used, the phosphorus-oxygen ratio (2 molecules of cytochrome *c* taken as equal to 1 atom of oxygen) reached 2.20, 4.6 min. after all the cytochrome *c* was reduced. The single value obtained under anaerobic conditions was 2.16, obtained 2.9 min. after complete reduction. These values are minimal, since it is possible that higher ratios might have been obtained had the experiment been prolonged. These values may be compared with 1.80 for a short-time experiment and 2.50 in a long-time experiment, when oxygen was the final hydrogen acceptor. (The high concentration of cytochrome *c* used, 1.5×10^{-4} M, inhibited the phosphorylation slightly; a ratio of 2.79 was obtained with 1.9×10^{-5} M cytochrome *c*.) It is clear from the last line of the table that 0.01 M potassium cyanide inhibits phosphorylation considerably.

These experiments suggest that all the phosphorylation which occurs when α -ketoglutarate is oxidized by oxygen occurs in those steps of the hydrogen transfer reaction between substrate and cytochrome *c*.

Full details will be published elsewhere.

I wish to express my thanks to Prof. S. Ochoa for his advice and encouragement, and the Rockefeller Foundation for the opportunity to join Prof. Ochoa's Laboratory.

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SUBJECTIVE JUDGMENTS

ON October 14, a meeting arranged as a private venture by a committee with Dr. R. G. Hopkinson (Building Research Station, Department of Scientific and Industrial Research) as secretary, was held at University College, London, to discuss subjective judgments. The attendance was large, the discussions were extremely lively, the views put forward were varied enough to satisfy the most determined opponent of uniformity, and altogether it was apparent that the problems raised are now attracting widespread and active attention both from the point of view of fundamental research and from that of the most appropriate methodology to be used in the study of a great many practical problems concerning human health, efficiency and comfort.

The morning discussion raised again the question of the measurability of sensation. After Sir Frederic Bartlett, who was in the chair, had opened the conference, Dr. D. R. Fry, of the Phonetics Department, University College, London, said that what is called 'measurement' in the case of sensation is the correlation of some aspect of the magnitude of a stimulus with some dimension of magnitude in the sensation. This is empirically possible. The magnitude usually, but not necessarily, adopted in the case of the sensation is a minimum perceptible

difference in some assigned dimension; but as a subject can also compare different values of the same dimension and determine that in one case he has a value or magnitude which is a certain fraction of another, or a certain 'number of times' greater than another, there is ground for believing that quantitative sensation scales are feasible. It is not to be supposed that the dimensions of the stimulus are themselves a measure of the sensation, or that the number of discriminable dimensions of the sensation are necessarily equal to the number of physically measured dimensions of the stimulus. All that is needed is a certain consistency in the assigned relations of measured stimulus differences and sensation dimension differences, and these relations have to be treated by statistical analysis. Whether this is 'measurement' can be disputed. That it is both possible and useful is certain.

With Prof. R. C. Oldfield, University of Reading, some of the results of the impact of modern general machine theory upon the interpretation of sensory evidence came into the picture. The attempt to set up psycho-physical scales is one depending upon the empirical determination of a function of a physical stimulus variable which is such that its values correspond with judgments made by a subject in accordance with a given character. The early dualism of stimulus-sensation has broken down completely, for we have always to take into account the characteristic structure and internal variable state of whatever response system or device is set at work in our experiments. In the case of psycho-physical judgments, there seem to be three characters of the internal responding device which are remarkably persistent, though whether they are always in operation and what particular mathematical formulation of relationship they demand are still matters for determination. The first is an element having two positions of equilibrium. This may mean—and in most cases of psycho-physical judgment it usually does mean—"a non-linear transformation of the external variable", for example, to a logarithmic form, and such transformation may involve temporal derivations of the external variable. The second is a shifting standard, structurally built into the response system, and together with the first character, leading to a discontinuous 'all-or-none' expression of continuous change in the external variable. The third is an 'indifference range', which means that there is no apparent change of output or interpretation within experimentally determined limits of 'stimulus' variation, but that outside such limits marked change may suddenly appear. Whether the functional relations of a physical stimulus variable with a sequence of step-judgments based upon sensorial likeness and difference could be in any sense regarded as a 'measure' of sensation, Prof. Oldfield refused to say. But he did consider that their elucidation would show that the process of judging physical stimulus magnitudes could be regarded legitimately as fully amenable to quantitative treatment.

Dr. W. D. Wright asserted categorically that sensation magnitudes cannot be measured, for there is no form of yardstick that can be laid alongside them. Discrimination data cannot be used, because the magnitude of a discrimination may be dependent upon any of a number of variables, both external and internal, and nobody can know which are operating. Contrast-qualities cannot be used because all the results of trial are equally consistent with a number of different assumptions and we have no crucial way

of actually determining which is necessary. Thus no formally expressed relationship between stimulus and sensation has any validity; but this does not prevent the commonly adopted logarithmic scales of intensity from having great practical value.

This discussion was continued by Dr. R. W. Pickford, Prof. H. Hartridge, Mr. F. H. Brittain and Mr. J. M. Waldram, of the Research Laboratories of the General Electric Co., Ltd., and Dr. M. H. Pirenne.

Dr. Pickford was not much inclined to believe that sensations are, in any literal sense, measurable; but he gave illustrations to show that the commonly accepted correlations of stimulus and sensation variations are of operational value. In a written communication Dr. Pirenne expressed substantially the same view.

Prof. Hartridge showed that subjective observations carried out entirely independently by Granit and himself in the field of colour identification agreed remarkably closely, both in a qualitative sense and in regard to associated frequency values of the physical stimuli.

Mr. Brittain made an interesting suggestion of a physical model the operations of which might be regarded as strongly analogous to those of a human perceptual mechanism. This reinforced the view that no measure of input, or stimulus, could be valid which failed to pay attention to the character of the transforming and conducting processes internal to the responding system.

Mr. Waldram described some original and important illustrations of the use of stimulus-sensation correlations of a quantitative order.

Following this the discussion became general and open, and a large number of provocative and down-right remarks were made. It is perhaps fair to say that there was exceedingly little agreement on any fundamental question, but almost complete agreement that even if sensations cannot be measured, they must be, and that the attempts which have been made are of great practical service.

In the afternoon meeting, the chair was taken by Dr. F. M. Lea, director of the Building Research Station (Department of Scientific and Industrial Research). The topic assigned was "The Subject as an Assessor of Sensation"; but the actual problems discussed concerned the methodology of experimental attempts to obtain reliable judgments based upon sensory evidence, and of their presentation in some numerical form, when the persons who make the judgments are also those who interpret the evidence.

Papers were presented by Dr. D. Richards, of the General Post Office Engineering Department, on the "Design and Analysis of Subjective Acoustical Experiments which involve a Quantal Response"; by Dr. R. Harper and Dr. G. W. Scott Blair (National Institute of Dairying) on "The Subjective Assessment of Deformable Materials and of Food Products"; by Dr. R. G. Hopkinson (Building Research Station) on "The Multiple Criterion Technique of Subjective Appraisal", and by Dr. E. C. Bate-Smith and A. S. C. Ehrenberg (Low Temperature Research Station, Cambridge) on "The Operation of Laboratory Taste Panels".

The general discussion was opened by Dr. N. H. Mackworth, who was followed by a considerable number of other nominated speakers, and these by an open debate which was carried on with very great vigour.

In the course of the afternoon, almost all the known psycho-physical methods were described, and illus-

trations of their alleged highly successful use were plentiful and varied. Dr. Hopkinson made a new and important point of method when he presented evidence to demonstrate that, if subjective judgments have to be made about the effects of a physical variable, more reliable results are secured if a limited number of criteria are used in succession instead of a single criterion.

Points arousing the greatest amount of difference of opinion were: (a) In discrimination experiments, is it better to allot control of the physical variables to the subject, or to the experimenter, or to a third person? (b) Do threshold determinations, whether absolute or relative, throw any light upon subjective assessments of complex groups of stimuli? (c) Do experts produce any better results from a general operational point of view than a random population, and are repeated experiments any better than a 'once-for-all' trial?

Two questions received inadequate notice: (i) The suggestion, made by Dr. Mackworth, that whenever possible performance criteria should be made to supplement direct subjective assessment received scant attention. This, in fact, is one form of the very difficult problem of the relationship between reliability and validation with which sooner or later everybody who makes use of subjective assessments must come to terms. But there was a persistent disposition to side-step this whole difficulty. (ii) The justification and types of statistical analysis and interpretation that are available, or should be considered, for dealing with arrays of data of the subjective assessment order were less considered than might have been expected.

In the end, Dr. Bate-Smith suggested that the conference seemed to be divided between those who say "You can't" and those who assert "We must". Perhaps, though he did not say so, he would favour some revision of the Emersonian dictum into a form such as:

When Theory whispers low "You can't"
Practice replies "I must".

And that is what most people seemed to think.

F. C. BARTLETT

BRITISH GELATINE AND GLUE RESEARCH ASSOCIATION

SECOND RESEARCH PANEL MEETING

THE second meeting of the Research Panel of the British Gelatine and Glue Research Association, held at Beale's Restaurant, Holloway Road, London, N.7, on October 12, was attended by representatives of member firms, of research associations interested in the uses of gelatine and glue, and of the Department of Scientific and Industrial Research. The Research Panel meetings are intended to give an opportunity for interchange of scientific and technical information in the industry by the reading of papers followed by discussion.

In the morning session, Dr. J. H. Bowes, of the British Leather Manufacturers' Research Association, read a paper on "The Composition of Skin and the Changes Produced by the Action of Alkalis", describing, in the main, the work she has carried out in the past few years. Dr. Bowes first discussed the