The final discussion stressed a number of the highlights of the meeting as well as guidelines to future work. One important point, a negative one, was the danger, especially in the case of the salmon, of prejudicing future population studies by the artificial transfer of fish from one area to another. Another, a positive one, was the need to validate the genetic basis of what are essentially studies of phenotypes, by carrying out breeding experiments with every species for which this is possible. The Council (ICES) resolved to publish the papers and the discussions following them in their *Rapports et Procès-verbaux des Réunions.*

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Bioelectrical Impedance

Because of the increasing use of electrical impedance to measure physiological phenomena, those interested in this technique convened under the chairmanship of S. E. Markovich (*1*) to present their findings in the use of impedance to measure blood volume changes in the head, thorax, abdomen, and limbs and to measure respiratory volumes. Intra-cerebral impedance values in a variety of brain lesions were also described. Thirty-three papers were presented in 2½ days; they will be published in the Annals of the New York Academy of Sciences.

There was much evidence of enhanced activity in three areas (clinical use, underlying physiological factors, and instrumentation). Increasing use is being made of transcranial impedance (rheoencephalography, REG) to characterize waveforms in normal persons in various age groups and in patients with known cerebrovascular disease and intracranial lesions. Studies were also reported in which the component extracranial circulation was reduced (by temporary bilateral occlusion of the temporal arteries); other reports described changes in the REG during the Valsalva maneuver. Direct-coupled systems have been used to obtain indicator-dilution curves made by injection of hyper- or hypoconducting solutions into a carotid artery. These studies indicate some promise of ability to study differences in perfusion of the regions supplied by these arteries. There were no reports of successful establishment of a quantitative relation between change in impedance (ohms) and the amount of blood flow (milliliters per minute) passing through the region between the electrodes.

The changes in transthoracic impedance which accompany the ejection of blood from the ventricles and those which accompany respiration are being used clinically to monitor stroke volume and tidal volume. The correlation between stroke volume (milliliters of blood ejected per heart beat) and the change in neck-abdomen impedance (in ohms) after the waveform is processed were described. In normal subjects, over a moderate range in cardiac output, the correlation is quite good. In relation to the left-to-right transthoracic impedance changes that accompany respiration, the amplitude of the impedance change is proportional to tidal volume but calibration with an air-volume measuring device (spirometer) is necessary in the individual subject. In general, the smaller the subject, the larger the increase in impedance per cubic centimeter of air inspired.

Chest-to-back changes in thoracic impedance which demonstrated differences in ventilation between the lungs were reported. Reduction in basal thoracic impedance with hydration and pulmonary edema were also described.

Much controversy still exists regarding the factors which underlie the basal impedance and its changes that can be recorded between electrodes on living tissue. Information in this area is urgently needed for a proper evaluation of the limits of ability to calibrate bioelectric impedance measurements. Both theoretical and practical studies to identify the pathway of current caused to flow through inhomogeneous living tissue were reported. Although electrode sizes and locations can be selected to permit optimum detection of desired physiological events, the important basic studies in the living organism in each area are slow in coming, despite the obvious need.

There is a considerable difference of opinion regarding the appropriate type of instrumentation for the study of a given phenomenon. There were advocates of the use of two, three, and four terminals, crusaders for low and high frequency, and adherents of either constant-current or constant-voltage. It is too soon to draw definite conclusions on the efficacy of any one method over another in obtaining the best measurement of a physiological event under all circumstances, which consider convenience and safety to the subject as well as time required to make the measurement. Fortunately, all agree that bioimpedance should be measured with a current that will not stimulate the subject or alter the event being measured.

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Note

1. The International Conference on Bioelectrical Impedance, held in New York City from 29 September to 1 October 1969, was sponsored by the New York Academy of Science. The 70 participants included delegates from Canada, Austria, Czechoslovakia, Finland, Bulgaria, and Italy in addition to workers from the United States.

Inelastic Behavior of Solids

If scientific progress thrives on controversy, the field of the inelastic behavior of solids is due for major advances. Fifty scientists, representing both the theoretical and the experimental viewpoints, were present at the recent Battelle Institute Colloquium on the Material Sciences, which was held in Columbus and Atwood Lake, Ohio, 15–19 September 1969. During the conference, inelastic behavior was discussed in terms of continuum, quantum, and statistical mechanics, of the classical reaction rate and the classical dislocation theories, of experimental metallurgy, and of phenomenological studies. Primary areas of controversy were identified, but little consensus was reached on the issues involved in treating any one aspect of inelastic behavior.

The conference was designed to bring together the leading proponents of each of the two fundamental approaches to the subject: continuum mechanics and dislocation dynamics. In applying continuum mechanics, the discrete mechanisms by which a material actually deforms in response to applied loads are ignored in the hope of interrelating the pertinent macroscopic parameters. The advocates of the microscopic viewpoint, on the other hand, are directly concerned with individual crystal defects and their interactions. Thus, material behavior is currently being described by (i) treating the material as a continuum that deforms according to some experimentally determined constitutive relation and by (ii) treating the deformation as the aggregate of the movement of each of the numerous discrete defects that it contains. Results necessary for the constitutive equations needed for the continuum approach must be obtained from considerations of the microstructure; thus, both approaches are valuable and necessary. The central question is how they can best be reconciled.

Plastic flow is accomplished by the generation, motion, and multiplication of very large numbers of crystal dislocations, and much of the discussion focused on the problem of treating these phenomena quantitatively. A major difficulty is that the number of mobile dislocations in a crystal cannot be measured directly, and no new solutions were offered to this long-recognized obstacle. J. E. Dorn (University of California, Berkeley) exploited the approach wherein all of the moving dislocations are considered to have the same velocity. This idealization is particularly useful for the metallurgist because it is the only method that reveals the differences between materials. All other approaches involve correlations of one sort or another.

The simplest correlation model is obtained by "smearing" the physically discrete dislocations into a continuous distribution. Although the procedure greatly simplifies the mathematics, as A. K. Head (Commonwealth Scientific and Industrial Research Organization, Melbourne) pointed out, by ignoring the discreteness of dislocations, it is impossible to account for important phenomena such as work-hardening. A method outlined by E. Kröner (Clausthal-Zellerfeld Technical University) would describe the discrete dislocation distribution in terms of correlation tensors. The first-order tensor is simply the dislocation density and, because much of the analysis of work-hardening has been expressed only in terms of the dislocation density, it is therefore possible, in principle, to overcome this objection. The successively higher-order tensors in Kröner's theory describe the dislocation arrangements in successively greater detail. Although Kröner's approach is attractive conceptually, the experimentalists were horrified at the prospect of trying to determine the tensors.

In other presentations, E. Smith (Manchester University) suggested a compromise: a combined discrete and smeared approach, which could be useful if one knew a priori which dislocations to leave discrete. N. Fox (Sheffield University) viewed plasticity from the standpoint of multipolar continuum mechanics and showed how the dislocation density, the Burger vector, and other quantities familiar to the metallurgist could be defined in terms of this general continuum theory. All the conferees agreed that, although a basic description of plastic flow must involve dislocation velocities and densities, the phenomenological theory of plasticity will be predominant in engineering applications. The simple concept of strain will still be needed in the foreseeable future.

Because the deformed state of the material is so difficult to describe in terms of a configuration, R. S. Rivlin (Lehigh University) advocated continuum treatments in terms of loading history. Expressed simply, one knows much better what was done to a material to put it into its current state than one knows its current state. Kröner disagreed with this approach on the grounds that there are an infinite variety of possible histories that could produce similar states. In general, the metallurgists would tend to support Kröner's view, and continuum mechanics people, Rivlin's view. Rivlin's view would tend to give similar states when suitably different paths are followed, and thus these two views may not be so incompatible as it might appear.

The philosophy behind developing theories for generalized continua came under close scrutiny. Commonly, one develops insights based on simplified models of a realistic situation to determine the physical interpretation that should be given to particular variables appearing in the governing equations of nonclassical continuum theories. Others prefer to solve the problems that can be solved, even if a continuum that is more general than the one common to classical mechanics is introduced, and then to examine the results to see if they are physically meaningful and if they predict new phenomena. Rivlin cautioned that lack of a sound physical model has led some investigators too far astray when they attempted to develop new theories.

Another theme revolved around the gap between theory and experiment. Since the colloquium was dominated by theorists, the majority opinion was that experiments are holding up progress. However, it was admitted that even some very simple problems, which can easily be treated experimentally, are beyond current theory. For example, creep rates of polycrystals can be easily measured but cannot be predicted from the creep properties of single crystals. On the other hand, dynamic yield stresses cannot be predicted, and considerable time was spent inquiring whether they have been measured. C. H. Karnes (Sandia) reported that the usual assumption of uniform stress and particle velocity at the point of impact of two bars is not correct, and this report, in turn, cast doubt on the validity of the analysis of J. Bell (Johns Hopkins) and N. Cristescu (Mathematical Institute, Budapest), who concluded that the yield stress is rate-independent. Meanwhile, the available measurements and theories of dislocation mobility agree on a linear relation between stress and velocity in this regime (~ 1 to 10^4 cm/sec), which in turn suggests a linear relation between yield stress and strain rate, as reported by Dorn on copper and S. J. Green (General Motors) on aluminum. The tenor of the ensuing discussion was that phenomenological, one-dimension wave propagation experiments are useful to the engineer, even though it is not clear exactly what they measure.

The usually controversial area of fracture provided surprisingly little heat, perhaps because it has reached a stage where several promising new approaches have been outlined but not fully developed. The energy-momentum tensor of J. D. Eshelby (Sheffield University), which was reinvented more recently but independently by J. R. Rice (Brown University), was discussed by these two authors and was applied by G. C. Sih (Lehigh University) to calculate crack speeds and stopping distances in an edge-loaded specimen. Rice also presented the very interesting result that the region of most heavily strained material at the crack tip extends to a distance about equal to the crack-tip displacement. Rice contends that fracture will occur in a particle-containing alloy when this dimension exceeds the particle spacing. He presented experimental evidence in support of this hypothesis and, in so doing, provided the best example at the meeting of a merging of the various viewpoints represented.

The proceedings of the colloquium will be published in book form by McGraw-Hill. The fifth colloquium, on the subject "Critical Phenomena," will be held next year in Switzerland.

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