reader straight to the forefront of research in the field considered.

One point which may puzzle the reader a little relates to the question of just whom the work is intended for. Medical people unacquainted with experimental psychology will find the going very hard; because of the limited space available to each contributor the argument, the theoretical analysis and the description of experiments are necessarily very much abbreviated and not readily understandable to anyone but an expert. Experts, on the other hand, would not normally turn to a publication of this kind for information in their own subject; there are well-known sources for publication of reviews of limited areas. Perhaps the most likely readers will be students of psychology immediately before or after their degree examinations; for them an authoritative summary of this type, up to date and well written, will be a godsend. Unfortunately they might find the price rather off-putting; 30*s*. for 80 pages works out at about 1*s*. for 3 pages, which is rather expensive for a paper-bound issue.

A perusal of the contributions makes very apparent the truth of certain generalizations often made about experimental psychology. Thus it is clear that an enormous amount of very ingenious and well-controlled work is going on in psychological laboratories; no quarrel is possible with the technical competence of the work reviewed. However, what is missing are the general laws and high-level theories which bind together a field, or even a small part of a field. This is often excused on the grounds of the great youth of psychology; the passing years, however, do not seem to bring us any further into the Promised Land! Perhaps we are not always looking in the right direction or perhaps the rather self-conscious anti-theoretical bias of many psychologists prevents them from discovering these generalizations which alone can make the subject a unified science. The reader might be excused for wondering whether, in fact, all these contributions belong to one single science, as there seems to be very little congruence between them; as in the typical psychological text-book the chapters are independent of each other, there is no logical structure, and they might be rearranged quite arbitrarily without affecting one's ability to apprehend the various contributions.

This feature of the present issue of the *British Medical Bulletin*, and of experimental psychology as a whole, is perhaps not unrelated to the exclusion of personality. Psychology has tended to concentrate on functional relationships between stimulus and response; in this way it was hoped that the paradigm of the physical sciences could be taken over. However, simple *S–R* types of analysis have proved abortive; the same stimulus may produce different responses in different people, or even in the same person at different times. It has become imperative to introduce the organism in the formula, and much lip-service is paid to this by writing functional relationships in terms of *S–O–R*. However, individual differences, which are the characteristic properties of the organism, still tend to be regarded in the same way as experimental errors, that is, as a nuisance to be eliminated by averaging. This is as sensible as a physicist trying to eliminate the differences between the elements, say with respect to conductivity or melting point, by simply running averages over large and random aggregates of materials. It is only when it is realized that individual differences are not only a legitimate subject-matter for scientific research but also form an essential part of all experimental psychology that a greater degree of organization will become apparent in the contributions of experimental psychologists. However, this is a fault of the subject, not the editor or the writers, and it would be churlish to end on a critical note instead of recommending wholeheartedly what is undoubtedly one of the best issues of the *British Medical Bulletin* for a long time.

H. J. EYSENCK

LIMITATIONS OF THE RESEARCH PAPER

THE research paper, which appears throughout the world each year in its hundreds of thousands, has been cast in a traditional form for decades. It was not ever thus. The early *Proceedings of the Royal Society* and others of less eminence were not only lively but showed a high degree of subjectivity, thereby leaving us valuable clues to the nature of the men who formed these and other specific bodies and the workings of their minds. Scientists have become more reticent and humble and sometimes deceive themselves into thinking that they are producing completely objective accounts of their work, which have been described as "didactic dead-pan". There is much excuse for this. Scientists would like to feel that they produce results which others can verify and experiments which others can reproduce. Moreover, editors of scientific journals would encourage a succinct form of reporting and would prefer tabulated results to an account of the mental processes of the research worker, even if he were able to catch his mind at work and analyse step by step the formation of his ideas.

A series of Third Programme talks given in the autumn of 1963 under the title of "Experiment", published in *The Listener* and now available in the form of a B.B.C. paper-back*, consists of a number of variations on Prof. P. B. Medawar's opening talk, "Is the Scientific Paper a Fraud?". He was not challenging the techniques and skills of the research worker or the veracity and even value of his facts, but was making a plea for a reconsideration of what is understood as scientific method. Francis Bacon, in presenting induction as the method of science, saw that the process of deduction only uncovers and makes explicit information that is already present in the axioms or premises from which the process of deduction started.

"The process of deduction reveals nothing to us except what the infirmity of our own minds has so far concealed from us." In the nineteenth century, John Stuart Mill formulated more precisely the principles of induction which he believed to be the method of science. Briefly, observations, unprejudiced and even naïve, were to be made in sufficient quantity and, out of all this sensory evidence, generalizations will grow and take shape "almost as if some process of crystallization or condensation were taking place". J. S. Mill wished to apply to sociology the methods which seemed to have proved so useful in the physical sciences, but the application of induction to sociology proved to be singularly unfruitful. The theory sustaining the inductive method can be challenged on several grounds. To start with, there is no such thing as unbiased observation, for all observation is a function of past experience. Again, the formulation of a scientific idea and the demonstration or proof, though confused by Mill, are two separate activities. In deduction they may well be the same, but in scientific activity they are different; but, most important, a generalization cannot contain more information than the sum of the particular statements on which it is founded. Thus, it is not surprising that Bertrand Russell in 1903 said that "induction was a mere method of making plausible

* British Broadcasting Corporation. *Experiment: a Series of Scientific Case Histories first broadcast in the BBC Third Programme.* Edited by David Edge. Pp. 72. (London: British Broadcasting Corporation, 1964.) 4*s*.

guesses", and Karl Popper in *The Logic of Scientific Method* says, "There is no need even to mention induction", though, of course, he does.

Hypotheses, which are the start of and incentive for the scientific enquiry, are the result of inspiration, insight or, crudely, guesswork, and their deductive consequences are tested by experiment. This alternative view of the nature of scientific method, of Prof. Popper, may be called the hypothetico-deductive method, which was first formulated by William Whewill, the Master of Trinity College, Cambridge, who was a contemporary of Mill. Prof. Medawar, who opens the series of talks, and J. W. N. Watkins, who closes it, make a plea for more case-histories of scientific discoveries.

"The scientific paper is a fraud in the sense that it does give a totally misleading narrative of the processes of thought that go into the making of scientific discoveries. The inductive format of the scientific paper should be discarded."

To illustrate the thesis which has been summarized here, there are reprints of seven lectures on widely assorted subjects: "The Magnetic Proton", by O. R. Frisch; "The Hunting of the Diesel" (the cyclic variations in its speed), by D. Welbourne; "The Earth's Dynamo", by Sir Edward Bullard; "Paying Attention" (a psychological investigation), by D. Broadbent; "The Edinburgh Spectrophone", by T. Cottrell; "The Computer Botanist" (the use of the Southampton computer in analysing the results of ecological studies), by W. T. Williams; "The Peenemünde Mystery" (a real 'spy' story), by R. V. Jones.

The little book, which costs only 4*s*., ought to be studied by every sixth form and university student, and research worker. W. L. Sumner

UTILIZATION OF GLUCOSE CARBON *IN VIVO* IN THE MOUSE

By Dr. R. VRBA

Medical Research Council, Neuropsychiatric Research Unit, Carshalton, Surrey

THERE have been many investigations of the metabolism of glucose labelled with carbon-14 in individual organs and in tissue preparations *in vitro*, but there is relatively little information about the fate of glucose carbon in the organism as a whole. The object of the investigation described here was to obtain quantitative data on the extent of the conversion of glucose carbon atoms into high-molecular substances in a whole intact animal *in vivo* and to determine the nature of the 'non-glucose sources' of the respiratory carbon dioxide.

Glucose-U-^{14}C, when injected into an intact animal, is eventually converted almost completely into $^{14}CO_2$; however, this process is not very rapid, since it takes several hours before half the injected glucose-^{14}C can be recovered in the expired carbon dioxide[1]. It is known that an unestimated part of the glucose carbon is incorporated into substances such as lipids, amino-acids and proteins, which are not commonly included as intermediates in the generally accepted schemes of oxidation of glucose to carbon dioxide. It has also been shown that only a part of the expired carbon dioxide is formed by the direct oxidation of glucose: a considerable part of the respiratory carbon dioxide comes from what have been described as 'non-glucose sources'[2]. A rapid and extensive incorporation of glucose carbon atoms into amino-acids in the brain and other organs has been observed to occur *in vivo*[3,7], and it has been shown that glucose carbon is utilized for the synthesis of proteins and lipids in the brain and other organs[3]. Although it is known that the utilization of glucose in various organs can be influenced by fasting, hypoglycæmia, drugs and other factors[1,4], it is not known how much of the injected glucose is actually assimilated *in vivo* into high-molecular cell constituents and what is the relative velocity of these processes.

Experiments have now been carried out to account quantitatively for the distribution of the total labelled carbon from glucose-U-^{14}C in large and small molecules at various intervals after injection of glucose-U-^{14}C. To my knowledge no experiments of this type have previously been published.

Male mice (25–30 g each) were first treated with antibiotics to decrease the intestinal flora (neomycin, 250 mg/kg in 0·2 ml. of water per os, 24 h before injection). They were then injected intraperitoneally with 15 μc. glucose-U-^{14}C (as provided by the Radiochemical Centre, Amersham, Buckinghamshire) and killed by dropping into liquid nitrogen either immediately after the injection (3 control animals) or at intervals ranging from 15 min to 8 h. During this period each mouse was kept individually in a desiccator, to which 3 gas absorption flasks (containing 15 ml. of 2 N sodium hydroxide each) were attached in series. The third gas absorption bottle was attached to a water pump in such a way that air was constantly sucked into the desiccator and, together with the expired carbon dioxide, was forced successively through the three gas absorption bottles where all expired $^{14}CO_2$ was trapped. The contents of the absorption bottles were then combined, the bottles washed and together with washings made up to 100 ml. (fraction carbon dioxide) and, after suitable further dilution, directly plated for counting.

Acid-soluble fraction. The hard-frozen mouse was then powdered in a pre-cooled brass mortar and the homogeneous powder obtained was transferred quantitatively into five volumes of perchloric acid (5 per cent v/v), cooled to 0° C. The tissue was homogenized for 3 min using the high-speed 'Ultra-Turax' homogenizer (Janke and Kunkel KG, Staufen i. Br.), with blades rotating at 24,000 r.p.m. The homogenate was centrifuged at 2,500 r.p.m. (1,500–2,000*g*) in a M.S.E. Major centrifuge (0° C), and the sediment re-homogenized in another five volumes of perchloric acid. (All other homogenizations and centrifugations mentioned here were performed in the same way.) This procedure was repeated three times, and the combined supernatants were made up to 500 ml. This acid-soluble fraction (40 ml.) was neutralized to *p*H 7 with 60 per cent potassium hydroxide at 0° C, the precipitated potassium perchlorate was separated by sedimentation overnight in a cold room (0° C) and centrifuged. The precipitate was re-suspended in 40 ml. of water and removed by sedimentation and centrifugation. The combined supernatants (fraction *A.S.*) were made up to volume and plated for counting.

Lipid fraction. (1) The acid-insoluble residue from the above procedure was homogenized in 5 volumes of Bloor's mixture (ethanol–ethyl ether, 3 : 1 v/v) and after standing for a week at room temperature the suspension was centrifuged. The pellet was then homogenized in 5 volumes of Folch's mixture [$CHCl_3/CH_3OH$, 2 : 1 v/v] and centrifuged. The combined supernatants were made up to 500 ml. with methanol and suitable portions were plated for counting (fraction *L*1).

(2) The foregoing 'lipid fraction' contains impurities, mainly lipid-bound protein, and therefore it was subjected to the following procedure: 10 ml. were neutralized with potassium hydroxide [60 per cent w/v] to the point of decolorization of phenolphthalein and centrifuged in order to eliminate traces of free perchloric acid; the supernatant