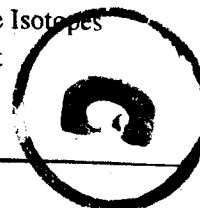


27

3146  
94

Desert Research  
Cosmic Radiation  
Ballooning for Research  
The Velocity of Electromagnetic Waves  
Social Scientists in Action  
Separation of Radioactive Isotopes  
Research Report  
Correspondence



INDEX



24-27

72  
Am, N46  
N53-27  
168372

SCIENCE NEWS

27

*verified  
m*

*3:46 -  
54*



K KRISHNAMURTHY  
PO BOX NO 384  
MOUNT ROAD  
MADRAS

*First published February 1953*

*Subscriptions to*  
**SCIENCE NEWS**

*and*

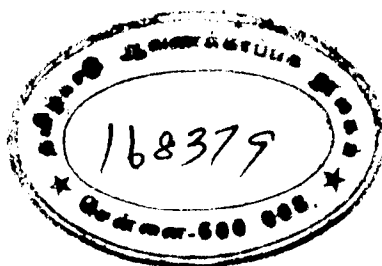
**NEW BIOLOGY**

*are accepted at*

*9s each*

*for four issues*

*including postage*



*Made and printed in Great Britain  
for Penguin Books Ltd  
by The Campfield Press, St Albans*

## CONTENTS

|                                                                                               |     |
|-----------------------------------------------------------------------------------------------|-----|
| DESERT RESEARCH<br>R. N. Elston                                                               | 7   |
| COSMIC RADIATION<br>E. P. George                                                              | 30  |
| BALLOONING FOR RESEARCH<br>A. J. Herz and R. M. Tennent                                       | 46  |
| THE VELOCITY OF ELECTROMAGNETIC WAVES: THE<br>MOST ACCURATELY KNOWN CONSTANT<br>W. C. Vaughan | 59  |
| SOCIAL SCIENTISTS IN ACTION<br>Anthony H. Richmond                                            | 69  |
| FIELD CENTRES                                                                                 | 93  |
| THE SZILARD-CHALMERS EFFECT AND THE SEPARA-<br>TION OF RADIOACTIVE ISOTOPES<br>D. G. Tuck     | 97  |
| RESEARCH REPORT<br>A. W. Haslett                                                              | 106 |
| CORRESPONDENCE                                                                                | 118 |
| SOME BOOKS RECEIVED                                                                           | 125 |
| ABOUT OUR CONTRIBUTORS                                                                        | 127 |
| INDEX (COVERING NUMBERS 24-27)                                                                | 129 |

*31 illustrations between pages 96 and 97*

## DESERT RESEARCH

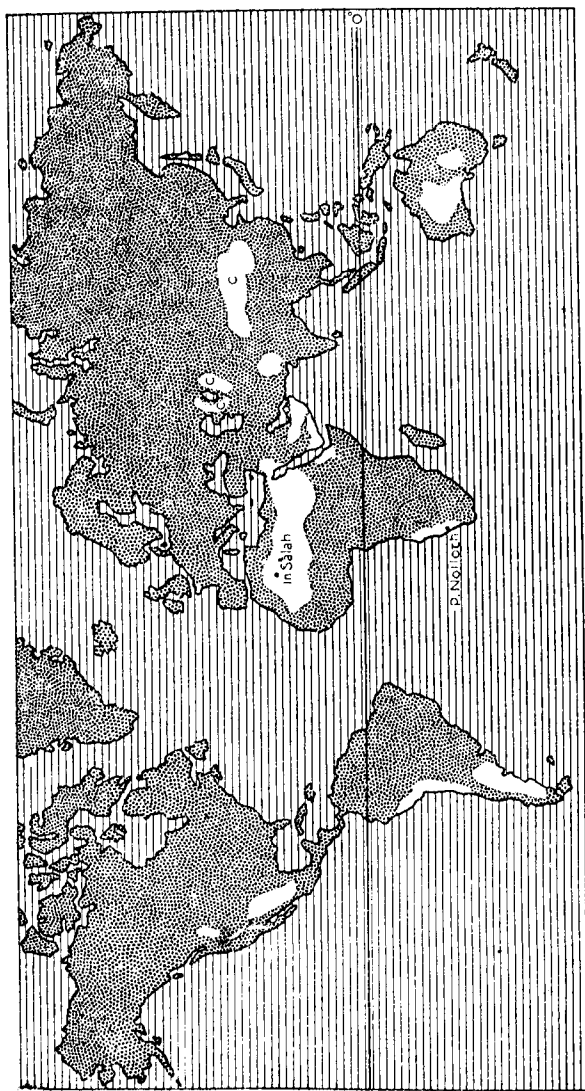
R. N. ELSTON

A DESERT is an area which produces insufficient vegetation to support habitation under natural conditions: it is not merely a region short of water. The Greenland ice-cap is as much desert as is the Sahara, and there are cold-sandy and cold-stony deserts as well as hot ones. In the past, the encroachment of frozen and cold deserts on lands formerly habitable would have been a challenge to research, had there been scientists to undertake it. Now it is the hot-sandy and hot-stony deserts which are generally increasing in size, and most of the research to be described in this article relates to deserts of the hot-dry-sandy type. These are both the most readily created by human activity and the most amenable to improvement, that is, to increasing vegetation-cover.

Lack of rainfall dominates hot-desert environments, but by itself is an inadequate index of aridity. The effectiveness of any rainfall is controlled by the rate of evaporation, and this in turn is determined by the surface temperature and by the relative humidity of the air at ground level. Temperature is determined by latitude, hours of sunshine, and air-movements, and the relative humidity of surface air is affected by wind.

Permanent rivers may traverse deserts, contributing to the available water. Most of them never reach the ocean, but are lost in sands or become part of an inland drainage system. The depth of sand is limited, rarely reaching more than some 50 metres (150 feet), and in deserts where there is but a small thickness of sand the nature of the underlying material may be such that moisture percolating through the sand is retained at a depth varying between 3 and 20 metres (10 to 60 feet).

Rainfall, as is well known, is affected by the distribution of mountains. The Thar desert of north-west India, incidentally



Map 1. Location of world's major deserts. Those marked 'C' are cold-winter (hot summer) deserts; all shown on the map are hot-summer deserts.

the hottest part of the world, is inaccessible to the south-west monsoon and, for that reason, is a desert. There are other instances, of which the Sahara is an example, where desert-formation is either obscure or inadequately explained.

Most of the large areas below sea-level are of a desert nature. The giant inland drainage basins of Asia, Australia, and Africa provide typical examples in the Lake Eyre region, the Southern Sahara, and the Aral and Caspian seas respectively.

Desert rainfall takes place as a rule during violent cloud-bursts, leading to the formation of deeply incised gullies which are a typical feature of desert landscapes. These gullies are found also, but to a lesser extent, in mere humid regions, where they are camouflaged by covers of vegetation.

In deserts, surface erosion is caused chiefly by rapid and extreme changes of temperature, which arise from the lack of cloud-cover. Rock surfaces are alternately heated, cooled, and fragmented, bringing about the eventual formation of sand particles. These particles are piled up, under the influence of winds, into dunes which themselves move. In cases where the initial rock surface is harder or more resistant to being broken up, or else in deserts where the range of temperature is less, stone-desert surfaces are commonly formed. These are known as hamada in Africa, gobi in Mongolia, and gibber-plains in Australia. They are usually flat.

Fierce and high winds are characteristic of both hot and cold deserts and are more trying to living creatures than the heat or the cold, both of which can be adequately combated by clothes or their lack. In addition, winds increase the spread of sand deserts, both by wind storms and dune-movements.

The two main impetuses to improve deserts are to prevent their further spread and, if possible, to utilize their areas for the increase of the world's food supply. A fast-eroding, movable land surface is a threat to surrounding better and more stabilized regions. A desert is a source of infection, threatening the economy of productive lands by which it is usually surrounded. The desire to increase the world's food supply, by maintaining a self-supporting population in the area, or by exporting produce

to better-living areas by virtue of a high production per head of the desert dwellers, is a desirable but generally questionable aim.

Desert research, in any real sense, began in the last century with the investigations carried out by plant anatomists and physiologists. They noted the specialized adaptations of plants to growing in arid or salt-concentrated environments, and introduced the term 'xerophyte'\* as a general description of such plants. They studied the physiological conditions governing xerophytism in plants growing in dry or salty habitats in temperate regions, such as coastal marshes and sand-dunes. (This work will be described in more detail later, together with modern aspects.) Botanical investigations in deserts were also concerned with the problem of seed-survival and with the salt-tolerance of desert plants. Similar investigations on problems of animal and insect life were commenced in the middle of the nineteenth century. Examination of the physical properties of wind-blown sand, the origin and mode of development of sand ridges of the *barchan* and *seif* types (Fig. 1 and Inset 26-7 respectively) were well under way by the end of the last century.

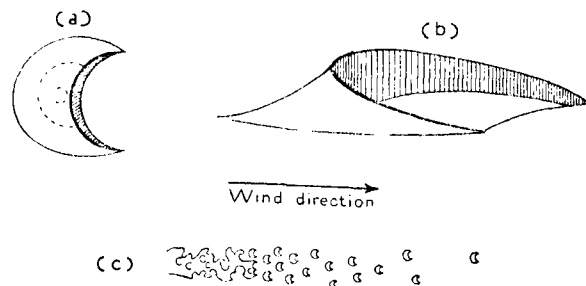


Fig. 1. *Barchan* type dunes: (a) from on top, (b) perspective sketch, (c) typical distribution in plan. (a) and (c) are after R. A. Bagnold, *Physics of Wind-Blown Sand*. See text (pp. 14-15).

\*The term 'xerophyte' is now limited to those plants able to endure conditions of drought, while salt-marsh plants are known as 'xeromorphs'.

All earlier information about deserts came from travellers' reports, which have been largely responsible for the spreading of over-optimistic beliefs about the potential productivity of deserts. Continuous and accurate weather-records in arid regions go back, at the best, some eighty years, and even now recording stations are few and far between. Intervals in the Sahara and the arid districts of Australia are never less than fifty miles, and sometimes are as much as four hundred miles.

More recent work will be discussed under three headings: climatic, physical investigations, and studies of plants, soil-water regimen, and ecology.

#### CLIMATOLOGY

Little can be said about the meteorology of deserts, as little is known. However, a considerable amount of work has been done on the larger-scale aspects of climatology, a subject comfortably studied from a desk in some temperate region, on the basis of data collected by patient sufferers in desert recording stations. Needless to say the data are mostly from desert-fringe stations or from oases.\*

Desert environments, to recapitulate, are characterized by extremes of temperature, which are greater or less according to the elevation of the site and its position in relation to major wind systems. Cloudless skies lead to rapid cooling of land surfaces at night. Rainfall, where it occurs, is usually heavy and of the cloudburst variety. It is distributed unevenly in time and has an enormous range of variability about the yearly mean. No rain for several years is frequent, and floods are not uncommon in some deserts. The rate of evaporation from the surface is high, and is incompletely determined by temperature; variations in evaporation-rate between regions with similar temperature conditions are due mainly to cloud-cover and wind conditions. Strong and powerful winds are common, but there are many calm days in most desert regions.

\*Oases are not strictly a part of deserts as the climate is artificially altered.

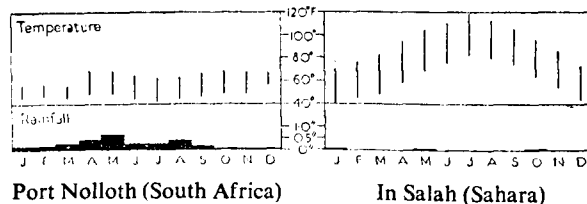


Fig. 2. Effect of location on range of variation of desert climates: left, maritime climate (Port Nolloth); right, interior of continent (In Salah); above, monthly temperature-range (lowest minimum to highest maximum); below, monthly rainfall totals. Both locations are rather extreme examples, and are chosen for contrast. Note the big temperature-range at In Salah. The annual temperature-range (range of monthly mean temperatures) is 6.5° F. at Port Nolloth, and 45° F. at In Salah. Annual rainfall totals are 2.32 inches and 0.3 inch respectively.

One is often struck by the insistence in desert climatology on the delineation of desert boundaries. The problem is one of wrong wording. There are no boundaries to any major bi-climatic region. Any convenient straight line can be drawn to separate regions of five-inch and two-inch rainfall but, climatologically speaking, is relatively useless. It indicates that two stations, usually a hundred to three hundred miles apart, each recording, say, two-inch rainfall for, at the best, fifty years, have been joined by a purely arbitrary line for the convenience of drawing up a pleasingly complete map for an atlas. Such a line does not show how often two inches falls in a year, in what season and at what intensity it does so, nor the relationship between such rainfall and the high temperatures and dependent high evaporation-rates of desert climates.

Many attempts have been made to express the limits of deserts by using the existing meteorological records. Aridity is increased by high evaporation, low humidity, strong winds (which remove humid air) and by low pressure. Any system which attempts to delineate arid-region boundaries should take into account all these factors *plus* temperature, altitude, and degree of maritimeness (proximity to the sea). The more factors accounted for, the

more complex are the expressions derived. Most of these systems have been evolved in sympathy with vegetation distribution. They attempt to demarcate the major bio-climatic regions. A full discussion of these varying systems, with maps, can be found in *Ecological Crop Geography* by K. H. W. Klages (see under *Further Reading*).

Early formulations made use of such concepts as the ten-inch rainfall limit or the limit of tree growth. In tropical regions the twenty-inch limit is generally taken as the arid boundary, and in temperate regions the ten-inch limit, because of the increased evaporation at higher temperatures. 'Temperature-efficiency' and 'precipitation-effectiveness' indices were derived, based on elaborate formulae, each purporting to delineate arid regions from non-arid. The most efficient of all indices is the *P/E* index, which expresses the relationship of rainfall (precipitation), *P*, to evaporation, *E*. If *P/E* is calculated for monthly data, the number of months per year in which *P/E* is greater or less than a certain value (deduced experimentally or empirically), gives a suitable index of aridity.\* However, one may agree with Austin Miller 'that records of climatic elements are incompetent to define the limits of aridity'.

Despite the predominance of the 'aridity index' in desert climatology, some work has been done on other aspects. The single element of temperature is important on its own account.

Deserts are among the world's hottest places. The Thar desert of north-west Pakistan has the world's highest recorded temperature of 148° F. (64° C.). In North Africa and Central Australia shade temperatures of 120° to 130° F. (48–54° C.) have been recorded. What are the effects of such intense heat? Those on the form and habit of plants will be discussed later. There are also physical differences in the effectiveness of different colours as absorbers of heat. Heating is more effective on dark colours than on light ones and more effective in shadeless than in shaded areas. This, in effect, means that light-coloured vegetation should induce a lower soil-temperature and a more favourable

\*This is discussed further in the section on *Plants, Soils, and Ecology*.

micro-climate close to the ground, than should dark vegetation on a light or dark soil. This is indeed the case. But there are other questions still to be answered. For example, are pink plants better able to withstand extreme radiation than green ones, or mottled surfaces better able to do so than plain? Many desert plants are pinkish and their exposed surfaces are mottled, e.g. the melons of arid regions.

It has often been noticed that clouds roll up on most days (usually in the afternoons) but seldom release any rain. In Yudnapinna, for example, with seven inches rainfall and in a region of semi-arid scrub-steppe in north-western South Australia, I found that in two thirty-day periods there was only one rainy day in each, whereas the number of possible rainy days, based on frontal analysis, was three to four times as many. This was in a good year, with rainfall above average. The possibility of seeding these clouds, by the now well-known techniques, has not been investigated very fully. A reasoned discussion of this problem has been given by K. Pulvermacher in an article quoted under *Further Reading*. The chief point held against 'artificial rain' is the uncertainty whether the cloud seeded would not, in any case, have produced rain elsewhere. Does one add to the total 'raininess'? Probably not, but rain where you want it is useful.

#### PHYSICAL INVESTIGATIONS

Physical investigations in deserts have been on the problems of wind-blown sand, hydrology, and soil-water regimen.

##### *Wind-Blown Sand*

Any account of the physics of wind-blown sands leans heavily on a work of that title by R. A. Bagnold, a most intriguing study, which has never been adequately followed up. In sandy deserts large areas are covered by sand-dunes of various types. The two most important are the *barchan* types, consisting of crescentic, tent-like dunes (Fig. 1), found only where the wind is predominantly from a single direction; and the *seif* type, consisting of parallel, long dunes found where wind-direction is variable.

Dunes of both types are masses of piled-up wind-blown sand.

There are important differences between dune formations and the ripples found often on sand surfaces. One difference is that in ripples the coarsest grains are at the crests and the finest grains below them, whereas in sand-dunes the finest grains are at the top and the coarsest at the bottom. Another is that ripples are usually transverse to wind-direction, as also are dunes of the *barchan* type, whereas this is rarely or never the case with *seif*-type dunes.

*Barchan*-type dunes vary greatly in length, width, and height; the greatest length recorded being 400 metres (1,300 feet), and the greatest height 30 metres (100 feet). They usually occur in belts or chains, coinciding in direction with the prevailing wind-direction, whereas the individual dune lies, as already stated, transversely to the wind. A dune-belt comes to an end because the frequency of dunes along it dwindles to nothing, rather than that the dunes themselves decrease to nothing in size. The end-dunes of a belt are only slightly smaller than those in the middle, but they are farther apart and hence fewer in number near the edges of the belt. In some cases, the dunes do not separate out, but end in hills. The slip-faces of the dunes peter out into undulations. This is attributed to a decrease in the mean rate of sand-flow (*less* wind-blown sand), caused by interference from vegetation.

The formation of *barchan* dunes could conceivably be controlled by cultivating creeper plants over them, possibly from air-sown seed, treated to withstand desert conditions and germinated by stimulating the release of rain from suitable cloud-formations, possibly some few weeks later. Such a project would have a large chance of being a failure. This high probability of failure in a particular case has been a deterrent of pilot schemes, and is one reason why so little work of this kind has been attempted in deserts.

Little is known about *seif* dunes. They appear as long parallel ridges, as shown in Inset 26-7, with swells and dips at regular intervals. Slip-faces are parallel to the predominant wind-direction and do not cut across it as in *barchan* dunes. The most

important feature of *seif* dunes is their extremely orderly arrangement. There are few data about their size, the repetition-distance between ridges, or the rate of movement. Nor is there any clear explanation of why they are formed. The greatest height recorded for a *seif* dune is 210 metres (700 feet). Their lengths vary from about 60 to 120 kilometres (40 to 80 miles), and the repetition-distance may be anything from 1 to 10 kilometres ( $\frac{1}{2}$  to 6 miles).

Some idea of the extent of *seif*-dune areas may be gathered from the fact that in southern Iran and in the Simpson Desert of Australia dunes are recorded that would stretch from London to Birmingham, the whole area covered by dune-belts being many times that of Belgium. Botanical work that points the way to controlling and limiting these dunes is being actively pursued. An example is the work of Professor Petrov at Repetek in Siberia.

#### Hydrology

Since rainfall is scanty and erratic in arid regions, underground water, if available in any quantity, could be associated with irrigation schemes and used to create fodder reserves for cattle, ranged over the extensive arid-'surrounds'. There has been no adequate survey as yet of the potential water supply of any arid region, although there is an obvious need for such information. Such investigations as have been undertaken have led mostly to the same dismal conclusion: that there just is not any great supply of underground water. What there is proves mostly too salty for human use continuously, and of little use for cattle or irrigation. Desalting techniques\* are not considered generally to be economically feasible.

The well-known artesian basins of Australia have a definite limit to the number of bores that can be sunk in them without diminishing the flow per bore. One cannot take from a water supply at a greater rate than it is replenished. Estimates of the 'rate of fill' of artesian and other underground supplies indicate very long periods. They may take thousands of years to fill, but

\*See *Science News* 26, 83-7 (1952).

can be emptied in a matter of a hundred or so if too much water is drawn off.

#### Soil-Water Regimen

There are many commonly held misconceptions about moisture-levels in desert soils. Whereas surface soils are often very dry, much moisture may be held at lower levels. Professor Frank Debenham reports that in some areas of the Kalahari there are several zones of water levels. At 12-ft depth, an old rainfall level was reached, and at 40-ft depth there was a reservoir of water, presumably from some far-off source. It is further claimed that this water-level is held by a layer of air, filling the spaces between soil particles and forming, as it were, an airlock. This is a most interesting possibility and is supported by a large volume of work, which has been carried out on the water-regimen of the sandy and clay deserts of the Kara Kum and the Kyzyl Kum (see Map 4), where there are water-retaining clays in many parts at depths varying from 4 metres (13 feet) to 10 metres (33 feet). It would appear, however, that these deserts have vastly superior water-resources in their lower soil-levels to those of, say, the Libyan or Arabian deserts. This distinction is very relevant both to other aspects of Soviet research, which will be mentioned later, and to any widespread optimism based on current Soviet schemes. In respect of sub-soil water, the U.S.S.R. has definitely the best deserts.

#### PLANTS, SOILS, AND ECOLOGY

Vegetation, if it is to survive, must establish an equilibrium with the environment in which it develops. Since the availability of water is the most important limiting factor of arid environments, desert plants will be expected to show adaptations of form that enable them to withstand better 'lack of moisture' or drought. These adaptations include increased ability to store water, thickening of the leaf cuticle, reduction of leaf-surface or the entire absence of leaves, and the ability to survive as a seed through many years of aridity. Drought-evading plants are divided into two groups: succulents and emperals.

The succulents, such as cacti, store large amounts of water in cavernous leaves or specially adapted stems. They are usually green all over and, even after severe desiccation, can respond to moisture. A bud from a cactus has been kept on a desk-top in an arid climate for two years. It became severely dessicated and withered to a brown colour. When transferred to a laboratory in a humid temperate climate it sprouted roots, although it was still lying on a desk top. Being tough and spiky, cacti are relatively poor fodder, although certain desert animals, camels and goats, have mouths adapted to eating the worst of them.

Empherals, on the other hand, avoid droughts in a remarkable way. They exist as seeds in the dry spells, germinate only when sufficient rain falls to ensure their growth to maturity, and then set seed for the next dry spell. Such seeds are coated with an inhibitor, which prevents them from germinating until sufficient rain falls to wash the chemical inhibitor away. In addition, this rain is usually enough to guarantee full growth to maturity. Much work remains to be done on these inhibitor substances.

During the latter part of the nineteenth century these adaptations were noted and analysed by plant physiologists, within the limitations of techniques then available. Drought-evasion in seeds was recognized as a special case. Adaptations in the anatomy of the plants were thought to reduce the rate of transpiration, that is, the amount of water given out by the plant through its leaves. However, around the beginning of the second quarter of the present century, Academician N. I. Maximov and his colleagues showed that this all too plausible interpretation is incorrect. Many plants live in deserts because they can endure drought, not because they avoid desiccation by conserving their water supply. Drought resistance has come, therefore, to be regarded as a property of the plant cell. Very lately, Maximov has shown that the ability of a cell to avoid desiccation, or to withstand its effects, depends on the viscosity of its protoplasm. These views, it should be noted, are discounted by Professor M. Zohany of Jerusalem, where also there has been much work on desert problems. Under field conditions, he has made measurements on species of *Zygophyllum*, small, straggly, fleshy-leaved,

creeping plants, common in arid regions, and has recorded transpiration rates much lower than any that have previously been reported for desert plants. There may be room for both views. Without structural modifications, desert plants might transpire even faster than they do. Both the form of the plant and the properties of its cells may assist drought-withstanding plants.

But this is not the whole story of drought-resistance. There is the further question of the potentiality of the drought-resisting plant for providing food for livestock.

Under non-arid conditions, the interest of the agronomist is in the ability of the plant to use soil nutrients and fertilizers with maximum efficiency. In a desert, or under semi-arid conditions, this is no longer the limiting factor. The corresponding interest is in the amount of protein (roughly indicated by weight of dry matter) which can be built up during development from seed to mature plant, for a given amount of water transpired.

Much recent research has centred on this concept of 'efficiency of transpiration', defined by Maximov as the amount of dry matter accumulated by the plant for each 1,000 parts of water transpired, using equivalent units. For example, a plant that transpires 2,000 grammes of water during its development, and produces in all 4 grammes of dry matter, would have an efficiency of transpiration of 2. The following table shows some typical data, mostly obtained by Shantz and Piemeissel, for some crop, and other, plants.

|                                             | Efficiency |
|---------------------------------------------|------------|
| Millet                                      | 3.65       |
| Sudan grass                                 | 2.63       |
| Wheat                                       | 1.82       |
| Lucerne                                     | 1.32       |
| Russian thistle ( <i>Salsola pestifer</i> ) | 3.18       |
| Lamb's Quarter ( <i>Chenopodium album</i> ) | 1.52       |

Of these plants, the last two can grow under semi-arid conditions, and millet and sudan grass under relatively arid conditions, whereas wheat and lucerne are restricted to more humid environments. Among the plants listed there is no general differ-

ence in efficiency of use of water, according to the amount that normally is available; and, in so far as truly desert-living plants have been examined, there is again no evidence of any specially high efficiency.

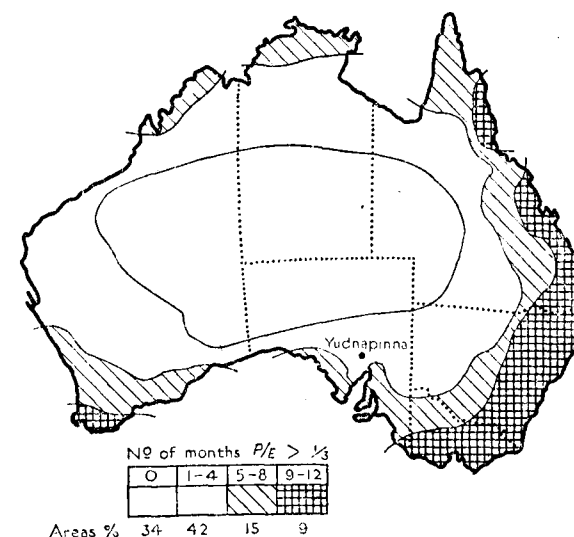
In relation to adaptation, this means that, although desert-living plants may avoid damage during periods of even acute water-shortage, they are no better than any other plants in the use that they make of water for growth. Only water can make the desert bloom; plant-breeding and the introduction of new species can, at the best, only make the desert slightly more habitable.

On the other hand, given that water is available, efficiency of transpiration is the best index that we have of the use that a plant will make of it. It is a figure of merit as a potential fodder-plant, and it is highly desirable that further measurements should be made under field conditions, using portable equipment, in arid regions.

### Effective Rainfall

The effectiveness of rainfall in relation to plant growth is well brought out in work carried out at the Waite Institute, South Australia, by Prescott, Trumble, Woodruffe, and others. They considered that rainfall is 'effective' during any given period of time if, on the average, it is greater than one-third of the evaporation from a free water surface. Using monthly data, they plotted on a map the distribution of stations according to the number of 'effective rainfall months', those in which  $P/E$  was greater than  $1/3$ . Map 2 shows, for Australia, the regions having varying numbers of months of effective rainfall. It will be seen that the central region has no month of 'effective rainfall' and here the permanent vegetation will have drought-resisting adaptations (such as reduced leaves, spines, thick cuticles, etc.). These characters will diminish the grazing potential of such scant herbage as may exist. In all, these are very poor areas. Plants which survive dry spells as seeds (empherals) will occur in abundance after short periods of sporadic rainstorms, possibly at intervals of years. Regions with 1-5 months of 'effective

rainfall' are quite good for grazing stock, sheep or cattle, but are speculative for agriculture. Wheat has been grown at Yudnapinna in the 1870s-80s (location shown on map), but these years were years of above-average rainfall. A similar rainfall regimen occurred in the years 1948-49-50, but experiments with crops were not attempted. Similar work, if done for other continents, would supply a valuable series of maps showing the approximate limits of pastoral expansion. One would imagine these limits to be already well-established, but the ground-nut and some other recent adventures in food-production discount this idea.



Map 2. Bioclimatic map of Australia. Areas are shaded according to length of growing period (months of effective rainfall), based on the work of Davidson, Prescott and Trumble.

In general, soil zones correspond directly to the regions of 'effective rainfall'. This is to be expected if soil is regarded as a function of climate principally. Given a relatively uniform

temperature, rainfall is the most effective climatic agent in soil forming and conditioning.

The mallee\* soils of Southern Australia are thought to be derived from wind-blown calcareous material. In general they are deficient in phosphates, but contain large quantities of calcium and potassium salts. The texture is that of a sandy loam and usually these soils support a savannah woodland type of vegetation. The more northern regions of mallee soils lie along the line of 5-months' 'effective rainfall' (see Map 2). They support large flocks of sheep and very small numbers of people, whose production per head is high. This is good sheep country as diseases are at a minimum, flock control relatively easy, and no shelter need be provided nor provision made for wintering. With a supply of water sufficient for limited irrigation, this country could easily grow fodder reserves to augment the feeding capacity in bad years, of which several are to be expected each decade.

#### *Climatic Effects of Windbreaks*

In countries with cold winters, windbreaks induce increased crop-yields by causing more even distribution of winter snow, and therefore reduced losses of water on melting. Changes are effected in the water-regimen and in the micro-climate of the windbreak-protected regions, and these changes benefit crops and plant-growth in general. The windbreak acts as a kind of aerodynamic screen and breaks up wind eddies into smaller ones. The effect on snow-distribution has been confirmed for steppe lands in high latitudes. A 30 per cent increase in soil moisture for the first metre of soil has been recorded (occurring mostly in May or June, when water shortage is most acute in hot arid lands). This effect increases yields.

In steppe lands and arid regions, evaporation is greater than precipitation. Any increase in soil-moisture, caused by shelter-belts, leads to increased transpiration by plants in summer, and

\*A local term referring, originally, to shrub-steppe vegetation consisting of certain types of eucalypts which send up several trunks from an underground bole.

so to increased humidity. This, in turn, augments the summer rainfall, an effect which may also be helped by increased turbulence of air-currents over flat lands, again caused by shelter-belts. It has been estimated that a 10-12 per cent increase of precipitation is caused by shelter-belts planted across steppe-lands of a semi-arid nature.

In the true arid regions, the shelter-belts are only effective in the presence of irrigation water. They alter the micro-climate of oases. Because of increased evaporation in large oases, the relative and absolute humidity is increased and the temperature lowered. Data show a 2° C. lowering in July, and in September a 3° or 4° C. lowering of temperature for a large oasis. The effect on soil temperatures is also significant, as can be judged from the following figures: whereas the temperature of exposed surface soil has been recorded at 1 p.m. as 65° C. (149° F.), that in a neighbouring irrigated and shelter-protected field of lucerne was 35° C. (97° F.). The difference is too large to be explained by irrigation effects alone. The cooler air of the oases is reported to produce also a considerable effect on the micro-climate of the desert surrounding it.

#### DEVELOPMENT SCHEMES IN ARID AREAS

Historically, the use of arid areas to support human populations requires to be considered in the light of the limitations already discussed. The essential limitation is that imposed by water-supplies. Without irrigation, the range of rainfall which, over any long period of time, is marginal in particular conditions, is distinctly limited. With irrigation, the marginal range of rainfall is shifted in a downward direction, according to the quantity of water which can be made available. But, again, there is in most areas a limitation in quantity. Over long periods there tend, therefore, to be oscillations in the use of arid areas, and these oscillations are probably more determined by the stability or otherwise of human communities than by other considerations. The most that can be claimed for modern technical skills is that they enable available surface water to be distributed over larger areas than was possible in earlier ages; that underground water

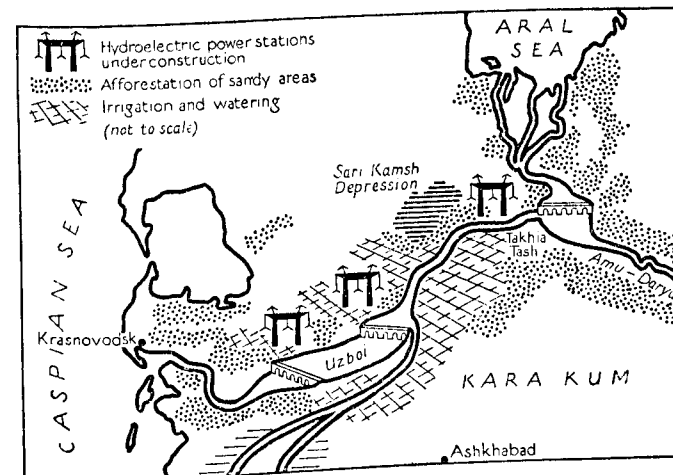
can be tapped to the probably limited extent that it can provide permanent supplies; and that improvements in transport may make it practical to rear livestock for consumption outside the area in places where this could not before have been done.

Large areas of semi-arid land, now derelict, have in former times supported considerable populations, based on irrigation-systems, which were destroyed by war or neglect. These areas include some of the outlying regions of the Sahara, parts of south-western and central Asia, and parts of central and northern South America. The cultivation of many of these areas must have originated in what can fairly be described as development schemes. Elsewhere, the effect of modern schemes (such as in India and Egypt) has been in large measure to restore to use land which earlier had been irrigated. The Gezira scheme in the Sudan is an example of an area first irrigated in modern times.

The most recent scheme of major interest is the Stalin plan for irrigation, afforestation, and power-generation over an area in south-west Asia estimated at 8 million hectares (20 million acres), of which 1.3 million hectares (3.2 million acres) are to be irrigated. In common with most other modern schemes, it is a scheme for the redevelopment of land formerly utilized. In the area proposed for crop-irrigation, it is comparable with the Gezira scheme.

An impression of the scheme for Soviet south-west Asia can be gained from the sketch-map. Briefly, it is to direct water from the Amu Darya river (the Oxus) into parts of the Kyzyl Kum and Kara Kum deserts and the arid region of the south-west Caspian, making use of the old river-bed of the Usboi and a canal-feeder system, and to direct water from the Sir Darya River into part of the Kyzyl Kum desert. Eventually, these regions are to be made self-sufficient in fuel and power resources, their areas of shifting dune-sands stabilized by tree-cover, their rivers dammed and controlled for electricity-generation and irrigation, and they will provide large areas for stock-raising.

V. V. Dokuchayev and K. A. Timiryazev laid the basis of this work for their development of pedology, the science of soil-classification and development. They paid particular attention



Map 3. To show construction schemes in S.W. Soviet Asia (diagrammatic representation after Manton).



Map 4. S.W. Soviet Asia: location map showing extent of desert (shaded).

to the water-regimen of soils, especially steppe soils and soils of semi-arid and arid regions. The advantage possessed by desert soils in this region from water-retention at a quite modest depth has already been mentioned. P. A. Kostychev developed a system of farming, which was further improved by W. R. Williams, to include the improvement of soil fertility by the use of shelter-belt afforestation, by-cropping, pond-reservoirs throughout fields, superior seeds, and new varieties of plants, the whole being known as the 'travopolye' system.

Visotsky developed methods for the successful planting of forests in deserts, and T. D. Lysenko further developed cluster or 'hills' sowing of tree seeds in semi-arid regions, to enable seeds to establish themselves in competition with steppe plants. Very large areas are being planted. Pasture regions are to be created among these forests aided, of course, by irrigation. The type of trees used, after much experimentation with numerous varieties, are oak, pine, saksaul. The cluster method of planting plus manuring techniques are used extensively. The property of soil water-retention at quite moderate depths is again relevant to this work.

Throughout the Kara Kum desert, there are large areas in which the water-table is relatively high, the surface sand being underlain by clay at quite shallow depths. The present Soviet plan is impressive for the length of antecedent research, which began in the late nineteenth century and has continued without break; for the extended period of planning, accompanied by further research and many expeditions, before practical development was begun; and, finally, for the drive and speed of work now that decisions for development have been taken. But in considering whether results on the same scale could be achieved in arid regions generally, it must be remembered that both in structure of sub-soil and availability of mountain-fed rivers, the deserts of south-west Asia are a particularly favourable case.

The north-western Kalahari of Bechuanaland, the possibilities of which are being investigated at the present time, is a semi-arid region rather than a true sand-desert.

#### ECONOMICS OF DESERT IMPROVEMENT

What sort of community is best adapted to desert or arid conditions? Past communities solved the problem of living in deserts by adapting their social organization and mode of obtaining sustenance. The Kalaharian Bushmen have, in addition, developed physical adaptations such as the fat-storage hump which enables them to withstand food-shortage at erratic intervals. Such adaptations, though common in the animals of arid regions, are rare in humans. The Australian aborigines, like the Bushmen, are adapted to eating anything possible – roots, insects, and even tree-bark. They roam over large areas in search of their foods, whereas the advanced type of nomad herds domesticated animals, on which he may come to depend for his livelihood. Is this the best adaptation to a desert environment?

Nomadism involves a knowledge of the desert, its favoured watering places and pastures. The nomad travels from favoured place to place, hoping to survive on the journey. His life is made precarious by not being entirely sure of what lies ahead. This defect could easily be overcome by establishing a 'central nomad information centre', equipped with aircraft and radio. The nomad could thus be directed to suitable areas where the narrowly defined desert rainstorms had recently passed. Such a system would increase output per head, possibly to an extent which would make him more than just self-sufficient. But one cannot see that any startling advance in productivity could arise from such schemes.

The second approach is after the nature of the Stalin plan for south-west Soviet Asia. For this, there must be a reasonable supply of water, fed preferably from ice-field mountainous regions. As far as can be known, these conditions are peculiar to Asia and North America. Africa and Australia just do not possess water supplies of this type for such elaborate and costly schemes to be effective with any reasonable degree of certainty.

Australia has developed large areas of desert and semi-arid lands under pastoral leases, which give little encouragement to improvement. The semi-arid lands in particular have been

immensely successful for sheep herding and less successful for cattle raising. There is evidence, however, of a considerable deterioration in the pastures of these areas, due to over-grazing and faulty management, and to the acute labour shortage in these regions.

Other difficulties, common to semi-arid areas in Africa and South America, are associated with transport. Cattle must be moved to markets, and in arid regions such movement is slow and leads to serious loss of condition and consequently of marketable value. The provision of railheads or roads is essential. Attempts, so far at a loss, are being made in north-west Australia to fly carcasses from regional abattoirs to markets. This approach may be useful in other arid regions, especially in Africa.

What of the use of mechanical equipment in arid regions? Usually productivity is too low to warrant the capital expenditure involved. Only if outside aid is forthcoming can mechanization of desert economy be contemplated. A good example is provided by Israel, where foreign subscription and incoming capital and labour have developed many arid regions quite successfully, even for agricultural purposes.

An important question, not commonly considered by enthusiasts for arid-area development, is whether an equivalent capital expenditure would not be better devoted to the improvement of more dependable areas, in order to increase the productivity per head. So much good agricultural land in farm areas is so inadequately utilized, owing to lack of capital, knowledge of modern farming techniques and a low standard of general education, that these areas may well deserve higher priority. The greatest immediate effort, in respect of deserts, should be to stabilize their surfaces by some kind of vegetation-cover, and so limit their further advance into lands which support permanent populations.

As a general rule, given adequate water supplies of suitable quality, deserts can be improved and the production per head of desert dwellers raised. So far, however, except for favoured regions, desert researches have not shown how these supplies

may be obtained. The outlook for forming an effective plant-cover over deserts, by improved types of plants bred for the purpose, is virtually an open question. There is no indication of such success now or in the immediate future, without water of sufficient quality and quantity for the irrigation of shrubs or trees.

#### FURTHER READING

The best general introduction is in German:

Walthur, B. *Das Gesetz der Wüstenbildung*. Berlin, 1900.

Also recommended:

Pickwell, G. *Deserts*. New York, McGraw Hill, 1939.

A clear and readable account of climatology in relation to plant-growth will be found in:

Daubenmire, R. F. Chapter 3 of *Plants and Environment*. New York, John Wiley, 1947.

For a discussion of the artificial release of rain in a semi-arid area, see:

Pulvermacher, K. 'Artificial Rain in South Africa'. *Discovery*, **12**, 219 (July, 1951).

On sands and dunes:

Bagnold, R. A. *The Physics of Wind Blown Sands*. London, 1939.

Madigan, C. T. 'Australian Sand-ridge Deserts'. *Geographical Review*, **26**, 205 (1936).

For different aspects of hydrology, see:

Youhotsky, J., and Youhotsky, M. J. *The Australasian Engineer*. Sydney, 1943.

Debenham, Frank. 'The Kalahari Today'. *Geographical Journal*, **118**, Pt 1 (March, 1952).

A good general account of ecology, climate, and soil-water relationships will be found in Daubenmire's *Plants and Environment*, already quoted.

For the 'effective rainfall' concept, see:

Trumble, H. C. 'The Climatic Control of Agriculture in South Australia'. *Transactions of the Royal Society of South Australia*, **61**, 41, etc. (1937).

A general account of Soviet research and development plans is given in:

Grigoryev, A. A. *Geographical Journal*, **118**, 168 (1952).

## COSMIC RADIATION

E. P. GEORGE

THE earth is subject to continuous bombardment by a stream of assorted atomic particles, some of which reach it with very great energy. These particles are known as the primary cosmic rays. When they collide with the nuclei of the nitrogen and oxygen atoms of the atmosphere, which they usually do in the first 5 or 10 per cent, measuring downwards from the top, they invariably break up the nucleus that they hit, and an appreciable fraction of the energy is converted into new unstable forms of matter known as mesons. The heavier mesons decay into lighter ones, and some of them decay into light quanta or photons which in turn produce electrons (a positive and a negative one at the same time), so that by the time the secondary radiation reaches sea level it contains quite an assortment of components: fragments of atomic nuclei (protons, neutrons, alpha-particles) disintegrated higher up in the atmosphere, mesons of various sorts, and high energy photons and electrons. Strictly speaking the beam at any appreciable depth in the atmosphere should be called the secondary cosmic radiation, although sometimes the qualifying terms 'primary' and 'secondary' are dropped. In order to avoid confusion they will be retained in this article. Thus the secondary radiation at sea level has a very different composition from the primary beam, the latter having been modified and filtered by the atmosphere.

There are two very broad divisions into which cosmic ray research may be classified, which I will call 'cosmic' and 'nuclear'. Under the heading cosmic I put all questions referring directly to the primary radiation, such as the nature of the primary particles, their distribution in energy, time, and space. What mechanisms can be thought up to explain their existence and which, if any, are tenable in the light of our present knowledge?

Do the primary particles originate in the solar system, are they uniformly distributed throughout our galaxy, or do they fill the whole of the known universe, as their name suggests? Under the heading nuclear I put all the studies of high-energy collisions that have been made using primary or secondary particles. Questions that arise under this heading are the nature and energy of the various types of nuclear fragments resulting from these collisions, and of even greater interest, the masses, lifetimes, decay schemes, and collision probabilities of the various types of mesons emitted. A certain amount of the work in this field is now rightly being taken over by the various machines which accelerate atomic particles to great energy in the laboratory and as bigger and better machines come into operation on both sides of the Atlantic (mostly on one side!) this trend will be continued. Also, several reviews of mesons have appeared in *Science News*\* and, for these and other reasons, it is intended in this article to concentrate more on the 'cosmic' side of cosmic rays.

The division into 'cosmic' and 'nuclear' is not watertight: one may very well use some property of a nuclear collision to deduce either the charge or energy of a primary particle, and similarly the properties of the secondary particles are frequently used to deduce something about the primary radiation. These divisions have been introduced to produce some ordering of our knowledge concerning the cosmic rays, and while our major concern here is with the cosmic aspects of the primary rays, I shall step outside these limits as occasion demands.

### THE PRIMARY PARTICLES

Great advances have been made recently in our knowledge of the primary particles following two technical developments, namely, improved photographic emulsions for recording atomic particles and improvements in balloon flying techniques.

If a charged particle passes through an ordinary photographic emulsion it produces an effect similar to light, and on processing

\**Science News* 16, 9 (1950); 18, 86 (1950); 21, 20 (1951); 26, 7 (1952).

the plate in the normal way a fine row of blackened grains may be observed along the path of the particle if the processed emulsion is examined under a microscope. This property has been known for some time, though until recently the tracks were faint and uncertain and not very suitable for quantitative measurement. Pierre Demers, working in Canada, then showed that the technique could be put on a quantitative basis if the proportion of active agent in the emulsion (small grains of silver bromide) was increased about 10-fold. The British photographic companies (Kodak and Ilford) then went into production of the Demers-type emulsion, bringing about further improvements in their turn until today there is now available a whole range of nuclear track emulsions suitable for various purposes. The density of grains in the track of a particle is proportional to  $1/v^2$ ,  $v$  being the velocity of the particle, hence for recording the fast cosmic ray particles the emulsions of greatest sensitivity are usually employed. The grain-density is also proportional to the square of the charge on the particle. Hence, for particles of high charge or moderate velocity, or both, the grain density will be very great. Under these conditions, the track becomes clogged with grains, it is not possible to count them individually, and some other property of the track must be used. One property that has been found very useful is the density of so-called delta-rays along the track. As a fast particle moves through the photographic emulsion, it occasionally collides with an electron so energetically that it, in its turn, is able to leave a small track stemming out from the main track. These subsidiary tracks look like whiskers sticking out from the main track, and these whiskers are called delta-rays. It is precisely when the grain density gets too great to be used that the delta-ray density is of sufficient magnitude to be a convenient tool to take over the job of specifying the nature of the particle causing the track.

The primary cosmic rays interact with matter so strongly that in order to be able to study them it is necessary to get within a few grammes of the top of the atmosphere, which means getting the recording apparatus to heights of the order of 100,000 feet. This has only been possible recently, and the means of doing so

are described in the following article by Herz and Tennent, to which the reader is referred for further details. A photographic plate, because of its lightness and simplicity, commends itself strongly as apparatus for use at a height of 100,000 feet or more. Although systems of Geiger counters and even cloud chambers have been sent up in balloons to these heights, nearly all the recent advances of importance have been made using photographic plates.

Making use of the fact that the earth is a great magnet, early cosmic ray workers had shown that the primary cosmic rays were charged and the first inference was that the primary particles were electrons. Then, using the property that, because of magnetic deflexion, positive particles approach more easily from the West and negative ones from the East, it was established that the primary particles were not only charged, but positively charged. The electron hypothesis had to be abandoned and it was assumed instead that the primary particles were protons, and this remained our picture until Phyllis Freier at Minnesota and Professors H. L. Bradt and B. Peters at Rochester, N.Y., joined forces in 1947 to fly the first nuclear emulsions to very great heights, using the new balloons that had just become available.

On developing their plates, they found a number of thick black tracks containing many delta-rays – and on counting the delta-rays nuclei of various atoms were identified, the heaviest so far recorded in the primary radiation being nuclei of iron. This came as a great surprise to them, as it did to all of us. It is of interest that Bradt and Peters had been newly appointed by the University of Rochester to work on the large cyclotron there, the second large one to operate in the United States. It was the idea of Bradt and Peters to study the output-beam of the machine using nuclear emulsions and, since it was not working at the time, they thought they would get some practice in this new technique by studying the tracks of cosmic ray particles. In order to get the highest energy particles they sent their plates up in a balloon as high as it would go and discovered the so-called heavy primaries. They never returned to their cyclotron;

and they and others have pressed on ever since with their chemical analysis of the primary radiation.

Nuclei of atoms heavier than hydrogen were found to contribute about 15 per cent of the total flux of primary particles. Because they each contain several neutrons and protons, an individual heavy nucleus makes a greater contribution to events in the atmosphere than does a single proton. In all, they contribute 30 per cent of the incident protons and all the incident neutrons, 40 per cent of the incident energy, and 50 per cent of the ionization in the upper atmosphere.

In the years 1948 to 1951, the presence of these heavy primary particles was confirmed by observations with cloud chambers, Geiger counters, and several other forms of particle-counter.

#### CHEMICAL ANALYSIS OF THE PRIMARY PARTICLES

Except for the proportions of lithium, beryllium, and boron (atomic numbers 3, 4, and 5), there is general agreement between various laboratories as to the composition of the primary radiation. The abundance of the various chemical elements is found to be quite similar to that of the matter forming the universe as deduced by spectroscopic study of the sun, the stars, and the dust between the stars – the so-called 'cosmic abundance' of the elements. The results are collected for comparison in Table I.

TABLE I: Comparison of Chemical Analyses of the Primary Cosmic rays and the Matter of the Universe

| Element   | Cosmic Rays | Matter of the Universe<br>(Cosmic abundance) |
|-----------|-------------|----------------------------------------------|
| Hydrogen  | 100,000     | 100,000                                      |
| Helium    | 10,000      | 10,000                                       |
| Oxygen    | 260         | 63                                           |
| Nitrogen  | ?           | 46                                           |
| Carbon    | 260         | 23                                           |
| Neon      | 30          | 2.6 to 70                                    |
| Iron      | 30          | 5                                            |
| Magnesium | 40          | 2.9                                          |
| The rest  | 30          | 3                                            |

Hydrogen is by far the most abundant element, with helium in second place, occurring about one tenth as frequently as hydrogen. Finally, the heavier elements all put together are about one tenth as frequent as helium; the frequency of any given species falls off rapidly with increasing atomic weight.

The astrophysicists tell us that there is practically no lithium, beryllium, or boron in the universe. This might be due to the fact that these light elements are consumed very rapidly in the nuclear chemistry occurring in stellar interiors. It becomes of especial interest to see if there is a corresponding lack of these elements in the primary radiation – and here we get diametrically opposite answers from the two universities which have worked chiefly on this question; the Rochester workers say that there is effectively no lithium, beryllium, or boron in the primary radiation, whereas at Bristol they say these elements are about as abundant as all the rest counting from carbon upwards. The discrepancy is one of interpretation. It depends on the method used to work back from the observed frequency of delta-rays along a heavy primary track to an actual assignment of atomic weight to the particle causing it. Rochester placed their faith in a theoretical formula which they derived from another one, due to Professor N. F. Mott, which related to different circumstances. Bristol, on the other hand, have approached the problem purely experimentally and have determined for themselves the curve relating to delta-ray frequency and atomic weight. They find that this disagrees with the theoretical curve used at Rochester. It seems this is another example of abiding by the motto of Cavendish, *Hypotheses non fingo*, for the case for the Bristol results now looks pretty good, and in what follows I will accept their conclusions that in the case of lithium, beryllium, and boron, the parallel between cosmic and cosmic-ray abundances breaks down, there being large quantities of these elements in the primary cosmic rays.

#### THE ENERGY SPECTRUM OF THE PRIMARY PARTICLES

The primary particles do not all arrive at the earth's surface with the same energy, but with energies distributed over a wide range

of values. At any given latitude there is a lower limit to the energy with which particles can arrive. This limit is determined by the earth's magnetic field, and varies from zero at the poles to  $15 \times 10^9$  electron-volts at the equator. By flying plates at various latitudes it is possible to find out how many particles there are with various energies in the limits of 0 to  $15 \times 10^9$  eV.

To measure the energy of particles beyond this upper limit, we have to make use of other properties of the radiation. The ones that have proved most useful are certain types of collision that the primary particles make in the atmosphere or in nuclear emulsions. When a primary particle makes a collision, a whole lot of different things can happen, depending on the charge of the incident particle, its energy, and whether it makes a head-on or a glancing collision with the target nucleus, etc. Among the variety of resulting effects, there are two types of collision that have proved useful in determining the energy of the incident particle. Both have been studied in detail. In the first, the incident heavy primary breaks up into quite a few alpha-particles, which, because of the high momentum of the incident particle, are all thrown forward in a narrow cone or 'jet'. An example of such a collision is shown in Inset 28. The target nucleus is of course also disintegrated, but its fragments are of much lower energy and are emitted in all directions, so being easily distinguished from the alpha-particle jet. From the theory of relativity it follows that the mean angle of the particles in the jet with respect to the primary is inversely proportional to the energy of the primary, or in other words:

$$E = k / (\text{mean angle of jet}) \quad (\text{Eqn 1})$$

The constant,  $k$ , follows in an unambiguous way from relativity theory and some well-established properties of emitted alpha-particles.

Using equation (1) the Rochester group pushed up the study of energies to about 100 times greater than the upper limit set by geomagnetic studies, that is they were able to measure up to about  $10^{12}$  eV.

The alpha-particle cone is easy to recognize, since the alpha-

particles are very fast and all have a charge of 2 units. Thus they all leave tracks 4 times as dense as fast singly-charged particles (grain density varies as the square of the charge). Sometimes jets are found consisting of fast singly-charged particles and hence at minimum ionization. It has been established that these showers consist mostly of particles, of which the masses are in between those of the electron and proton, and which are called mesons. An example of such an event, observed at Bristol is shown in Inset 29. In this example, the angle of the jet is so small that close to the collision the tracks all overlap and for a short way give the appearance of being a heavy track rather than a lot of light tracks. Farther away the jet opens up and the individual tracks can be distinguished. It is found that this type of collision resulting in a meson jet also enables a determination of the energy of the incident particle to be made. Equation 1 can again be used, but with a different value of  $k$  since we are now dealing with mesons and not with alpha-particles. By this means, energy measurements up to  $10^{14}$  eV have been made, higher by a factor of 100 than the upper limit using alpha-particle jets. The practical upper limit is reached when the jet-angle gets too small to measure.

To go beyond this limit, use is made of the fact that at energies beyond  $10^{14}$  eV, the energy liberated is so large that quite a shower of particles reaches sea level simultaneously; the particles from the original collision themselves make weaker and less spectacular collisions lower down which nevertheless result in an increase in the total number of particles occurring in the event. This process, at the highest energies so far known, is able to survive through several generations of successive collisions, and delivers, at sea level, a large number of particles – in the region of 100,000 to 1,000,000 – simultaneously in a circle of radius approximately 100 metres. Such a process is called a nucleon cascade. From observations of the number of particles present in the cascade at sea level, it is possible to estimate the energy of the particle causing the event. In this way, first used by Pierre Auger at Paris, the flux of particles with energies in the region of  $10^{14}$  to  $10^{17}$  eV has been estimated.

Piecing together all the evidence obtained in these various ways, the following picture emerges:

(1) The higher the energy, the fewer the particles. The flux of particles with energy greater than  $E$  falls off approximately as  $1/E\sqrt{E}$ ; so that for an increase of energy of 10 times, the flux decreases by a factor of 30.\*

(2) At all energies, the chemical composition is approximately the same, i.e. the rule: Protons/alpha-particles/the rest is as 100:10:1 applies at all energies.

(3) The absolute flux of primary particles varies from 2 per square centimetre per second near the poles to 0.2 per square centimetre per second at the equator.

To put these energies into some sort of perspective let me mention that the high-energy cyclotron at Harwell accelerates protons up to energies close to  $2 \times 10^8$  eV – and that a few machines in America accelerate protons up to 3 to  $4 \times 10^8$  eV. The only machine of higher energy is the cosmotron at Brookhaven with an output of  $2 \times 10^9$  eV. Next year, Professor E. O. Lawrence's bevatron at Berkeley should be operating at an output of  $6 \times 10^9$  eV.† It will be seen that these are all very small compared with the energies of particles which are met with in the cosmic rays. On the other hand, the intensity of the beam from these machines is of course greater than the intensity of the cosmic ray beam by a factor of several million. Thus at moderate energies it is more efficient to study nuclear interactions with artificially accelerated particles, but at energies above a few times  $10^8$  eV, the much weaker cosmic ray beam is the only source of bombarding particles. Each method helps the other.

\*For particles of energy greater than about  $10^8$  electron volts, the above formula is good enough to work on. For particles of lower energy, the facts are more actually expressed by the statement that the flux falls off as  $1/(1+E)\sqrt{1+E}$ , where  $E$  is measured in units of  $10^8$  eV.

†For an account of these machines, see 'The Acceleration of Charged Particles to High Energies' by L. L. Green in *Science News* 22.

#### DISTRIBUTION IN TIME AND SPACE OF THE COSMIC RAYS

Presumably the primary rays start their journey to the earth from somewhere, and at some time in their history acquire the enormous energies with which they arrive, and I would like to discuss the sort of observations that give us a few meagre pointers on which to base our ideas. For example, our galaxy is a lozenge-shaped disc of thickness  $10^{17}$  kilometres and diameter  $10^{18}$  kilometres. Suppose that the cosmic rays originated in the stars and travelled from them to us in straight lines. Then we should expect their intensity to be much greater when the Milky Way is overhead than at any other time. Actually this is not so – the rays are distressingly constant in intensity throughout all hours of the day and night and do not depend on whether the Milky Way or any particular constellation is overhead.

Because of the obvious difficulty of making protracted observations near the top of the atmosphere, nearly all the regular monitoring of intensity has been made at the surface of the earth, or a little beneath it. This means that what is being monitored is not the primary particles but the secondary ones, mostly mesons, to which they give rise. Extensive studies by A. Duperier in London and by H. Elliot in Manchester have shown that it is possible to account for most of the day-to-day fluctuations in terms of variations in the overlying atmosphere.

When all the local atmospheric effects have been ironed out there remain one or two residual effects which seem to be truly cosmic. Most of these appear to be connected in some way or other with the sun, but this does not by any means imply that the rays come from the sun, but rather that there is some effect of the sun on the cosmic ray beam.

Thus there is the effect first noted by K. G. Melmsfors in Stockholm and confirmed by Elliot in Manchester that the difference in intensity of two counter-telescopes pointing in two different directions in the sky is not constant but varies in a systematic manner throughout the day. The atmospheric effects would influence both telescopes equally and on subtracting the two

intensities should cancel out. This points to some small directional irregularity in the primary cosmic rays, but this irregularity depends on the local solar time and not on stellar or sidereal time. Elliot explains the effect by means of electric fields established in streams of ions emitted by the sun, the cosmic rays on passing through these streams having their energies altered slightly. What is curious is that the effect is markedly smaller now than it was when first noted four years ago. This would suggest some slow pulsation taking place in the sun which gradually alters the strength of these solar streamers. J. A. Simpson in Chicago has been monitoring the daily frequency of the neutrons in cosmic rays – and finds a very marked 27-day recurrence cycle. This again does not necessarily mean that the primary rays come from the sun – it could equally well be explained in terms of a modulation of the cosmic ray beam by solar activity.

There are also erratic jumps in the cosmic ray intensity associated with sunspots. The earth's magnetic field also is usually very much disturbed at this time, owing to the large currents of electrons shooting out of the sunspot craters, and since the intensity of the radiation is known to depend on the local value of the earth's magnetic field, this again looks like an indirect effect. This is illustrated in Figure 1, which shows a record of the cosmic ray intensity during a few days of sunspot activity, compared with readings of the earth's magnetic field for the same period.

The effects mentioned above are usually all quite small, of the order of 1 per cent, and it is known that the effects in question are all confined to the lower energy particles which are influenced by the earth's magnetic field. A new result which has just come from Manchester is very exciting, because it is both a large effect, and involves the particles of highest energies which are responsible for the large showers in the atmosphere which can be picked up at sea level. The showers are picked up by recording coincidences between groups of Geiger counters in the same horizontal plane separated by large distances. The larger the separation between recording counters the larger the energy of

### Cosmic Radiation

41

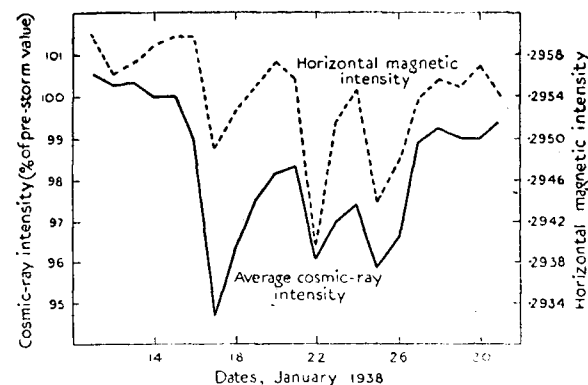


Fig. 1. Cosmic-ray intensity during the magnetic storm of 16 January 1938.

the shower, those recorded at 300-metres separation being of energy  $10^{16}$  to  $10^{17}$ eV. Elliot has found that the showers recorded at counter-separations up to 150 metres come as often at one time of day as at another, to within 1 or 2 per cent, but that the showers recorded over a base of 300 metres show a marked variation during the solar day. The maximum is at noon, when there are 25 per cent more showers than the average. No significant variation is detectable if the results are plotted against sidereal rather than solar time. This means that, again, this must be an effect due to the sun.

What is required is some explanation of the effect which will also automatically explain why it does not take place for showers of not much smaller energy observed over a base of 150 metres. Such an explanation is provided by a theory published by G. T. Zatsepin of Moscow; he showed that one consequence of the relativity theory was that a beam of ordinary visible light, as viewed from an observer on one of these high energy primaries, looks like a beam of gamma-rays of quite high energy. If one of these heavy primaries passes near the sun, then, to it, the intense beam of sunlight in which it finds itself looks like a beam of gamma-rays, and the apparent energy of the

gamma-rays increases with the energy of the heavy primary. Now experiments at Berkeley, California, and at Harwell have demonstrated that gamma-rays can break up nuclei if their energy is sufficiently high. Since there is a threshold energy for this so-called photo-nuclear disintegration, it follows on Zatsepin's theory that heavy primaries of low energy can pass through a light-beam unscathed, but if their energy is increased, then beyond a certain critical value they will be split up into fragments by ordinary visible light, the fragments all travelling along together with a very small angle between them. The critical energy turns out to be in the region of  $10^{16}$  to  $10^{17}$  eV, and the separation of the fragments on reaching the earth is calculated to be several hundred metres. Zatsepin's theory thus accounts in a natural way for the critical onset of diurnal variation for showers bigger than a certain size. Because the showers are not very frequent, the number observed is not very great, and more observations are required before we can be sure about the existence of the effect and its explanation in terms of Zatsepin's theory. The present observations are very suggestive.

All of the above effects have been ascribed to the influence of the sun, and it is not surprising that this object should have as dominant an influence on the cosmic rays as it has on many other aspects of terrestrial existence. Attempts to detect correlation between the cosmic rays and the position of the stars rather than that of the sun have not proved so successful. But, again, the first people to find anything convincing have been the Manchester workers; they find a small but definite influence of magnitude 0.02 per cent, that is 1 part in 5,000. The smallness of this variation when the Milky Way is overhead accounts for the conflicting results that have been obtained in the past. This means that the rays come to us uniformly from all directions throughout the universe to within 99.98 per cent, and this is a fact which any theory of the origin of the rays would have to account for.

#### THEORIES OF THE ORIGIN OF THE RAYS

Ever since the discovery of cosmic rays many people have evolved theories of their origin. All of them have this in com-

mon, that they do not give a plausible explanation as to how the rays acquire their extreme energies. Thus R. A. Millikan at one time thought they might arise through the annihilation of matter, but this gives maximum energies of the order of  $10^9$  eV; and, in any case, the heavy primaries are themselves quite complex conglomerations of matter. Fred Hoyle and others have favoured super-novae or other types of explosive origins. This again breaks down on account of insufficient energy being available, and also because any violent origin is certain to break up the heavy nuclei during the rapid acceleration to which they would be subject. The fact that heavy primaries are observed eliminates all theories based on an explosive origin.

There is a whole group of theories which envisage acceleration in some weak electric fields in the universe – a sort of celestial cosmotron. Some of these theories are based on the existence of magnetic fields throughout the galaxy, for which there is no convincing evidence as yet. The only theory which looked like being within sight of being successful was one announced by Enrico Fermi a couple of years ago. Fermi's theory was basically quite simple. He argued that if you had a space containing protons and large objects, e.g. footballs, then eventually, owing to their mutual collisions, the two groups of particles, protons and footballs, will each acquire the same energy *per particle*. Even a slowly moving football has an energy of many thousands of ergs. This would be enough energy, in the case of a proton, to lift it into the cosmic ray class, say  $10^{15}$  electron volts. The only further requirement is to identify some known stellar objects with the footballs. These Fermi took to be clouds of gas which are known to be wandering about our galaxy. Fermi's theory works very well for protons, and it can even be adjusted, without artificiality, to give the right distribution of energies. Unfortunately, as Fermi pointed out himself, it breaks down completely for the heavy primaries. Because of their high charge, the heavy primaries lose energy at a rate faster than they acquire it – and they never get going!

The situation today is that there is no satisfactory picture of the origin of the cosmic rays. Fermi's is the most plausible

suggestion, and this falls down on the heavy primaries. Of the other theories, some are *a priori* absurd, and the remainder are only capable of accelerating particles up to about  $10^{10}$  electron volts, which is too low by a factor of  $10^7$  at least.

#### DATING THE WORLD USING COSMIC RAYS

Frequently the question is asked, 'What use are cosmic rays?' By usefulness the questioner means usually the conversion of their inflowing energy into some controllable form of power, for example, electrical power, or making some weapon more lethal than the last. It is safe to state quite categorically that all such applications of the cosmic radiation are quite out of the question, because there simply is not enough power available. The number of particles falling on a square centimetre is known, and the average energy of the particles is known, and hence multiplying these two figures together we get the flow of energy, or the power available. The result depends on the latitude, because the earth's magnetic field cuts off the low-energy particles to an extent which varies from the poles to the equator. For the vicinity of London, if we could collect together all the cosmic ray energy falling on a square kilometre, and convert it to a usable form, we should get an output of 26 watts, just enough to light a rather feeble electric light bulb! The flow of cosmic ray energy is just about the same as the energy-flow in starlight, and the idea of harnessing it is just about as hopeless.

The main use to which the cosmic rays have been put is in collecting useful data about atomic nuclei, especially under conditions of high-energy bombardment. In this way, for example, nearly all that we know concerning mesons has been discovered in cosmic rays.

One interesting sideline from the study of the disintegrations produced by cosmic rays has been noted lately by Fred Singer of the U.S. London Embassy, and promises to throw new light on the question of the age of the earth. The ages of the oldest rocks, and of meteors, have been determined by measuring the amount of helium they contain. To obtain such estimates, it has been assumed that the helium in the rocks results from the dis-

integration of radioactive elements, which emit alpha-particles or helium nuclei. From the radioactive content of the rocks, and knowing the rate at which alpha-particles are emitted, it was possible to work out how long it must have taken for the observed amounts of helium to accumulate. Times of the order of a thousand million years are usually obtained by this method, but sometimes widely varying results are found.

The cosmic rays also provide a possible source of alpha-particles in the interior of rocks. There are alpha-particles in the primary beam, and some of these will be simply slowed down and brought to rest, and will be indistinguishable from the alpha-particles from radioactive disintegrations. There is another source in the heavy particles which break up on collision into several alpha-particles (Inset 28). Finally the target nuclei, when struck by cosmic rays of any type, emit a mixture of protons, alpha-particles and other particles. The contribution of alpha-particles from this last source is estimated to be the greatest. The problem thus arises of distinguishing between alpha-particles of radioactive origin and those from cosmic rays, and thus correcting the age-estimates, which so far have ignored the cosmic contribution. Singer has pointed out that, whereas the radioactive alpha-particles are all helium nuclei of mass 4, the helium contributed by cosmic rays consists of a mixture of masses 3 and 4. He has determined the relative amounts of these two isotopes in the cosmic helium; he finds the ratio of helium-3 to helium-4 to be 0.3. Then, in order to separate the cosmic component from the total helium found in a meteorite, it is only necessary to determine separately the amounts of the two isotopes present. The helium of mass 3 is all of cosmic origin, and from this the amount of helium-4 of cosmic origin can be calculated. This must then be subtracted from the total amount of helium-4 present to get the amount which is of radioactive origin. This idea has been tested out recently by Professor F. A. Paneth at Durham. He finds that more consistent age-estimates are obtained on the basis of Singer's suggestion that allowance should be made for the effects of the cosmic radiation.

## BALLOONING FOR RESEARCH

A. J. HERZ AND R. M. TENNENT

THERE are today but few opportunities of record-breaking that do not involve risk to life or limb, but there is one exception, the flying of high-altitude balloons. The balloons are fitted with automatic recording instruments and are used to explore the outer layers of the earth's atmosphere and the conditions which prevail there. In the early days the balloons used for scientific purposes were manned by observers who took readings of temperature and pressure as the balloon rose. Consequently the balloons had to be very large to lift so heavy a load, and great altitudes were not possible; this limited their usefulness, though it was, perhaps, fortunate for the observer. Pilotless balloons were first suggested in 1892 as a means of making scientific observations in the atmosphere, and in this article we shall describe some of the work which has been going on for a number of years in different parts of the world, and which is resulting in the development of what began as a Bank Holiday spectacle into a useful, if temperamental, tool for serious research. It is this apparatus which enables scientists to break records, and it is comforting to reflect that, when making a new altitude record, it is only the balloons that risk their skins.

There are three main fields of research today in which instruments have to be carried into the upper atmosphere. The first of these is meteorology, where daily information on the weather conditions at high altitudes has become increasingly important. Jet-powered aircraft now cruise at heights of 40,000 feet or more above the ground, and reliable weather forecasts are therefore needed for high altitudes. To obtain the necessary information, small balloons carrying a so-called radio-sonde are released several times a day from a number of meteorological stations in this country and abroad, and also from 'weather ships' out at

sea. As the balloon rises, the pressure, temperature, and relative humidity of the air are transmitted back to the ground station by the radio-sonde attached to the balloon. At the same time the height and position of the balloon are plotted on the ground by radar. These data are correlated so that the wind speeds and weather conditions at different heights may be calculated. Altitudes of 60,000 feet are commonly obtained on these routine flights, but greater heights are possible under favourable conditions. The balloons rise at a speed in the neighbourhood of 1,000 feet per minute until they burst, after which the equipment comes down at about the same speed on a parachute.

The second line of research in which balloons are needed is concerned with the composition of the atmosphere. Here, samples of air have to be taken at known altitudes and conveyed safely to ground level. It is exceedingly difficult to devise apparatus which will do this satisfactorily, especially as the weight of the equipment is severely limited by the carrying power of the balloons used – a topic which will be discussed later.

Finally, there is cosmic-ray research, where the greatest heights attainable are required, and where, in addition, it is often imperative that the balloons should remain floating at the maximum altitude for several hours. As cosmic-ray research has, perhaps, given the greatest impetus yet to the development of high-altitude balloon techniques, we shall discuss balloon-flying with special regard to that branch of modern physics. It should be understood, however, that the methods and techniques discussed are applicable also in other branches of high-altitude research.

Let us first consider the special nature of cosmic-ray physics and the data required by the scientist concerned with it. As may be recalled from the preceding article by E. P. George, cosmic rays are particles, atomic nuclei, which come to the earth from somewhere in space. When these particles reach the earth's atmosphere, they collide with the atoms in it, and in such collisions the incident cosmic particle and the target nucleus are both destroyed or severely damaged. To study the 'primary radiation', it is therefore necessary to carry equipment into the

upper atmosphere by balloons – and that to as great an altitude as possible.

An additional reason for experiments at great heights lies in the uncertain nature of the low-energy component of the primary radiation, which is not travelling fast enough to penetrate very far into the atmosphere. Because of magnetic cut-off\* these low-energy particles can reach the earth only near the magnetic poles, and it is therefore of importance to develop apparatus that is easily transportable so that flights can be made at different geomagnetic latitudes.

Since the number of primary particles passing through recording apparatus per second is small, a special technique is necessary in order to maintain cosmic ray apparatus at great heights for periods of several hours or more. This is especially so when the photographic-emulsion method is used: unless the plates have been exposed for more than about one or two hours at altitudes above 80,000 feet, the results would not justify the time taken in searching the plates for tracks caused by the primary radiation. In order to keep the plates relatively clear from tracks and nuclear disintegrations produced at lower altitudes, the balloon must rise to its maximum height quickly, float for several hours at this height and then either release the equipment, which returns to earth on a parachute, or descend to the earth with it (see Fig. 1).

Before describing the details of the construction of the balloons, and their use, we shall try to explain the principles on which the methods are based. A balloon is essentially a body of which the average density is less than that of the surrounding air, and so it rises upwards to the less dense upper atmosphere until it reaches such a height that the average density of the balloon assembly, the ratio of its weight to its volume, is equal to the density of the air around it. The calculation of the height to which a balloon will rise is based on Archimedes' principle and is arrived at by consideration of densities which are afterwards translated into heights by means of tables.

Now let us consider the two main types of balloons that are

\*See preceding article, p. 36.

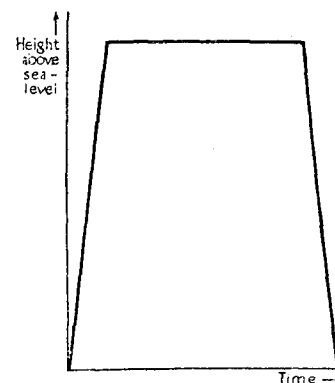


Fig. 1. Ideal flight-curve for cosmic-ray balloon.

available to modern physicists. They are the open-necked, in-extensible balloons, and the closed extensible balloons.

The open-necked balloons are of the same type as the well-known passenger-carrying balloons whose construction has hardly changed since Professor Charles made his first ascent from Paris in 1783. They consist of an envelope in the shape of an inverted pear, filled with hydrogen to such an extent that they will rise at a predetermined rate, but the amount of gas put in by no means fills the balloon envelope (see Inset 30). As the balloon rises, the pressure decreases both outside and inside the envelope, and so the gas inside expands, the force lifting the balloon remaining constant. Owing to the decreased air resistance the rate of rise may increase slightly as great heights are reached. Eventually the balloon can grow no larger without stretching and the gas starts escaping through the open neck. The rate of ascent decreases and the balloon can rise only until its average density is no longer less than that of the surrounding atmosphere. We should thus expect the flight curve of an open-necked balloon to look something like Fig. 2. Actually, owing to slight effusion of gas through the neck and diffusion through the envelope, the balloon will drop very slowly after reaching its

maximum altitude unless the load is slowly reduced by dropping ballast. Note that but for the loss of gas the balloon would not return to earth of its own accord.

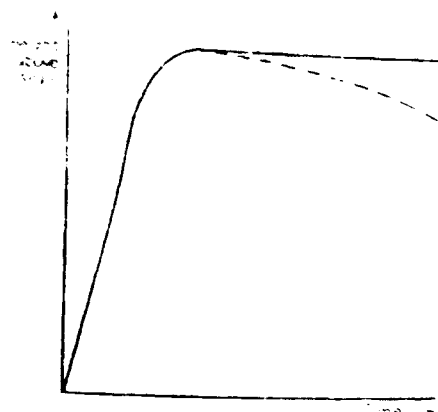


Fig. 2. Flight-curve of open-necked balloon.

The closed extensible balloon, on the other hand, consists of a sealed expansible envelope (usually rubber) containing hydrogen and is nothing more than a larger version of a child's toy balloon. There being no opening through which the gas can escape, it exerts a force on the balloon fabric which, consequently, expands. Thus the lift remains approximately constant, and the balloon rises steadily until the fabric can expand no more and the balloon bursts. We see, then, that a closed balloon will give a flight curve similar to that shown in Fig. 3. Unlike the open-necked balloon, this type is only too efficient in returning the apparatus to the earth.

The volume of an open-necked balloon is proportional to the cube of its diameter ( $d^3$ ), while the weight is proportional to  $d^2$ . It is therefore of advantage to make the balloons as large as possible, for then the density of the balloons is least, and the attainable height greatest. The height attainable by a closed balloon is

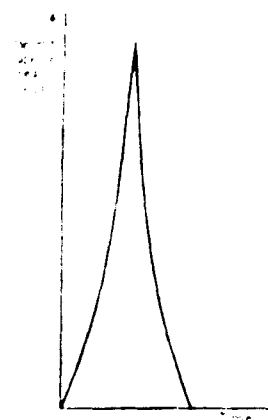


Fig. 3. Flight-curve of closed extensible balloon.

critically dependent, not only on its size, but also on the amount of gas put into it, and this in turn is governed by the load it has to carry. The greater the load, the more the balloon must be filled in order to make it rise at a convenient rate, and the sooner the gas in it will have expanded to the bursting volume of the balloon. Generally, large closed balloons are capable of carrying *light* loads to greater heights than open-necked balloons, but this advantage is offset in some experiments by their inability to float at the maximum altitude.

We shall now explain some of the finer points of the balloon techniques, and how their relative merits work out in practice.

#### OPEN-NECKED OR CONSTANT-VOLUME BALLOONS

As already mentioned, these balloons are a development of the kind used for carrying passengers. If great heights are to be reached, the balloon itself must be made as light as is consistent with strength, and its shape must be made such that excessive stresses do not occur in any part of the envelope. Much experimental work was done for many years on these questions,

especially in the U.S.A., where experimental balloons made from cellophane were tried out in the 1930s. These experiments, however, were not very successful and constant-volume balloons did not come into their own until the advent of modern plastic materials which are light, very strong, and nearly impermeable to gas. Successive sheets of material can also be joined together by 'ironing', which makes it possible to fabricate a large balloon comparatively quickly.

In the United States the development of large, plastic, open-necked balloons was greatly assisted by the military authorities through their project 'Skyhook'. Skyhook balloons are now produced in quite large quantities, and many are flown by the U.S. authorities in investigations of the upper atmosphere. The organization flying these balloons also makes flights for cosmic-ray physicists in the United States who thus have at their disposal an expert team with all the available facilities for making successful flights. Alternatively, the facilities of the balloon manufacturers are at the disposal of research workers in the United States. The proportion of balloons failing is still quite high, but this is not so serious because the apparatus is simply picked up and flown again. Skyhooks of many sizes are available, the largest being capable of reaching altitudes of up to about 105,000 feet with a total load of the order of 50 pounds weight.

In Britain, great progress in the development of constant-volume, open-necked balloons has been made in a comparatively short time by the team of cosmic-ray physicists working under the direction of Professor C. F. Powell at Bristol University. Their balloons, which are made at the University from transparent plastic sheet, now seem to be quite comparable in performance with the American Skyhooks – a remarkable achievement if one considers that they were developed from scratch within a few years by only a small group of enthusiasts.

The Bristol-type balloons, like the Skyhooks, are pear-shaped, and the largest of them are about 100 feet high when inflated, giving a ceiling altitude somewhat less than 100,000 feet. Smaller ones are rather more reliable in their behaviour, and they are

used when a lower ceiling altitude is permissible. The troubles which beset the flying of these balloons – or have done so in the past – are legion, so only a few of the more serious ones can be mentioned here to give an idea of the difficulties which have to be overcome. To start with, the neck of an open-necked balloon must be open, otherwise the balloon will burst as soon as the envelope has become filled out and the pressure risen sufficiently. This sounds rather trivial, but after many failures it was found necessary to make a 'cage' around the neck to prevent it from becoming entangled or twisted during the ascent. Another source of trouble is that gas is lost continuously through the neck and also by diffusion through the envelope. This means that the balloon will begin to descend as soon as it has reached its maximum altitude. Ballast must therefore be dropped to make up for the loss of gas. Mechanisms which will do this reliably under the conditions encountered in the stratosphere are difficult to construct. Then, when a level flight has been achieved, the apparatus must return to the ground after a known period. For this purpose, clock-operated release mechanisms are needed, and these, too, tend to be most unreliable in the stratosphere. The best kind so far seems to be one where a time-switch passes a current through a wire which becomes hot and cuts through the nylon rope holding the apparatus. In Inset 30 one of Bristol University's 50-foot balloons can be seen just after being launched. The cage holding the neck open is clearly visible; below it there is the release mechanism, the parachute, the radar reflector (see below), and, finally, the first of a string of boxes containing apparatus to be exposed to the cosmic rays.

In view of the great size of these balloons, the weather must be extremely calm when they are launched; they are therefore usually sent up at early dawn when the ground winds are least. It is also important that the winds in the upper air be suitable, for the balloon must not drift in such a direction that it will drop its apparatus into the sea or into some other place where recovery is difficult or unlikely. This last rule can, of course, be relaxed when the data required are transmitted back to the ground station during the flight, as, for example, in experiments

in which counters are used to detect the radiation. In that case, recovery may, however, be desirable for economic reasons.

Of the flights launched by Bristol University, about two in three are successful from the ballooning point of view, that is a level flight at the desired altitude is obtained. However, the apparatus is not always recovered, or, though recovered, it may have failed in some respect, so that the rate of successful *cosmic-ray* flights is only about one in three.

Apart from Professor Powell's group in Bristol, large plastic balloons have also been made by Professor von Friesen and his team at the University of Lund, Sweden. Their balloons are of a more cylindrical shape than the ones discussed so far, and they, too, have been found to give satisfactory flights.

#### CLOSED BALLOONS

The balloons which are normally used by the meteorological services all over the world are rubber ones (variously called 'sounding' or 'weather' balloons) of the closed extensible type. Since they are in regular production, the more common sizes of these balloons are readily obtainable and comparatively cheap: a point very much in their favour when one considers the limited budgets of most research laboratories. It is this type of balloon that we have been flying for several years at Imperial College, London.

As has already been explained, a closed balloon, with a load suspended from it, will continue to rise until it bursts. This conclusion is arrived at most simply by using the gas laws and assuming that the skin of the balloon has no influence apart from separating the gas inside the balloon from the air surrounding it. More accurate calculations show that the conclusion remains correct for all cases of practical importance. The behaviour of a closed extensible balloon depends, therefore, on its weight (which is part of the total load), and on the size at which it bursts.

A third factor which has an important influence on the behaviour of the balloons is their resistance to ozone and ultraviolet radiation. The higher a balloon rises in the atmosphere,

the more intense the ultraviolet rays of the sun become. In addition, there is a layer containing a high concentration of ozone in the upper atmosphere. Natural rubber deteriorates rather rapidly under the influence of these agents, so that the performance of balloons made from it is not as good as would be expected from calculations. On the other hand, neoprene, an artificial rubber, is very resistant to ozone attack, and its properties are said to improve when it is exposed to radiation. Thus, for flights during daylight, neoprene balloons are preferable to rubber ones. At night, the situation is reversed, probably because at very low temperatures neoprene loses its elasticity more rapidly than does natural rubber.

In Great Britain the balloon most used by the Meteorological Office is a natural-rubber one, of 500 grammes nominal weight, which will carry a load of six pounds to about 60,000 feet; 2,000-gramme balloons of more than 30 feet bursting diameter have also been used when information about conditions at very high altitudes was needed.

Unfortunately, neoprene balloons are not made in this country, and they have to be obtained from the United States. The two sizes mainly used for cosmic-ray work are a 700-gramme balloon of about 28 feet bursting diameter, and a 2,400-gramme balloon of 39 feet bursting diameter (Inset 31).

The purpose of giving these figures is to show one of the main advantages of the extensible type of balloon: it is very much lighter than the equivalent constant-volume plastic kind. For example, the balloon shown in Inset 30, which weighs about 13,000 grammes, has a volume of 400 cubic metres, while the bursting volume of a 2,400-gramme neoprene balloon is 875 cubic metres. Thus, with a small load, an extensible closed balloon can reach a higher altitude than the constant-volume balloon of the same maximum size. For example, a single 2,400-gramme neoprene balloon can carry several pounds of apparatus to an altitude of more than 120,000 feet before it bursts – an altitude quite inaccessible to even the largest constant-volume balloons in use at present. The second advantage of extensible balloons is their relatively small size at ground level. The largest

neoprene balloons are only about 12 feet in diameter when inflated ready for launching, and can be handled by one man even in a fairly strong wind.

As we have mentioned already, the disadvantage of the closed balloon lies in its inability to float at altitude, and as this excludes most cosmic-ray experiments, many workers have attempted to overcome this fault. The most successful method used so far has been to fly clusters of relatively small balloons instead of single large balloons. The reasoning on which this technique is based is the following. Suppose we have a large number of small balloons, all tied together and to the load. Then a certain number of them will provide a lift approximately equal to the load, whilst the additional lift of the remaining ones provides the force which makes the whole assembly rise. As the balloons ascend, some will burst, either because they are weaker than the average or because they were intentionally overfilled. As a result of these bursts, the total lift decreases, and the cluster and its load finally stop rising or begin to descend.

It will be seen that in this technique the lift is changed in steps, and whether equilibrium is reached at any stage is entirely a matter of chance, the chance increasing with the number of balloons used. A very efficient ballast-release could be used to improve matters if the balloons did indeed burst one at a time, but that has not been found to happen in practice. When the balloons are near their bursting point they become very sensitive to sudden shocks and, as a result, the bursting of one balloon will usually cause several others to burst. Other disadvantages of using large clusters are that they are expensive and that a large number of people is required to assist in the launching.

A variant of this approach has been tried in various places, Imperial College amongst them. In this method, the balloons are sent up in pairs, and an attempt is made to adjust the amount of gas in one of them so that it can just support the load at the altitude at which it is intended to float. The other balloon is used to provide additional lift during the ascent, and is removed in some way when the floating altitude has been reached. A series of experimental flights and calculations have shown, however,

that it is not possible to adjust the filling of a balloon so that it will *exactly* counterbalance a known load at a given altitude. Our knowledge of the factors involved is insufficient to allow us to make the necessary calculations with the accuracy required.

One by-product of the series of flights carried out by Imperial College at the Meteorological Office Station at Larkhill, Salisbury Plain, has been what may be the high-altitude record for the British Isles: in October 1951 an altitude of 124,500 feet above sea level was reached by a pair of neoprene balloons. A similar height has been reported only once before, also in 1951, by Dymond and Pullar of Edinburgh University, who used rubber balloons.

Other methods of using extensible balloons for flights at constant altitude are possible, and are being tried. Some of them look promising, though it is too early as yet to say anything definite.

#### TRACKING AND RECOVERING OF THE BALLOONS

We have seen already that in the case of balloon flights made for meteorological purposes, signals describing the condition of the air are transmitted to the ground station by the radio-sonde, while the position of the balloon is determined by radar. In cosmic-ray research, data about the radiation may be sent back in a similar way, but this does not concern us here; what is important from our point of view is a knowledge of the altitude of the apparatus at different times, and of the approximate location of the point at which the equipment landed.

There are two ways of measuring altitude, and slightly different quantities are measured in each. In the first method, the atmospheric pressure is measured directly either by a radio-sonde or by a recording instrument which can be read as soon as the equipment has been recovered. We therefore obtain a direct measure of the quantity of air above the balloon at any time, but the accuracy is limited by the kind of gauge available for measuring very low pressures at high altitudes.

Alternatively, the height of the balloon can be measured by radar. This is a very exact measurement, but in order to interpret

the cosmic-ray data one has to convert heights into atmospheric pressures, and the assumptions then made may reduce the accuracy quite considerably. Tracking by radar has, however, the great advantage of telling us where the equipment has landed, and this is most important if speedy recovery is required. In practice, therefore, one would like to have both a direct measurement of pressure and a radar record of the positions of the balloons.

If the equipment falls, as is desirable, into a fairly densely populated country district, it is usually found very soon. The finder then reads the label which asks him to notify the police and the University concerned and promises him a reward if he does so. This system works very well in Britain, where the people are both literate and honest, and the apparatus is usually recovered complete within a day of the flight. Alternatively, the balloon may be flown so that the equipment lands in the sea, and a search made in the area predicted by the radar operators, using a boat in radio communication with the ground station.

In conclusion we can say that great advances have been made in balloon-flying techniques in this century, and flights may be made now with reasonable chance of success. It is to be hoped that greater heights will be possible soon, and that from the apparatus carried by the balloons sufficient information will be obtained to enable us to trace the source of cosmic rays.

## THE VELOCITY OF ELECTROMAGNETIC WAVES: THE MOST ACCURATELY KNOWN CONSTANT

W. C. VAUGHAN

THE velocity  $c$  of electromagnetic waves in free space is probably the most important fundamental constant known to modern physics. Interest in its value was confined to the sphere of physical optics until the middle of the last century when the work of Faraday and Maxwell gave this constant a more general significance in the theory of electromagnetic radiation. This was, however, only a prelude to the immense importance it was later to gain as a consequence of Einstein's equation,

$$E = mc^2$$

which provides the link between mass and energy. Until about thirty years ago there had been no urgent practical demand for a highly accurate estimate of  $c$ , but nevertheless investigators had striven continuously to improve methods for its measurement from the first realization that light was propagated with finite velocity. By 1939 the accepted value of  $299,774 \pm 11$  kilometres per second probably placed  $c$  in the category of the most accurately known physical constant. At that time, a round figure of 300,000 kilometres per second was generally regarded as sufficiently accurate for most practical purposes. The refinements of the measuring technique were, in fact, believed to have attained an accuracy 20 times greater than was necessary. Few physicists could then have foreseen that under wartime conditions there would be either the demand or the opportunity for developing methods of even higher precision. In the next few years, however, with the rapid development of radio methods

of position-finding, it was soon realized that precise values of  $c$  were of more than academic interest, and that the belief in the accuracy of the accepted value might not after all be justified. There was thus a new interest in the still more accurate determination of  $c$  – an interest which has since been reinforced by the use of new methods of measurement.

The full account of endeavours to measure  $c$  is one of the most fascinating episodes in the history of physics: here only a brief synopsis can be given.

In the 5th century B.C., Empedocles of Agrigentum taught his pupils that light was not instantaneously propagated, but this proposition remained no more than a much debated conjecture for the next 2,000 years. Galileo seems to have been the first to have attempted to put it to a practical test, but as he had no idea of the immense velocity involved, his experiments were far too crude to lead to any positive conclusions. It was nevertheless Galileo's suggestion that observations of the eclipses of the satellites of Jupiter might be employed for the determination of longitude that led the Danish astronomer Olaus Römer to his discovery and explanation of their irregularities. In 1676 Römer suggested that the seasonal variation of 996 seconds which he had noticed in the recurrence of the eclipses was, in fact, the extra time required for the light to travel an additional distance equal to the diameter of the earth's orbit about the sun. Assuming this to be about 190 million miles, he gave the velocity of light as approximately 190 thousand miles per second.

Römer's announcement appears to have excited little interest amongst his contemporaries and, although his conclusion was accepted by Newton and Huyghens, it was rejected by others including Descartes. Complete confirmation came almost exactly fifty years later with Bradley's discovery and measurement of the phenomenon known as the 'aberration of light.'\*

\*The slight change in the apparent direction of the light from a star caused by the motion of the telescope (for this purpose that of the earth) while the light from the star is passing down it; the angular displacement varies from 0" to 20" according to conditions.

In 1849, Fizeau made the first direct measurement of  $c$  in terms of a terrestrial distance and obtained a value of 315,300 km. per second over a total path of about 17.2 km. His method depended on the rhythmic interruption of a light-beam by a rotating, toothed wheel, and the reflexion of the beam so as to retrace the same path until the wheel again confronted it. The importance of the Fizeau experiment, apart from its ingenuity, lies in the fact that it was such that the possible error could be estimated. For this reason it was the forerunner of a whole series of improved methods. Perhaps the chief interest which now attaches itself to the Fizeau method is that it is recognizable as an almost exact optical counterpart of the modern radar pulse methods of determining range.

About the same time that Fizeau was engaged on these researches, Wheatstone was using a rapidly rotating mirror to examine the nature of electric sparks. Acting on a suggestion of Arago, Fizeau and Foucault together succeeded in applying this principle to measuring the velocity of light by a method generally associated with the name of the latter. In 1862, Foucault gave 298,600 km. per second as the value of  $c$ . Because the path-length which he used was only about 20 metres, he was also able to confirm that the velocity of light in water was markedly less than in air.

Substantial improvements in the Foucault method were made by A. A. Michelson who, by employing a carefully designed optical system, was able to increase the path-length to 30 km. with a corresponding increase in accuracy. His earlier work in this field and his contributions to the technique of interferometry brought Michelson in 1907 the distinction of being the first American physicist to receive a Nobel Prize. During a period of nearly 50 years he systematically developed the Foucault method and in 1935 published a final value of 299,774  $\pm 11$  km. per second.

From 1927 onwards, W. C. Anderson had been concerned with modernizing Fizeau's method, and this work continued throughout the war. The main features of Anderson's method were the replacement of the mechanical means of interrupting

the light-beam by an electrical system, and an improved method of observation. The outgoing beam was in fact, modulated, i.e. its intensity was made to vary in a rhythmic manner by passing it through a Kerr cell. In its simplest form the latter consists of a pair of parallel metal plates immersed in a liquid such as nitrobenzene. This arrangement has the property of rotating the plane of polarization of a beam of polarized light passing between the plates, by an amount depending on the electrical potential difference applied between them. If the emergent beam is then passed through an analyser, such as a Nicol prism, which favours transmission of light vibrating in one particular plane, its intensity can be made to vary in sympathy with an alternating voltage applied to the cell. Anderson divided the modulated beam into two parts each of which was sent by different paths to a photoelectric cell. With this arrangement, it is possible to determine the velocity of propagation in terms of the path difference and the frequency of modulation. Using this system, Anderson arrived at a value 299,771 km. per second, for which he claimed an accuracy of about 1 part in 20,000. It will be noticed that this result is in close agreement with Michelson's value.

#### MORE RECENT MEASUREMENTS

Visible light occupies less than one octave of the spectrum of electromagnetic waves, which ranges from the extremely short gamma-rays emitted by radioactive substances to the very long waves used for radio communication. There is, of course, overwhelming experimental evidence to support Maxwell's theory which requires identical natures and the same free-space velocity for all radiations in this vast spectrum. Actual measurement of this velocity has however been possible only in one other region of the spectrum, namely the radio-frequency range. This includes some 16 octaves and would appear to offer attractive possibilities for accurate determinations of  $c$ . The wartime development of radar aids to navigation naturally concentrated attention on this part of the spectrum. By 1942, very precise systems of radar position-finding were coming into use, and

work with these began to throw some doubt on the accuracy of previously accepted values of  $c$ . For some time, small discrepancies were attributed to the refractive index of the atmosphere which, near the earth's surface and under the normal atmospheric conditions in temperate latitudes, has a value of about 1.00035. This reduces the velocity of propagation some 0.035 per cent below that *in vacuo*. It should be noted in passing that, except for Michelson's determination – which was made in a mile-long evacuated pipe – this correction has been applied in obtaining the other values quoted earlier in this article, and that they are therefore free-space estimates. For reasons which will become apparent, such corrections are more difficult to make under the conditions encountered in radar position-fixing; but by the end of the war it was considered that the observed discrepancies did not arise entirely from refraction in the atmosphere.

Since world-wide transmission had been possible for many years, it might be thought that earlier attempts to exploit radio methods for the precise determination of  $c$  could have been made. Certain serious difficulties however stood in the way of taking advantage of the very long paths which radio transmission made available. Firstly, the phenomenon of coastal refraction, discovered in the earliest radio direction-finding experiments, shows that the proximity and nature of the earth's surface has some effect on the velocity of propagation. Secondly, in long-distance transmission it is almost impossible to determine the exact path-length. Many of the newer radar pulse techniques were, however, suitable for the precise measurement of the time taken to send a signal over a path which could be accurately determined. In themselves, these systems offered the means of verifying the doubts which their use had engendered. The urge to use these new methods when peace returned was irresistible to many of the workers who had been responsible for their development, and their subsequent investigations led in turn to a more critical examination of the earlier optical methods. Post-war researches on the value of  $c$  therefore followed three distinct trends; firstly, direct measurement by radar methods;

secondly, improvement of Anderson's optical method; thirdly, indirect estimates from the properties of resonant cavities.

In 1947, R. A. Smith, E. Franklin, and F. B. Whiting described researches with a modified form of the G-H method of air navigation using wavelengths between 4 and 15 metres. In this system, signal pulses sent from a transmitter are returned by a responder, i.e. a receiver connected directly to a transmitter. The elements of the experiment are in some ways similar to those of Galileo's abortive attempt, and are indeed the radio counterpart of Fizeau's method. The transmitter is pulsed at precise intervals which are short enough to allow the train of outgoing and incoming pulses to be displayed on a cathode-ray tube. This display is used to compare the time interval between them with that between pulses derived from a quartz oscillator of accurately known frequency. In this series of experiments, the distance between transmitter and responder was about 120 km., and due allowance was made for the short time taken for the signal to pass through the equipment itself. The effect of passage over different types of terrain was examined by using a second responder at a slightly different distance, the path to the first lying entirely over the sea, and that to the second over undulating country. No significant differences were observed in the velocity over these two routes, and a mean velocity of  $299,695 \pm 5$  km. per second was claimed for the velocity of metre waves at or near sea level.

Whilst the foregoing investigations were progressing, F. E. Jones was making similar experiments with the range-measuring radar system known as 'Oboe'. A wavelength of about 9 centimetres was used and the velocity of propagation over paths of 50 km. and 67.5 km. was determined. These measurements gave a value  $299,687 \pm 25$  km. per second for the velocity of centimetre waves over the sea at sea-level. In a second series of experiments, the mean velocities for paths between the ground and an aircraft flying at different heights were obtained. These showed a slight increase in velocity up to a value of 299,750 km. per second when the aircraft was at 30,000 ft.

In 1948, E. Bergstrand, of the Geographical Survey Office,

Stockholm, prompted no doubt by the parallel experiments then taking place in the radio field, returned to Anderson's method with the idea that high-frequency light-signalling could be used for the measurement of distances. Bergstrand examined carefully the possible sources of error in Anderson's method, modified it, and, from experiments during 1949, published in 1950 a value of  $299,793.1 \pm 0.25$  km. per second. At the same time, he experimented on the measurement by this method of the distances between islands off the Norrland coast of Sweden and also between points in Lapland.

In his measurements of the velocity of electromagnetic waves, Bergstrand used total paths (out and return) of lengths about 18 km., 14 km., and 10 km., and a light-beam modulated at a frequency of 8.2 megacycles per second. His experimental arrangements show the highest degree of refinement, and his results have been almost generally accepted as at least as accurate as those obtained by any other method. One authority, Professor A. Karolus, after an exhaustive study of all the available evidence, remains unconvinced that Bergstrand's result is more accurate than the earlier final value given by Michelson, despite the confirmation given by Bergstrand's figure to the results derived from the most recent radio-resonance methods, to which we must now proceed.

In all the determinations which have so far been described, accuracy was sought by timing the passage of light or radio signals over paths of the greatest practicable length. In 1924, however, J. Mercier attempted indirect measurement of  $c$  over a distance of only a metre or two. The essence of his method was the determination of the wavelength of an electromagnetic wave of known frequency guided by a pair of parallel wires. If this conductor-system terminates in a conducting bridge, the outgoing wave is reflected at the termination and returns to the source. The system in fact carries two waves travelling in opposite directions, and if little energy is lost in their propagation they will be of almost equal amplitude. It is not difficult to arrange, by suitable adjustment of the length of the conductors that the reflected wave arrives back at the source exactly in

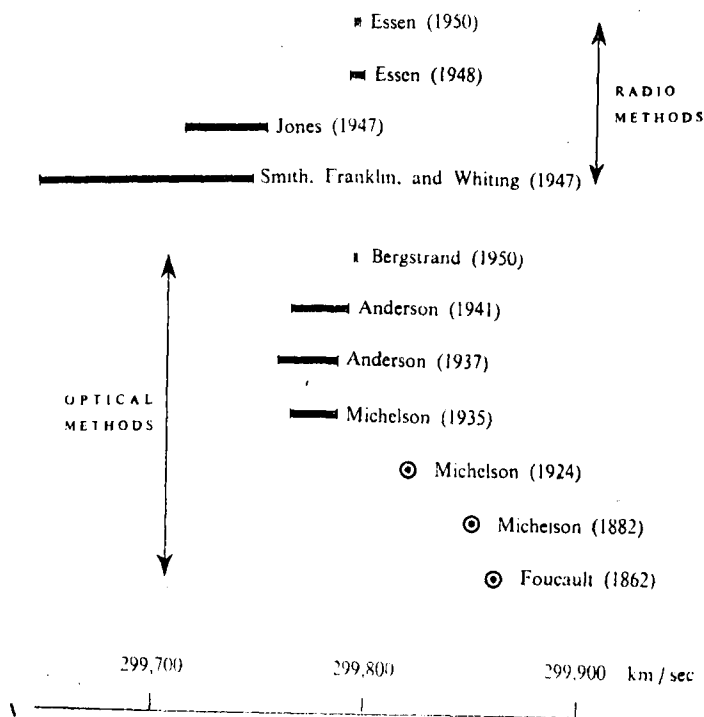


Fig. 1. The velocity of electromagnetic waves: representative determinations from 1862 onwards. The three earliest measurements are shown as points (i.e. with no indication of probable error); later measurements as lines, representing limits of error or probable error. Radio and optical methods are grouped together.

step with the outgoing wave. The condition for this is that the guiding system should be exactly an odd number of quarter-wavelengths. Under these circumstances the arrangement behaves as a resonator and is similar to a tuned circuit with a sharply defined resonant frequency. A short-circuited conductor system of this sort could therefore control the frequency of a

valve oscillator. In the simplest case, the frequency, which can be readily compared with a quartz standard, corresponds to a wavelength exactly four times the length of the conductor system. Now the wavelength is the distance travelled by the wave-front in the period of one vibration. Since the frequency is the number of vibrations per second, frequency multiplied by wavelength gives the distance the wave-front travels in one second. This is, of course, the velocity of propagation.

Mercier's method gives the velocity of the guided wave, and this can be shown to be less than the free-space value by an amount which depends on the energy lost from the system. Unfortunately it is not very easy to compute a reliable correction for this because account must be taken not only of the losses in the conductors themselves, but also of end-effects and of the energy radiated into the surrounding space. Mercier's method, although not ranking as one of high precision, was the forerunner of a series of determinations of the National Physical Laboratory in Great Britain and at Stanford University, California.

As might be expected, two parallel metal strips are more effective than a pair of wires in guiding an electromagnetic wave. A hollow metal tube, i.e. a waveguide, is better still since it eliminates all losses into the surrounding space. If one end of the hollow tube is closed to give total reflection, the waveguide counterpart of Mercier's resonant system is obtained. During the war much experience was gained in the use of resonant cavities of this nature. They are found to resonate at particularly sharply defined frequencies which depend only on their physical dimensions. A small resonator has an extremely high resonant frequency, and the electric currents which are the manifestations of the wave are, at such elevated frequencies, confined to the inner surfaces of the cavity and do not penetrate appreciably into the metal. Under these circumstances it is possible to deduce a very precise estimate of the free-space velocity from the resonant frequency of the cavity and its physical dimensions.

Following a series of measurements made with a completely enclosed evacuated cylinder which was silvered on its inner

surfaces to give the highest possible conductivity, L. Essen and A. C. Gordon-Smith in 1948 published the value of  $299,792 \pm 3$  km. per second for the free-space velocity of electromagnetic waves. In these experiments the cavity was excited by tiny probes at its resonant frequency of 3,000 megacycles per second which corresponds to a free-space wavelength of 10 cm. In 1950, Essen gave an even more precise estimate, namely  $299,792.5 \pm 1$  km. per second as the result of work with an even smaller cavity having a resonant frequency in the region of 10,000 megacycles per second (free-space wavelength 3 cm). The efforts to obtain this degree of precision are impressive. The dimensions of the resonator, which was a cylinder some 7 inches in length, were measured to within a hundred-thousandth part of an inch, and the frequency was determined to one part in a million. Simultaneously with this investigation, the late W. W. Hansen and K. Bol were carrying out almost identical work at Stanford University, and this yielded a result only slightly below that of Essen.

Figure 1 shows what may be regarded as the main landmarks in the survey which this article has attempted, and in conclusion it is perhaps worth while picking out some of the truly amazing features of the 300-year search which has elevated  $c$  to the category of the most accurately known physical constant. The earliest information came from measurements having the scale of the solar system; the most recent determinations were obtained with equipment which scarcely filled a laboratory table. Even before 1939,  $c$  was probably known more accurately than any other physical constant and it was scarcely to be expected that a second World War would create both the stimulus and provide the means for obtaining a still higher degree of precision. This post-war work supports the view that the error in the estimate 299,792 km. per second probably does not much exceed 0.001 per cent. Finally, could there be more striking confirmation of a common free-space velocity for all electromagnetic waves than that given in 1950 by the almost identical results of Essen and Bergstrand, the former using wavelengths almost one hundred thousand times those used by the latter?

## SOCIAL SCIENTISTS IN ACTION

ANTHONY H. RICHMOND

How does the social scientist set about studying a problem? In *Science News* 12, Dr Dennis Chapman has given a general picture of research in the social sciences. The present article will attempt a 'close-up' of social scientists in action on a particular problem, that of racial relations in Britain. It will begin with methods of approach, proceed to the research techniques used by social scientists, and end with a brief account of actual investigations on this particular problem.

If, with Professor Ginsberg, we define sociology as 'the study of Society, the whole web and tissue of human inter-action and inter-relations', it will be clear that this involves the collection of data from a wide variety of sources. Human behaviour is constantly changing and yet at the same time can only be understood in the light of what has happened in the past: historical data, therefore, are important to the sociologist. Only in the light of history, for example, can the formation of rigid 'stereotypes' about people of other classes, nationalities, and races, be properly understood. These fixed ideas about other people, often quite false or having only a small kernel of truth and at best misleading, are an important factor governing inter-group relations in general and racial relations in particular. The sociologist will also seek comparative material from the past and present of other societies as well as his own; hence anthropological studies are important. Psychology and psychiatry have an important contribution to make by throwing light on the complex workings of the human mind showing motives and conditioning factors in human behaviour. The sociologist may also make use of data provided by demographical studies of population changes and movements, as well as from special surveys and investigations of his own devising, for the collection of relevant social

and economic statistics, or the compiling of case-studies of individuals and community-studies of larger groups.

There is no one particular method of enquiry appropriate for the sociologist. He will choose the method of approach and the specialized techniques which are most suitable for the collection of the data necessary to answer the questions and test the specific hypotheses with which he is concerned. Dogmatic assertions that this or that method or technique is *par excellence* that of sociology have no place. Arguments may rage as to the relative importance of the statistical approach as against the case study or the historical methods; a proper understanding of human behaviour and relationships can be achieved only by a co-ordination of all these methods. The sociologist will start with a number of broad questions to which he wishes to find the answer and which he will break down into a number of specific and testable hypotheses. The degree of precision and certainty which he can achieve will vary with the problem at hand; in certain types of statistical study errors can be reduced to a minimum and a high level of prediction made possible, while in other cases generalizations will be more approximate or tentative. It is futile to argue as to whether sociology can be really scientific; the essential criterion is whether the research worker is clear, logical, and objective in his interpretation of data, recognizing its limitations and claiming no more for his results than is justified by the reliability of the material and the complexity of the situation.

The method of approach that will be adopted by the sociologist depends naturally upon the kind of questions with which he is concerned. The following are the principal questions which research workers studying racial relations in Britain have set out to answer. Later in this article, after some of the research techniques used by sociologists have been discussed, a brief account will be given of some of the actual investigations which have been conducted in an attempt to solve these problems:

- (1) What are the different racial groups in Britain, how did they come here, where do they live, how many are there, etc.?
- (2) What are the occupations of coloured people in Britain, and what is their social status in the community? To what extent

is there discrimination against them? Is there a colour bar in Britain?

(3) What has public opinion to say about coloured people? What do people in Britain know about the Colonies and Colonial people? Do they approve of coloured Colonial workers coming to Britain?

(4) What are the psychological origins of racial prejudice? Are some people more likely to be prejudiced than others?

(5) What sort of life do people lead in the various coloured communities in Britain? Are there any social or cultural differences which still persist, or is complete assimilation taking place?

(6) How do coloured people, especially immigrant Colonials, adjust themselves to life in Britain? How do they settle down in family life and at work?

#### TECHNIQUES OF RESEARCH

It is necessary to distinguish between the method of approach adopted by the social scientist and the research techniques which he may use. A particular method may require the use of one or several different techniques of enquiry. Mention will be made here of a few of the more important techniques which have actually been used in the study of racial relations.

#### Content Analysis

In addition to all the ordinary methods of historical research which may be used in the study of social change the technique of content analysis has been especially adopted by the sociologist for his particular purposes. It is essentially a device for achieving a greater degree of objectivity in the analysis of documentary evidence. It may be, for example, that the sociologist wishes to have some idea of the way in which public opinion has fluctuated over a period with regard to a racial minority group resident in a particular city. A crude index of opinion in this way might be devised by counting the number of favourable and unfavourable references in the press and plotting this ratio over a number of years. While recognizing the limitations of such a

device it might be possible to show interesting connexions between the fluctuations in this ratio and the levels of employment and unemployment in the city. Such evidence treated with caution could be important in substantiating hypotheses concerning the relation between economic insecurity and racial prejudice and discrimination.

Content analysis has been used also in the analysis of interview data for psychological purposes. Here again the proportion of favourable and unfavourable references could be used as a crude index of prejudice, where it is not possible or desirable to use detailed questionnaires.

#### *Random Sampling*

Of all statistical techniques this is one of the most valuable to the sociologist. It is rarely possible to obtain data from all the people concerned in a particular study, especially if this is on a nation-wide scale, yet it is often important to be able to make generalizations regarding the behaviour or attitudes of the members of one large group towards another. Merely to collect data in a haphazard way from the more immediate and easily contactable sources might lead to seriously biased results. The use of the random sample ensures that the sociologist derives his information from a complete cross-section of the population with which he is concerned. In this way his results can be stated accurately and with a known degree of possible sampling error. It is not necessary here to go into detail regarding sampling methods which have been described fully elsewhere. It must, however, be emphasized that great care has to be used in compiling interview schedules for use in sample surveys. The use of misleading questions, or the attempt to probe into complex issues which cannot reasonably be simplified into a codified answer, may lead to spurious results which are all the more dangerous because of their apparently 'scientific' form of presentation. It is better to have the tentatively formulated generalization of the investigator who has studied a limited number of cases intensively than the dogmatic assertion of the sociologist quoting dubious statistics.

#### *Control Groups*

An important safeguard against the abuse of statistical data is provided by the use of control groups. The ideal conditions of a laboratory experiment are rarely available to the social scientist. He has to make do with a situation in which the number of possible variables is enormous. The story of the sociologist who found a positive and significant correlation between the arrival of migrating storks and periodic fluctuations in the birth-rate has a moral in it for all social scientists. By using control groups the number of variables in the situation can be substantially reduced and more reliable results obtained. In studying the rents paid by coloured workers in a particular city, for example, it would be important to compare these with the rents of white workers in similar occupations, with families of the same size. If this is not done, results may be attributed to racial factors which should properly be explained in terms of economic circumstances, and *vice versa*. Similarly in studying the effects of exposure to mixed racial contacts in schools on the attitudes and behaviour of school children it would be important to compare these attitudes with those of children whose knowledge of coloured people was not so direct.

#### *Functional Penetration and Participant Observation*

In the first-hand study of human relationships the problem of the observer and the role he is to adopt looms large. This is particularly important because in many cases the very fact that an observer is present will itself influence the behaviour of the persons concerned, so that they will not act normally; they will say and do things which are calculated to please or to deceive, to impress or even to get rid of the observer. The sociologist recognizes this and therefore endeavours to make his observations from a vantage point which is least likely to affect the normal behaviour of the individuals or groups concerned. There are two principal ways in which he can do this. Firstly, he can adopt a role which will bring him into contact with the people he wishes to observe or question, but which will be accepted by them as

'natural' and not calling for any special reaction on their part. The choice of a role will obviously depend upon the nature of the information sought. Often a direct approach is possible, in which it is frankly admitted that some research is being conducted and the respondents' co-operation would be welcome in providing certain information about themselves or their opinions. In such a case the role will merely be that of an interviewer calling at the respondent's house or work-place. In other circumstances such a direct approach would not be successful. Some time might be necessary before sufficient *rapprochement* or confidence is built up between observer and observed and delicate matters can be broached. To achieve a 'functional penetration' of the group or groups they wish to study, sociologists have adopted many different roles. In the case of racial relations the role of welfare worker, adult education officer, club or community-centre leader, café or bar-tender, or even a 'down-and-out pub-crawler', can be useful in eliciting information and observing behaviour.

One of the difficulties about observations made through some form of 'functional penetration' is that the research worker is always limited to a greater or lesser degree by the role he adopts. He cannot go far outside that role without occasioning the suspicion and hostility of the people concerned. It is often of far greater value if the research worker can gain acceptance by the group *as one of themselves*. Secondly, therefore, there is the technique of 'participant observation'. In these circumstances the fact that a piece of research is being undertaken is normally not divulged to anyone and the role played involves a complete identification with the group concerned. Thus, in studying the reactions of white workers in a factory to coloured employees, the research worker would probably take a labouring or semi-skilled job in the factory and take lodgings in the neighbourhood where the coloured and white workers live. By actually participating himself in the situation and carefully recording his observations, as well as his own personal reactions, considerable insight will be gained. In studying the reactions of coloured workers towards the white, it is obvious that only another

coloured man or woman could undertake this type of 'participant observation'. The essence of this technique is the successful 'disguise' of the research worker. Such a technique may raise ethical problems, especially when dealing with situations that have serious economic, religious, or political implications. It is important, then, that the sociologist maintain a position of strict integrity, treating confidential information with the same caution as a doctor or lawyer. He should not allow himself to be involved as a partisan on one side or the other, unless the role adopted itself compels such action as part of the participation: as when a social scientist seeks membership of a subversive political party specifically in order to study its methods of organization and the human relationships within it.

#### *Guided Interview*

The interview, in its various forms, is a basic tool of social research. To the sociologist an interview may mean anything from the recording of casual remarks heard in the course of 'participant observation', or the contents of a conversation in a public-house, to the recording of replies to a detailed 'interview schedule' or questionnaire of twenty pages. The latter is known as the 'guided interview'; it is especially valuable because the replies to carefully formulated questions can be coded and transferred to punched cards for easy handling, so that the results of thousands of interviews can be computed with little difficulty. A pilot survey is usually conducted so that the interview schedule can be amended if it appears ambiguous or misleading in any way. Interviewers using this technique are trained to ask the questions precisely as worded in the schedule and to express no attitudes or opinions themselves which might influence the reply of the respondent. When large numbers of interviews are being handled, any tendency for the interviewer to introduce, consciously or unconsciously, a bias of his own creation, can usually be detected by comparing the results of his sample of interviews with those of other interviewers covering a similar section of the population. The guided interview can be used to elicit facts, opinions, attitudes, and various psycho-

logical factors relating to intelligence and personality. The essential criterion must always be that the information sought is reducible to a precise formula to which the respondent can indicate assent or dissent. The more complex forms of behaviour and attitudes are best studied by some less rigid method which permits the respondent a greater freedom to express himself.

#### *Unguided or 'Open-ended' Interview*

Behaviour, attitudes, and opinions can rarely be expressed by a simple formula without distorting the truth. Attitudes are often ambivalent or contradictory, and opinions are belied by action. To take a facetious example, a market surveyor may ask, 'Do you like ice-cream?', and offer the alternative replies 'Yes,' 'No,' or 'Indifferent'. So presented the question will mean little to a man whose reply might be that he likes ice-cream of a particular brand, strawberry flavoured, but that he never actually eats ice-cream nowadays because his doctor has forbidden it! While an ingenious questionnaire might be devised to meet these contingencies it is usually better, where the subject-matter is complex, to use the unguided interview. In this case there is no detailed interview-schedule, although the investigator may be armed with a number of questions designed to set the respondent's trend of thought in a particular direction. Once he or she is talking about the matters of interest to the research worker the respondent will be left to pursue the subject without interruption, encouraged now and then by appropriate remarks from the interviewer, who will be carefully noting all that is said. Sometimes it is possible to make actual notes in shorthand or longhand, and occasionally a simultaneous electric recording may be made of the interview. Often it is not even desirable to show that an interview is taking place, in which case the research worker must train himself to remember in detail all that has been said in its exact context and wording. As an interview of this kind may occupy an hour or more this is a difficult task, although with practice it is surprising what accuracy can be obtained, provided that an immediate record is made.

The advantage of the unguided interview technique is that it

provides a much greater insight into the character and personality of the respondent as well as revealing information that might never have come to light in the course of a formal guided interview. The unguided interview may be considered as something between the free association technique of the psychiatrist and the use of a questionnaire; it has some of the advantages and disadvantages of both methods.

#### *Cumulative Interview*

When the sociologist studies an individual or group of people he often needs to watch their behaviour in a number of different situations. A true picture of a person, his attitudes and his behaviour, can rarely be formed on the basis of one interview. People behave differently at home from at work, or when they have to shoulder responsibility from when they are acting as subordinates. In studying, for example, the adjustment of immigrant Negroes from the Colonies to life in Britain, it is necessary to observe their behaviour in a number of different social situations. The accumulation of observations and interviews collected over a period will give a much more accurate picture than could be obtained at any one time. This technique has been called the 'cumulative interview';\* it is used in making case studies of individuals or groups and enables a 'total picture' of the individual's character to be built up.

#### *Life History*

The technique of the cumulative interview enables a picture to be obtained of a person's character and behaviour at a particular time, but it is often important to have information about his or her past life, if a proper understanding of the present situation is to be obtained. Life histories were used by W. I. Thomas and F. Znaniecki in the study of the adjustment made by Polish peasants who had emigrated to America, with such valuable results that other sociologists and social psychologists

\*I am indebted to Dr Dennis Chapman for suggesting this term to describe a technique that I have used extensively in my own researches.

have adopted this method, especially in the study of racial relations and related problems.

It is obvious that a technique of this kind has distinct limitations. The memory of one's past life tends to be obscured and even distorted by later events. Wherever possible the sociologist must seek an independent check of all factual information contained in personal documents, whether life-histories or interviews. But, even where facts are inaccurate or misrepresented, personal documents can still be used to throw light on the personalities of the individuals concerned; in fact, the discrepancies themselves may provide a clue to the psychological interpretation of the data.

#### *Field Notes*

A research worker's field notes will be an invaluable aid in the reconstruction of situations. In addition to interviews conducted, field notes will contain detailed observations of events, together with a description of the circumstances at the time. A first-hand account of a racial disturbance, for example, would be invaluable data to a sociologist endeavouring to study racial relations; but more mundane, everyday, observations are also important. In fact, the anthropologists' maxim of noting everything, however small or irrelevant it may seem at the time, often pays dividends, especially at the early stages of research. Apparently insignificant details can often throw a flood of light upon a situation, when added to further information obtained later. In studies of racial relations physical appearance, language and accents (or a passing whiff of marijuana) may be important clues to the understanding of subsequent behaviour.

Occasionally, field notes can be supplemented by electrical recordings, photographs, or even films. These have the advantage of being permanent records, that can be studied at leisure, of events which might occupy only a few moments and of which the significance might otherwise be lost. Photographic records have been used, for instance, in observing the play groupings of coloured and white children. But such refined tools can never replace the research worker's own field notes.

#### STUDIES OF RACIAL RELATIONS IN BRITAIN

A short summary will now be given of some of the research projects undertaken in Great Britain and the conclusions reached from them. It is impossible in the space available to do justice to researches some of which have taken several years to complete; and, before forming any opinion as to the limitations and achievements of this type of social research, it is hoped that readers will examine the fuller reports listed at the end of this article.

#### *Historical Studies*

Historical studies of racial relations in Britain have sought to answer the first group of related questions set out on an earlier page. The principal racial groups to be found in Britain, in addition to the indigenous Caucasian peoples, include Negro and negroid peoples from West Africa and the West Indies; Arabs and East Africans, including Somalis; East Indians (from India, Pakistan and Malaya, etc.) and some Mongols, mainly British-born Chinese from Hong Kong and Malaya; together with the descendants born in Britain of each of these races, mainly by mixed marriages. Of these various groups by far the largest is the Negro and negroid group, although, relatively speaking, the proportion of coloured people to the total population is still very small. It is not possible to obtain exact figures, as nearly all are British subjects of whom no separate records are kept. Estimates have put the total coloured population of Britain in the region of 50 or 60 thousand, but this is not very reliable. The proportion is largest in the main port towns such as London, Cardiff, Liverpool, North and South Shields, and Glasgow, but there is a growing settlement in the Midlands, resulting from the search for employment.

The most important historical study of racial relations in this country is that by Dr K. L. Little, who confines himself to the Negroes. He traces the history of the Negro in Britain from the first coloured settlements, mainly by slaves in the seventeenth century, to the present day. He discusses the legal and parlia-

mentary struggle for the abolition of slavery and the slave trade, and shows how the period of Colonial expansion and other factors has influenced the development of English racial attitudes. Present settlements of Negroes have largely been the product of immigration during and after the two world wars, especially of seamen and ex-servicemen from the Colonies. Dr Little shows the difficulties that Negroes in Britain have faced in endeavouring to find housing and employment in the face of prejudice and discrimination against them in the community at large, and the effect of this on their attitude towards white people.

#### *Economic and Social Status*

Negroes and other coloured people in Britain occupy positions of social status ranging from that of an unemployed 'down and out' and ex-convict through the ranks of labourers, semi-skilled and skilled tradesmen, clerks and students, to doctors, lawyers, University professors, and public entertainers in the highest income groups. In this sense, therefore, it can be said that there is no colour bar in Britain. Yet this statement requires qualification if it is not to present a seriously biased view of the situation. Because the highest posts are open to coloured people, and because their right to service in restaurants and hotels can be protected in the highest courts of the land, it does not follow that they do not meet a good deal of prejudice and discrimination on the way. This is particularly true in the spheres of housing and employment.

One of the most important studies of the economic and social status of coloured people was conducted by Mr D. Caradog-Jones in Liverpool in 1938-9. He was greatly assisted by being able to use for control-group purposes (after appropriate adjustments for changes in price levels, etc.) the results of the economic and social survey of Merseyside which he had completed a year or two earlier. A sample of coloured families resident in Liverpool was taken, which, while not altogether a random one, did represent a fair cross-section of the coloured population. Information was obtained, by means of questionnaires and

guided interviews, regarding the size of family, the occupation of the head of the household, employment history, earnings and other income, the rent paid and the number of rooms occupied by the family. The field worker employed on the survey was himself a West Indian Negro who had been resident in the city for some twenty years; it was possible for him to obtain greater co-operation and ensure more accurate data than a white interviewer in the same circumstances.

The principal conclusions reached in this enquiry were that (1) 75 per cent of the males in the families interviewed were unemployed, which, despite widespread unemployment in the city at the time, represented a much higher rate of unemployment than among white men in similar occupations (mainly seamen); (2) coloured families tended to fall below the 'poverty line' as defined in the Social Survey of Merseyside, in greater proportion than white families; and (3) coloured people tended to pay a higher rent for similar accommodation compared with white families and this was one of the principal reasons for their depressed conditions of life.

These conclusions are supported by investigations by Dr Little in Cardiff. He emphasizes the part played by discrimination against coloured seamen during the years of depression before the second world war, in lowering standards of living among coloured families in that city. The fact that the Special Restrictions (Coloured Alien Seamen) Order of 1925 was often operated against any coloured seamen whatever his nationality meant that British Colonial Negroes were often unfairly discriminated against. More recent investigations made by the present writer in Liverpool suggest that, while the unemployment problem among Colonials and other coloured people is not nearly so serious as it was between the two wars, some discrimination does continue, both in employment at sea and on shore. Similarly, the housing problem, while serious for anyone in Britain today, is particularly bad for coloured men and women in Liverpool because prejudice against them in various parts of the city confines the majority to the so-called 'South End', where unscrupulous landlords (both coloured and white)

can exploit the situation to their own advantage. The situation in Liverpool appears to be repeated wherever there are large settlements of coloured families.

#### *Public Opinion Studies*

While many coloured people now in Britain were born there, and so have an essentially English, Scottish, or Welsh cultural background, the majority of coloured immigrants to Britain have come from the British Colonies. One of the most important factors governing racial attitudes in British people is their knowledge, or lack of it, about the Colonies. Extraordinary 'stereotypes' exist which picture every coloured person as coming from an essentially primitive culture, lacking in the most elementary provisions of western civilization. A surprisingly large number of apparently well-educated people seem to be ignorant of the tremendous advances that have been taking place in the Colonies during the last hundred years and are exceedingly surprised when they meet an educated and well-spoken Negro, with high professional or trade qualifications, often obtained in his own country.

A survey of public opinion on Colonial affairs was conducted in 1948 by the Social Survey of the Central Office of Information on behalf of the Colonial Office. A random sample was taken of the total adult population (over the age of 16 years) of England, Scotland, and Wales, from National Registration records. Altogether, nearly 2,000 people were interviewed, which enabled results to be compiled with a sampling error of not more than 3 or 4 per cent. After a pilot enquiry, a detailed interview schedule was drawn up in which 20 questions were asked, including such basic data as the age, sex, and occupational status of the respondent. The interviews were distributed throughout Britain, and the age and occupational distributions in the sample corresponded closely to the known distributions in the country as a whole.

This survey of public opinion on Colonial Affairs revealed that only 25 per cent of the population knew the difference between a Dominion and a Colony. After the difference had been

explained to them, 50 per cent could still not name correctly a single colony and only 18 per cent could name three or more. Seventy-one people (4 per cent of the sample) even named 'America' as one of our Colonies! In the light of this, it is not surprising that a high degree of ignorance was exhibited about the kind of people inhabiting the Colonies and the industrial and agricultural products obtained from them: 63 per cent could not name correctly any item of Colonial produce and where it came from. It was found that ignorance was greater in the older age groups than the younger, and was greatest among housewives and unskilled workers.

It would not be difficult to devise a national sample-survey of attitudes towards Colonials and other coloured people resident in Britain, on similar lines to the survey described above. In fact, an investigation of this kind has been conducted, although the results are not yet available for publication. The enquiry does, however, appear to bear out the impression of investigators using other methods of approach, namely that roughly a third of the population is strongly prejudiced against coloured people, another third has mixed feelings which are often unfavourable, and that even among the most favourably disposed there are some who would not go so far as to accept coloured people on a complete basis of equality in all circumstances. It can hardly be doubted that this antipathy is closely related to, though not fully explained by, the ignorance revealed in the 1948 survey of public opinion on colonial affairs.

#### *Racial Prejudice*

A great deal of research has been done recently in America on the psychological origins of prejudice, in which it has been shown that antipathetic attitudes towards other national, racial, or cultural groups are closely related to each other and are frequently found among people of a particular personality-type. Much of the American research needs to be re-examined in the light of conditions in Britain, but many of the conclusions reached have been substantiated in this country. One of the most valuable studies is an investigation by Dr J. Robb into anti-

semitism in Bethnal Green.\* The Jews are not strictly a racial group, but they are an ethnic or cultural group, and attitudes towards them appear to have much the same psychological origin as colour prejudice and other forms of racial antipathy. After collecting a great deal of historical and sociological data regarding the relationships between the Jewish and Gentile communities in East London, Robb took a random sample of the adult male non-Jewish population and interviewed them. An interesting technique was used in which the degree of anti-semitism was measured by the readiness with which stereotypes and antipathetic attitudes were expressed without direct openings being given by the interviewer. The interview was mainly concerned with housing and town-planning and the kind of neighbours that the respondent would prefer. If the person interviewed mentioned immediately a preference for non-Jews he was ranked high in the prejudice scale; at the other end of the scale where those who, even after direct questioning on the subject, still said that they had no objection to Jewish people as neighbours. Dr Robb then sought an opportunity for further interviews with the two extreme groups, the most prejudiced and the least, in the course of which a number of personality tests were given. Content analysis was used in the analysis of interviews. Dr Robb's principal conclusion (necessarily oversimplified here) was that anti-semitism, like other forms of prejudice, was a reaction against experiences of deprivation and insecurity from childhood to adult life, in which Jews merely became the objects against which the person vented his feelings of inferiority and frustration. Such attitudes are reinforced by irrational thinking and ignorance, but are not removed by reason and education alone: the roots of prejudice in emotional insecurity and anxiety must also be removed.

#### Community Studies

Community studies of coloured populations in Britain have been conducted in Cardiff, Liverpool, and Tyneside, and further

\*'Anti-Semitism in a Working Class Area'. *Unpublished Ph.D. thesis*. University of London, 1950.

studies are at present in progress in London, Liverpool, Manchester, and elsewhere. The first of these investigations was that conducted by Dr Little in Cardiff towards the end of the second world war. As a white man and a pioneer research worker in this field, Dr Little had a number of difficulties to face, not the least of which was the suspicion and hostility of the coloured inhabitants themselves towards any kind of 'prying' into their affairs. The original role that Little adopted to make contacts was that of a physical anthropologist making an anthropometric study of children of mixed marriages in one of the schools. He quickly found that this was not a position which was conducive to sympathetic attitude on the part of coloured people and various other means were used to gain acceptance in the community and a satisfactory *rapprochement* with his informants. Discussion groups of various kinds provided one useful *entrée*, although language problems sometimes created further difficulties in making contacts. A measure of identification with coloured people and sympathy with them regarding colour prejudice and discrimination was necessary before the barriers between white and coloured people could be broken down and their co-operation elicited. Once resistance had been broken down the coloured people of Cardiff, as elsewhere, were only too willing to talk about themselves and their experiences.

At the time of Dr Little's enquiry, the coloured populations of Cardiff consisted mainly of Arabs, West Africans, West Indians, Somalis, and East Indians, among whom the Arabs predominated. There were also the Cardiff-born descendants of these immigrants, mainly of marriages or liaisons with white women. Little estimated the total size of the community as not more than 7,000. The majority of the men were seamen and the community had grown mainly since the first world war. The social isolation of the coloured community from the white population of Cardiff was emphasized by the fact that the neighbourhood (Loudon Square) in which the coloured families had settled lay on the dockside and was actually cut off physically from the rest of the city by a canal and a railway junction. Colour prejudice in the city, combined with the limited opportunities for employment

during the depression, have left their marks on the behaviour and attitudes of the coloured population which are often as hostile towards the white population as the latter are to the coloured. Dr Little traces the social and economic implications of this situation together with its effects on family life and the position of the new generation of coloured people of mixed parentage that is growing up in the city.

The difficulties experienced by Dr Little in making proper contacts with his informants were faced also by research workers in Liverpool and elsewhere, although more recent investigations have had the benefit of his experiences. In the writer's own studies of the West Indians in Liverpool he had the advantage of access to a large amount of documentary material that was available in Colonial Office and Ministry of Labour records, particularly with regard to a group of West Indian Negro immigrants who came over during the war to work in war-factories. In addition, the existence of a flourishing community-centre for coloured people and their white friends in Liverpool, in which adult education classes could be conducted, greatly facilitated his task. No language difficulties were involved in relation to West Indians since English is, in any case, their native language. Greater problems faced Mr M. Broady in his 'pilot' study of the Chinese community in Liverpool.\* Broady had the advantage of speaking some Chinese, but unfortunately he had to learn a completely new dialect in order to make himself understood among those Chinese who did not have a good command of English. His ability to write Chinese characters, he believes, was of considerable assistance to him in establishing contacts. His principal role was that of a 'student teacher' working in a neighbouring school which had a number of children of Chinese descent. His desire to learn the Chinese language and to know more about Chinese habits and customs gained him acceptance into a number of Chinese families which enabled him to make a number of case-studies. The Chinese community

\*'The Chinese Family in Liverpool'. *Unpublished B.A. thesis*. University of Liverpool, 1952.

in Liverpool, unlike the Negro, has not grown very much in recent years and remains at the figure of about 500 adult males estimated in Caradog-Jones's *Social Survey of Merseyside* in 1934. It has always been culturally a more compact community than the Negro and more self-sufficient in many ways. While it is easier for Anglo-Chinese men and women to gain acceptance in the white community because of their light skins and attractive appearance, compared with the Anglo-Negroid person, the Chinese have not been assimilated into the white community to the same extent and Chinese customs, particularly with regard to family relations, tend to be retained.

Perhaps one of the most interesting studies, from the methodological point of view, is that of Dr S. Collins who is himself a West Indian Negro. Collins studied the coloured communities on Tyneside, that is the predominantly West Indian and West African community of South Shields and the Moslem community (including Arabs, Pakistanis, etc.) of North Shields. The fact that he is himself a coloured man gave Dr Collins considerable advantage over white investigators in gaining the acceptance of other coloured people and obtaining their co-operation in his enquiries. Even his position was not an entirely simple one, because in attempting to live as one of the local people in private lodgings or hostels for seamen and others, he aroused some suspicion because of his obvious educational advantages. Furthermore, as a West Indian he was not always completely accepted by Moslem peoples and he found it necessary to acquire a basic knowledge of Arabic in order to establish communication with some of the men.

Dr Collins's study brings out some interesting comparisons and contrasts between the two settlements. The Moslem community on the north side of the Tyne is more compact, consisting of a core of some sixty families in which white families are not found. They occupy new semi-detached houses of three to five rooms, constructed by the municipal authorities for the purpose of housing the coloured population. The rest of the Moslem population live in the old section of the town close to the main Moslem settlement, and occupy one- and two-roomed flats or

live in boarding houses. Two rooms are set aside for religious observances and there are a number of cafés and similar places of recreation. The Negro group on the south side of the river consists, by contrast, of some one hundred and fifty men and their English wives and children in three separate areas of the town. Fifteen families have new houses dispersed among the white settlement; one-sixth the size of the Moslem group, these coloured families are dispersed over three times the area. Both groups have been settled for some three generations in all, but there is an interesting distinction between the 'Old Timers' and the newcomers. The former have lived in the area the longest and have achieved a fair degree of adjustment to, though not assimilation into, the white community. The newcomers, on the other hand, are often despised by the 'Old Timers' because they do not know the kind of behaviour that is expected of them, and are liable to behave in an unruly way and court a bad name for the coloured population as a whole. It is interesting, however, to note that there have been no incidents of serious conflict between white and coloured groups in either North or South Shields, as has sometimes occurred in Cardiff and Liverpool.

Religion plays an important part in integrating the Moslem community despite the diverse nationalities represented. Language barriers still exist, but either English or Arabic tends to become the means of communication. In the Negro group in the south, West Indians usually have the advantage of speaking English and a better education than the Africans, but any attitude of superiority on their part is much resented by the Africans, who tend to take more pride in their tribal culture. Nevertheless, despite the sub-groups that exist, there is a high degree of cohesion in the coloured community as a whole which is largely the result of the reaction to colour prejudice found in the community; on the other hand the younger generation, growing up on Tyneside, tends to seek its recreation and employment outside the coloured community and tries to achieve acceptance in the white society; they are at best only partially successful and, in the Moslem community in particular, there

are strong forces acting within the family to keep them within the coloured community.

Dr Collins has some interesting light to throw upon the position of white women within the coloured communities. The majority of wives of coloured men in Britain are white but, owing to the prejudice against mixed marriages in this country, there is a definite tendency for coloured men to be forced into association with women of a somewhat lower social status than themselves. The professional man and the student often marry the clerk or typist, the skilled tradesman the labourer's daughter or factory hand, and the coloured labourer often, though not always, finds that only the near-prostitute can afford to face the stigma attached by public opinion to marrying or living with a coloured man. Dr Collins emphasizes the importance of the part played by the white wife of a coloured man in acting as an intermediary between him and white society. For example, in renting a house it is the wife who will conduct the negotiations, not revealing until afterwards that her husband is coloured, as a direct approach by him may lead to a refusal to let. Similarly, in relationships with official bodies such as the Ministry of Labour, the wife will often attend to assist her husband, especially where his knowledge of English is poor. The wives often acquire a working knowledge of their husband's language and in the Moslem community may become converts to Islam and bring their children up in this faith. The long absences from home of the coloured seamen mean that the wife often has greater authority and responsibility than would normally be the case. Her marriage to a coloured man has usually meant an estrangement from her own family, although a reconciliation sometimes takes place.

In general, it is clear from all the community studies that have been conducted in various cities, that the immigrant coloured men who have settled in this country for three or four generations have not become assimilated into the community at large, despite the fact that they have married into the white population. They have formed separate communities more or less isolated socially, if not physically, from the white population,

who have often resented the presence of coloured families in the neighbourhood. While children growing up have an essentially English, Scottish, or Welsh cultural background (according to where they live) they still do not feel that they are accepted as full citizens owing to the prejudice and discrimination which they experience.

#### *Social Adjustment*

It remains to ask how the coloured person, and particularly the immigrant Negro, reacts to his experiences of life in this country and adjusts himself to it. It cannot be denied that there are many who do not make a satisfactory adjustment at all. Sometimes this is due to personal instability which would probably show itself in any case, although it is clearly aggravated by the experiences of colour prejudice and the like which the coloured man must face. More often than not irresponsible behaviour is a direct result of the bitterness and hatred that discrimination breeds. It is unfortunate that crimes of violence, the peddling of drugs, gambling, and living off immoral earnings are the type of things which find their way, all too frequently, into the popular press. Fortunately they are not typical, and by far the large majority of coloured men and women live normal peaceful lives and resent this kind of behaviour among the small irresponsible element of coloured people as much as do whites. The conclusion drawn from the writer's own research into the adjustment of a group of West Indian Negro workers in Britain is that the factor likely to contribute most to the satisfactory adjustment of the Negro immigrant is the opportunity to gain status and prestige in some walk of life. Whether in his work, by his marriage, through success in sport such as cricket, or through adopting a leadership rôle within the coloured community itself, the Negro who can command the respect and esteem of other coloured and of white people is much more likely to make a satisfactory general adjustment to life in Great Britain.

One of the most important aspects of status and esteem in our society is the skill and ability shown by a man in his daily

work. In studying the adjustment of the West Indian Negro immigrants the writer was able to devise two scales, one of the skill exhibited by the man in his work, and the other of his general adjustment to life in this country. A very high degree of association was shown between the two. While it is difficult to say whether skill contributed to adjustment, or adjustment to skill, the association is significant if only from the point of view of selecting any further immigrants to this country, either for training or to assist in the manpower problem.

#### CONCLUSION

This brief survey of research methods and techniques used in the study of racial relations has attempted to give an impression of the way in which the social scientist attempts to analyse the immensely complex field of human relationships. Whether such investigations deserve to be called scientific, the reader must judge. The important thing would appear to be that data are collected in the most objective fashion possible and interpreted impartially and without exaggerated claims for the validity of theories and hypotheses, which, as in all scientific studies, must be subject to constant revision and refinement in the light of new evidence.

#### FURTHER READING

For historical background and community-studies in Cardiff and Tyneside, see:

Little, K. L. *Negroes in Britain*. London, Kegan Paul, 1948.

Collins, S. 'Social Processes Integrating Coloured People in Britain'. *British Journal of Sociology*. Vol. III, No. 1 (1952). 'Social Position of White and "Half-caste" Women in Coloured Groupings in Britain'. *American Sociological Review*, Vol. 16, No. 6 (1951).

For questions of occupational and social status, and adjustment in Liverpool, see:

Caradog Jones, D. *Economic Status of Coloured Families in the Port of Liverpool*. Liverpool, University Press, 1940.

Richmond, A. H. 'Economic Insecurity and Stereotypes as Factors in Colour Prejudice'. *Sociological Review*, Vol. XLII, No. 8 (1950). 'Relation Between Skill and Adjustment of a Group of West Indian Negroes in Britain'. *Occupational Psychology*, Vol. XXV, No. 3 (1951).

## FIELD CENTRES

GILBERT WHITE wrote from Selborne in Letter X to the Honourable Daines Barrington, dated 1 August 1771, about the acquiescence of 'faunists' in bare descriptions: '... because all that may be done at home in a man's study, but the investigation of the life and conversation of animals, is a concern of much more trouble and difficulty, and is not to be attained but by the active and inquisitive, and by those that reside much in the country.' That is, by field studies, which in his own case included botany, climatology, and much else. Four years earlier, in Letter X to Thomas Pennant, Esquire, he wrote that 'It has been my misfortune never to have had any neighbours whose studies have led them towards the pursuit of natural knowledge; so that for want of a companion to quicken my industry and sharpen my attention, I have made but slender progress from my childhood.' The extent of progress embodied in *The Natural History of Selborne* not only entitles White to be regarded as the founder of field studies in Britain, but is also a lasting illustration of the advantage of repeated observation within a limited area. Inset 1 is a view of Selborne from the 'long hanging wood called The Hanger': it was in this wood that he noted the ecological changes, as they would now be described, which followed from the clearing of old beech trees.

The Council for the Promotion of Field Studies was founded in 1943 to provide working facilities and expert guidance in the field sciences, especially through the establishment of study and research centres in suitable localities of Great Britain. A first encouragement to the enterprise was the change in emphasis in the biological sciences from description and classification to studies of plant and animal communities. Educationally, there was a need for the supplementing of school facilities at the sixth-form level; and, at the university level, for residential and laboratory accommodation in areas which offered more varied opportunities for field observation and research than exist near most

universities. In meteorology, there was a need for such training as could be applied to the making of local forecasts and in the planning of field records. In geology, the need for field facilities was an old one, if more diffuse.

The opportunities provided by the four centres so far established by the Council are illustrated in Inset 2-23. The centres are Flatford Mill, on the River Stour in Suffolk; Juniper Hall, Surrey, on the lower slopes of Box Hill above the Mole Valley; Malham Tarn, Yorkshire, the centre of one of the classical areas of British geology; and Dale Fort on the Pembrokeshire coast, of which the Skokholm Bird Observatory is a sub-centre. There are at all four centres accommodation for residential courses, libraries, and elementary laboratory facilities, and advanced laboratory facilities at Flatford Mill and Malham Tarn. Similar provision is being made at Juniper Hall, and is to be made also at Dale Fort, probably by 1954. For the training and guidance of students there is at each centre a technical staff of not less than two - Warden, and Assistant Warden or Field Assistant - of complementary interests. One-week courses in the different field sciences are provided at all centres, with variations in content and emphasis according to the opportunities available. There are plans, at present in abeyance, for the establishment of further field centres.

Flatford Mill (Constable's Mill) was the first centre to be opened (Inset 2-5). As a site for research, its most obvious advantage is that the mill sluices are the limit of tides on the river. There is thus an immediate variety of habitats. Changes in plant and animal communities have been caused by works, undertaken within the past two years, to prevent a salt-water invasion of the valley, which before was increasing, and are being studied as a long-term project. Woodland and meadow, estuarine mud-flats, and grazing marshes are other habitats, either in the immediate neighbourhood or within reasonable distance.

Juniper Hall Field Centre (Inset 6-7) was the next to be opened. The Mole, above which it lies, has been described 'as the type and model of all the Wealden Rivers'; the phenomena of

the Wealden drainage system can nowhere be better studied. Chalk woodlands, grass and scrub communities, marshland, and the bracken and heath which cover the Lower Greensand outcrop of the Leith Hill area are available habitats. Within the range of day excursions it is possible to examine typical surface topography and exposed sections of all the divisions of the Cretaceous System, the London Basin Eocene Series, and the southern Pliocene deposits:

The Warden, Mr G. E. Hutchings, has discussed the relationship between the kinds of research that can be done by students on short courses and the long-term interests of amateur and professional workers using the centre as a base:

For students attending short courses of instruction it is not a difficult matter to set problems of geographical or ecological interest; but the results are rarely reliable and serve only to suggest lines of more exacting research. It is . . . not fair to the students to use time during short visits for the routine work of large research projects. It is nevertheless interesting to record at least one example of a useful investigation carried out by a group of visiting students from the Botany Department of the University of Manchester. Their work was a vegetation reconnaissance of about three-quarters of a square mile of preserved chalk downland between Juniper Hall and the escarpment of Box Hill. The distribution of a large number of forest, scrub, and sward communities was mapped on the scale of 1/2,500, and various research problems . . . were proposed, mostly relating to succession. This and other studies . . . have suggested the desirability of experimenting . . . with a scheme of primary survey of vegetation and land-use, recorded on 6-inch scale maps.

Malham Tarn Field Centre (Inset 8-13) owes its main interest for geologists, and much of its interest for biologists, to the Craven Fault system which limits the plateau of North-West Yorkshire and dominates the whole area to the south of the Tarn. Inset 10 shows how obvious to the eye is the line of the Mid-Craven Fault, with Millstone Grit and Bowland Shales predominant to the south, and a great limestone plateau to the north. There is a corresponding contrast in vegetation, with opportunities for studying the ecology of moorlands, bogs,

mountains and limestone pavements. The 'Moss' (Inset 11), at the west end of the Tarn, has old raised bog, fen carr, reed swamp, and marsh, and offers a generation of work for botanists. In fresh-water biology, there are comparisons to be made between the fauna of the various streams and pools, some of which are acid, draining off peat, and others, including the Tarn, alkaline. There is also an interesting mixture of bird species. In meteorological training, the passage of 'fronts' is well shown by accompanying quick changes which are accentuated by altitude (1,300 ft). The holding of an archaeological course at the centre by Dr Arthur Raistrick led in 1950 to the discovery of an Iron Age musical instrument ('the Malham pipe').

Dale Fort Field Centre (Inset 14-18) offers many prospects in marine biology. Along the indented and omnidirectional coastline of western Pembrokeshire, there are wide variations in exposure, and most types of environment are to be found; compare, for example, Inset 16, 17, and 18, which show respectively an exposed cliff-beach, saltmarsh and tidal mud, and a shingle spit. In Dale Bay there is a sandy bottom, with opportunities for dredging and trawling from the Centre's boat. On land, there are cliff, woodland, and marsh communities.

Skokholm Bird Observatory (Inset 19-22) is administered from Dale Fort. As well as the normal trapping and ringing, a survey is in progress covering all forms of animal and plant life, and there is room for research on the distribution of littoral species in relation to exposure. Visits are paid also, but infrequently, to Grassholm Island (Inset 23).

A. W. H.

Short accounts of the Flatford Mill, Malham Tarn, Dale Fort and Juniper Hall Field Centres have been given in *Nature*, **167**, 712, 757, 801, and 886 respectively (1951).

Leaflets are available from the Council for the Promotion of Field Studies, c/o British Museum (Natural History), London, S.W.7. Acknowledgement is made to the authors of these publications and (especially) to Mr F. H. C. Butler, Director and Secretary of the Council.

## FIELD CENTRES



1. Gilbert White (1720-93) of Selborne can be regarded as the founder of field studies in Britain. The picture is a view of Selborne from The Hanger: 'The high part to the south-west consists of a vast hill of chalk, rising 300 feet above the village; and is divided into a sheep down, the high wood, and a long hanging wood called The Hanger'. (Photograph by Robert Atkinson.)



2. Flatford Mill Field Centre (Constable's Mill), Suffolk. Fresh water from the River Stour is controlled by sluice-gates, lock, and overflow channels beside the Mill.



3. Flatford Mill Field Centre: fresh-water biology on the Stour. Long-term ecological studies are in progress.



4. Flatford Mill Field Centre: saltmarsh at Dovercourt. *(The photographs on these and the following eight pages are by E. Dudley C. Jackson; copyright, Council for the Promotion of Field Studies.)*



5. Flatford Mill Field Centre: a small moated wood, willow holt, and 3-acre meadow provide variety of habitats.



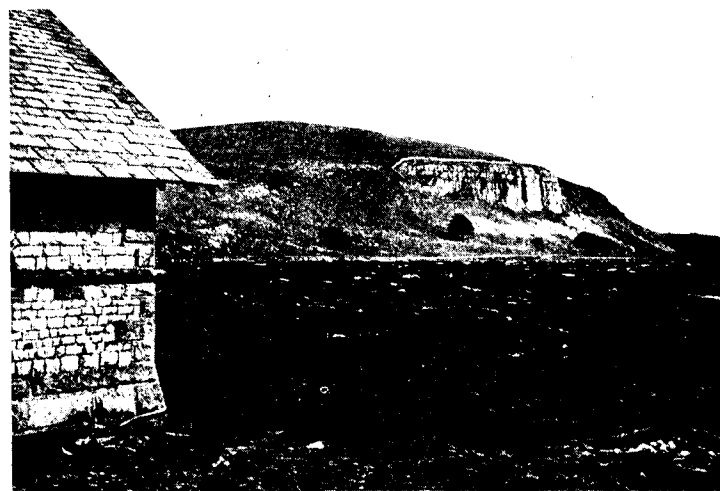
6. Juniper Hall Field Centre, Surrey, affords immediate access to chalk downland and marshland, and is near the Weald and the London basin.



7. Juniper Hall Field Centre: meteorology course. Other courses at university and VIth form levels are held in botany, entomology, geology, and geography.



8. Malham Tarn Field Centre, Yorkshire: The Tarn House, altitude about 1,300 ft, in the shelter of High Folds Scar.



9. Malham Tarn Field Centre: The Tarn from the north, showing Great Close Scar. The Tarn, which covers 153 acres, is a typical calcareous water with a rich rooted vegetation.



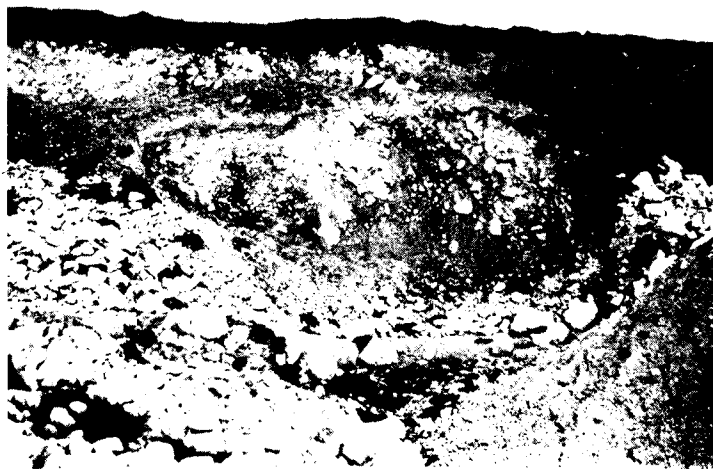
10. Malham Tarn Field Centre: the line of the Mid-Craven Fault, of pre-Namurian age, is marked by dip and trees. Millstone Grit and Bowland Shales to the south (*right*); limestone plateau to the north (*left*).



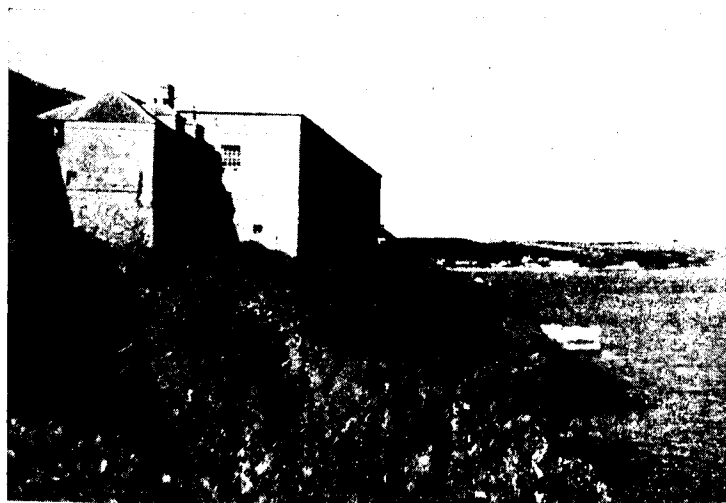
11. Malham Tarn Field Centre: heather and cotton-grass on surface of Tarn Moss at the west end of the Tarn.



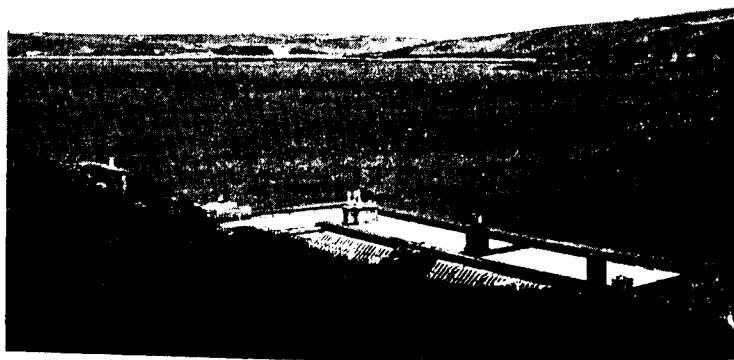
12. Malham Tarn Field Centre: head of dry valley (old river-course) between the Tarn and Malham Cove. The Tarn waters now plunge underground and join the Aire at a point well below the Cove.



13. Malham Tarn Field Centre: glacial drift, with limestone boulders. Evidence of glaciation is widely apparent in the area.



14. Dale Fort Field Centre, Pembrokeshire: Dale Fort, built into the Old Red Sandstone of the Dale Peninsula, with the village of Dale beyond. From the jetty below the boat leaves weekly for Skokholm (Inset 19-20).



15. Dale Fort Field Centre: Dale Roats, overlooking the Fort, towards the Gann estuary.



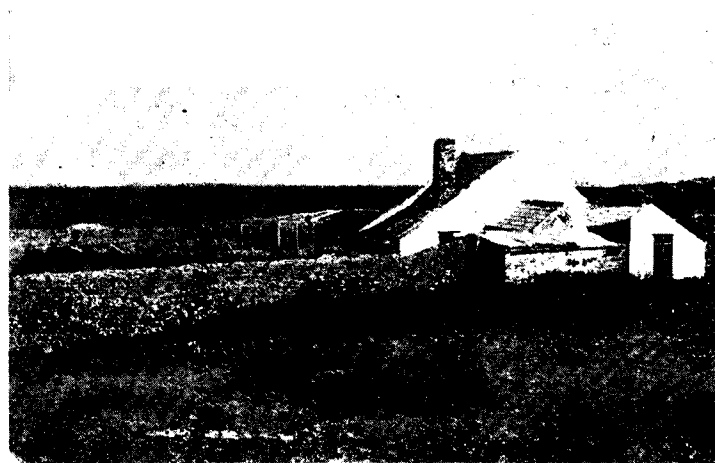
16. Dale Fort Field Centre: differential erosion of cliffs in Marloes Bay. Strata are tilted vertically, with Silurian beds well exposed nearby. The bay is open to Atlantic gales, and its fauna typically impoverished.



17. Dale Fort Field Centre: salt-marsh stretches of the Gann estuary. Here is exposed a broad expanse of muddy sand, well washed by the tide which, on retreating, exposes a succession of zones with characteristic and varied fauna.



18. Dale Fort Field Centre: remaining spit of shingle near the Gann estuary.



19. Skokholm Bird Observatory, Pembrokeshire, administered from Dale Fort Field Centre: the house and garden trap. Large colonies of Manx shearwaters, puffins, and gulls, and many pairs of oyster-catchers, wheat-eaters, and storm petrels are unusually accessible to students.



20. Skokholm Bird Observatory: Skokholm Island looking towards the Pembrokeshire mainland. Part of Heligoland trap in left foreground.



21. Skokholm Bird Observatory: puffins 'billing'. This and the two following photographs are reproduced by courtesy of P. J. Conder.



22 (left). Skokholm Bird Observatory: adult wheatear at nest.



23 (right). Grassholm Island, Pembrokeshire: adult and nestling gannet. Occasional visits from Dale Fort are made also to this island, which lies well out in the Atlantic.

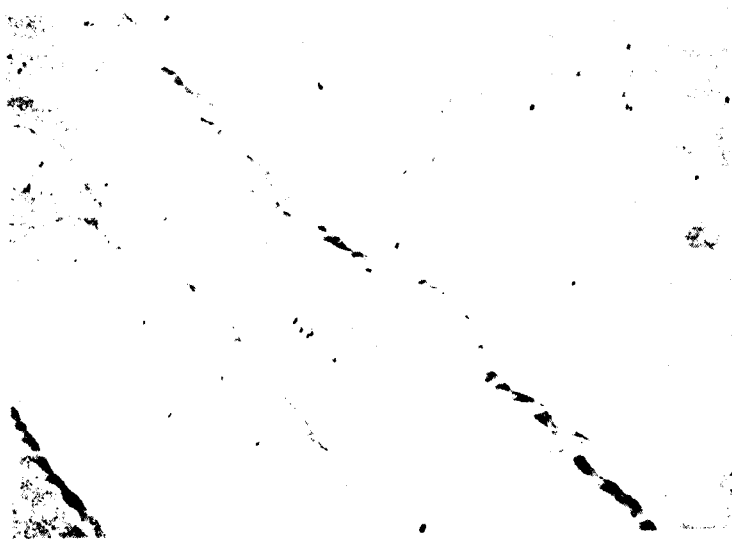
## DESERT RESEARCH



24. This and the following picture show the effect of over-grazing on semi-arid scrub steppe in South Australia: typical appearance, with little or no grazing.



25. Similar and neighbouring country to that shown above, but after severe over-grazing.

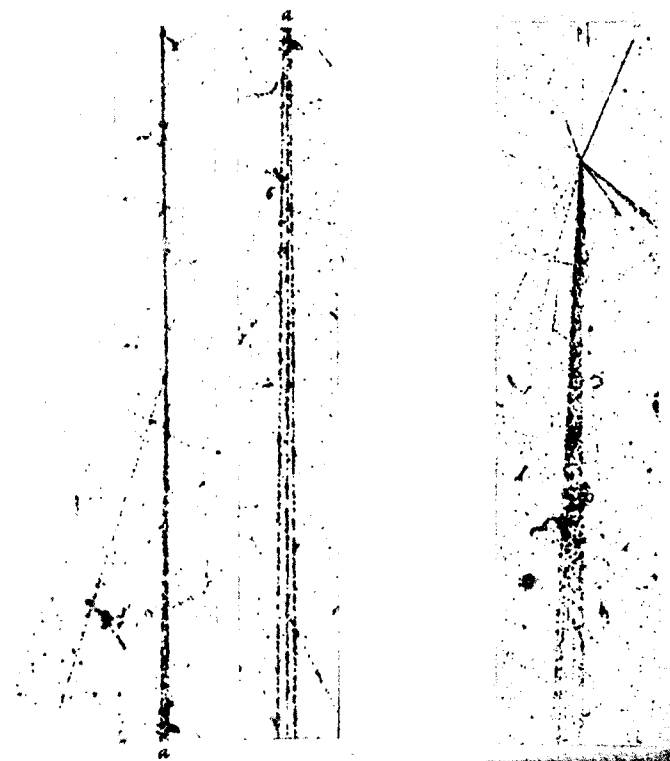


26. *Seif*-type dunes: sand-ridges on the Birdsville Track, near Cooper Creek, South Australia.



27. *Seif*-type dunes: the big sand-ridge at Andado, Northern Territory, Australia. (This and the previous photograph are reproduced from C. T. Madigan's *Crossing the Dead Heart* by permission of the publishers, Georgian House, Melbourne : London, Phoenix House.)

## COSMIC RADIATION



28 (left). Formation of jet of alpha-particles (helium nuclei). The picture has been cut into two halves which should be joined at *a*. A primary carbon nucleus collides with a proton in the photographic emulsion. The proton recoils at about  $25^\circ$  angle. The carbon nucleus breaks up into 3 alpha-particles. The opening angle of the alpha-particle cone enables the energy of the primary particle to be determined.

29 (right). Collision of an energetic primary proton with a nucleus in the photographic emulsion, resulting in a narrow jet of mesons, accompanied by slow fragments of the struck nucleus emitted at much wider angles. From the angle of the meson jet, the energy of the primary proton is estimated to be  $6.5 \times 10^{11}$  electron-volts. (This and the previous photograph are from the H. H. Wills Physical Laboratory, University of Bristol : they are reproduced by permission of the Editor and publishers of the *Philosophical Magazine*.)

## BALLOONING FOR RESEARCH



30 (left). Open-necked, constant-volume balloon, made from transparent plastic sheet at Bristol University. Length, about 50 ft; weight, 28 lb. Parachute, radar reflector and load are seen. Will carry a load of about 20-lb. weight to 75,000 ft.

31 (right). Closed balloon: 2,500-gramme neoprene balloon, of about 10 ft diameter at ground level; bursting diameter, about 39 ft. The radar reflector is of similar size to that in Inset 30. The load is out of the picture. (Imperial College.)

## THE SZILARD-CHALMERS EFFECT AND THE SEPARATION OF RADIOACTIVE ISOTOPES

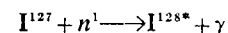
D. G. TUCK

THE use of radioactive indicators has provided chemists, biologists, metallurgists, and research workers in many other branches of science with experimental results which otherwise either could not have been obtained at all, or only with great difficulty. The pages of scientific journals contain many papers describing radioactive tracer experiments of various types; some interesting examples have been noted in *Science News* 2 (p. 114 onwards) and *Science News* 6 (pp. 130-4). In this article we shall be chiefly concerned with the chemists' point of view and the way in which some of the difficulties inherent in certain aspects of radio-chemical work have been overcome.

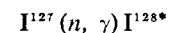
One of the most important criteria in judging the value of experimental data is their accuracy. In radioactive tracer work, the accuracy will depend on the accuracy of the measurements made with a Geiger-Müller counter, or some alternative form of counting apparatus. These are subject to what are termed random or statistical fluctuations, which arise from the atomic nature of matter. Such fluctuations are unavoidable, since the decay of a radioactive substance is itself random, the accurate values given for half-lives, decay constants, etc., being the average for a very large number of disintegrations. To give an example, a certain (long-lived) radioactive source may give 12,000 disintegrations in 2 hours, but in any one minute there might be 98, 100, 101, 99, 103, etc. It can be shown by mathematical processes, that if one counts a total of  $N$  disintegrations, then the error due to statistical distribution is  $\pm\sqrt{N}$ , so that the percentage error is  $\pm\sqrt{N}/N \times 100$ .

Obviously, if  $N$  is 100, the percentage error is 10 per cent; if  $N$  is 10,000, only 1 per cent, and if  $N$  is 1,000,000, the error falls to 0.1 per cent. Thus one of the most important points in radiochemical work is the necessity of using an amount of radioactive element sufficient to obtain quantitative results of reliable accuracy. In other words, one must always aim for a high specific activity – that is a high activity (and consequently large number of disintegrations) per unit weight of active element or compound, since it is desirable to carry out counting on as small an amount of substance as possible. In many cases, this can be achieved quite simply. For example, let us consider the extraction of thorium B (one of the natural radioactive isotopes of lead) from a solution of its related elements in the thorium series. It is not possible to separate thorium B by direct precipitation, since the solution will not contain a workable amount, but this can be easily overcome by adding some lead, say as lead nitrate; about 1 mgm will suffice. This will mix with the thorium B ions in solution, and precipitation of the lead ions, say as lead sulphate, or electrodeposition as lead dioxide will bring out also the radioactive thorium B. We have now a milligram of lead compound, which can be easily handled by the standard radiochemical micro-techniques; for example, dissolving it in nitric acid will give a solution of lead nitrate which can be used in tracer experiments. A similar type of treatment can obviously be applied in some cases to the separation of artificial radioactive elements from target materials after bombardment in the cyclotron or other accelerating machines.

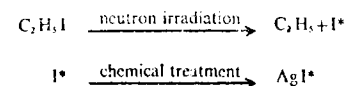
This type of treatment can clearly be applied only in those cases where the target and the radioactive element formed from it are chemically different. Unfortunately this prevents an easy separation of the products when the element produced is isotopic with the target; in other words, is chemically identical with it. This is the case in the type of nuclear reaction in which a neutron is absorbed by an atom of the target with almost simultaneous emission of a  $\gamma$ -ray. Such a reaction is described as an  $(n, \gamma)$  reaction. For example:



where the asterisk denotes that  $\text{I}^{128}$  is radioactive. The same process can be written more shortly:



This type of reaction is found particularly with slow neutrons, and all elements will form radioactive isotopes in this way. At first sight there is no method of obtaining the active isotope in any more concentrated a form than is found at the end of the neutron bombardment. However, in 1934, L. Szilard and T. A. Chalmers, two research workers in the Physics Department of St Bartholomew's Hospital, London, were able to report the successful application of a new principle to such systems. They studied the reaction set out above. But instead of using the element iodine as target, they used a compound, so that the velocity of the neutron might knock the (now) radioactive iodine atom out of the molecule: the separation, that is, was to be between chemically combined, inactive iodine and free radioactive iodine. If this is not merely to be a temporary effect, the compound chosen must be one which will not react or exchange with elementary iodine; in that case, the radioactive iodine should be obtained in a form chemically different from the target. Separation of the two then becomes a matter of chemical technique. For their first experiments Szilard and Chalmers used the organic compound  $\text{C}_2\text{H}_5\text{I}$  (ethyl iodide), which is insoluble in water, and neutrons from a radium-beryllium source†. After the irradiation a trace of inactive iodine was added as carrier, and by extraction with water, reduction and precipitation as silver iodide, the radioactive iodine was separated:



† This forms neutrons by the reaction,  $\text{Be}^9 (\gamma, n) 2\text{He}^4$ .

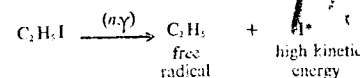
On measuring the activity of the silver iodide and of the target after extraction, it was found that 90 per cent of the activity had been successfully separated. The theory had been confirmed: the separation was possible.

Workers in other countries were quick to follow up these results. In 1935 an extensive report on the effect of slow neutron bombardment on elements in all parts of the periodic system was published by E. Fermi and his co-workers in Rome. They found two interesting examples of the type of effect discovered by Szilard and Chalmers. In one case, bombardment of sodium chlorate produced free radioactive chlorine, which was separated in the same way as iodine. Similarly, irradiation of the arsenic organic compound,  $(\text{CH}_3)_2\text{AsOOH}$  (cacodylic acid) produced radioactive arsenic, which was precipitated with hydrogen sulphide as arsenic sulphide. Many other similar separations have since been achieved with inorganic salts and complexes.

With such inorganic target materials, extraction of the radioactive isotope formed is generally a matter of straightforward chemistry (although more recent researches have brought to light some facts which are at present inexplicable). The experimental data on the separation of the halogens (chlorine, bromine, and iodine) from irradiated organic halides presents a much more bewildering array of difficulties in the way of obtaining a high yield of the radioactive element. A review of these facts shows that the presence of free halogen makes little or no difference to the amount of elemental radioactive halogen which can be extracted with water, but that the presence of aniline plus a small amount of acid causes a considerable increase in the yield. Dilution of the target with some solvent, such as alcohol, results in extremely high yields of the radioactive element, as does bombardment of the target as a vapour. On the other hand, the presence of compounds containing the hydroxyl ( $-\text{OH}$ ), carboxyl ( $-\text{COOH}$ ), amino ( $-\text{NH}_2$ ), and methoxy ( $-\text{OCH}_3$ ) groups causes the yield of the free radioactive element to fall, and, in fact these groups are found to exchange. Thus, if phenol ( $\text{C}_6\text{H}_5\text{OH}$ ) is mixed with a target of

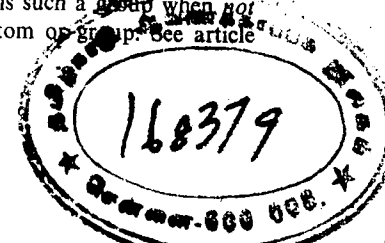
$\text{C}_2\text{H}_5\text{I}$ , much of the activity is found as  $\text{C}_6\text{H}_5\text{I}^*$ ; in some of these experiments between one-half and two-thirds of the activity could not be extracted with water.

A fairly comprehensive theory embracing these phenomena has been advanced by Prof. W. F. Libby of Chicago. In the first place, it had been clearly shown that the cause of removal of the radioactive atom from the target molecule was not the kinetic energy acquired from the impinging neutron, but the energy of recoil from the ejection of a  $\gamma$ -ray, which immediately follows neutron capture. This energy is proportional to the square of the  $\gamma$ -ray energy; in the case of the iodine atom it is about  $96 \times 10^6$  electron-volts (due to the emission of a  $\gamma$ -ray of 4.8 Mev.). The energy necessary to break the C-I bond is only 2.0 ev., so that every iodine atom which captures a neutron must break away from the molecule to form a free atom. Consequently, the formation of large quantities of  $\text{C}_2\text{H}_5\text{I}^*$  from the target of ethyl iodide is not due to failure of the C-I bond to break, but rather to processes taking place after this bond ruptures. Libby suggested that the radioactive iodine atom will acquire sufficient energy to separate it completely from the remaining free radical,† which subsequently forms a saturated molecule:



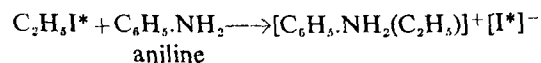
Because of its high kinetic energy, the only obstacle which can halt the radioactive iodine atom is an atom of similar size, atoms of smaller mass having little or no effect. Suppose such a collision takes place; the area can be imagined as being surrounded by a cage formed from the molecules in the imme-

† A radical is a group of atoms which occurs as part of a molecule and is transferred as a whole in a chemical reaction. A free radical (normally of very short free life) is such a group when not combined chemically with any further atom or group. See article by George Porter in *Science News* 19.



diate vicinity. The effect of the collision will be to transfer most of the kinetic energy to the stable iodine atom, which will then itself be removed from its parent molecule with a velocity much the same as that possessed by the radioactive atom previously. Because of the cage effect, the halted radioactive iodine atom and the free radical just formed will be retained, and will combine to form a molecule of radioactive ethyl iodide.

This theory readily leads to an explanation of the effect of aniline in giving high yields of elementary radioactive iodine. The newly formed ethyl iodide will possess considerable vibrational energy, and so the following reaction can take place:



The product of this reaction is a salt, known as a quaternary ammonium compound: the iodine it contains is in ionic form, and can readily be split off and separated by extraction with water. This salt-forming reaction is well known in organic chemistry, but requires energy for its completion and takes place normally only on heating. Thus the aniline does not react with the inactive target material, but will react with the energetic  $\text{C}_2\text{H}_5\text{I}^*$  molecule.

The dilution and vaporization factors can be easily understood on this basis. Dilution supplies a large number of light atoms and molecules which effectively reduce the energy of the radioactive atom by a large number of collisions, until its energy is so low that it does not possess sufficient to break any C-I bonds, and it will therefore come to rest as the element. Vaporization reduces the ability of the target to form reaction cages which will retain the atom and the free radical in the same vicinity after a bond-breaking collision, since the molecules have a much greater freedom of movement in the vapour state.

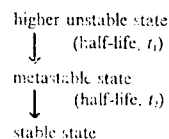
The exchange observed between the active halogen atom and the various groups ( $-\text{OH}$ ,  $-\text{COOH}$ , etc.) has been explained. Some radioactive iodine atoms will eventually lose a

proportion of their energy by non-bond-breaking collisions until they reach the point where collision with such a group will be such that the group will be removed from the molecule, and the free radical formed can react with the radioactive atom retained by the reaction cage. This fact has recently been used in what has been termed 'radio-synthesis'; by utilizing the high neutron flux inside the pile, compounds such as  $\text{CH}_2\text{I}\cdot\text{I}^*$  (methylene iodide),  $\text{C}_6\text{H}_5\text{I}^*$  (iodobenzene), and  $\text{CH}_3\text{Br}^*$  (methyl bromide) were obtained free from carrier. This type of synthesis obviously should be of very great value in tracer studies, especially in biological work, where dilution with inactive carrier is undesirable.

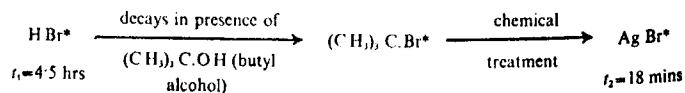
It is now recognized that the Szilard-Chalmers effect is only a part of the so-called 'chemistry of the hot atoms'. The name arises from the analogy between the high kinetic energy of atoms at high temperatures and the high kinetic energy imparted to radioactive atoms by recoil following emission of an  $\alpha$ -,  $\beta$ -, or  $\gamma$ -ray. In both cases normal chemical properties are modified by the high energy: the main difference lies in the comparative ease with which the effects of radioactive atoms can be followed because of their activity. Thus although the examples given have applied to ( $n, \gamma$ ) nuclear reactions, other reactions should also produce similar effects. One interesting example of this is the bombardment of boron trioxide with deuterons; the nuclear reaction is  $\text{B}_3\text{O}^0(d, n)\text{C}_6^{11}\text{I}^*$  so that deuteron capture is followed by neutron emission and formation of radioactive carbon. However, instead of forming elementary carbon, the activity is found in the form of a mixture of  $\text{C}^{11}\text{O}$  and  $\text{C}^{11}\text{O}_2$  due to the recoiling carbon atom taking with it one or two oxygen atoms from the  $\text{B}_2\text{O}_3$ . There it is clearly the hot carbon atom which can be compared with the hot iodine atom of the original Szilard-Chalmers reaction.

One very interesting use of the Szilard-Chalmers effect has been for the separation of nuclear isomers: nuclei, that is, which have the same charge and mass, but differ in their radioactive properties. Some radioactive elements have been shown to decay from an excited unstable state to a stable state in two

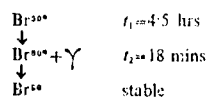
stages. It has been suggested that the intermediate stage is metastable, so that the overall decay can be represented as



It is not proposed to examine this theory further, but to consider briefly the method by which one pair of these isomers has been separated, and their separate half-lives measured. Bombardment of bromine with slow neutrons gives rise to two different radioactivities, with half-lives 4.5 hours and 18 minutes respectively. These were thought at one time to correspond with  $\text{Br}^{80}$  and  $\text{Br}^{82}$ . But when undoubtedly  $\text{Br}^{82}$  was prepared by the reaction,  $\text{Se}^{82} (d, 2n) \text{Br}^{82}$ , its half-life agreed with neither of these figures. The two half-lives are, in fact, those of the two isomers of  $\text{Br}^{80}$ , which have been separated by the method shown:



By introducing butyl alcohol, a molecule is made available with which the lower isomer can react when ejected in its 'hot' state by recoil following emission of a  $\gamma$ -ray from the longer lived isomer. The decay scheme is:



Even if this recoil energy is not sufficient to break the bond, the  $\text{HBr}^*$  molecule may become so excited as to cause rupture to take place immediately after gamma-ray emission. Other pairs of isomers separated by similar methods include those of  $\text{Te}^{127}$  and of  $\text{Te}^{129}$ .

It may seem from this brief review of an ever-widening subject that the theory and use of the Szilard-Chalmers reaction and related effects is completely understood. This is far from the truth in many cases, and much is being done and remains to be done. So far, however, considerable achievements have been secured and some very useful techniques have been added to the science of radiochemistry.

## REFERENCES

- Szilard, L., and Chalmers, T. A. *Nature*, **134**, 462 (1934).  
 Libby, W. F. *J. Am. Chem. Soc.*, **69**, 2523 (1947).  
 Fermi, E. *et al. Proc. Roy. Soc. 'A'*, **149**, 522 (1935).  
 For a general review see:  
 Maddock, A. G. *Research*, **3**, 557 (1949).

## RESEARCH REPORT

A. W. HASLETT

### CELL NUCLEI AND CELL PLASM

IN a note in *Science News* 19 (p. 77), reference was made to the development of the technique of micromanipulation through the work of Pierre de Fonbrune and Dr J. Commandon at the Institut Pasteur, and especially to their experiments on the removal from an amoeba of its cell nucleus and the later replacement of this by a nucleus from a different amoeba. The effects of such transfers between amoebae of different species had then been lately described by workers at the Chester Beatty Research Institute, attached to the Royal Cancer Hospital, and the Department of Zoology, King's College, London. The advantage of the method is that it enables the interaction between nucleus and cell plasm to be studied in a simple organism, subject to disturbances resulting from transfer as such. The same method has now been applied by M. J. Ord and Professor J. F. Danielli of King's College, and E. B. Harriss and L. F. Lamerton of the Physics Department, Royal Cancer Hospital, to a different problem: the effects on cell plasm and nucleus of treatments which affect the mutation rates of cells exposed to them, and which are of actual or potential interest for the treatment of cancers.

The principle of the method is as follows. Either whole amoebae, or amoebae from which the nuclei have been removed, can be exposed to the treatment under study. In the first case, the treated nucleus can be transferred to an untreated amoeba, the combination of treated nucleus and untreated cell plasm being thus obtained. Alternatively, an untreated nucleus can be transferred into either a treated whole amoeba or into treated cell plasm. Using the later divisions of the amoeba as an index of damage, the effects can thus be compared of treating the whole amoeba and either the nucleus or cell plasm separately. The first

experiments were on the effects of one of the nitrogen mustards ( $\beta\beta$  dichlorodiethyl methyl amine), and were done at King's College. Later, experiments on the effects of high-energy x rays were done at the Royal Cancer Hospital. *Amoeba proteus* was used in both sets of experiments.

Only preliminary accounts have so far been published, and there is no information as to the numbers of amoebae observed or the range of variation between amoebae exposed to similar treatments. The following are stated to be the main differences. There is a fourfold difference in the ratio, nuclear sensitivity/cell-plasm sensitivity, as between nitrogen mustard and x rays: with nitrogen mustard, the dosage required to produce lethal damage in half the treated cell plasms is 10 times as great as that required to produce lethal damage in half the treated nuclei; with x rays it is 2.5 times as great. Secondly, dosage is more critical with x rays, both for nucleus and cell plasm, than with nitrogen mustard. With x rays, a dosage can be chosen which is lethal to all nuclei, but not to any cell plasm; with nitrogen mustard this is not possible, in spite of the greater difference in sensitivity under the conditions already quoted. If dosage is increased to the point when all nuclei are lethally damaged, so also are some cell plasms. Thirdly, there is evidence of qualitative differences, on which there is already evidence from other methods.\* With x rays, delay in division is prominent for the first division, and small for the second; with nitrogen mustard, these effects are reversed. Again, whereas, with x rays, lethally damaged nuclei do not usually divide at all, with nitrogen mustard they usually do.

For the establishment of the method, there is an obvious importance in the observation of differences following different treatments, since they suggest that the method is really showing something. As well as the differences quoted, it is concluded that, both with nitrogen mustard and with x rays, the cell plasm and

\*For example, the distribution of chromosome-breakages in plant root-tip cells: breakages after treatment with nitrogen mustard tend to be localized in particular chromosome regions; those after x-ray treatment are more generally distributed.

the nucleus are probably damaged independently; or, more precisely, that the cell plasm is damaged directly in each case, and that damage to the nucleus is probably independent of damage to the cell plasm. Since there is already evidence, from other methods, of apparently specific damage to the nucleus, the chief interest from this new method lies in the suggestion of direct damage to the cell plasm. It need hardly be added that, as with any other new method, the conclusions drawn from it should be viewed with caution at this stage. It is also obvious that there will be very wide possibilities for research, if the method can be substantiated.

Ord, M. J., and Danielli, J. F. *Nature*, **170**, 921 (1952).

Harriss, E. B., Lamerton, L. F., Ord, M. J., and Danielli, J. F. *Nature* **170**, 922 (1952).

#### SHEEP, COBALT, AND VITAMIN B<sub>12</sub>

The problem of sheep, cobalt, vitamin B<sub>12</sub>, and pernicious anaemia has moved in an expanding spiral since the discovery, in 1935, that sheep need an appreciable quantity of cobalt. The immediate interest was in relation to 'pining', a disease of sheep which has been known for more than a century and which has since been reported from every continent. H. R. Marston wrote from Australia about this discovery that the recovery of 'pining' sheep after dosing with 1 milligramme of cobalt per day 'is the most dramatic thing I have seen'. Later, he showed that about 0.1 milligramme per day was enough, if ingested frequently. Cobalt, in appreciable quantity, is needed also by cattle. But in an area of South Australia, in which ruminants are unable to survive because of cobalt-deficiency, it has been noted that 'marsupials abound, horses do well, and rabbits reach plague proportions'; and, under laboratory conditions, attempts to induce cobalt-deficiency in rats have not succeeded. It was thus already a problem to explain the greater need of ruminants for cobalt, compared with other animals.

The problem seemed at first to be accentuated rather than otherwise when, in 1948, an anti-pernicious anaemia factor,

vitamin B<sub>12</sub>,\* was isolated from concentrated liver-extracts and found to contain some 4 per cent of cobalt. The human requirement for vitamin B<sub>12</sub> is about 1 microgramme per day, which implies a cobalt requirement of around 0.05 microgramme. Vitamin B<sub>12</sub> was the first substance of biological origin which was found to contain cobalt, and there is still no evidence of any further requirement for cobalt. The disproportion between man and sheep is thus startling. Weight for weight, 0.02 microgramme of cobalt daily should be enough for a sheep; but its actual requirement is some 5,000 times greater. Again, although a 'pining' sheep suffers from acute anaemia in the later stages of the disease, it responds not at all to such dosage with vitamin B<sub>12</sub>, as would be effective in human pernicious anaemia.

A possible explanation was soon suggested. Whereas there are some micro-organisms which require vitamin B<sub>12</sub> to be supplied to them ready made, and which indicate by their growth-rates the quantity available to them, there are other micro-organisms which produce substances both related to vitamin B<sub>12</sub> and possessed of similar activity.† Still others neither need vitamin B<sub>12</sub> nor produce it. It seemed, therefore, that the main apparent requirement of sheep for cobalt might be explained as a requirement for the growth of those bacteria in their rumens which contribute to digestion.

More recent work at Cornell University in the United States, in Australia by Marston and others for the Commonwealth Scientific and Industrial Research Organization, and in New Zealand, has led to an almost complete reversal of this position. The essential observation that 'larger amounts of vitamin B<sub>12</sub> result in a positive response in cobalt-deficient lambs' was first reported by D. E. Becker and S. E. Smith of the Department of Animal Husbandry, Cornell University. Australian experiments

\*Vitamin B<sub>12</sub> is thought to be identical with the 'extrinsic [anti-pernicious-anaemia] factor' of Dr W. B. Castle; an 'intrinsic factor', present in normal gastric juice, but probably deficient in some types of anaemia, is apparently needed to combine with it.

†See, for example, 'Vitamin B<sub>12</sub>, Antibiotics and Growth', by H. O. J. Collier. *Science News* **23**, 20 (1952).

have taken the problem some way further, both as regards the sheep itself and also its rumen bacteria. Whether judged by appetite, weight, or the oxygen-carrying capacity of its blood, a 'pining' sheep responds to injections of Vitamin B<sub>12</sub> in these larger quantities at least as completely as, and sometimes more quickly than, it does to cobalt given by mouth. This was at a dosage-rate which, in proportion to weight, was more than 100 times the normal human requirement and more than 20 times that used in the treatment of human pernicious anaemia. From the Cornell experiments, it looks as if about half this dosage would have been about the least to produce an effect.

So far as the rumen bacteria are concerned, the effect of the Australian work has been to disprove directly the theory that the digestibility of the sheep's food is affected by cobalt-deficiency. Cobalt may be needed by other micro-organisms in the rumen, but not by those that help digestion. There are changes, as would be expected, in the population of those micro-organisms in the rumen which utilize cobalt in the sense that they produce from it substances with vitamin B<sub>12</sub>-like activity. Their output is large, normally, compared with the requirements of the sheep, and relatively large quantities are excreted. At the stage when a 'pining' sheep is first beginning to lose appetite, and if kept on the same fodder would die, the quantity of vitamin B<sub>12</sub>-like substances excreted may still be from ten to twenty times as great as would save the life of the sheep, if given to it as injections. With cobalt in normal supply, the amount of the vitamin excreted may be many times greater.

There is no published evidence as to why the sheep should need more vitamin B<sub>12</sub> than does man, nor has any reason for the difference been suggested. The original problem has thus been restored, but in terms of vitamin B<sub>12</sub> and no longer of cobalt. It might be solved in part by experiments with the radio-actively labelled vitamin, but used in larger quantities than have before been available. Alternatively, it may be thought that the real problem is to explain the conservative use made of vitamin B<sub>12</sub> by mammals in general; the ruminant, living on normal pastures, is so abundantly supplied by its rumen bacteria that, in

these conditions, it could derive little biological advantage from conserving supplies.

- Becker, D. E., and Smith, S. E. *Journal of Nutrition*, **43**, 87 (1951).  
 Smith, S. E., Koch, Berl A., and Turk, K. L. *Journal of Nutrition*, **44**, 455 (1951).  
 Marston, H. R., and Lee, H. J. *Nature*, **170**, 791 (1952). (Also two following contributions.)  
 Anderson, J. P., and Andrews, E. D. *Nature*, **170**, 807 (1952).

#### THE PERCEPTION OF HEAT

Since the human body reacts more slowly to warmth than to cold, it has been argued that the nerve endings which respond to warmth must be placed more deeply in the skin. From observations of the pain threshold for microwave and infra-red radiations, H. F. Cook of the Department of Physics Applied to Medicine at the Middlesex Hospital, London, has lately concluded that heat-pain is experienced 'when end-organs located at approximately 1.5 millimetres below the surface reach a temperature of about 46° C. (115° F.)'. The argument is in two stages. The first is the measure of agreement that has been found on the skin-temperature reached with either method of heating when pain is first experienced. In Dr Cook's measurements with microwaves of 10-centimetre wavelength, neither area, site, nor rate of exposure were found to be important in this respect; over a wide range of conditions, the critical requirement for the onset of pain was that the skin-temperature should have reached about 46° C. The range of variation was from 44.7° to 47.5° C., according to the conditions of the experiment. Measurements made in other laboratories using infra-red radiation suggest that skin-temperature is again the limiting factor, and that the temperature which can be tolerated is about the same (45-48° C.). The second part of the argument involves a comparison between the rates of energy-absorption in the two cases. Ideally, these should have been measured in the same laboratory, and with the same area of skin exposed. In practice, there are no strictly comparable sets of figures, and some allowances are necessary.

These, however, are not such as should disturb the main comparison. At the surface of the skin, about four times the intensity of microwaves can be tolerated as of infra-red radiation. But, whereas the whole of the infra-red energy is absorbed near the surface, a considerable proportion of the energy of microwaves penetrates to greater depths. As a first approach, it is assumed that pain will be experienced when the end-organs reach a critical temperature; and that the temperature reached is determined by the rate at which energy is absorbed at all depths between the end-organs and the surface. This is during prolonged irradiation, and so in approximately steady conditions.

To estimate the depth of the end-organs, it is then only necessary to calculate the depth down to which the total rate of energy-absorption is the same for microwaves and for infra-red radiation, pain being just experienced in each case. The answer is about 1.5 millimetres, in the sense that it is neither 1 millimetre nor 2 millimetres, but probably about half-way between. Since the temperature-gradient is small in the first few millimetres of tissues under the conditions of measurement, the critical skin temperature is taken to apply also to the end-receptors within the limits of accuracy attainable. Hence Dr Cook's general conclusion, as already quoted.

Cook, H. F. *Journal of Physiology*, **118**, 1 (1952).

#### THE FOURTH RADIOACTIVE SERIES

The distinction between the uranium, thorium, and actinium series of natural radio-elements suggested to A. S. Russell in 1923 that there should exist also a fourth radioactive series not yet found in nature. The distinction between the then known series arises from the fact that changes in mass-number resulting from radioactive breakdown come in all cases from the emission of an alpha-particle, when four units of mass are lost to the nucleus. The emission of a relatively light electron (beta-decay) changes only the charge of the nucleus, and not its mass-number. Within a single radioactive series, mass-numbers therefore differ from one another only by multiples of four. Thus, for example,

the thorium series begins with thorium-232, the mass-number of which is divisible by four, as also are the mass-numbers of all later members of the series, down to lead-208, which is its stable end-product. Similarly, all members of the uranium series, beginning with uranium-238, have mass-numbers which are two more than a multiple of four; and members of the actinium series, beginning with uranium-235, have mass-numbers three more than a multiple of four. But the series with mass-numbers one more than a multiple of four was still missing at the time. In 1935, Professor Fermi, then working in Rome, found that one member of this series, thorium-233, was formed from natural thorium by exposing it to slow-neutron irradiation. The case may yet prove important: carried out on the larger scale of a nuclear reactor, the conversion of natural thorium into thorium-233 is the first stage in the process by which thorium, useless in itself as a source of energy, can be converted into uranium-233, which is a fissile material. With this exception, the discovery of the formerly missing series, the neptunium or  $(4n+1)$  series, was the result of wartime research on atomic energy. The new development is the discovery by D. F. Peppard and others of the Argonne National Laboratory, Chicago, that each of the three longest-lived members of the series exists in nature on a detectable scale, although in minutely small quantities.

The apparent improbability of this discovery is shown by comparison with the three natural radioactive series. Their occurrence in nature depends on the existence, at the head of each of them, of a long-lived 'parent', of which the half-life is either long compared with the age of the earth (about  $3 \times 10^9$  years), or at least comparable with it. The shortest-lived of them is actinouranium (uranium-235), with a half-life of  $7.07 \times 10^8$  years, or about one-quarter of the age of the earth. Its abundance must have decreased during the earth's history by a factor of not more than about 20. But in the neptunium series, the long-lived parent, neptunium-237, has a half-life of only about  $2.25 \times 10^6$  years, or less than one thousandth of the probable age of the earth. This means that, however great its initial abundance, the chance that even one single atom of neptunium would have sur-

vived from the beginning of the earth to the present time would be negligibly small.

Obviously, that is not the whole story, or neptunium would not have been found. It was pointed out by Professor Seaborg in 1947 that neptunium-237 should be formed continuously in uranium ores by a process which, with A. C. Wahl, he had discovered in 1942. This process can be regarded as a variant of the now familiar one by which plutonium is formed from uranium-238 in a nuclear reactor. The first step in the latter case is the absorption of a neutron by uranium-238, with uranium-239 as the first product. Alternatively, the absorption of a neutron may be followed immediately by the emission of two neutrons, so that, instead of uranium-239, uranium-237 is formed. As can be seen from its mass-number ( $236 + 1$ ), this is a member of the  $(4n + 1)$  or neptunium series. Neptunium is formed directly from it, with the emission of an electron. It was by this process that enough long-lived neptunium was obtained from a nuclear reactor for its chemical properties to be studied. Both processes – the gain of a neutron leading to plutonium-239, and the loss of a neutron leading to neptunium-237 – should take place also in the natural ores of uranium; and, in 1950, the occurrence of plutonium in minute quantities in concentrates of pitchblende from the Belgian Congo was confirmed by Peppard and his colleagues.\* The research now reported confirms Seaborg's second prediction: that neptunium-237 should be detectable. For every ton of uranium-238, some 1.5 microgrammes of neptunium-237 have been found to be present, and neptunium, like plutonium, shown to be a naturally occurring element. Its abundance is about one-tenth of that of plutonium in the same ore; and, since the average lifetime of its atoms is about one hundred times longer, the process leading to its formation must be about one thousand times less common than that leading to plutonium. Estimates have also been made of the proportions of uranium-233 (half-life,  $1.62 \times 10^5$  years) and of thorium-229 (half-life,  $7 \times 10^4$  years), these being the two elements with the next longest lives in the neptunium series. The proportion of uranium-233 is

\**Science News* 20, 110 (1951).

about 1/14th that of neptunium-237 in the same ore, as would be expected from its more rapid rate of breakdown.

Hagemann, F., and others. *Physical Review*, **79**, 435 (1950).

Peppard, D. F., and others. *Nuclear Science Abstracts*, **6**, 471, abstract 3811 (1952).

#### ACCELERATOR PLANS

Even before the publication of the first experimental results with the Brookhaven 'cosmotron', or proton synchrotron,\* the existence of design-proposals has been made known for the construction of a further machine in which protons will be accelerated to an energy ten times as great: thirty thousand million electron-volts (30,000 MeV), compared with three thousand million electron-volts (3,000 MeV), the design-output of the cosmotron. As with the earlier transition from cyclotron to proton synchrotron, the aim is to reduce the size of the magnet necessary, so achieving a bigger increase in energy for a given cost than would otherwise be possible. The Brookhaven proposals are reported to have been made known in time for a meeting of the European Council for Nuclear Research, held at Amsterdam in October 1952, at which it was decided to plan for the construction of a similar accelerator.

With any form of cyclic accelerator, the radius of the machine is determined by the energy to which the particles are to be accelerated, and the value of the magnetic field. The 'economy' in the proton synchrotron was the result of so arranging matters that, instead of spiralling outwards as they are accelerated, the protons are caused to follow an approximately circular path throughout. In this way, the area across which a magnetic field must be supplied to constrain the protons to a closed path while they are being accelerated is reduced greatly compared with a

\*For a general account, see 'The Acceleration of Charged Particles to High Energies' by L. L. Green in *Science News* 22, especially pp. 67-70. The bringing into operation of the 'cosmotron' was reported in *Science News* 26, 67 (1952).

cyclotron in which the whole area of the machine must be covered. But the extent of reduction is limited in practice by the impossibility of keeping the protons to a single, precisely determined track. In the 'cosmotron', for example, the design-radius is 360 inches, but a track 27 inches wide is provided, and the magnetic field is required to be uniform across the whole track-width. The intention of the Brookhaven proposals, to be published shortly by M. S. Livingston and H. S. Snyder, is to limit the track-width to 2 inches, so that, while the track-length will be ten times longer, the area to be covered will be less, and the size of the magnet can be reduced. Since the 'track' consists of an evacuated pipe, there will be a further gain in respect of vacuum requirements. The cross-section of the 'cosmotron's' pipe is 162 square inches; with the intended design, it is thought that a cross-section of 2 square inches will be sufficient. The volume to be evacuated will thus be only one-eighth as big.

To enable the protons to be confined within so relatively small a pipe, it is proposed to break up the uniform magnetic field of the proton synchrotron into a series of short sections in which the protons will alternately diverge and be brought to a focus again in the manner of a lens. It is also proposed to use a number of electrical oscillators to provide acceleration instead of one only. With so radical a departure in construction, it can be assumed that a smaller model will be built first, as was done with the Berkeley proton synchrotron, now under construction.

*Physics To-day*, Vol. 5, No. 11, p. 27 (November 1952).

*Scientific American*, Vol. 187, No. 5, p. 41 (November 1952).

Livingston, M. S., and Snyder, H. S. *Physical Review* (in the press).

#### ARCTIC SOIL-TEMPERATURES

The variation of temperature with depth in soil and rock subject to permanent frost is being studied in two drill-holes, of depth 307 ft and 453 ft respectively, at Resolute on Cornwallis Island in the Canadian Arctic (Latitude, 74° 41' N.). The experiment was undertaken as a result of experience gained in drilling to less great depths in connexion with the siting of a seismological

station. The drill-holes go through a 6-ft layer of frozen gravel, underlain by limestone with occasional faults and cracks. Regular temperature readings are being taken in both holes. Short-period fluctuations are practically negligible at about 5-ft depth, and seasonal fluctuations are practically negligible near the 50-ft level, where there is a time-lag of about six months. At 98-ft depth, there is a steady temperature of  $-13.50^{\circ}\text{C.}$ , and at 450-ft depth,  $-9.54^{\circ}\text{C.}$  The observations should lead to an accurate determination of the upwards rate of heat-flow in this region, and it is hoped that they will be extended later to greater depths. A preliminary account has been given by Andrew Thompson, Controller of Meteorological Services, and P. C. Bremner of the Department of Transport, Toronto.

*Nature*, 170, 706 (1952).

## CORRESPONDENCE

### CONSCIOUSNESS AND THE BRAIN

MRS Margaret Knight in her article 'Consciousness and the Brain' (*Science News* 25) effectively refutes an argument used by some interactionists to show that the brain-dependence view of the mind-body relationship is self-contradictory. In the course of her discussion she makes some remarks about 'absolute scepticism' which call for comment; the sceptical position has a certain popular appeal and needs firm handling.

It is true that absolute scepticism is irrefutable. But this is not because it is logically tenable. It is because it is meaningless; and what is meaningless cannot be proved either true or false. If someone suggests that what we normally call waking life is perhaps after all really dreaming, the proper way to silence him is not to try to refute him but to show that the words 'dreaming' and 'waking' have meaning only in relation to each other. To suggest that our waking life is really a dream is meaningless because it denies the distinction between waking and dreaming, while at the same time using a word which has meaning only if there is such a distinction. Similarly, to say that 'all the information we receive through the senses may be false' is meaningless because it would deny the distinction between empirical truth and falsity, while at the same time using a word ('false') which has meaning only if there is such a distinction. If *all* information were false we should have no use for the word 'true', nor, consequently, for the word 'false'. Again, to say that our eyes may be 'distorting mirrors which misrepresent the outer world' is meaningless because it would deny the distinction between a distorted and an undistorted representation, while using a word ('distorted') which has meaning only if there is such a distinction. If *all* mirrors distorted we should have no use for the phrase 'undistorting mirror', nor, consequently, for 'distorting mirror' either.

I would add that I see little hope of Mrs Knight's article bringing interactionists and brain-dependence theorists to closer grips. A fundamental difference of viewpoint is that the interactionists emphasize what they deny, the brain-dependence school emphasize what they assert. Interactionism denies that all mental activities depend on physical processes; but its grounds for making assertions about non-physical dependence are not experimental but metaphysical. Brain-dependence theories, on the other hand, assert that all mental activities, in so far as they can be described, classified, and correlated, do depend on physical processes; and their evidence is experimental, not metaphysical. No wonder it is difficult to find a meeting-place for neurologists who are not interested in unclassified aspects of consciousness and metaphysicians who are.

BERNARD MAYO

Department of Philosophy, University of Birmingham

I WONDER if I may be allowed to comment on Mrs Knight's interesting article and to say a word in defence of the philosophers. It seems to me that what some of them at least are saying, when they criticize the brain-dependence hypothesis, is that knowledge of the kind found, for example, in mathematics and logic cannot be extracted from the laws of neurology; that this is a special case of deriving the general from the particular.

Mrs Knight tells us: 'On the brain-dependence hypothesis, the result we reach is entirely determined by these processes. But that is no reason for distrusting the result, any more than it would be a reason for distrusting the results of calculations worked out by electronic machines' (p. 101). She overlooks that in the latter case the reason why we do not distrust the results of the machine's calculations is because there are human intelligences, mathematicians, etc., whose job it is to interpret these results and to check them according to previously laid down mathematical criteria. Without such a process of interpretation the results are without significance – mere perforations on a tape. She admits this when she says 'We trust the electronic

brain because we know that its operations proceed in accordance with mathematical laws' (p. 102), i.e. laws which do not depend on empirical data for their truth or falsity; their validity is determined solely by internal consistency, or freedom from contradiction.

Mrs Knight's analogy would seem to point to the reverse conclusion – namely, that brain processes only have a significance when there is an intelligence to interpret them. Knowledge about brain processes is a second-order type of knowledge involving complicated experimental and observational procedures, in the statement of which mathematics and logic are involved. She seems to assume that a physiological fact is just as simple and straightforward as our immediate perception of 'red'. Indeed, the brain-dependence hypothesis inverts their order of priority, glossing over the facts that scientific descriptions are of a very different logical order from perceptions. It confuses two very different things: (1) our immediate awareness of the elements given in our perceptual field, (2) the physical and physiological data of science, derivative from the observations of many investigators and involving complex inferential procedures. No one would deny that a correlation may be set up between (1) and (2), but if we treat them as being of the same logical type we commit a simple fallacy. Further, the brain-dependence hypothesis would make physics as well as mathematics and logic depend on brain physiology. But since the laws of brain physiology ultimately depend for their significance, as well as coherence, on mathematical and logical laws, we find ourselves in a vicious circle; as is often the case with vicious circles, this arises from a simple confusion of logical types.

W. MAYS

Department of Philosophy, University of Manchester

MRS Knight's article must have been read with interest and pleasure not only by specialists but by many people like myself, learned neither in psychology nor philosophy.

As one of the unlearned, I should like to draw attention to

a point which rather puzzles me. Why is so little attention given to a hypothesis practically implied in the suggestion that 'mental processes depend on processes in the brain', the hypothesis that mind or consciousness is a brain activity? This hypothesis, already suggested by Pavlov, I believe, seems to me to reconcile the statements cited by Mrs Knight as representative of the interactionists and the brain-dependence school.

To the uninitiated, no common-sense reason is apparent why consciousness should not be an aspect of brain activity just as the 'quasi-material' flame of a candle is an aspect of the burning process. If this hypothesis were adopted, brain and mind could be regarded as having a relation practically analogous to that between the living organism and the life activities associated with that organism.

But no one, so far as I know, tries to answer the question: 'Is life dependent on the organism, or do life and the organism interact?' Inviting, as it does, affirmation on one side and denial on the other, it seems to be a wrong question. Clearly life is dependent on the organism, equally the organism is dependent on life.

If natural selection has been the principal agent in evolution, organisms and the life processes associated with them have evolved together, in partnership, as it were. The life processes are presumably determined by the form of the organism. But the organism equally owes its form to the activities which take place in it.

The brain is part of the human organism and the brain activities are surely part of our life processes. Brain and the general pattern of brain activity have presumably evolved in partnership, and neither can be called wholly dependent on the other.

So, if mind is a brain activity, it seems that we can say without necessarily contradicting ourselves: 'The mind of man is something that depends on the action of the brain, but the mind and the brain interact; the view that mind is a by-product of matter should not be seriously accepted as the whole truth'. If mind is brain activity, the view that mind is a by-product of matter seems neither more nor less valid than the view that matter is

the instrument of mind. As a basis of human conduct the latter view appears preferable, but the former view might well be borne in mind as possibly presenting another aspect of the whole truth.

C. J. MITCHELL

Petts Wood, Kent

*Mrs Margaret Knight writes:*

I am most grateful to your correspondents for their letters, and for the interesting points that they have raised. To deal fully with all of them would require another article, so I will confine myself to replying as briefly as possible to the points I regard as salient.

I agree (of course) with Mr Mayo that the question, 'is all the information that we receive through our senses false?' is by nature unanswerable. Mr Mayo says that it is not only unanswerable but meaningless, and I think he may well be right.

If I may attempt to re-state his argument: to suggest that all our sense-perceptions may be distorted is like suggesting, with respect to a column of troops who are marching in time, that they may all be out of step. The only possible meaning of 'out of step' is 'not stepping in time with the others'. Similarly the only possible meaning of 'distorted', as applied to a sense-perception, is 'inconsistent with other perceptions'. Thus the suggestion that all our perceptions may be distorted is meaningless.

Whether one accepts or rejects this argument depends on whether one accepts or rejects the penultimate sentence, which raises enough philosophical issues to fill several lecture-courses. As I said above, I think Mr Mayo may well be right; and if he is right, and absolute scepticism is in fact a meaningless doctrine, the argument relating to it does not deserve even the summary treatment it received in my article.

In reply to Dr Mays, I did not say, and I do not think the brain-dependence hypothesis implies, that 'mathematics and logic depend on brain physiology'. To put my point crudely, 'twice two are four' is not just a fact about the way our brains

work; it would be truer to say that our brains work as they do because twice two are four.

Dr Mays points out that the perforations or other symbols produced by the calculator are of no significance until they have been interpreted by human beings. I entirely agree: I am surprised that he should think I had overlooked this fact, for as I said in my article 'There is a profound and obvious difference [between the human being and the calculator] in that the human being is conscious and the calculator is not. When we feed a problem into the calculator . . . it does it "blind" - it does not know what it is doing, or know the answer when it has produced it'. I agree with Dr Mays also that results worked out by calculators must be not only interpreted but checked - in the sense that the human being in charge of the calculator must assure himself from time to time that it is working properly by feeding it a standard calculation of which the result is known. But this does not affect my argument about the brain-dependence hypothesis. I was not suggesting that calculating machines can never go wrong. The point is that when the machines are in order we accept the results; we do not reject them on the ground that they are produced by material processes.

I confess I am baffled by Dr Mays' final paragraph. He says that the brain-dependence school 'commits a simple fallacy' by failing to realize that facts about brain physiology are of a different logical type from facts based on sense perception. An example of the sort of statement regarded as evidence for the brain-dependence hypothesis is 'damage to the occipital lobe of the brain involves disturbance of visual perception'. Does this involve a confusion of logical types?

I cannot quite accept Mr Mitchell's view that conscious processes bear the same relation to the brain as vital processes do to the body, but there is much to be said for his main thesis, viz. that consciousness is an aspect of brain activity. With minor reformulations this view would closely resemble the so-called 'double aspect theory', which is now widely accepted. The gist of the theory is that mental and material are not, as is often supposed, incompatible characteristics, but that some brain-

processes have both mental and material properties. Thus we have not two series but one – not a series of brain processes, and a parallel and dependent series of mental processes, but a single series with two different characteristics. It is impossible here to consider all the implications of this theory, but they are fully and lucidly discussed by Professor Broad in *The Mind and its Place in Nature* (see especially pp. 625-30).

## SOME BOOKS RECEIVED

**CLIMATE AND THE BRITISH SCENE** by Gordon Manley (Collins, New Naturalist Series, 1952), pp. 314, 25s.

Without appearance of congestion, Professor Manley has provided in one volume an introduction to past and present methods of climatology, as much meteorology as is necessary for his purpose, and an account of the British climate, with two excellent chapters on the effects of landscape features, including soil and vegetation cover, and another on evidences of climatic changes from the last ice-age onwards, and even some cautious discussion on what may be meant by bracing and relaxing. He writes pleasantly, and the eighty-odd photographs, half in colour, are well chosen; it would be a help with some of them to indicate the direction in which the pictures were taken.

**PHYSIOLOGICAL APPROACH TO THE LOWER ANIMALS** by J. A. Ramsay (Cambridge University Press, 1952), pp. 148, 15s.

This is the author's response to a problem set by the Cambridge Joint Advisory Committee for Biology: to proceed from 'the human body, its structure and function' to 'the variety of animals'. He takes a succession of problems – nutrition, circulation, respiration, excretion, muscle and nerve, sense organs, co-ordination, and behaviour – and, without over-nicety of reservation, shows how they present themselves 'according to the size of the animal, the plan upon which its body is organized and its way of life'. The result is an exceptionally interesting book, intended for early university and possibly late school students.

**REGENERATION AND WOUND-HEALING** by A. E. Needham (Methuen, Monographs on Biological Subjects, 1952), pp. 152, 8s 6d.

In spite of the theoretical and practical importance of the subject, Mr Needham's book is the first general treatment in English since 1901. Extreme compression, in a field in which the gap between detail and generalization is still immense, has made for difficult reading.

**ANIMAL FORMS AND PATTERNS** by Adolf Portmann (Faber, 1952), pp. 246, 25s.

Professor Portmann's statement that 'the animal forms surrounding us are not utterly haphazard, but "compositions" which are being performed' is a fair summary, in its first half, of the case for a book on animal form, and, in its second half, of the philosophical outlook which colours this one increasingly. The line drawings are of unusual quality, and the translation reads smoothly.

**RADIOISOTOPE TECHNIQUES: PROCEEDINGS OF THE ISOTOPE TECHNIQUES CONFERENCE, OXFORD, JULY 1951, VOL. II INDUSTRIAL AND ALLIED RESEARCH APPLICATIONS.** (Her Majesty's Stationery Office, 1952), pp. 177, 25s.

The conference, of which this is the second volume of proceedings, was sponsored by the Atomic Energy Research Establishment. Sections are included on metallurgical applications, gamma radiography, counting techniques, chemical applications, ion exchange, non-destructive testing, the elimination of static charge by air-ionization, and radioactivation analysis. Publication in this form provides a useful work of reference, and should be of value also in encouraging more extended use of the techniques available. [Vol. I, containing the proceedings of the medical, biological, and agricultural sessions of the conference, is to be published later.]

**THE SKY AND ITS MYSTERIES** by E. Agar Beet (Bell, 1952), pp. 238, 15s.

In spite of its title and an early reference to 'the great dome of heaven', this is a simply written but serious introduction to astronomy, with up-to-date suggestions for reading, and more emphasis than usual on what is known.

## ABOUT OUR CONTRIBUTORS

**R. N. ELSTON**, aged 27, is a graduate of Sydney University and studied at the Waite Institute, Australia. He has worked as a plant-breeder in Victoria, and in 1951 was a Demonstrator in Botany at Melbourne University. Interests are in ecology, plant geography, and genetics with particular reference to arid lands. Recreations: swimming, Eastern folk-dancing and music, learning languages and writing poems in them; fond of school-teaching.

**E. P. GEORGE** graduated at London in 1935, and started cosmic-ray research under P. M. S. Blackett in 1937 at Birkbeck College. Has mostly worked on the radiation observed below ground, in underground railway stations and coal mines. Now Lecturer in Physics at Imperial College.

**A. J. HERZ** is an Assistant Lecturer in the Physics Department at Imperial College where he graduated in 1949. Since then he has been doing research in the Cosmic-Ray Laboratory.

**ANTHONY H. RICHMOND** is Lecturer in Social Theory in the University of Edinburgh. He is a graduate in economics and sociology of London and Liverpool Universities. He was previously a member of the research staff of the Department of Social Science, University of Liverpool, and worked there on aspects of racial relations. He is author of a number of articles in the fields of sociology and social psychology, and has a book on racial relations awaiting publication.

**R. M. TENNENT** is 24 and a Demonstrator at Imperial College. After graduating in physics from The Polytechnic, Regent Street, London, W. 1, he spent two years in industry before turning to an academic career. At Imperial College he has been studying cosmic rays, using the photographic emulsion technique.

**D. G. TUCK** carried out research work in the Londonderry Laboratory for Radiochemistry of Durham University from 1949 to 1952, and is now working at the Institut du Radium in Paris.

**W. C. VAUGHAN, M.B.E.**, is an officer of the Royal Air Force serving in Germany. He was awarded the degree of Ph.D. for experimental research in radio physics in the University of London, and is the author of a number of scientific papers in this field.

INDEX  
FOR NUMBERS  
24-27

## SUBJECT INDEX

Numbers 24-27

References are in all cases to page and number, e.g., 29(24). Articles are indexed under what is judged to be a key-word in their titles (printed in small capitals). Cross-references are suggested under a number of general subject names. Paragraphs under the heading *Research Report* are indicated by (R.R.). Continuing references are, in general, not given.

- |                                                                                                                                                                                                                                                                                                               |                                                                                                                                                                     |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| ACCELERATOR Plans (R.R.), 115(27).<br>Brookhaven proposals to follow 'cosmotron'                                                                                                                                                                                                                              | Atomic physics. <i>See</i> : ACCELERATOR, BALLOONING, COSMIC, POSITRONIUM, PROTONS, RADIO-FREQUENCY                                                                 |
| Actinium series, 112(27).                                                                                                                                                                                                                                                                                     | Avery, O. T., 43(24)                                                                                                                                                |
| Actinouranium, 113(27)                                                                                                                                                                                                                                                                                        |                                                                                                                                                                     |
| Adams, B. A., 83(26)                                                                                                                                                                                                                                                                                          |                                                                                                                                                                     |
| Affray, H.M.S., 90(25)                                                                                                                                                                                                                                                                                        |                                                                                                                                                                     |
| Agriculture. <i>See</i> : DIETARY, RAT, SHEEP, SOIL                                                                                                                                                                                                                                                           | Bacteria, 'species' of, 9(25)                                                                                                                                       |
| Aircrow, supersonic, 82(25)                                                                                                                                                                                                                                                                                   | Bacterial chromosomes? Inset 14-15(25)                                                                                                                              |
| Aitken, R. G., 55(24)                                                                                                                                                                                                                                                                                         | Bagnold, R. A., 14(27)                                                                                                                                              |
| Alfrey, G. F., 117(24)                                                                                                                                                                                                                                                                                        | BALLOONING for Research. A. J. Herz and R. M. Tennent, 46(27). Use for meteorology, 46; cosmic ray research, 47; open-necked balloons, 51; closed, 54. Insets 30-31 |
| Alpha-rhythms, 9(24)                                                                                                                                                                                                                                                                                          | Barnes, H., 90(25)                                                                                                                                                  |
| Anaemia, pernicious, in ruminants, 108(27)                                                                                                                                                                                                                                                                    | Becker, D. E., 109(27)                                                                                                                                              |
| Anderson, W. C., 61(27)                                                                                                                                                                                                                                                                                       | Behrens, M., 26(24)                                                                                                                                                 |
| ANIMAL CARBON, SOURCES OF (R.R.), 111(25). Tracing of processes of carbon-fixation by radioactive sodium-bicarbonate                                                                                                                                                                                          | Benedetti, S. De, 108(25)                                                                                                                                           |
| Annihilation-radiation, 106(25)                                                                                                                                                                                                                                                                               | Bergstrand, E., 64(27)                                                                                                                                              |
| ANTARCTIC EXPEDITION, The Norwegian-British-Swedish, 1949-52. E. F. Roots, 9(26). Report of investigations: meteorological, 11; glaciological, 13; seismic soundings of ice-thickness, 20; geological, 24; climatological, 27; biological, 29; oceanographic, 30; magnetic, 30; physiological, 31. Inset 1-25 | Binary. <i>See</i> : STARS                                                                                                                                          |
| Anti-vitamin. <i>See</i> : RAT-POISON                                                                                                                                                                                                                                                                         | Biochemistry. <i>See</i> : ANIMAL, CELLS, CORTISONE, MINERAL SALTS, RAT, SELENIUM, TEETH                                                                            |
| Antonovitch, S., 10(24)                                                                                                                                                                                                                                                                                       | Biology. <i>See</i> : CONCEPTS                                                                                                                                      |
| ARCTIC Soil-Temperatures (R.R.), 116(27). Drill-hole tests in Canadian Arctic                                                                                                                                                                                                                                 | Black, A. L., 112(25)                                                                                                                                               |
| Aridity, index of, 13(27)                                                                                                                                                                                                                                                                                     | Blood-tests of Antarctic workers, 31(26)                                                                                                                            |
| Artesian wells in deserts, 16(27)                                                                                                                                                                                                                                                                             | Booker, H. G., 117(26)                                                                                                                                              |
| Astronomy. <i>See</i> : PALOMAR, COSMIC, RADIO TELESCOPE                                                                                                                                                                                                                                                      | Botany. <i>See</i> : DESERT, FIELD, MINERAL SALTS, SEAWEEDS, SELENIUM, SOILS, VIRUS                                                                                 |
| Atom, and periodic system of elements, 77(24)                                                                                                                                                                                                                                                                 | Boivin, A., 43(24)                                                                                                                                                  |
|                                                                                                                                                                                                                                                                                                               | Bradt, H. L., 33(27)                                                                                                                                                |
|                                                                                                                                                                                                                                                                                                               | Brain and consciousness, 97(25), 118(27)                                                                                                                            |
|                                                                                                                                                                                                                                                                                                               | Bremner, P. C., 117(27)                                                                                                                                             |
|                                                                                                                                                                                                                                                                                                               | Broadly, M., 86(27)                                                                                                                                                 |
|                                                                                                                                                                                                                                                                                                               | Bronsted, J. N., 15(25)                                                                                                                                             |
|                                                                                                                                                                                                                                                                                                               | Brookhaven 'cosmotron', 115(27)                                                                                                                                     |
|                                                                                                                                                                                                                                                                                                               | Brüche, E., 34(26)                                                                                                                                                  |
|                                                                                                                                                                                                                                                                                                               | Burch, C. R., 41(26)                                                                                                                                                |

- Callow, R. K., 115(25)  
 Californium, 90(26)  
 Caradog-Jones, D., 80(27)  
 Carbon, Sources of animal, 111(25)  
 Caspersen, T., 41(24)  
 CELL Nuclei and Cell Plasm (R.R.), 106(27). Micromanipulative transfer of treated amoebal nuclei and plasm. Effects of treatment by nitrogen mustard and x-rays, 107  
 CELLS and CHROMOSOMES, The Chemistry of. D. L. Woodhouse and H. S. A. Sherrat, 22(24). Typical cell-structure, 23; nucleic acids, 27; nuclear proteins, 35; quantity determination, 39; composition of chromosomes, 40; chemically directed mutation, 43. Inset 20-2  
 Chalmers, T. A. *See*: RADIOACTIVE  
 Chancourtois, B. de, 68(24)  
 CHEMICAL CHANGE, Mechanisms of. K. D. Wadsworth, 55(26). Bonds and fission, 57; Kinetic Theory and observed reaction rates, 60; Principle of Maximum Simplicity, 64; oxidation of hydrocarbons, 71  
 Chemistry of 'hot atoms', 103(27)  
 Chemistry. *See*: CELLS, CHEMICAL, CRYSTAL, ION-EXCHANGE, PERIODIC, RADIOACTIVE  
 Cherwell, Lord, 67(26)  
 Chloroplasts, 25(24)  
 Chromosomes, Chemistry of. *See*: CELLS  
 Climate. *See*: ANTARCTIC, DESERT  
 Cobalt needs of ruminants, 108(27)  
 Collins, S., 87(27)  
 Colour vision, 65(25)  
 CONCEPTS OUT OF CONTEXT. N. W. Pirie, 7(25). 'Species', 9; 'Purity', 12; 'Efficiency', 17  
 CONSCIOUSNESS AND THE BRAIN. Margaret Knight, 97(25). Philosophical problems of interactionist and brain-dependence theories. Correspondence, 118(27)  
 Cook, H. F., 111(27)  
 Cooper, B. S., 116(25)  
 Cornforth, J. W., 115(25)  
 CORTISONE, Raw Materials for (R.R.), 114(25). Extraction of hecogenin from sisal  
 COSMIC RADIATION. E. P. George, 30(27). Primary and secondary radiation, 30; primary particles, 31; chemical analysis, 34; energy spectrum, 35; distribution in time and space, 39; theories of origin, 42; world-dating and, 44. Inset 28-9  
 Cosmic ray research. *See*: BALLOONS  
 Cosmotron, 123(26)  
 Council for the Promotion of Field Studies, 93(27)  
 CRYSTAL GROWTH (R.R.), 116(25). Unusual property of germanium  
 Cytochrome in plant absorption, 55(25)  
 Danielli, J. F., 106(27)  
 DE LAMATER. Insets 14-15(25)  
 Delta-rays in cosmic-ray tracks, 33(27)  
 Demers, P., 32(27)  
 DESERT RESEARCH. R. N. Elston, 7(27). Climatology, 11; sand-forms, 14; hydrology, 16; vegetation and ecology, 17; effective rainfall, 20; development schemes, 23; economics, 27. Insets 24-27  
 Deutsch, M., 107(25)  
 Dicoumarol, 113(25)  
 DIETARY SELF-SELECTION EXPERIMENTS. D. E. Tribe, 47(25). 'Instinct' for diet, 46; response to deficiencies, 47; factors in choice, 50  
 Dirac, P. A. M., 65(24), 105(25)  
 D.N.A. (deoxypentose nucleic acid), 28(24); and nuclear counts, 43(24)  
 Dollo's Law, 8(25)  
 Doppler effect, and binaries, 57(24)  
 Dounce, A. L., 26(24)  
 Dunes, sand, 14(27)  
 Dyson, J., 38, 41, 43(26)  
 Eddington, Sir A., 59(24)  
 Eel, electric, 109(25)  
 Einstein, A., 109(26), 59(27)  
 ELECTRIC FISHES (R.R.), 109(25). Pulse-response to bare and insulated wires in water  
 Electro-encephalogram, 9(24)

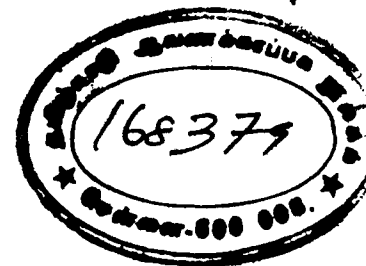
- ELECTROMAGNETIC WAVES, The Velocity of. W. C. Vaughan, 59(27). Measurements of velocity of light, 60; measurements in radio-frequency range, 62; accord between recent measurements, 68  
 Enzymes and cell energy, 25(24)  
 Electron microscope, 34(26)  
 Engineering. *See*: GAS, TITANIUM  
 Essen, L., 68(27)  
 Evolution. *See*: CONCEPTS  
 Fermi, E., 43(27), 100(27), 113(27)  
 Fessard, A., 109(25)  
 FIELD Centres for research, 93(27). Inset 1-23(27)  
 Fission, types in chemical change, 57(26)  
 FLUORESCENCE OF TEETH, 118(26)  
 Fluorescence in examination of works of art. *See*: ULTRA-VIOLET  
 Fine structure, 32(25)  
 Franklin, E., 64(27)  
 Free radicals, in separation of radioactive isotopes, 101(27). *See also*: CHEMICAL CHANGE  
 Fredericia, L. S., 48(25)  
 Freier, Phyllis, 33(27)  
 Fruit trees, virus diseases of, 122(26)  
 Gabor, D., 39(26)  
 Galton, Francis, 7(24)  
 GAS TURBINES, CURRENT LINES OF RESEARCH AND DEVELOPMENT IN. J. Hodge, 77(25). Early forms, 77; criteria of efficiency, 78; jet-engine, 80; supersonic airscrews, 82; shaft-power turbines, 83; thermodynamic efficiency, 87; cheap fuel problems, 88. Inset 17  
 Geology. *See*: ANTARCTIC, ARCTIC, DESERT, FIELD, TELEVISION  
 Geothermal energy. Inset 12-13(25)  
 Gill, E. W. B., 117(24)  
 Golla, F. L., 10(24)  
 Gordon, J. G., 48(25)  
 Glaciers, recrystallization in, 14(26)  
 Goldacre, R. J., 60(25)  
 Granit, R., 67(25)  
 Gunn, Ross, 116(24)  
 Gyromagnetic ratio of atoms, 37(25)  
 Harris, L. J., 47(25)  
 Harriss, E. B., 106(27)  
 Hartridge, H., 71(25)  
 Heat-exchange in Antarctic, 12(26)  
 HEAT, Perception of (R.R.), 111(27). Microwave and infra-red investigation of depth of nerve-ending  
 Hecogenin, extraction from sisal, 115(25)  
 Hillier, J., 35(26)  
 Hinshelwood, Sir C., 76(26)  
 Histones, 35(24)  
 Holmes, E. L., 83(26)  
 Hologram, 39(26)  
 Hoyle, F., 62(24)  
 Huxley, Julian, 65(25)  
 Hydrocarbons, oxidation of, 71(26)  
 Hydroelectric development in U.S.S.R., 94(24)  
 Hyperfine structure, 32(25)  
 ICE, RAIN, AND ELECTRIC CHARGE (R.R.), 115(24). Charge on individual drops. Potential changes during freezing and melting  
 Ice-thickness, seismic sounding in Antarctic, 20(26)  
 Interactionist theories of mind, 97(25)  
 Interferometer in resolution of binaries, 51(24)  
 ION-EXCHANGE. K. S. Spiegler, 78(26). Water-softeners, use and regeneration, 81; synthetic ion- and anion-exchange resins, 82; removal of salts, 83; drinking water from sea, 86; purification of sugar-beet juice, 87; separation of rare earths, 89; medical application, 91; ion-exchange membranes, 95. Inset 26-7  
 Ionospheric turbulence and radio-propagation, 117(26)  
 Imageless thought, 19(24)  
 Images, mental. *See*: MENTAL  
 Interference-contrast microscope, 38(26)  
 Irrigation development in U.S.S.R., 94(24)  
 Isotopes, separation of radioactive, 97(27)  
 Jet-engines, 77(25)  
 Joliot, F., 105(25)

- Keynes, R. D., 109(25)  
 Kinetics of chemical change. *See:*  
 CHEMICAL  
 Kleiber, M., 112(25)  
 Knoll, M., 34(26)  
 Kossel, A., 36(24)  
 Kretschmer, E., 9(24)  
 'Krilium', 118(24)  
 Kroll, W. J., 100(26)
- Lamb, W. E., 32(25)  
 Lamerton, L. F., 106(27)  
 Law of Mass Action in chemical change, 58(26)  
 Libby, W. F., 101(27)  
 Lindemann, F. A., 67(26)  
 Linnaean system of species, 8(25)  
 Lissmann, H. W., 109(25)  
 LITERARY STUDIES, Statistics as an Aid to. C. B. Williams, 99(24). Investigations into lengths of words and sentences. Correspondence 121(25)  
 Little, K. L., 79(27)  
 Livingston, M. S., 116(27)  
 Lorch, I. J., 60(25)  
 Lundegårdh, H., 55(25)
- McCarthy, M., 43(24)  
 MacLeod, C. M., 43(24)  
 Marker, R. E., 115(25)  
 Marston, H. R., 108(27)  
 Mass-luminosity relationship of stars, 59(24)  
 Machin, K. E., 116(26)  
 Mendeléeff, 68(24), *et seq.*  
 MENTAL IMAGES, Measurement of. P. L. Short, 7(24). Alpha-rhythm and imagery, 9; breathing and imagery types, 13; imagery in mental life, 18  
 Mercier, J., 65(27)  
 Meson, 105(25)  
 Meteorology. *See:* ANTARCTIC, ARCTIC, BALLOONING  
 Michelson, A. A., 61(27)  
 Micromanipulation of amoebal nuclei, 107(27)
- MICROSCOPY. A New Era in. J. G. Thomas, 33(26). Electron, 34; x ray, 35; phase-contrast and interference contrast, 37; wavefront reconstruction, 39; reflecting, 41; future possibilities, 43  
 Microwave absorption experiments, 29(25)  
 Miescher, F., 27(24)  
 Millikan, R. A., 43(27)  
 Mind-body problem, 97(25)  
 MINERAL SALTS ABSORPTION BY PLANTS, MECHANISM OF. J. F. Sutcliffe, 52(25). Absorption not passive, 52; ion concentration, 54; electro-chemical theory, 55; selective absorption, 58  
 Mirsky, A. E., 27(24)  
 Molecules. *See:* RADIO-FREQUENCY
- Nebulae. *See:* Palomar photographs. Inset 18-24(25)  
 Neoprene balloons, 55(27)  
 Neptunium series of radio-elements, 112(27)  
 New Zealand, prospecting for steam in. Inset 12-13(25)  
 Nitrogen mustard treatment of amoebal nucleus, 107(27)  
 Nuclear isomers, separation of, 103(27)  
 Nuclear manipulation. *See:* CELL  
 Nucleic acids. *See:* CELLS  
 Nucleoproteins, 9(25)
- Oceanography. *See:* ANTARCTIC, TELEVISION  
 Ord, M. J., 106(27)  
 Ore, A., 106(25)
- PALOMAR photographs. Inset 18-24(25)  
 Papi, F., 121(26)  
 Pardi, L., 121(26)  
 Pauli, 80(24)  
 Payne, B. O., 38(26)  
 Peppard, D. F., 113(27)  
 Perception of heat, human, 111(27)

- PERIODIC SYSTEM, The, and the Reduction of Chemistry to Physics. H. R. Paneth, 65(24). Mendeléeff's principle, 68; table of elements, 70; transition series, 73; translation into physical terms, 74; periodicities of ionization potential and atomic volume, 75; relationship to theory of atom, 77; Pauli principle, 80; higher atoms, 82; transuranic elements, 90  
 Perky, C. W., 8(24)  
 Peters, B., 33(27)  
 Phase-contrast microscope, 37(26)  
 PHILOSOPHICAL ANALYSIS and Scientific Progress. John E. Owen, 107(26)  
 Philosophy. *See:* CONCEPTS  
 Physics. *See:* ACCELERATOR, BALLOONING, COSMIC, PERIODIC, POSITRONIUM, PROTONS, RADIOACTIVE, RADIO-FREQUENCY  
 Pickering, E. C., 51(24)  
 Pictures in the Mind (Correspondence), 124(24)  
 Planck, M., 109(26)  
 Plants, selenium in, 121(24)  
 Plants, absorption of mineral salts by, 52(25)  
 PNA (pentose nucleic acid), 28(24)  
 Pollister, A. W., 27(24)  
 Positron, 105(25)  
 POSITRONIUM (R.R.), 105(25). Existence of a short-lived two-particle system  
 Powell, C. F., 52(27)  
 Powell, J. L., 105(25)  
 Precession of nucleus, 35(25)  
 Principle of Maximum Simplicity in chemical change, 64(26)  
 Promethium, 89(26)  
 Protamines, 35(24)  
 Proteins of nucleus, 35(24)  
 Proton-synchrotron. *See:* ACCELERATOR  
 PROTONS, Billion-Volt (R.R.), 123(26)  
 Psychology. *See:* CONSCIOUSNESS, HEAT, VISION  
 Pulvermacher, K., 14(27)
- Quastel, J. H., 118(24)
- Rabi, I. I., 34(25)  
 Racial relations. *See:* SOCIAL SCIENTISTS
- Radar in measurements of velocity of electro-magnetic waves, 63(27)  
 Radiation and energy levels, 24(25)  
 RADIOACTIVE ISOTOPES, The Szilard-Chalmers Effect and the Separation of. D. G. Tuck, 97(27). Radioactive tracer problems and technical developments; relation to chemistry of 'hot atoms', 103; separation of nuclear isomers, 103  
 RADIOACTIVE SERIES, The Fourth (R.R.), 112(27). Discovery of radio-elements in neptunium ( $4n + 1$ ) series  
 Radioactive tracers, 97(27)  
 RADIO-ASTRONOMY (R.R.), 113(26). Shape and diameter of the radio-sun; measurements during 1950-52 eclipses; radio-emission from supernova positions, 116  
 RADIO-FREQUENCY METHODS IN THE STUDY OF ATOMS AND MOLECULES. J. Little, 22(25). Techniques of absorption spectroscopy, 27; magnetic resonance, 34; nuclear induction, 41; spin and moments of nuclei, 43.  
 RADIO-PROPAGATION (R.R.), 117(26). Scattering by atmospheric and ionospheric turbulence  
 Rainfall, effective, in deserts, 20(27)  
 Ramberg, E. G., 34(26)  
 Random sampling in social science, 72(27)  
 Rare earths, 73(24)  
 RAT-POISON, ANTI-VITAMIN (R.R.), 113(25). Synthetic anti-vitamin, 'war-farin'.  
 Rays, cosmic. *See:* COSMIC  
 Reflecting microscope, 41(26)  
 Retherford, R. C., 32(25)  
 Reynolds, S. F., 117(24)  
 Rich, J. A., 106(25)  
 Road-testing machine. Inset 16(25)  
 Robb, J., 83(27)  
 Ross, A. S. C., 104(24)  
 Ruminants, 'pinning' disease of, 108(27)  
 Ruska, E., 34(26)  
 Russell, A. S., 112(27)  
 Ryde, J. W., 116(25)
- SAMPLE, Taking a. J. A. Nelder, 107(24). The statistical basis of sampling

- SANDHOPPERS' COMPASS (*R.R.*), 121(26).  
 Response to sun direction, polarization and time  
 Sand, wind-blown 14(27)  
 Science and Culture (Correspondence), 122(24), 120(25)  
 Scott, E. M., 49(25)  
 SEAWEEDES, Concentration of Trace-Elements by (*R.R.*), 120(26)  
 SELENIUM in Plants (*R.R.*), 121(24)  
 SHEEP, Cobalt and Vitamin B<sub>12</sub> (*R.R.*), 108(27). 'Pining' disease of ruminants  
 Sheldon, W. H., 9(24)  
 Siegel, R., 108(25)  
 Singer, F., 44(27)  
 Sial, as raw material for Cortisone, 115(25)  
 Skyhook pilotless balloons, 52(27)  
 Smith, A. H., 112(25)  
 Smith, F. G., 116(26)  
 Smith, R. A., 64(27)  
 Smith, S. E., 109(27)  
 Snyder, H. S., 116(27)  
 SOCIAL SCIENTISTS in Action. Anthony H. Richmond, 69(27). Techniques of research, 71; role of observer, 73; methods of interview, 75; studies of racial relations in Britain, 79  
 SOIL STRUCTURE (*R.R.*), 118(24). 'Kri-lum' as synthetic soil conditioner  
 Soil-temperatures, Arctic, 116(27)  
 Solomon, A. K., 112(25)  
 Soviet irrigation scheme in Asia, 24(27), 27(27)  
 Species. *See*: CONCEPTS  
 Spensley, P. C., 115(25)  
 Spin, in positron-electron system, 106(25)  
 Stamp, W. R., 90(25)  
 Stars, Double, W. H. Marshall, 46(24). Visual, 47; spectroscopic, 51; eclipsing, 53; frequency of, 55; use in estimating mass of stars, 59; theories of origin, 62. Inset 23-5  
 Statistics, and literary studies, 99(24)  
 Statistics of sampling, 107(24)  
 Steam, prospecting for, in New Zealand. Inset 12-13(25)  
 Steward, F. C., 60(25)  
 Stoneburg, C. A., 26(24)  
 Stratosphere temperature in Antarctic, 12(26)  
 Struve, O., 62(24)  
 Sun, effects on cosmic radiation, 39(27)  
 Sun, shape of radio-, 113(26)  
 Supernovae, in origin of binaries, 63(24)  
 — radio-emission from positions of, 116(26)  
 Supersonic airscrews and compressors, 82(25)  
 Synthetic ion-exchange resins, 82(26)  
 Szilard, L. *See*: RADIOACTIVE  
 TEETH, Fluorescence of (*R.R.*), 118(26). Investigations of substance and structure  
 Teleology in biology, 17(25)  
 TELESCOPE, RADIO (*R.R.*), 118(25). Construction by University of Manchester  
 TELEVISION, UNDERWATER, 90(25). Recent progress, 90; geological values, 92; lighting problems, 94. Inset 1-10  
 Thibaud, J., 105(25)  
 Thompson, Andrew, 117(27)  
 Thorium series, 112(27)  
 TITANIUM: A New Metal for Engineers. F. A. Fox, 98(26). Properties and sources, 99; extraction, 99; melting, 101; crystal structure, 103; applications, 104. Inset 28-9  
 Trace-Elements, Concentration of, by Seaweed, 120(26)  
 Transpiration of desert plants, 18(27)  
 Transuranic elements and the recurrence of the rare earths, position in the Periodic System, 90(24)  
 Transuranic elements, separation by ion-exchange, 89(26)  
 Transuranic elements. *See*: RADIOACTIVE SERIES  
 Trichromatism, 67(25)  
 Turbines. *See*: GAS  
 ULTRA-VIOLET Radiation in the Examination of Works of Art. George Savage, 47(26). Variations in fluorescence in repair materials, 49; dating of manufacture, 53  
 Uranium series, 112(27)  
 Urbain, M. G., 15(25)

- U.S.S.R., Hydroelectric and Irrigation, Development in, 94(24). Scope of scheme, 94; special conditions, 97. Inset 1-19  
 Valencies, 67(24)  
 Vegetation of deserts, 17(27)  
 Vendrely, C. and R., 43(24)  
 Virus, 'species' of, 9(25), taxonomy of, 10(25)  
 VIRUS DISEASES OF FRUIT TREES (*R.R.*), 122(26)  
 VISION, COLOUR. Katharine Tansley and R. A. Weale, 65(25). Spectral sensitivity of optic nerve fibres, 67; rival theories, 68; saturation of trichromatic matches, 72; polychromatic theory, 75; stimuli and sensations, 76. Inset 11  
 Vitamin B<sub>12</sub> need in ruminants, 108(27)  
 Vitamin K., 113(25)  
 Webley, D. M., 118(24)  
 White, M. J. D., 45(24)  
 Whiting, F. B., 64(27)  
 Windbreaks, value in deserts, 22(27)  
 Workman, E. J., 117(24)  
 Works of art, examination of. *See*: ULTRA-VIOLET  
 Xeromorphic and xerophytic plants, 10(27)  
 X-ray microscope, 35(26)  
 X-ray treatment of amoebal nucleus, 107(27)  
 Yardi, M. R., 106(24)  
 Young, T., 68(25)  
 Yule, G. Udney, 99(24)  
 Zatspein, G. T., 41(27)  
 Zernike, F., 37(26)  
 Zoology. *See*: ANIMAL, CELL, DIETARY, ELECTRIC FISHES, FIELD, HEAT, RAT, SANDHOPPERS, SHEEP, TEETH, VISION



# INDEX OF AUTHORS

Numbers 24-27

Only medical men are named as 'doctor' in this list; Professors, Fellows of the Royal Society, and holders of civil honours, have been described as such, but no mention is made of any other degrees, doctorates, or academic distinctions. Further information about any author is to be found in the column *About our Contributors*, which appears in each issue. The numbers in brackets indicate the number of the volume.

Elston, R. N., 7(27)

Fox, F. A., 98(26)

George, E. P., 30(27)

Haslett, A. W., 115(24), 105(25), 113(26),  
106(27)

Herz, A. J., 46(27)

Hodge, J., 77(25)

Knight, Margaret, 97(25)

Little, J., 22(25)

Marshall, W. H., 46(24)

Nelder, J. A., 107(24)

Owen, Prof. John E., 106(26)

Paneth, H. R., 65(24)

Pirie, N. W., F.R.S., 7(25)

Roots, E. F., 9(26)

Richmond, Anthony H., 69(27)

Savage, George, 47(26)

Sherratt, H. S. A., 22(24)

Short, P. L., 7(24)

Spiegler, K. S., 78(26)

Sutcliffe, J. F., 52(25)

Tansley, Katharine, 64(25)

Tennent, R. M., 46(27)

Thomas, J. G., 33(26)

Tribe, D. E., 46(25)

Tuck, D. G., 97(27)

Vaughan, W. C., M.B.E., 59(27)

Wadsworth, K. D., 55(26)

Weale, R. A., 64(25)

Williams, C. B., 99(24)

Woodhouse, D. L., 22(24)

# SCIENCE NEWS

*Outstanding articles from recent issues include :*

## SCIENCE NEWS 23

Models of the Atomic Nucleus: *J. Little*  
Cortisone: A Problem in Chemical Synthesis: *A. J. Birch*  
Vitamin B<sub>12</sub>, Antibiotics and Growth: *H. O. J. Collier*  
The Problems of Bird Orientation: *G. V. T. Matthews*  
Central Cerebral Processes: *G. M. Wyburn*  
Concert Hall Acoustics: *J. Moir*

## SCIENCE NEWS 24

The Measurement of Mental Images: *P. L. Short*  
Chemistry of Cells and Chromosomes: *D. L. Woodhouse and  
H. S. A. Sherratt*  
Double Stars: *W. H. Marshall*  
The Periodic System: *H. R. Paneth*  
Hydroelectric and Irrigation Development in the U.S.S.R.  
Statistics as an Aid to Literary Studies: *C. B. Williams*

## SCIENCE NEWS 25

Concepts out of Context: The Pied Pipers of Science: *N. W.  
Pirie*  
Radio-Frequency Methods in the Study of Atoms and Molecules: *J. Little*  
Dietary Self-Selection Experiments: *D. E. Tribe*  
The Mechanism of Mineral Salts Absorption by Plants: *J. F.  
Sutcliffe*  
Colour Vision: *Katharine Tansley and R. A. Weale*  
Current Lines of Research and Development in Gas Turbines:  
*J. Hodge*  
Under-Water Television

## SCIENCE NEWS 26

The Norwegian-British-Swedish Antarctic Expedition 1949-52:  
*E. F. Roots*  
A New Era in Microscopy: *J. G. Thomas*  
Ultra-Violet Radiation in the Examination of Works of Art:  
*George Savage*  
Mechanisms of Chemical Change: *K. D. Wadsworth*  
Ion Exchange: *K. S. Spiegler*  
Titanium: A New Metal for Engineers: *F. A. Fox*  
Philosophical Analysis and Scientific Progress: *John E. Owen*