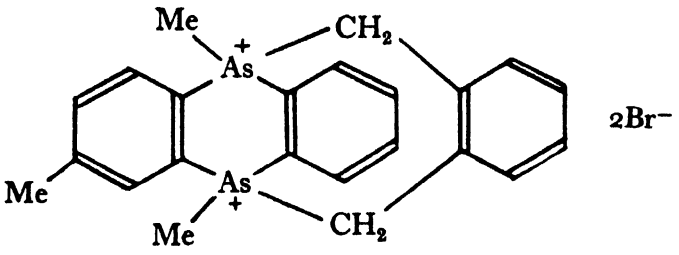



(V)



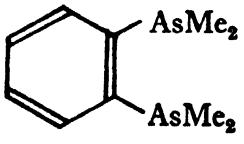
5:5′:10:10′-bis-*o*-xylylylbis(5-methyl-5:10-dihydroarsanthronium) dibromide (VI) in proportions depending on the conditions.

The unsymmetrical 3:5:10-trimethyl-5:10-dihydroarsanthren undergoes diquaternization with *o*-xylylene dibromide to give *o*-xylylene-*o*-phenylene-3-methyl-*o*-phenylenediarsine dimethobromide (VII). This lacks any element of symmetry, but optical resolution was not achieved.

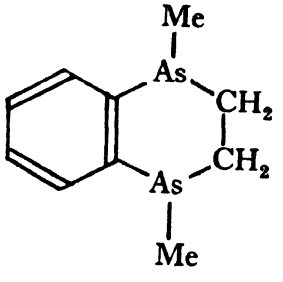



(VII)

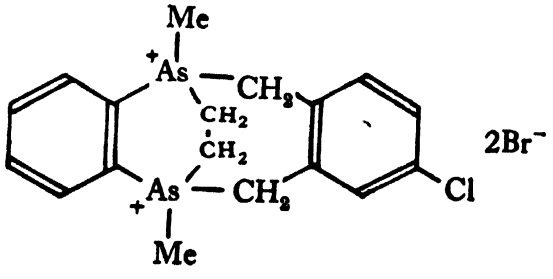
*o*-Phenylenebis(dimethylarsine) (VIII) and 1:4-dimethyl-ethylene-*o*-phenylenediarsine (IX) undergo similar diquaternization with *o*-xylylene dibromide. The latter diarsine reacts with 4-chloro-*o*-xylylene dibromide to give ethylene-4-chloro-*o*-xylylene-*o*-phenylenediarsine dimethobromide (X), which lacks any element of symmetry, but which was not resolved.




(VIII)

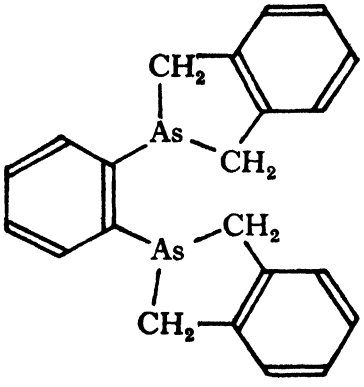



(IX)

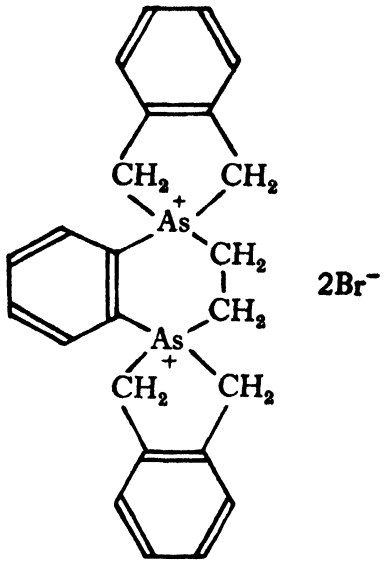



(X)

Thermal decomposition of the diarsonium salts obtained from the reaction of (VIII) and (IX) with *o*-xylylene dibromide leads in each case to the formation of *o*-phenylenebis(2-*iso*-arsindoline) (XI); under the same conditions (X) yields the corresponding *o*-phenylenebis-2-(5-chloro*iso*arsindoline). The reaction of (XI) with ethylene dibromide gives ethylene-*o*-phenylene-1:4-bis(*spiro*-As-*iso*arsindolinium) diarsonium dibromide (XII).

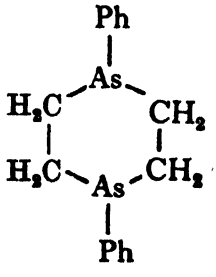


(XI)

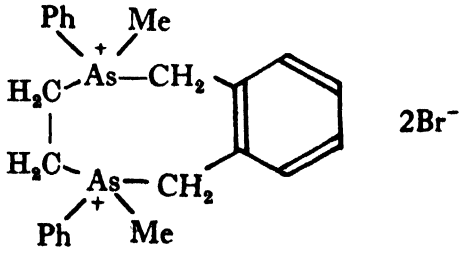


(XII)

The reaction of *s*-ethylenebis(phenylmethylarsine) with ethylene dibromide under certain conditions yields 1:4-diphenyl-1:4-diarsa*cyclo*hexane dimethobromide, which on thermal decomposition gives the free 1:4-diphenyl-1:4-diarsa*cyclo*hexane (XIII). When *o*-xylylene dibromide is used as the quaternizing reagent, 2:5-diphenyl-7:8-benzo-2:5-diarsa*cyclo*-octa-7-ene dimethobromide (XIV) is produced.



(XIII)



(XIV)

*For the* PH.D. *Degree*

# PERFLUOROALKYL SULPHIDES AND POLYSULPHIDES

*By* JOHN MITCHELL KIDD

*Sidney Sussex College, Cambridge, and the University of Manchester*

THE reaction between trifluoroiodomethane and sulphur yields bistrifluoromethyl disulphide $(CF_3)_2S_2$, trisulphide $(CF_3)_2S_3$, and tetrasulphide $(CF_3)_2S_4$; the reaction can be extended to the preparation of bisheptafluoropropyl disulphide $(C_3F_7)_2S_2$ by using heptafluoropropyl iodide. Bistrifluoromethyl di- and trisulphides can also be prepared from the reaction of carbon disulphide with iodine pentafluoride.

Evidence is presented to prove that the trifluoromethyl compounds contain unbranched chains of sulphur atoms. The perfluoroalkyl polysulphides are stable to air, water and dilute acid, at room temperature, but are decomposed by aqueous alkali, the trifluoromethyl compounds giving entirely carbonate, fluoride, sulphide and sulphur.

Irradiation of bistrifluoromethyl polysulphides with ultraviolet light yields bistrifluoromethyl sulphide $(CF_3)_2S$, which is stable to aqueous alkali; irradiation in the presence of mercury yields bis(trifluoromethylthio) mercury, $Hg(SCF_3)_2$. On treating the mercurial with anhydrous hydrogen chloride, trifluoromethanethiol, $CF_3SH$, is formed; this compound is decomposed by light and is rapidly hydrolysed in aqueous media. Evidence is presented to show that the hydrolysis of trifluoromethanethiol proceeds by initial loss of hydrogen fluoride to form thiocarbonyl fluoride, $CSF_2$, which is subsequently hydrolysed. Heptafluoropropanethiol can be prepared by a method identical to that adopted for trifluoromethanethiol, but its hydrolysis appears to be rather more complicated.

The reaction between trifluoromethanethiol and ammonia gives trifluoromethyl fluorodithioformate, $CF_3S.CSF$, and bistrifluoromethyl trithiocarbonate, $(CF_3S)_2CS$; two independent methods of synthesis of the latter compound are described.

On heating bis(trifluoromethylthio) mercury with chlorine, or on irradiating a mixture of bistrifluoromethyl disulphide and chlorine with ultra-violet light, trifluoromethane sulphenyl chloride, $CF_3SCl$, is formed. This compound can be used for the synthesis of bistrifluoromethyl di- and trisulphide; it is hydrolysed by water and aqueous alkali, and theories are presented to explain the results obtained.

The mercurial can be oxidized by hydrogen peroxide to give trifluoromethane sulphonic acid, $CF_3SO_3H$; the acid fumes copiously in moist air and is stable to aqueous alkali at 100°. The conductivities of aqueous solutions of the acid, its barium and sodium salts, and methane sulphonic acid, were measured.

Trifluoromethane sulphonic acid can be converted into the sulphonyl chloride, $CF_3SO_2Cl$, by treatment with phosphorus pentachloride; the sulphonyl chloride can also be prepared by the oxidation of trifluoromethane sulphenyl chloride with hydrogen peroxide or a mixture of chlorine and water. It is reduced, by a mixture of zinc dust and water, to trifluoromethane sulphinic acid, $CF_3SO_2H$, isolated as its zinc or sodium salt; the salts liberate fluoroform quantitatively on treatment with aqueous alkali at 100°. The zinc salt reacts with trifluoromethane sulphenyl chloride to give bistrifluoromethyl thiolsulphonate, $CF_3SO_2SCF_3$, which can also be obtained from the hydrolysis of the sulphenyl chloride with small amounts of water. The thiolsulphonate is stable to water, but is decomposed by aqueous alkali at 100° with the formation of carbonate, fluoride, fluoroform, sulphide and sulphur. A theory is presented to explain the observed results.

*For the* PH.D. *Degree*

# CHEMISTRY OF THE *OROBANCHE* AND *STRIGA* GERMINATION FACTORS

*By* ANTHONY RICHARD LANSDOWN

*Queens' College, Cambridge, and the University of Wales*

IT has been known for many years that the germination of the seeds of certain parasitic plants normally occurs only in the presence of substances produced by the roots of their host-plants. The object of the work described in this dissertation was the isolation and identification of the chemicals which stimulate the germination of the seeds of *Orobanche minor* and *Striga hermonthica.*

The methods of purification investigated were the same in both cases, namely, adsorption and partition chromatography, counter-current extraction, high-vacuum distillation, and crystallization. Of these counter-current extraction proved to be the most useful procedure.

For the *Orobanche* factor a considerable improvement in the purification procedure was developed, and a purified stimulant was obtained which has significant biological activity at a concentration of $10^{-9}$ mg./c.c. Some chemical work was carried out on this material, which may be a complex unsaturated lactone.

For the *Striga* factor, in view of the rapid loss of stimulatory activity, no attempt was made to isolate a highly active substance, but the crude factor was instead separated into its components, and work on the characterization of these components was carried out. Four components of the active mixture were isolated, none of which has any stimulant activity by itself. One of the components was definitely identified as a eutectic mixture of palmitic and stearic acids, and the other three components may also be carboxylic acids.

The difficulty of carrying out purification work on very small quantities of material was enhanced in this case by the rapid loss of activity of the stimulants and by the delay and inaccuracy of the biological test.

*For the* PH.D. *Degree*

# A THEORETICAL STUDY OF MOLECULAR STRUCTURE

*By* PHILLIP PLEYDELL MANNING, B.A.

*Emmanuel College, Cambridge*

THE molecular orbital theory of molecular structure, in the form using optimum orbitals, is extended to apply to an approximate wave function that is a linear combination of determinantal functions of the orbitals. The theory using a single determinant appears as the first approximation. The one-electron orbitals have extensive transformation properties that leave the wave function invariant, and throughout the development emphasis is placed on these transformations. With their use it is possible to deduce the main features of the orbitals and the wave function without the need for extensive numerical computation. The method is particularly useful when applied to the study of conjugated molecules, because the extensive transformation properties allow the construction of well-localized orbitals for the mobile electrons, so that the structure of the whole molecule may be described in terms of the constituent atoms and their interactions. The expression for the total electronic energy is rather complicated and is only studied briefly, but it is shown that the charge-density function can be used to express the interactions in a simple and quite detailed way.

One chapter is devoted to a method of introducing localized orbitals into the one-determinant theory based on the many-determinant approach. This can be done without approximation. This method is then applied to conjugated molecules and a critical study made of the existing theories for these molecules. Special attention is given to the validity of the approximations made when energy quantities are determined by comparison with experimental data instead of by *ab initio* computation, and it is shown that all the published methods require reinterpretation if the results obtained from them are to be fully understood.

*For the* PH.D. *Degree*

# THE MECHANISM OF THE OXIDATION OF THIAMINE

*By* PHILIP NESBITT, B.A.

*St John's College, Cambridge*

THE dissertation begins with a general review of the more important aspects of thiamine chemistry. The research work was carried out to provide more information on the proposals for the mechanism of the oxidation of thiamine suggested by Sykes and Todd (1951). It may be divided into three sections:

(1) The preparation of and attempts to cyclize *N*-formyl-*N*-(4-amino-2-methyl-5-pyrimidyl)methylbenzylamine and 4-amino-4-formamidomethyl-2-methylpyrimidine with a view to adding thiol radicals to the carbon-nitrogen double bond thus formed. However, cyclization could not be effected in either case.

(2) Attempts to prepare compounds of the type *R*—S—S—*R'* from the sodium salt of 'open-chain' thiamine or a model compound (*R*SNa) and benzenesulphenyl chloride (*R'*SCl). Only mixtures of symmetrical disulphides were obtained.

(3) The synthesis of 3-(2-methyl-4-methylamino-5-pyrimidyl)-methyl-5-2'-hydroxyethyl-4-methylthiazolium chloride hydrochloride ('*N*-methylthiamine') and the preparation of 3(4-hydroxy-2-methyl-5-pyrimidyl)methyl-5-2'-hydroxyethyl-4-methylthiazolium chloride hydrochloride ('oxythiamine'), in order to investigate their behaviour towards oxidizing agents and the action of heat on solutions of their disulphides in high-boiling solvents.

Several attempts to synthesize the pyrimidine moiety of *N*-methylthiamine were made, and the compound was finally synthesized by an adaptation of the method of Todd and Bergel (1937). The thiazole ring was then built on to the pyrimidine moiety by an adaptation of the method of Matsukawa and Yurugi (1943).

Oxythiamine was prepared by the deamination of thiamine.

On oxidation with potassium ferricyanide both *N*-methylthiamine and oxythiamine gave the corresponding disulphides.

These disulphides proved to be stable when their solutions in high-boiling solvents were heated.

Finally, a suggestion is made as to why the presence of a 4-amino group on the pyrimidine ring is essential for the fission of the disulphides and for the formation of products other than the disulphide on oxidation.

SYKES AND TODD (1951). *J. Chem. Soc.* p. 534.
TODD AND BERGEL (1937). *J. Chem. Soc.* p. 364.
MATSUKAWA AND YURUGI (1943). *J. Pharm. Soc. Japan*, **63**, 216.

*For the* PH.D. *Degree*

## THE SYNTHESIS OF SUBSTANCES RELATED TO THE STEROIDS

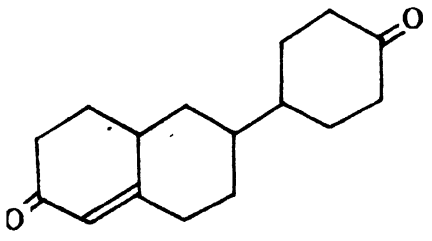
*By* JOSEPH ADEODATUS KWATEKWEI QUARTEY, B.A.
*Queens' College, Cambridge*

Wilds, Shunk, and Hoffman reported in 1949 (*J. Amer. Chem. Soc.*, 1949, **71**, 3266) the androgenic activity of (I), though similar analogues of progesterone and deoxycorticosterone are inactive (Wilds and Shunk, *ibid.*, 1950, **72**, 2388). In a review of the position (Birch, *J. Chem. Soc.*, 1950, p. 367) it was concluded that only compounds more closely related to authentic steroids are likely to possess significant activity.

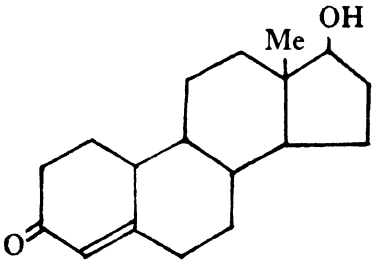
It was demonstrated that the $C_{19}$ methyl group could be omitted with retention of considerable activity; 19-nortestosterone (II), in which the configuration of the hydrogen atom at $C_{10}$ is probably $\beta$-, possesses at least 20 % of the activity of testosterone (Birch, *Ann. Reports*, 1950, **47**, 210), and 19-norprogesterone has since been shown to be a potent gestogen (Miramontes, Rosenkranz, and Djerassi, *J. Amer. Chem. Soc.*, 1951, **73**, 3540).

The whole problem of structure-specificity of the steroid molecule required for hormonal activity was examined. The conclusion is reached that the function of the $C_{18}$ methyl group is to keep the C—D ring-junction *trans*-. Therefore from considerations of the stability of *cis*- and *trans*- decalin systems, and employing the concept of polar and equatorial bonds (Barton, Tilden Lecture,

*J. Chem. Soc.*, 1953, p. 1027), the expectation would be that, with ring D six-membered, both angular methyl groups could be omitted with retention of activity. Accordingly (±)-11α-hydroxy-18:19-bisnor-D-homotestosterone (III) was obtained in the course of



(I)



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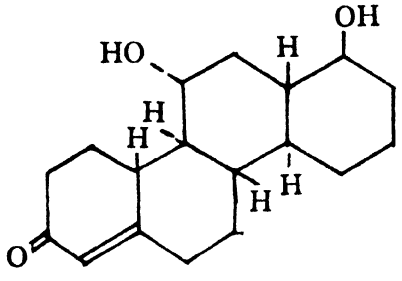

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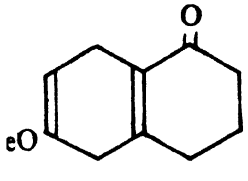

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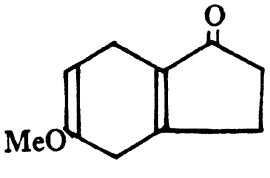

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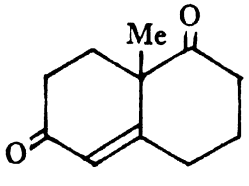

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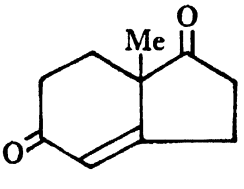

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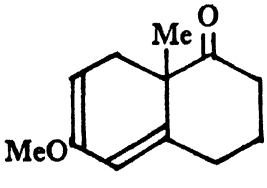

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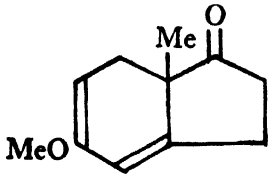


(IX)

the synthesis of hydrochrysene derivatives related to the steroids. The compound (III) was shown to possess a weak but definite androgenic activity (Birch and Quartey, *Chem. and Ind.*, 1953, p. 489). This establishes that D-homo-bis-nor-steroids in general may possess a high activity, which fact makes the problem of the abundant supply of synthetic hormone very much simpler, since their synthesis depends on reduction of readily accessible aromatic systems.

The introduction of angular methyl groups into the preformed nucleus was also examined. By direct methylation of (IV) and (V) with potassium amide in liquid ammonia followed by methyl iodide, the angular methylated derivatives (VI) and (VII) were synthesized. It is evident that the intermediates (VIII) and (IX) will be even more useful in the synthesis of steroid analogues; (IX) as rings C and D of the steroids, and (VIII) as rings A and B of the steroids or C and D of the D-homosteroids. As part of the general problem of angular methylation the conversion of conjugated steroid -en-ones to the unconjugated isomers was examined and a new method proposed.

*For the* PH.D. *Degree*

## THE RADIATION CHEMISTRY OF WATER

*By* JACK ROWBOTTOM

*St Catharine's College, Cambridge, and the University of London*

IN the first, and major, section of the dissertation an account is given of an investigation into the kinetics of the chain decomposition of aqueous solutions of hydrogen peroxide by light and by ionizing radiation. The rates of both reactions are proportional to the first power of the hydrogen peroxide concentration and to the square root of the radiation intensity; they have the same temperature coefficients. It is therefore postulated that these two modes of decomposition differ only in their primary steps. The value of the limiting quantum yield at high light intensities is observed to be 1·9, and hence the primary radical yield is $12{\cdot}6 \pm 1{\cdot}8$ water molecules decomposed per 100 eV. The significance of this result is discussed, and a new theory is proposed for

the action of ionizing radiations on water. The theory is supported by some hitherto unexplained results of other workers.

The second section of the dissertation describes experiments on some of the effects of ionizing radiation on vitreous silica, i.e. formation of colour centres, radiofluorescence and radiophosphorescence. The kinetics of formation of the three overlapping absorption peaks are shown to be first order, prolonged irradiation producing colour saturation. The nature of the centres responsible for these absorption peaks is discussed in the light of the experiments on their formation and on their destruction by ultraviolet light. It seems likely that the centres are analogous to the colour centres in irradiated alkali halide crystals. Further, it is shown that the radiophosphorescence decay follows a second-order law, and this is interpreted in accordance with modern theories of impurity activated phosphors. It was found that the radioluminescence properties of samples of vitreous quartz are largely independent of the extent to which they may be coloured by X-rays.

*For the* PH.D. *Degree*

## WAVE FUNCTIONS OF CARBON AND SOME POLAR MOLECULES

*By* ROOP CHAND SAHNI

*Trinity College, Cambridge, and the University of the Punjab*

THE dissertation deals with the application of quantum mechanics to the structure of some atoms and molecules, and is divided into two sections.

The subject of the first section is the construction of wave functions of simple polar molecules. A self-consistent field procedure was developed from the general molecular orbital theory and applied to the calculation of molecular orbitals and ionization energies of carbon monoxide. The electronic structure of this molecule is discussed in terms of molecular orbitals and localized orbitals in order to illustrate the properties of these orbitals for an unsymmetrical molecule.

A similar calculation was made on another polar molecule, boron hydride. The molecular orbitals, ionization potentials,

dipole moment, total energy and binding energy of this molecule were calculated. All the integrals involved were evaluated exactly. The calculated energy value was compared with the observed data. It was found that this wave function for boron hydride is more accurate than any other previously reported for a polar molecule. It was also found that, if the molecular orbitals are made orthogonal, the inner shell–outer shell mixing can be neglected, as this does not cause any appreciable error in the wave function or the properties of the molecule.

In the second section a short review is given of the method, developed by Dr S. F. Boys, of calculating atomic wave functions as linear combinations of determinants. The wave functions and the energies of the $^1D$, $^1F$, and $^3F$ excited states of carbon were calculated by this method. In this section the automatic calculation of a large number of vector coupling coefficients, required for the calculation of atomic and molecular wave functions, is also reported, together with their numerical values.

*For the* PH.D. *Degree*

## SOME POLYCYCLIC DERIVATIVES OF NITROGEN

*By* ALWYN SENIOR

*Downing College, Cambridge, and the University of Birmingham*

THE dissertation is divided into three sections:

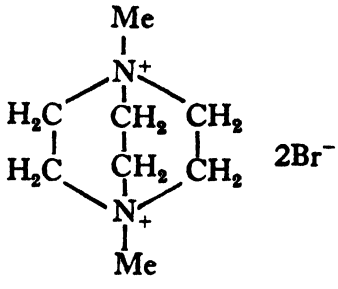
I. The interaction of (i) 1:4-dimethylpiperazine, (ii) 1:4-diethylpiperazine, and (*a*) ethylene dibromide, (*b*) trimethylene dibromide, and (*c*) *o*-xylylene dibromide.

II. The thermal decomposition of the quaternary ammonium salts formed in Section I.

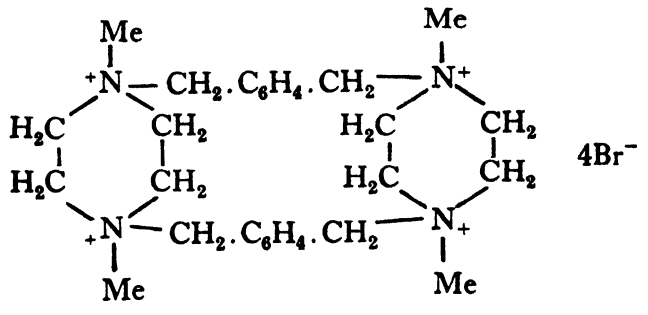
III. The preparation and constitution of 1:2:2:4:5:5-hexamethylpiperazine and its reaction with dibromides.

I. The reaction between an *NN'*-dialkylpiperazine and a dibromide might be expected to give either a diazabicycloalkane diquaternary bromide of the type shown by formula (I) or the dimeric tetraquaternary bromide (type 2). It is therefore

essential to establish the molecular weight of the reaction product. This was done, wherever possible, by the cryoscopic method, using aqueous solutions of the quaternary bromides. It was thus found that 1:4-dimethylpiperazine and ethylene dibromide react together to give triethylenediamine dimethobromide (I), but that the interaction of 1:4-dimethylpiperazine and *o*-xylylene dibromide gives the dimeric 1:1′-*o*-xylylene-4:4′-*o*-xylylene-dipiperazine-1:1′:4:4′-tetramethobromide (II).




(I)




(II)

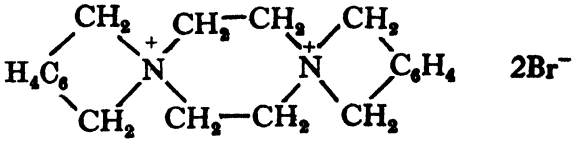
The interaction of 1:4-diethylpiperazine and (i) ethylene dibromide, (ii) *o*-xylylene dibromide, gave products which were too deliquescent to permit accurate molecular weight determinations. Their constitution as the monomer and dimer respectively is based on analogy with the corresponding methyl derivatives (I) and (II). Similarly the molecular weights of the products from the interaction of trimethylene dibromide and (i) 1:4-dimethylpiperazine, (ii) 1:4-diethylpiperazine, could not be established. However, thermal decomposition of these products gave evidence in favour of the monomer formula.

II. The thermal decomposition of the products formed by the interaction of *NN*′-dialkylpiperazines and (i) ethylene dibromide, (ii) trimethylene dibromide, gave comparable results. Although the mechanism of the decomposition is not understood, the order of elimination of groups from these compounds was found to be:

$$\text{Me},\quad \text{—CH}_2\text{CH}_2\text{—},\quad \left\{\begin{matrix}\text{Et}\\ \text{—CH}_2\text{CH}_2\text{CH}_2\text{—}\end{matrix}\right\}\ \text{equal}.$$

The dimers (type 2), formed by the interaction of *NN*′-dialkylpiperazines and *o*-xylylene dibromide, on thermal decomposition gave mainly bisdihydroisoindolium piperazinium dibromide (III).

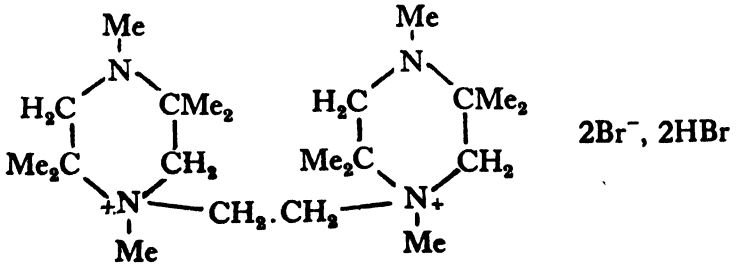
The structure of (III) was determined by X-ray analysis by Dr W. Cochran (Cavendish Laboratory).




(III)

III. The identity of the 1:2:2:4:5:5-hexamethylpiperazine prepared by the methylation of 2:2:5:5-tetramethylpiperazine (Conant and Aston, *J. Amer. Chem. Soc.*, 1928, **50**, 2783) was conclusively proved by showing the corresponding dihydrogen nitrate derivative to be centrosymmetric (Dr W. Cochran).

When 1:2:2:4:5:5-hexamethylpiperazine was heated with (i) ethylene dibromide, (ii) trimethylene dibromide, and (iii) *o*-xylylene dibromide, hexamethylpiperazine dihydrobromide was obtained. When, however, the hexamethylpiperazine was placed with an equimolecular quantity of ethylene dibromide in a sealed tube in sunlight for one week, compound (IV) was isolated.




(IV)

The complete difference in the reactions between the simple *NN'*-dialkylpiperazines and the hexamethylpiperazine with dibromides is thought to be due to the absence of the bed-form of the piperazine nucleus in the latter.

*For the* PH.D. *Degree*

# FREE RADICAL ADDITION TO UNSATURATED COMPOUNDS

*By* BERNARD ROBERT STEELE, B.A.

*Selwyn College, Cambridge*

THE photochemical reaction of trifluoroiodomethane with an unsaturated compound $\rangle C{=}C\langle$ proceeds by a chain mechanism involving free-radical intermediates and gives mainly $CF_3\overset{|}{C}\overset{|}{C}I$. The irradiation of trifluoroiodomethane with ultra-violet light produces a trifluoromethyl radical and an iodine atom, and the initial step in the chain reaction with an olefin is shown to involve attack by the trifluoromethyl radical. Evidence for this chain mechanism is presented, and a detailed study is made of the products formed when trifluoroiodomethane reacts with the following olefins: $R$CH:$CH_2$ ($R = CH_3$, F, Cl, $COOCH_3$, $CH_2Cl$), CHF:CHCl, CHF:$CF_2$, $CF_2$:$CH_2$, $CF_2$:CHCl, $CF_2$:CFCl, and $CF_2$:$CHCF_3$. Some observations on the free radical reaction of hydrogen bromide with olefins and the photochemical reaction of hydrogen iodide with fluoro-olefins are also included.

In each case the constitution of the product was established and used to deduce the direction of attack of a trifluoromethyl radical or a bromine atom. These results are correlated with other reported free radical addition reactions. The factors which may influence the rate and direction of the addition of free radicals to unsaturated compounds are discussed. From the evidence presented, the most satisfactory explanation is that orientation in radical addition reactions depends upon the relative stabilities of the two intermediate radicals which may be formed. Methods for the determination of radical stabilities are discussed.

*For the* PH.D. *Degree*

# STUDIES IN THE ORGANIC CHEMISTRY OF PHOSPHORUS AND MAGNESIUM

*By* FREDERICK HUBERT CAMPBELL STEWART

*Trinity College, Cambridge, and Queen's University, Belfast*

IN Section I of the dissertation an investigation of various possible syntheses of the *iso*phosphindoline ring system is described. A brief review of existing syntheses and attempted syntheses is included. Attempts to apply procedures known to be successful for other heterocyclic phosphorus compounds to this ring system were unsuccessful. A new synthesis of this ring system is described.

In Section II one of the unsuccessful attempted syntheses of the *iso*phosphindoline ring system was investigated in detail. A novel abnormal Grignard reaction was shown to be responsible for the failure of the synthesis, and the theoretical implications of this reaction are discussed and their examination is described.

The theoretical aspects of this reaction were then extended, and this extension led to a related abnormal reaction also involving Grignard reagents. This last reaction is of considerable potential practical value as a new synthesis of a wide range of previously inaccessible substituted anilines. Some examples of this practical application are given.

In Section III, the last in the dissertation, a short discussion of the possible influence of chelation on the chemical behaviour of Grignard reagents is given. The results obtained with a number of Grignard reagents derived from some bromobenzyl ethers (used in the other two sections) are quoted in evidence that chelation may indeed influence their properties.

*For the* PH.D. *Degree*

## THE SZILARD–CHALMERS EFFECT IN TRIPHENYLARSINE AND TRIPHENYLSTIBINE

*By* NORMAN SUTIN

*Trinity College, Cambridge, and the University of Cape Town*

THE radiative capture of thermal neutrons in crystalline triphenylarsine and triphenylstibine leads to a variety of active products. The products corresponding to the different degrees of bond rupture in the parent molecule were separated by chromatography and identified as the arsineoxides, arsonic acids, stibineoxides, stibonic acids and the free metals.

The acids and oxides are formed by the reaction of labile and reactive organo-metallic derivatives with traces of water and oxygen in the solvent. For triphenylarsine the reaction of the labiles obeys first-order kinetics with a half-life of four hours.

The products corresponding to the same degree of bond rupture do not contain equal proportions of the radioactive isotopes. The arsenic-phenyl bonds can be re-formed by heating the irradiated crystals to relatively low temperatures.

The products result partly from the failure of the recoil of the capturing atom to rupture all the bonds in the parent molecule and partly from the re-formation of some of the bonds in the cooling-down process and in the thermal region. The results are interpreted in terms of a model of the process whereby the recoiling atoms dispose of their excess energy.

*For the* PH.D. *Degree*

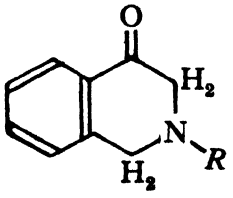
## SOME NEW HETEROCYCLIC DERIVATIVES OF NITROGEN AND SILICON

*By* ALAN VANTERPOOL

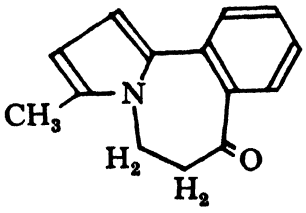
*Emmanuel College, Cambridge, and the University of Saskatchewan*

THE first section of the dissertation deals with the attempted preparation of three heterocyclic systems (I, IIA, and IIB)

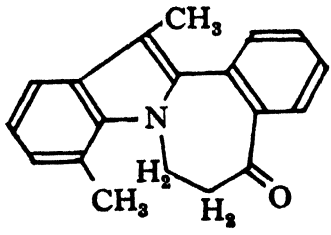
containing nitrogen, required in order to extend previous work (Mann *et al.*, *J. Chem. Soc.*, 1952, p. 1870, and earlier papers in this



(I)

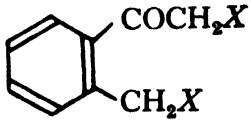


(IIA)



(IIB)

series). Previously reported unsuccessful work on the preparation of (I) (*R* is $CH_3$) by cyclization of benzylmethylglycine hydrochloride was repeated, extended, and confirmed; the results are interpreted in terms of modern theories of organic chemistry. An attempted new route to (I), by treating the previously unknown *o*-halomethylphenacyl halides (III) with amines, is described. The dibromide (III; *X* is Br) is too unstable for use as an intermediate, while the dichloride (III; *X* is Cl) reacts in some obscure fashion with amines, giving compounds of unknown structure. In particular, the substance $C_{23}H_{22}N_2$ obtained from (III; *X* is Cl)



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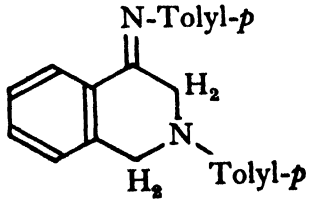


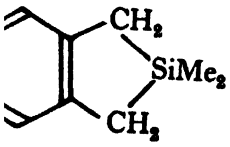
(IV)

and *p*-toluidine was extensively investigated, and in the light of chemical and physical evidence it is tentatively considered to be (IV). All attempts to obtain (I; *R* is *p*-tolyl) from $C_{23}H_{22}N_2$ were unsuccessful.

The synthesis of 1-(β-cyanoethyl)-5-methyl-2-phenylpyrrole and of 1-(β-cyanoethyl)-3:7-dimethyl-2-phenylindole from the corresponding N-unsubstituted compounds was achieved, but in very low yields, which precluded their use as intermediates in the preparation of (IIA) and of (IIB) respectively.

Very few systems are known in which a silicon atom has replaced a carbon atom in a ring, and the second section of the

dissertation deals with the preparation of some compounds of this type. The attempt to prepare 2:2-dimethyl-2-silaindan (V) from *o*-xylylene dibromide and dichlorodimethylsilane by the Würtz reaction was not successful; explanations are advanced for this

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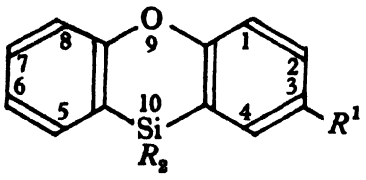


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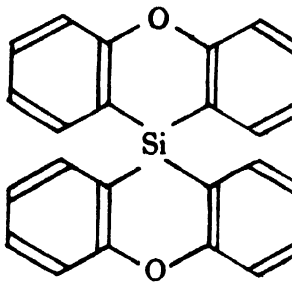


(VII)

result. The formation of several phenoxsilanes from the dilithio derivative of the appropriate 2:2′-dibromodiphenyl ether and a dihalosilane occurs readily, and the 10:10-dimethyl (VI; $R$ is $CH_3$, $R'$ is H), 10:10-diphenyl (VI; $R$ is $C_6H_5$, $R'$ is H), and 10:10-diphenyl-3-methyl (VI; $R$ is $C_6H_5$, $R'$ is $CH_3$) compounds were obtained, in addition to the interesting spirane (VII).

## (5) *PHYSICAL CHEMISTRY*

*For the* PH.D. *Degree*

## KINETICS OF FREE RADICAL REACTIONS

*By* MARGARET ISABELLA CHRISTIE, M.A.

*Newnham College, Cambridge*

THE application of the high-energy discharge lamp to photochemistry has extended the available light-intensity range by a factor of several thousand. By this means it has become possible to study directly the kinetics of elementary steps involving free radicals and atoms, which are postulated as labile intermediates in most photochemically initiated reactions.

For quantitative work information about the photochemically useful properties of the flash discharge was required: the first section of the dissertation is a report of a study directed towards this end. The effect of such parameters as energy of the discharge and nature and pressure of the gas filling on (*a*) energy distribu-

ion with wave-length, and (*b*) total output in the ultra-violet egion, was determined by photometric and actinometric nethods. The results are discussed in relation to the mechanism f the production of the continuum, which is attributed to the ecombination radiation of electrons.

The second section of the dissertation describes an investigation ıto the kinetics of the homogeneous recombination of iodine toms in the presence of the five inert gases, using the technique f flash photolysis. Iodine vapour at 0·15 mm. Hg pressure, in ıe presence of a known pressure of the third-body gas, was dis-ɔciated 50% into atoms by means of a flash discharge lasting ɛss than 1 msec. The concentration of iodine atoms as recom-ination proceeded was determined by recording the light ab-ɔrption of the system as a function of time by means of a hotomultiplier tube and an oscilloscope. It was found that the ɛrmolecular rate law

$$-d(I)/dt = k(I)^2M$$

obeyed, and the absolute rate constants $k$, at room temperature, re 1·73, 1·86, 2·42, 3·42 and $3{\cdot}44 \times 10^{-32}$ ml.$^2$ molecules$^{-2}$ s.$^{-1}$ for $M$ = He, Ne, A, Kr and Xe respectively. The data are discussed ı terms of the various theories of termolecular reactions.

*For the* PH.D. *Degree*

## THE NORMAL ADHESION OF CLEAN METALS AND ITS RELATION TO FRICTION

*By* GEOFFREY WHALEY ROWE, M.A.

*Emmanuel College, Cambridge*

THE experiments described in the dissertation confirm earlier bservations that the coefficient of friction between two rubbing ıetals is much greater after the specimens have been outgassed ıan under ordinary laboratory conditions. The results show, how-ver, that very slight contamination will prevent seizure, and that ɔmplete denudation is usually produced only after evaporation f some of the substrate metal.

A study of the seizure process reveals the dependence of seizure pon strong adhesion over a small area of metallic contact. This

area is established by normal loading and increases in extent as a tangential force is applied between the specimens, so that it becomes harder to break them apart after an attempt has been made to slide one upon the other. An equation is obtained which relates this normal adhesion to the tangential pre-stressing force, and is in fair accord with the experimental results.

Small coefficients of adhesion are found after normal loading alone, even though the surfaces are shown to be effectively free from protective films. The experiments suggest that the brittleness of asperity bridges formed across the interface permits the junction to fail under the influence of elastic recovery forces when the load is removed. The area of true contact is thereby diminished, so that a relatively small force is subsequently required to separate the specimens. If, however, the asperity bridges are annealed after deformation, they can extend more readily without fracture, and powerful adhesion is then recorded.

It is found, nevertheless, that adhesion is extremely sensitive to contamination; even the amount of contaminant deposited at a tank pressure of 1 m$\mu$ can be detected after a few hours. A new apparatus was developed which operates in a sealed and gettered glass envelope at a much lower pressure, in the region of $10^{-5}\mu$. It is recommended that conditions such as these should be used in future investigations of the properties of clean metal surfaces.

*For the* PH.D. *Degree*

## HOT SPOT SIZE AND THE INITIATION OF PRIMARY EXPLOSIVES

*By* KARTAR SINGH

*Gonville and Caius College, Cambridge, and the University of the Punjab*

THERE is a good deal of evidence from the work of Bowden and his co-workers that the initiation of explosion by impact and friction is mainly thermal in origin. The mechanical energy of the blow or rubbing is degraded into heat within small regions, called 'hot spots'. These hot spots are readily formed in two main ways: (i) by the adiabatic compression of small included air bubbles;

(ii) by friction on the confining surfaces, on grit-particles, or on the crystals of the explosive itself.

From measurement of the e.m.f. developed between the rubbing surfaces, and from other methods, fairly accurate estimates of the temperature of the 'hot spots' are available. Estimates of the size of the hot spots suggest that they are large compared with molecular dimensions. An alternative hypothesis states that a few adjacent molecules decomposing simultaneously constitute an explosion nucleus. In this hypothesis it is implied that all the heat liberated during the chemical reaction goes into the activation of a further group of molecules.

If the heat loss from the reaction centre is taken into consideration, the critical value of the diameter of the hot spot at a temperature of 380–400° C. is found to be of the order of $10^{-3}$ cm. No direct experimental evidence is as yet available on this point. The present investigations are an attempt to estimate the critical value of the diameter of these hot spots. Two methods were employed in the attack on this problem:

(i) bombardment of the primary explosives with high-velocity particles, e.g. fission products and protons;

(ii) the study of the effect of size of the crystals on their behaviour during thermal decomposition.

In the first method the high-velocity particles were produced within the crystal by means of incident radiations which have no appreciable heating effect. Although the tracks of these particles are characterized by intense chemical activity and high temperature, no explosion results on their passage through the crystals of primary explosives. The calculated values of the main linear ion density along the tracks of fission products and protons suggest that simultaneous decomposition of a few adjacent molecules does not play any dominant role in the initiation of an explosion. Calculations also show that a fission product is capable of raising a cylindrical region $3 \times 10^{-6}$ cm. in diameter and $10^{-3}$ cm. in length to a temperature of 400° C. The diameter of this hot region is doubled if the bombardment of the crystals is carried out at a temperature of 290° C. From the absence of explosion on bombardment, even at high temperatures, it is concluded that a hot spot about one-tenth of a micron in diameter fails to grow into explosion.

In the second method the behaviour of a group of crystals during thermal decomposition was investigated. It was observed that at a particular temperature there exists a critical value of the thickness of the crystal. Crystals having a thickness greater than this value always detonate, and crystals having a thickness smaller than this value decompose slowly. For example, the critical thickness of cadmium azide crystals at 330° C. is $17 \times 10^{-4}$ cm. On taking into consideration the conditions of heat transfer from a crystal of critical size it is concluded that a hot spot having a diameter of a few microns at a temperature of about 350° C. is capable of growing into explosion in solid and liquid explosives. This value compares favourably with the value derived theoretically.

On examination of the behaviour of the crystals during thermal decomposition interesting facts came to light. It was observed that crystals which decompose in the solid phase break along certain crystallographic planes during thermal decomposition. On the other hand, crystals which melt before decomposition break into small droplets. The fracture during solid-phase decomposition was explained in terms of formation and aggregation of crystal defects. It was further observed that irradiation with slow neutrons reduces the induction period and increases the rate of thermal decomposition. This, again, was explained in terms of formation of crystal defects.

*For the* PH.D. *Degree*

## ASPECTS OF EXPLOSIVE COMBUSTION

*By* BRIAN ARTHUR THRUSH, M.A.

*Emmanuel College, Cambridge*

THE kinetics of homogeneously initiated explosions of acetylene, ethylene and ethane with oxygen were studied spectroscopically. A small amount of photosensitizer (nitrogen dioxide) was added to the system, which was irradiated with an intense flash of ultraviolet light, and it was shown that the reaction is completely homogeneous and independent of flame propagation. Photographic and photoelectric methods of observation were used. For the

former a second flash recorded the absorption spectrum in $5 \times 10^{-5}$ sec. With the latter photomultiplier cells were used to record the light emission or absorption of two narrow spectral regions on a cathode-ray oscillograph. This method had a time resolution of $10^{-5}$ sec., and three measurements, using a calibrated xenon arc as source, enabled the temperature of the reaction to be determined by Schmidt's method.

The absorption spectra of CH, $C_2$ (singlet and triplet), CN, NH and OH were observed, as well as bands attributed to $C_3$, several of these spectra being new in absorption. The relative concentrations of these radicals are given throughout explosions carried out under various conditions. The radicals appeared after an initial period of less than $4 \times 10^{-3}$ sec., which shows weak continuous absorption. The more rapid changes in radical concentrations occurred within $2 \times 10^{-4}$ sec., after which the remaining radicals decayed exponentially with half-lives between $10^{-4}$ and $10^{-3}$ sec.

The measured temperatures normally agreed with the values expected for thermodynamic equilibrium, but the radicals sometimes showed light emission of duration less than $10^{-5}$ sec., which indicates a much greater temperature, and which must therefore be attributed to chemiluminescence.

The reactions and excitation conditions of the radicals observed are discussed, particularly in connexion with the investigations of flame spectra by many workers. The mechanism of carbon formation is also discussed, with special reference to the continuous spectra present.

*For the* PH.D. *Degree*

## THE IMPACT INITIATION OF EXPLOSIVES

*By* ALEXANDER McLELLAN YUILL

*Gonville and Caius College, Cambridge, and the University of Glasgow*

MOST initiating explosives do not possess known melting-points, since on heating rapid decomposition sets in before melting occurs. However, a few can be melted, and one, cyanuric triazide, was examined in the molten state. Its apparent high impact-sensitivity is due to the presence of air bubbles which can

be raised to a high temperature by adiabatic compression, a mechanism which is by now well known for high explosives. Even in the absence of air bubbles, pointed metal strikers are very effective. It is shown that the striker tip is being plastically deformed, and that the impact energy is concentrated in the tip and degraded to heat. A hot-spot temperature of 300–350° C. and duration *c.* 1 msec. is sufficient to initiate the molten cyanuric triazide.

A simple technique was devised whereby the effect on the decomposition of explosives of pressures up to 25,000 atm. could be evaluated. For the few explosives examined, high pressure tended to inhibit decomposition to a small but measurable extent.

Solid initiators, in the forms of single crystals and of compressed pellets, were impacted. It is shown that, in general, as the thickness of a crystal or pellet is decreased in the range 10–1000 $\mu$, the energy required for initiation increases. This is explained as a consequence of the theory of critical hot-spot size for growth of explosion.

The hardness, explosion temperature, specific heat and critical impact-initiation energy of a number of explosives were measured. No correlation was found between impact energy and hardness. The heat capacity of an initiator at its explosion temperature is correlated with its critical impact-initiation energy, indicating that initiation by impact is a simple thermal process. Further evidence that the mechanism of initiation of sensitive explosives is thermal was obtained by impacting lead azide at room temperature and at liquid-air temperature.

## (6) *PHYSICS*

*For the* PH.D. *Degree*

# THE MICROWAVE LINEAR ELECTRON ACCELERATOR AND THE MAGNETRON AS A POWER SOURCE

*By* ARTHUR WATSON AIKIN, M.A.

*Trinity College, Cambridge*

THE microwave linear accelerator is, in principle, capable of accelerating electrons up to any desired energy, and such an accelerator would be a very suitable tool for nuclear research. There are two main problems in the development of such an accelerator: the provision of an adequate source of radio-frequency power at a suitable wave-length, and the design of the corrugated circular wave-guide used for acceleration.

An attempt was made to obtain the very high powers required from a high-voltage pulsed magnetron on a wave-length of 25 cm. Very heavy strapping is necessary if a strapped anode is to be used, and to achieve this a form of internal strapping along the length of the anode was adopted. Design data were produced for the hole and slot type resonators used, and a theory was developed for the prediction of the mode separation of very heavily strapped anodes. The experimental development of an internally strapped anode is described; good agreement with the mode-separation theory was found.

Experiments with a linear accelerator designed to give electrons of 10 MeV. are described, and the energy and spectrum variations under various conditions are discussed. The energy performance of the accelerator is shown to be considerably less than the design value, and this is shown to be due to a discrepancy in the theory used in the calculation of the axial field strength to be expected for a given power flow down the corrugated wave-guide. A resonant cavity perturbation method of experimentally determining the field strength is described, and it is also shown that resonant cavity techniques may be used to measure the phase and group velocities and also the attenuation in experimental

sections of corrugated wave-guide. The experience gained and measurements on a number of experimental cavities are used to suggest some design features for accelerators of very high energy indeed.

*For the* PH.D. *Degree*

## STRUCTURAL STUDIES OF ALUMINIUM-RICH ALLOY PHASES

*By* PAUL JOSEPH BLACK

*Trinity Hall, Cambridge, and the University of Manchester*

THE work described is part of a programme of research on the structures of phases found in the aluminium-rich alloys of the metals from chromium to nickel. These are complicated structures and cannot be simply explained or related. They all have prominent Brillouin zones, and previous workers have correlated these with their electron-to-atom ratios by assuming that the transition metal atoms absorb electrons. This has also been proposed by Raynor in interpreting the phase diagrams, and attempts have been made to detect the effect using X-ray data.

In a brief survey of the techniques employed special attention is paid to the investigation of electron transfer. It is shown that the results of previous workers may be in error because of defects in the atomic scattering factors that they used.

The Brillouin zones of several iron compounds were measured. They give a wide range of values for the electron absorption by iron, and in some cases the value is unreasonably large.

The compound $FeAl_3$ was studied in detail. The solution and refinement of the structure, which has forty-eight parameters, and which can be related to close-packed structures, is described. Systematic variations in the mean contact distances of aluminium atoms with the numbers of their iron neighbours were found. The twinning of the crystals is explained. There is no accurate or consistent evidence for electron transfer in this structure.

A ternary compound, $FeAl_2Be_3$, was investigated. It is a type of Laves phase, with ordering of the small (iron and beryllium) atoms to give a monoclinic unit cell. Its relationship to other structures is discussed.

The general structural features of these compounds are considered. It is shown that several of them can be built from only two plane patterns of aluminium atoms, in different combinations which always give the transition atoms nine or ten neighbours. Other structures are more directly related to the close-packed arrangements, whilst some seem to be intermediate between the two types.

*For the* PH.D. *Degree*

## ATMOSPHERICS AND THE PROPAGATION OF VERY LONG RADIO WAVES

*By* PIERCE WILLIAM ARNOTT BOWE

*Fitzwilliam House, Cambridge, and the University of Sydney*

THE propagation characteristics of very long radio waves between the earth and ionosphere were investigated. Lightning discharges were used as sources of radiation for the radio-frequency range 0·6–50 kc./sec. This radiation is known as atmospherics. Results were obtained which give information regarding propagation conditions for radio waves of frequency below 16 kc./sec., and these extend the results obtained with long-wave transmitters.

The 'integrated level of atmospherics' was recorded continuously on various frequencies for two years, and this gave a general indication of changes from day to night and during disturbed conditions. The records are discussed in some detail with regard to the diurnal variation in order to extend the deductions by a previous worker, F. Gardner.

A more direct experiment, carried out in the summer of 1950, involved receiving atmospherics on narrow-band receivers on four fixed frequencies and thus determining four points on the 'received spectra' of the atmospherics. It was found that different atmospherics from a given distance had approximately the same received spectrum, and thus systematic changes due to distance could be deduced. It was found that below 10 kc./sec. the relative attenuation with distance at noon in summer increased with decreasing frequency and was about ten times at 3·5 kc./sec. what it was at 10 kc./sec. This factor was about two during night, giving a large day-to-night change. The attenuation was greater

during a 'sudden ionospheric disturbance' than it was during daytime.

The single-station observations described above yielded only indirect measurement of relative attenuation. To extend the results, spaced receiver experiments were carried out with identical receivers at Cambridge and Aberdeen. These gave direct measures of the absolute attenuation as the wave propagated between the two stations. The previous results were confirmed, and also some results were obtained regarding seasonal changes and the diurnal variation. It was also found that the attenuation for waves of frequency 0·6 kc./sec. was less than that for waves of frequency 3·5 kc./sec., and this was an important result since it had been predicted by the theory proposed by K. G. Budden.

Comparison of these determinations with a theory of mode propagation put forward by K. G. Budden gave a tentative explanation of the results. It appears that the results are in accord with the results obtained with long-wave transmitters, and it is hoped that further theory will enable deductions to be drawn about the physical state of the reflecting region.

*For the* PH.D. *Degree*

## SOME PROBLEMS IN LONG RADIO-WAVE PROPAGATION

*By* SIDNEY ALLAN BOWHILL, M.A.

*Downing College, Cambridge*

THE dissertation is concerned with two main topics. The first is the accurate determination of group heights of vertical incidence ionospheric reflexion at very long wave-lengths. Two experiments based on the Appleton and Barnett frequency-change method are described, as applied at frequencies of 30 and 80 kc./sec. A less accurate method, using the sharp leading edge of a morse dot from a commercial telegraphy transmitter, is also described. The heights found are in agreement with existing data. A new analytical method is described to derive the properties of the wave reflected from an exponential ionospheric layer in the presence of a vertical magnetic field and collisional friction.

The second topic is the study of the fading of very long radio waves. The analogy between a randomly fading radio signal and a random noise voltage is used to define the meaning of the statistical quantities 'fading speed' and 'depth of fading'. Simple methods of estimating these quantities from given fading curves are described, and are applied to night-time vertical incidence fading records over the frequency range 16–200 kc./sec. To aid the interpretation of these results, simultaneous fading records at 85 kc./sec. taken at pairs of aerials separated by from 1 to 15 km. are analysed to find their statistical correlation: this assigns a 'structure size' to the random variations in the diffraction pattern over the ground. Some experiments are described in which simultaneous fading records were taken at aerials placed at three corners of a square of sides 5 km. The analysis of these records detects any horizontal drift of the diffraction pattern and therefore of the irregularities in the ionospheric reflecting layer. Existing diffraction theory is extended to relate the diffraction pattern to the properties of the ionospheric irregularities. In addition to these vertical incidence results, some oblique incidence measurements are briefly reviewed.

*For the* PH.D. *Degree*

## STUDIES OF ANGULAR DISTRIBUTIONS FOR LIGHT NUCLEI

*By* ADRIAN VICTOR COHEN, M.A.

*Trinity College, Cambridge*

THE dissertation describes an investigation of the angular distribution of $\alpha$-particles emitted in two nuclear reactions, and the explanation of the results in terms of a phenomenological theory of nuclear reactions, which is for convenience recapitulated in the first chapter.

The first reaction examined was $^{18}O(p,\alpha)$. Angular distributions were determined, using protons of energies ranging between 430 and 890 keV. There are many overlapping levels in this energy range, and strong interference terms were observed in the angular distributions. The spins of several of the levels of the compound nucleus concerned in this reaction were determined;

it is a feature of this particular reaction that the absolute parities of levels cannot be unambiguously determined from the angular distribution measurements.

In the second experiment long-range $\alpha$-particles were observed from the reaction $^{15}N(p,\alpha)$, using protons of energies ranging between 230 and 960 keV. In this energy range two overlapping levels of the compound nucleus are involved, and very strong interference terms were observed in the angular distributions. This makes it certain that the two levels are of opposite parity, and further discussion shows that it is very likely that the lower level is (0, +) formed by $p$-protons. This disagrees with the assignment (1, −) that previous workers had made to this level by considering the size of its reduced proton width, and the reasons for this disagreement are discussed. It is probable that the present assignment, made from observations of the angular distribution, is the correct one, since the angular distribution is a far more direct measure of the nuclear symmetry, while the argument leading to the application of the reduced width criterion is indirect. It seems unlikely that this criterion can ever by itself lead to an unambiguous spin-assignment.

*For the* PH.D. *Degree*

## POLYPEPTIDES AND PROTEINS: X-RAY STUDIES

*By* FRANCIS HARRY COMPTON CRICK

*Gonville and Caius College, Cambridge, and the University of London*

THE general formulae were derived for the Fourier transforms of a simple helical structure and of a helical structure whose axis has been deformed into a more gradual helix. The theory is applied to the $\alpha$-helix model for a folded polypeptide chain suggested by Pauling and Corey. It is shown (with Cochran) that there is a striking general agreement between the observed X-ray diagrams of synthetic folded polypeptides (due to Bamford *et al.*) and the theoretical results for a simple $\alpha$-helix.

General packing considerations suggest that $\alpha$-helices of the same sense may tend to pack together, not parallel to one another,

but some 20° away from parallel. For fibrous proteins this may lead to coiled α-helices. It is shown that the general features of the classical α-keratin X-ray diagram can be explained by this model.

A study of Perutz's experimental data indicates that haemoglobin cannot consist of long, straight, parallel lengths of α-helix. It is tentatively suggested that it may consist of shorter lengths of α-helix packed together in a non-parallel manner.

Some experimental results are reported for horse haemoglobin. These show that it is not pseudo-centro-symmetric at low resolution. They also suggest that the 'bound water' may not all be on the surface of the molecule.

Preliminary studies were made of ox haemoglobin (carbon monoxide derivative). Two closely related orthorhombic unit cells are described. The results presented suggest that the pack of the molecules can be roughly described as pseudo-double-body-centred.

*For the* PH.D. *Degree*

## SOME EXPERIMENTS WITH ACCELERATED IONS OF HELIUM AND HYDROGEN

*By* GEORGE ALEXANDER DISSANAIKE

*Downing College, Cambridge, and the University of Ceylon*

SECTION I of the dissertation describes a study of the charge exchange of helium ions in metals in the energy range 0·13–1·1 MeV.

The equilibrium fractions of $He^0$, $He^+$, and $He^{2+}$ ions in a helium beam traversing thin metal foils of beryllium, aluminium and silver were measured with the use of a magnetic analyser. Special techniques were employed in the preparation of the metal foils and in the detection of the low-energy particles. The equilibrium fractions were found to be independent of the metals used. The variation with ion velocity of the ratio of the cross-sections for electron loss and capture respectively by the helium ions was studied in detail.

Section II describes some experiments on the nuclear transmutation of boron-11 by protons and by deuterons.

The decay of the 2·4 MeV. level in $^9Be$ was studied through the reaction $^{11}B(d\alpha)^9Be^*$ with a fast coincidence circuit, using the

neutron time-of-flight to separate out the neutrons or $\gamma$-rays emitted from $^{9}Be^{*}$. The delay spectra and the angular correlation of the emitted particles establish evidence for the decay mainly by neutron emission to the ground state of $^{8}Be$.

The $\alpha$-particles from the disintegration of $^{11}B$ by protons were studied up to 2 MeV. bombarding energy with the use of a magnetic analyser. Resonances for the production of short-range $\alpha$-particles were found at 0·64 MeV. and at about 1·35 MeV. Estimates of the absolute cross-sections and the widths for the different modes of disintegration of the $^{12}C^{*}$ nucleus were made.

The $(\alpha_1 - \alpha_2)$ angular correlation in the reaction

$$^{11}B(p\alpha_1)\,^{8}Be^{*}(2\alpha_2)$$

was investigated with fixed geometry by studying the energy distribution of the continuum of $\alpha$-particles formed in the break-up of the $^{8}Be^{*}$ nuclei. The results are consistent with the assignment of a spin 2− to the 0·64 MeV. resonant state in carbon-12.

*For the* PH.D. *Degree*

## MECHANICAL PROPERTIES OF ICE AND THEIR RELATION TO GLACIER FLOW

*By* JOHN WALLINGTON GLEN, M.A.
*Clare College, Cambridge*

ATTEMPTS to describe the flow of glaciers theoretically have been hindered by lack of knowledge of the actual behaviour of ice under stress, and the investigation was designed to provide such information. A method was devised for producing blocks of polycrystalline ice with grains of random orientation, and these blocks were tested in compression, both within 0·02° C. of the melting-point and at temperatures down to −13° C. Results show that ice does deform continuously under stresses of the order of magnitude of those occurring in glaciers, but that it is incorrect to regard ice as a liquid with a very high but constant viscosity, as has been assumed by most authors in the past. In fact the strain rate varies much more rapidly with increasing stress and, over the range of stresses investigated (1–10 kg.cm.$^{-2}$), the relation between the

steady strain rate $\dot{\epsilon}$ and stress $\sigma$ can be written in the form $\dot{\epsilon} = k\sigma^n$, where $n$ is a constant of the order of 4 and $k$ varies with the temperature. This result gives support to more recent attempts to treat glacier flow as a problem in plasticity. The variation of strain rate with temperature at a given stress can be represented as a Boltzmann relation $\dot{\epsilon} = A \exp(-Q/RT)$ except very close to the melting-point. The recrystallization of the specimens was also studied.

A method is described for growing cylindrical single crystals of ice with their optic axes at any desired orientation to the cylinder axis; when this angle is about 45° the crystals are very ductile and can be stretched to more than twice their original length. These specimens were used to attempt to determine the glide elements of ice; the results confirm that the basal plane is the glide plane, but attempts to discover the glide direction were inconclusive, and suggest that ice may not possess a definite glide direction.

These results are discussed in relation to the behaviour of metals, previous laboratory experiments on ice, results from measurements on glaciers themselves, and theoretical treatments of glaciers.

*For the* PH.D. *Degree*

## SOME OBSERVATIONS ON THE *j-j* COUPLING MODEL OF ATOMIC NUCLEI

*By* ANTHONY JOHN MICHAEL HITCHCOCK, B.A.

*Trinity College, Cambridge*

THE dissertation reports the results of a series of calculations on the structure of atomic nuclei based on the *j-j* coupling model of Mayer. In its original form the model is a purely empirical mode of correlation of the spins, parities and magnetic moments of odd-$A$ and even-even nuclei. The work falls into two related sections. In the first the predictions of the model are extended to odd-odd nuclei, and in the second the hypotheses of the model are examined and an attempt is made to show that some of the original hypotheses are deducible from the nature of the forces between nuclear particles.

The odd-even effect for nuclear masses is reinvestigated, for the classical explanation of the effect by Wigner is not applicable to the *j-j* coupling model. It is shown that the model does predict an effect of the right type, with one exception, which is shown to be experimentally genuine. The spins and parities of odd-odd nuclei are also calculated. The various empirical rules proposed for these are examined, and it is shown that their empirical validity is more restricted than had been assumed, and theoretical justification for the restricted form is obtained. A detailed series of calculations for specific nuclei is also made. Experimental agreement is generally good but not perfect. It is deduced that the limits of the model's validity are reached in these calculations.

Turning now to an examination of the postulates on which the model is based, the assumption of a pairing energy is examined. It is shown that the previously accepted theoretical explanation is faulty, and the proper one is derived. The new explanation accounts for certain anomalies in the previous scheme and agrees excellently with experiment.

The more fundamental assumption of *j-j* coupling is also examined, and an attempt is made to show that it is the consequence of the tensor component of nuclear forces. It is shown that the effect of these forces is of the right kind qualitatively but does not agree with experiment quantitatively even to order of magnitude. It is deduced that some other reason for *j-j* coupling must be sought.

It may be concluded that the *j-j* coupling model is usually applicable to odd-odd nuclei. Progress was also made towards a complete deduction of nuclear structure from nuclear forces.

*For the* PH.D. *Degree*

## A REFLEXION ELECTRON MICROSCOPE

*By* DERREK JONES, M.A.

*Christ's College, Cambridge*

THE electron microscope was designed to work either by reflexion or transmission. Certain conditions, aimed at making the instrument generally useful for the examination of solid surfaces, were

laid down at the outset, and the precise specifications of a microscope were developed from these. Particular attention was paid to the provision of an objective working distance sufficiently long to allow the possibility of experimenting with the specimen, mechanically or thermally, during examination. A detailed description of the microscope is given.

The work done with the microscope aimed mainly at clarifying the possibilities and limitations of reflexion microscopy. The working conditions are not the same as in transmission microscopy, and it is important to determine the precise effect of such parameters as aperture angle, angle of incidence, and voltage. The alignment of the instrument is discussed, and the early results are described.

The experience gained during this work led to a further consideration of the theory, and a new pole-piece was designed so as to reduce the confusion caused by chromatic aberration to a minimum while still retaining the object-point clear of the top surface of the objective lens. The ideal characteristics of a reflexion specimen stage and a specimen furnace are discussed, and designs for them are described. The new specimen stage allows the surface of the specimen to be rotated in its own plane, thus enabling a series of pictures of the same region viewed from different directions to be taken.

Further experimental work, using the new components and attaining a higher resolution, was carried out; the earlier results were checked and extended. Rotation series of pictures were taken, and the continuous formation of specimen contamination by the electron beam was observed to lead to the production of multiple shadows on the specimen surface during such a series.

The high-temperature furnace was tested, and photographs of polished silver in the temperature range 15–750° C. were made. No specimen contamination was observed on the heated specimen, and it is possible that a low-temperature furnace may be of considerable use in reflexion microscopy in eliminating the effects of contamination.

In the last chapter of the dissertation the limitation of resolution by the optical system and by non-optical effects is described, and the advantages and limitations of the reflexion method of surface

examination are compared with those of the scanning microscope and the ion-emission microscope.

*For the* PH.D. *Degree*

## SOME REACTIONS WITH LOW-ENERGY α-PARTICLES

*By* GEORGE ARNOLD JONES, M.A.

*Gonville and Caius College, Cambridge*

THE reactions described in the dissertation are initiated by α-particles in the energy range 0–2 MeV. Although the first successful attempts at artificial disintegration of nuclei employed α-particles, very little has yet been done in the above energy range, since the α-particles previously used were from natural sources or from cyclotrons, neither of which can conveniently produce the required intensity and energy definition at such low energies. The present work was rendered possible by the recent equipping of the Cavendish 2 MeV. H.T. set and electrostatic generator for the production of α-particle beams. Examples are given of reactions involving the emission of charged and uncharged particles and of photons.

In two of the reactions—$^{9}\mathrm{Be}(\alpha n\gamma)^{12}\mathrm{C}$ and $^{7}\mathrm{Li}(\alpha\gamma)^{11}\mathrm{B}$—the chief point of interest was the determination of probable spin and parity assignments for the energy levels involved from the angular properties of the reactions; the theoretical analysis of such properties is briefly outlined.

Two other reactions—$^{6}\mathrm{Li}(\alpha\gamma)^{10}\mathrm{B}$ and $^{10}\mathrm{B}(\alpha p)^{13}\mathrm{C}$—appear to confirm the approximate charge-independent nature of nuclear forces: the former lends support to theoretical calculations upon the applicability of isotopic spin selection rules; the latter concerns itself with the existence of a supposed level in $^{13}\mathrm{C}$ for which no corresponding level has been observed in the mirror nucleus $^{13}\mathrm{N}$.

A further experiment using the reaction $^{7}\mathrm{Li}(\alpha\gamma)^{11}\mathrm{B}$ is a determination of the Doppler shift of radiation arising from the relative motion of source and observer. The simple first-order expression is shown to be correct within the limits of experimental precision.

The technique is of possible use for the determination of life-times of $\gamma$-emitting states of order $10^{-13}$ sec.

The reaction $^{13}C(\alpha n)^{16}O$ was investigated incidentally to unsuccessful attempts at detecting the possible reactions $^{12}C(\alpha\gamma)^{16}O$ and $^{16}O(\alpha\gamma)^{20}Ne$; upper limits for the reaction rates of these are given.

*For the* PH.D. *Degree*

## APPLICATIONS OF AN X-RAY MICROBEAM TECHNIQUE

*By* ANTHONY KELLY

*Trinity College, Cambridge, and the University of Reading*

X-RAY beams of very small diameter (down to $8\mu$) were used to examine the effects of deformation on the individual grains of polycrystalline metals. A study was made of the crystalline texture of deformed specimens of aluminium, iron, zinc and lead. In all of these metals a particle structure was detected within the deformed grains. This consisted of regions of small plastic curvature (particles) separated by regions of larger plastic curvature (boundaries). The particle size varied with deformation, and a limiting value was found, usually $\sim 10^{-4}$ cm.

With X-ray microbeam back-reflexion methods particles could not be detected in heavily deformed specimens of the metals copper and gold, and so a study of worked foils of these metals was made with a microbeam transmission technique. These foils were also examined by means of electron diffraction, and the theory of the X-ray method was modified in order to obtain quantitative information from the electron diffraction patterns. Particles of size $\sim 6000$ Å. were found within the foils.

An investigation was made of the effects of time at room-temperature and of low-temperature annealing on the structure of worked specimens of aluminium, copper, zinc and lead. The distinction between particle and boundary regions was found to sharpen on annealing, owing to a rearrangement of the matter within the boundaries.

The experimental results are interpreted in terms of the current dislocation theory of plastic deformation, and a tentative

explanation of the formation of particles is put forward. The ideas advanced in this explanation lead to predicted values of the strength of metals which are of the correct order of magnitude.

Finally, examples are given of the application of fine X-ray beams to the study of three particular crystallographic problems.

*For the* PH.D. *Degree*

## THE THEORY OF THE INTERMEDIATE STATE OF SUPERCONDUCTORS

*By* CHARLES GOETHE KUPER, M.A.

*Fitzwilliam House, Cambridge*

THE intermediate state arises when a superconducting body is subjected to a magnetic field large enough to destroy part of its superconductivity. Two cases arise: the magnetic field may be externally applied, or it may be produced by currents in the body.

The experiments of Meshkovsky and Shalnikov on the domain structure of a tin sphere in an external field conflict with Landau's 'branching' model. As an alternative, a simple unbranched laminar model is considered; the laminae are flat, with no curvature near the edge of the specimen (in contrast with Landau's unbranched model). The magnetic Gibbs free energy is minimized, to determine the size of the superconducting regions and the fraction of superconducting phase. The theoretical magnetization curves for ellipsoidal specimens are calculated. They are in good agreement with experiment, provided suitable values are assigned to the interfacial surface energy. The properties of the model are compared also with those of Landau's unbranched model, and are shown to be similar.

For wire carrying large currents marked deviations from F. London's theory were observed by Alexeevsky and other workers—the restored resistance being greater than predicted. London's model consists of a chain of touching conical superconducting domains along the axis of the wire. With the added assumption that electrons are diffusely scattered at normal superconducting interfaces, it is shown that London's model becomes adequate to account for these deviations. The resistance is raised

considerably by the scattering, if the separation between domains is comparable to the mean free path of electrons in the normal phase. Thermodynamical considerations determine the scale of the structure, which is indeed comparable with the mean free path, and also show that the interfacial surface energy may be neglected. The value of the mean free path, chosen to account for the deviations from London's theory, is not inconsistent with Chambers's results.

The diffuse scattering of electrons at phase boundaries decreases the thermal conductivity in the intermediate state. This decrease may be considerable in specimens where the domain size is comparable to the mean free path. The calculated effect is shown to agree quite well in magnitude with recent experiments by Detwiler and Fairbank (using external fields).

*For the* PH.D. *Degree*

## NUCLEAR RESONANCE REACTIONS AND THEIR USE IN THE INVESTIGATION OF NUCLEAR STRUCTURE

*By* ANTHONY MILNER LANE, B.A.

*Selwyn College, Cambridge*

THE dissertation falls essentially into two sections. The first contains a general derivation of the nuclear 'dispersion formula' along the lines laid down by Kapun and Peierls (*Proc. Roy. Soc.* **166**, 277) and Wigner and Eisenbud (*Phys. Rev.* **72**, 29). The second section discusses the possibility of predicting values for the nuclear constants occurring in the dispersion formula, using in particular the nuclear shell-model.

In the derivation of the dispersion formula the differences between the points of view of the authors mentioned above are discussed, and their respective merits are pointed out. The interpretation of the 'level-shift' occurring in the formula is discussed in some detail, and the use of the general many-level formula in the statistical region is indicated. Finally, a number of topics relating to dispersion theory are discussed. It is shown how electromagnetic phenomena (radiative capture) can be rigorously

included in the formalism. In an appendix is presented an outline of how the basic derivation of the dispersion formula may have to be revised in the light of the recent work of Weisskopf, Porter and Feshbach (*Phys. Rev.* **90**, 166) on the 'complex potential' model of the nucleus. This model suggests that, in certain circumstances, a nucleon entering a nucleus moves in a potential well for some time before being absorbed. Such potential well effects are difficult to include in the usual formulation of the theory and necessitate a new approach.

In the second section of the dissertation the nuclear shell-model is used to make predictions about the values of the widths of energy levels for both heavy-particle and radiative emission. The situations of *L-S* and *j-j* coupling are first discussed, and the predictions are compared with the observations of nuclei in the $1p$ shell. It is found that neither extreme mode of coupling makes accurate predictions, but that there is a definite correlation between the observed values and pairs of predicted values that suggests that intermediate coupling may be more successful. A detailed application of the intermediate coupling model in the case of $^{13}C$ and $^{13}N$ shows, in fact, that this model can explain the experimental data very well. Altogether five independent data are fitted, apart from seven others which depend only upon the shell-model and not upon the perturbing mode of coupling.

The dissertation is concluded with a discussion of the mirror-nuclei and the estimation of the level-shifts in certain cases with the use of a shell-model.

*For the* PH.D. *Degree*

## NEW X-RAY COUNTER SPECTROMETER TECHNIQUES

*By* ANDREW RICHARD LANG

*Trinity College, Cambridge, and the University of London*

THE principles involved in the design of a precision counter spectrometer are outlined, and the mechanical parts and control circuits are described. The automatic recording equipment includes a novel printing recorder used in conjunction with a scaling circuit.

The requirements of an X-ray source for an accurate spectrometer are discussed, and modifications made to a standard X-ray generator are detailed. A study of electron trajectories by means of a rubber model shows that the form of X-ray tube focal patterns can be satisfactorily explained more simply than previously supposed. A design is given of an X-ray tube cathode system which produces an excellent focus without the use of bias. A simple arrangement for compensating for the effect of voltage supply fluctuations on X-ray output is applied successfully.

A new diffraction technique using a divergent beam and applicable to transmission specimens is described. Its value in determining preferred orientation textures is illustrated.

An account is given of four novel methods of diffracted beam monochromatization, and examples are given of their applications. These techniques permit observation of very high angle reflexions, suppression of fluorescent background, and recording of patterns due to $K\alpha_1$ radiation only. The choice of monochromator crystals is discussed, and a new method for studying the perfection of large single crystal faces is described.

A review of X-ray detectors is followed by an account of work done with Geiger, proportional and scintillation counters. The advantages of the proportional counter in the way of freedom from counting losses, ability to discriminate against unwanted radiations and low background rate are demonstrated, and details are given of designs suitable for X-ray use in conjunction with a single-channel pulse analyser.

*For the* PH.D. *Degree*

## MEASUREMENTS OF RADIO-FREQUENCY EMISSION FROM THE SUN AND SOME OBSERVATIONS OF RADIO STARS

*By* PATRICK ALOYSIUS O'BRIEN

*Corpus Christi College, Cambridge, and the University of South Africa*

THE dissertation is divided into two main sections:

(1) The main body of the work deals with measurements of the distribution of the undisturbed radio-frequency brightness across

the solar disk at wave-lengths of 1·4, 3·7 and 7·9 m. The measurements were made using approximately east-west interferometers of variable aperture, and the results indicate that the effective diameter of the sun increases with increasing wave-length.

At a wave-length of 1·4 m. measurements were also made with interferometers whose axes were inclined at various angles to the solar axis of rotation. These results show that the shape of the sun at this wave-length is roughly elliptical, the radial extent of the emission being about 25 % greater in the equatorial direction than in the polar direction.

During the period of the observations, July 1951 to September 1953, the brightness temperature at the centre of the disk remained approximately constant for each of the three wave-lengths, but the radial extent of the emission diminished appreciably. This behaviour is shown to follow the general decline in the intensities of the red and green coronal lines. It is suggested that the observed changes in the radial extent of the distribution might be due to coronal streamers.

A comparison of the averaged distributions with the theoretical work of other authors shows that the theory predicts too much radiation near the limb and too little radiation for large radii. The latter discrepancy can be explained if the electron density at large radii from the centre is higher than the values obtained from optical observations. The discrepancy near the limb cannot be explained simply, and it appears that this may be caused by the effects of scattering by irregularities in the corona. The results suggest that scattering is most pronounced in the lower corona, and that it decreases near times of sunspot minimum. It is stressed that observations of the distribution of brightness for a complete sunspot cycle would be desirable.

An account is given of daily routine measurements of the solar flux at a wave-length of 7·9 m. during most of the year 1953.

(2) A survey of radio stars in the northern hemisphere, using an interferometer of high resolving power at a wave-length of 7·9 m., is described. The thirty-one radio stars that were located are compared in intensity and position with those detected in previous surveys at other wave-lengths. The weaker stars in the surveys do not coincide in position, and this appears to be due to

the effects both of the confusion between overlapping radio stars and of differences in their spectra.

Measurements are described of the distribution of brightness over two radio sources of large diameter, one associated with a nebulosity in the constellation of Gemini, and the other located close to the galactic centre.

*For the* M.Sc. *Degree*

## PROPORTIONAL COUNTER STUDIES OF VERY WEAK RADIOACTIVITIES

*By* JEAN-MICHEL PICTET

*King's College, Cambridge, and the University of Zürich*

THE proportional counter method was investigated for measuring specific radioactivities of the order of 10 disintegrations per minute per gram; the sample was converted into a gaseous derivative and measured as a constituent of the counter filling. Two problems were studied concerning respectively the counting of $^{14}C$ for application to radiocarbon dating (Section I) and the measurement of a possible decay of $^{113}In$ by preferential $L$ capture decay (Section II).

*Section I.* A brass counter of capacity 2·5 l. was built and placed coaxially inside a coil producing a magnetic field of 500 Gauss. A maximum operating voltage of 4000 V. limited the pressure to 1 atm. or less, according to the type of filling. Proportions of carbon dioxide above 10% in fillings with argon were found to affect the resolving power; this is not the case with ethylene, and the application to radiocarbon dating was envisaged. With an ethylene filling of 30 cm. Hg pressure the magnetic field reduced the fraction of $^{14}C$ counts lost in the discrimination of background from $\frac{1}{2}$ to $\frac{1}{8}$. Under these conditions an ethylene filling synthesized from the carbon content of a living specimen would produce 10 counts per minute.

*Section II.* Indium was studied in the form of indium trimethyl vapour. A heatable Maze counter is described, having a capacity of 4·6 l. and equipped with a system of circulation by convection

which allows a control of the vapour pressure. Indium trimethyl was found to be strongly electronegative, and the maximum permissible quantity of vapour in the counter was of the order of 5 mg. A theoretical study of the lines emitted after a possible $K$ and $L$ capture decay of $^{113}$In, and of the peaks expected from the counting, was developed. From this study and from the results obtained in the experiment the minimum half-life of $^{113}$In by $L$ capture decay is estimated to be $7 \times 10^9$ years.

*For the* PH.D. *Degree*

## A RESONANT CAVITY ELECTRON ACCELERATOR

*By* ERIC JOHN RIISNAES, M.A.
*Corpus Christi College, Cambridge*

THE simplest type of machine for producing high-energy-charged particles using a microwave power supply is a single cylindrical cavity resonating in the lowest TM-mode. Such a cavity was constructed and driven by an experimental magnetron at 25 cm. wave-length developed by the linear accelerator group at the Cavendish Laboratory. The theory of such a cavity is reviewed, and in particular the problem of feeding power into it from an oscillator is discussed. It is shown that about half the available power has to be dissipated in a stabilizing load. A method was developed to reduce this waste of power by using a gas-discharge switch which did not fire until nearly a microsecond after the start of the pulse. This device increased the maximum electron energy obtainable by about 30 %. The application of such a switch to more efficient accelerators is discussed.

After a number of difficulties, eventually traced mainly to R.F. breakdown of various sorts, had been removed, the cavity accelerator was made to operate successfully. The maximum electron energy obtained was about 2·2 MeV., using the discharge switch, with 2 MW. of R.F. power available from the magnetron. This agreed approximately with the predicted value, and compared favourably with other accelerators of the same type. The electron energy spectrum was measured and found to agree with theory.

An attempt was made to excite nuclear isomers with lifetimes between $10^{-6}$ and $10^{-3}$ sec. by irradiating substances with X-ray pulses from the accelerator. Subsequent events were then sought with a scintillation counter. Unfortunately, it was found that excessive noise was produced in the counter by the X-rays, and the probability of detecting events was reduced greatly below the expected value. No events were observed in the substances studied, leading to the conclusion that there were no isomeric states in tantalum, zinc or bismuth with lifetimes in the microsecond region and excitation cross-sections greater than about $10^{-30}$ sq.cm. per 2 MeV. electron.

*For the* PH.D. *Degree*

## THE $\beta$- AND $\gamma$-RAY SPECTRA OF CERTAIN ARTIFICIAL RADIOACTIVE SUBSTANCES

*By* HYMAN ROSE

*Peterhouse, Cambridge, and the University of Wales*

THE major part of the dissertation describes experimental studies of certain radioactive isotopes which were carried out with the use of a thin magnetic lens $\beta$-ray spectrometer in an effort to obtain more precise information concerning the law of interaction in $\beta$-decay, about which considerable uncertainty exists.

The shape of the low-energy $\beta$-ray spectrum of $^{170}$Tm was investigated by $\beta$-$\gamma$ coincidence methods (in collaboration with R. Richmond). The spectrum was found to have an allowed shape, from which it was deduced that $^{170}$Tm has spin one and odd parity, and that the low-energy $\beta$-transition is first forbidden with axial vector or tensor interaction, the latter interaction being somewhat more likely.

The spectrometer was then modified to enable the $\beta$-$\gamma$ angular correlation of certain isotopes to be measured as a function of $\beta$-ray energy. With the assumption that a single nuclear matrix element is operative in the low-energy $\beta$-ray transition, the results for $^{170}$Tm give a good agreement with the theoretical predictions for the matrix element $\int \beta\boldsymbol{\sigma} \times \mathbf{r}$ occurring in the first forbidden

tensor interaction, but appear to rule out the corresponding $\int \boldsymbol{\sigma} \times \mathbf{r}$ of the first forbidden axial vector interaction. It is, however, possible that a suitable mixture of matrix elements might also fit the experimental data. An explanation is suggested for the high comparative lifetimes of the $\beta$-ray transitions of this isotope.

The $\beta$-$\gamma$ angular correlation of $^{76}$As was also investigated, and the experimental observations were compared with the theory for various $\beta$-interactions and spin assignments. It was concluded that, if the 0·567 MeV. $\gamma$-ray is electric quadrupole radiation, it is necessary to consider a mixture of matrix elements and interference in order to explain the observed correlation. However, agreement with the theory for a single matrix element is possible, assuming that this $\gamma$-ray is magnetic dipole radiation. Then either the first forbidden matrix element $\int \boldsymbol{\sigma} \times \mathbf{r}$ of the axial vector interaction alone or the corresponding $\int \beta\boldsymbol{\sigma} \times \mathbf{r}$ of the tensor interaction alone can account for the correlation.

The spectrometer was also used to measure the internal conversion electron coefficients of the 152 keV. $\gamma$-ray in $^{188}$Re. For this experiment use was made of a Geiger counter fitted with a thin end-window of nylon which had a transmission of 100 % for electrons of energy greater than 40 keV. The experimental data were compared with the theoretical values for various multipolarity assignments.

*For the* PH.D. *Degree*

## ON THE ORIGIN OF INERTIA

*By* DENNIS WILLIAM SIAHOU SCIAMA, M.A.
*Trinity College, Cambridge*

THE purpose of the dissertation is to present a tentative theory to account for the inertial properties of matter. The first two chapters describe the history of the problem. Chapter I ends with the ideas of Mach and an attempt to answer criticisms of them. The second chapter is devoted to Einstein's work, which shows

that inertia is connected with gravitation. However, as Einstein himself was the first to point out, general relativity does not fully account for inertia. Thus a new theory of gravitation is needed.

The next two chapters describe a tentative theory of gravitation and inertia. The theory of the first chapter is only approximate, but it brings out some of the physically important points in a mathematically simple manner. The second chapter describes the precise theory, according to which local observations of inertia suffice to specify the large-scale structure of the universe. This structure corresponds to the steady-state model of Bondi and Gold. The evidence in favour of this model is briefly referred to.

In the last chapter the formation of galaxies is discussed. This problem is of particular interest in cosmology because previous theories appear to be inadequate to deal with it—the existence of irregularities presents logical problems, and it appears to be difficult to find an adequate mechanism of their formation. Neither of these difficulties arises in the present theory. Galaxies are formed as a result of the gravitational perturbation of the intergalactic gas by the pre-existing galaxies. The cluster containing the parent of the Milky Way is tentatively identified, and in this way the value $\sim 6 \times 10^9$ years for the age of the Milky Way is obtained.

*For the* PH.D. *Degree*

## ANGULAR CORRELATION MEASUREMENTS ON α-PARTICLE NUCLEI

*By* JOHN SEED

*Christ's College, Cambridge, and the University of London*

A METHOD was devised for the observation of angular correlations between α-particles and γ-rays produced in a nuclear reaction by proton bombardment where the range of the elastically scattered protons is greater than that of the α-particles.

Magnetic analysis was used to separate the α-groups from each other and from scattered protons, and the α-particles were detected by a thin zinc sulphide screen and photomultiplier. A sodium iodide scintillation counter was used to detect the γ-rays.

Using the method, $\alpha$-$\gamma$ correlations were measured in the reaction $^{19}F(p,\alpha\gamma)^{16}O$, and from this information the spin and parity assignments $(J,P)=(2+)$ and $(J,P)=(1-)$ were made to the third and fourth excited states respectively of $^{16}O$. It was previously known that the spins and parities of the first and second levels were $(0+)$ and $(3-)$ respectively; the above assignments show, therefore, that the first four levels are consistent with the $\alpha$-particle model of the nucleus, and, following the treatment of Wheeler and Dennison, it is predicted that the fifth level should lie at about 7·6 MeV. and have $(J,P)=(2-)$.

The spins and parities of $^{20}Ne^*$ states involved in the reaction $^{19}F(p,\alpha\gamma)^{16}O$ were also deduced, and in cases where interference between states occurs in the reaction the phase differences agree with those predicted by modern dispersion theory.

The apparatus was also used to observe $\alpha$-$\gamma$ correlations in the reaction $^{15}N(p,\alpha\gamma)^{12}C$. From the measurements the first excited state of $^{12}C$ is shown to have $(J,P)=(2+)$, in agreement with the $\alpha$-particle model. Tentative predictions of the model for higher levels are discussed.

*For the* PH.D. *Degree*

## ANGULAR CORRELATIONS IN NUCLEAR REACTIONS

*By* ALAN GERALD STANLEY, M.A.

*Trinity College, Cambridge*

SECTION I of the dissertation develops the theory of angular correlations for a three-stage nuclear reaction in which a nucleus is hit by a charged particle with the successive emission of another charged particle and a $\gamma$ quantum. This is extended to a four-stage process, where the emitted particle is followed by two $\gamma$ quanta in cascade. The factors governing the limitation of the anisotropy of the correlation and the production of interference terms are discussed. An expression is derived for the energy-dependent resonance denominator by means of a time-dependent perturbation method.

Section II describes angular correlation experiments on deuteron-induced reactions carried out on the one million volt high-tension accelerator in the Cavendish Laboratory. A conventional coincidence circuit with a resolving time of 0·2 $\mu$sec. was used to detect coincidences between the emitted charged particles and $\gamma$-rays. The correlations in the reactions $^{14}N(d,\alpha\gamma)^{12}C$ and $^{9}Be(d,p\gamma)^{10}Be$ were consistent with the emission of quadrupole radiation from the first excited levels of $^{12}C$ and $^{10}Be$, in agreement with the assignment of spin 2 and even parity. The correlations in the $^{14}N(d,p\gamma)^{15}N$ reaction indicated that the transition from the first excited level of $^{15}N$ at 5·3 MeV. proceeds by dipole emission. This result proved more difficult to interpret, as the level is known to form a close doublet.

In Section III an account is given of experiments on the $^{10}B(\alpha,p)^{13}C$ reaction carried out on the electrostatic generator of the Cavendish Laboratory. Several new resonances were discovered between 1 and 2 MeV. The analysis of the $\gamma$ spectrum led to the discovery of 0·2 MeV. radiation, which was shown to be due to a cascade transition from the 3·9 MeV. level in $^{13}C$ to the ground state via the level at 3·7 MeV. 30% of the total radiation from the 3·9 MeV. level is attributed to the cascade reaction. The angular distribution of the 0·2 MeV. radiation was determined by a novel technique. The angular distributions of the high energy (3·7 and 3·9 MeV.) radiation and the angular correlations of the $\gamma$-rays with the protons were measured at five resonances. Theoretical curves could be fitted to the experimental results. The 3·9 and 0·2 MeV. radiations were shown to be caused by magnetic quadrupole and electric dipole transitions respectively, in agreement with the assignments of spin $\frac{5}{2}$ with even parity to the 3·9 MeV. level, and spin $\frac{3}{2}$ with odd parity to the level at 3·7 MeV

*For the* PH.D. *Degree*

# NUCLEAR REACTIONS PRODUCED BY THE BOMBARDMENT OF BORON BY LOW-ENERGY α-PARTICLES

*By* JOHN ROGER WORMALD, M.A.
*King's College, Cambridge*

ISOTOPIC targets of $^{10}B$ and $^{11}B$ were bombarded by α-particles of energies between 1 and 2 MeV. produced by accelerating $He^+$ ions in the Cavendish Laboratory electrostatic generator. The reaction products were examined by means of a magnetic analyser and other detectors.

The $^{10}B(\alpha,p)^{13}C$ reaction was observed to have seven resonances at α-particle energies of 1·13, 1·24, 1·39, 1·51, 1·64, 1·68 and 1·83 MeV. Four groups of protons were observed with $Q$-values of 4·13, 1·00, 0·41 and 0·27 MeV. owing to the residual $^{13}C$ nucleus being left in its ground state or in one of the first three excited states at 3·13, 3·72 and 3·86 MeV. The emission of deuterons from the $^{10}B(\alpha,d)^{12}C$ reaction and neutrons from the $^{10}B(\alpha,n)^{13}N$ reaction was also observed.

The yield curves of most of the groups of particles were measured. The angular distributions of several of the groups of particles were measured at a number of the resonances. Spin and parity assignments of $3-$ and $4+$ were shown to be highly probable for the resonances at α-particle energies of 1·51 and 1·64 MeV., and assignments of $4-$, $4-$ and $4+$, were shown to be probable for the 1·13, 1·68 and 1·83 MeV. resonances respectively. It was also possible to show that the third excited state of $^{13}C$ had spin and parity $\frac{5}{2}+$.

The $^{11}B(\alpha,p)^{14}C$ reaction was observed to have a single resonance at an α-particle energy of 1·58 MeV., with the emission of a single group of protons corresponding to $Q=0{\cdot}85$ MeV.

An appendix describes an unsuccessful attempt to construct an ion-source producing $He^{2+}$ ions.

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