It was inevitable in a field which is at such an early stage of exploration that the subjects discussed lack coherence, but it was clear to everybody that large territories are awaiting exploration, and the work so far done barely scratches the surface. The whole discussion served to bring together those who have been working on these complex biological materials, with the physical chemists whose work has hitherto been largely confined to simple systems. It was apparent that the work done in isolating natural lipoproteins and fat-containing particles provides a practical starting point for investigations in which the precise methods of the latter are applied to substances of direct biological importance.

J. A. V. BUTLER

ACOUSTICS OF ROOMS

AT this critical period of post-war reconstruction, the problems of architectural design are rising with special acuteness, accentuated by new methods of building construction and limited material resources. One of the most pressing of these problems is the fulfilment of acoustic requirements in committee and lecture rooms, studios, theatres and concert halls. The importance of acoustic design is reflected in the increasing interest in acoustical research and in the growing demand for instruction in acoustics in the schools of architecture. The importance of the subject is equalled by its difficulty. It is the meeting-ground of art and mathematics, of psycho-physical and physical studies. Even on its objective side it is highly complex and resistant to analysis.

The Acoustics Group of the Physical Society is therefore to be congratulated for arranging the course of six lectures on room acoustics which were given in the Royal Institution by Dr. Richard H. Bolt, director of the Acoustics Laboratory of the Massachusetts Institute of Technology and president of the Acoustical Society of America. These lectures, supplemented by three colloquia, presented to British architects and acoustic engineers a summary of accepted theory, a report of recent progress, and a review of problems requiring further investigation.

The course opened with a discussion of the classical theory of W. C. Sabine and A. Jaeger. This theory was based on the assumption of uniform diffusion of sound energy in the room. It predicts an exactly exponential decay of sound energy with a definite value of reverberation time which is inversely proportional to the total sound absorption of the air boundaries. Using modern methods of sound recording, it is easily shown that the assumption of uniform diffusion is, in general, not in accordance with facts, for variations in sound-level are observed when a non-directional microphone is used at different points in the room or when a directional microphone is used in different orientations about a fixed point. The experimental decay curve usually shows fluctuations, and when these are smoothed out, the resulting curve is not strictly exponential, the rate of decay decreasing with time. Serious departures from theory may be observed when the reverberation method is used for measuring the absorption coefficients of acoustic absorbents, for even when diffraction effects are kept small, the measured values of absorption depend not only on the particular room used, but also on the position and orientation of the tested sample. Nevertheless, the conditions assumed by Sabine are the ideal conditions for room acoustics, and recent work has been directed towards discovering the means of attaining them.

A wave theory is required to give a complete account of the phenomena. The primitive conceptions are still simple. The air in the room has a large number of normal modes of vibration, each having a characteristic natural frequency. The wave equation is separable in the co-ordinate systems appropriate for a number of shapes of air space, and the corresponding normal mode solutions for rigid and for slightly absorbing walls are obtainable in a straightforward manner. When a steady source of sound is used, forced vibrations of the wave states take place, and transient free vibrations are excited by starting and stopping the sound. Photographs due to Knudsen[1] were displayed showing the transients excited by stopping a single-frequency source.

The wave theory for the case of a rectangular room with slightly absorbing walls was treated in some detail. Here the normal modes are a system of plane waves, and the natural frequencies can be represented by a lattice of points in the first octant of a three-dimensional frequency-space. The vectors representing the points have a magnitude proportional to the frequency and a direction parallel to the wave normal. The lattice is the basis of calculations of the number of normal modes of any type having frequencies between given limits[2]. The chief types are the oblique, tangential and axial modes, and these have characteristically different damping constants and energies per unit amplitude. The oblique waves have the greatest and the axial waves the least rates of decay. The shape of the smoothed reverberation–time curve is thus explained. It follows that, in such a rectangular room, strictly exponential decay cannot be obtained even for high-frequency sound.

The statistics of the eigen states of rectangular rooms were examined by Dr. Bolt in terms of fluctuation parameters, and the treatment was made more general by the use of non-dimensional frequency and room-shape variables. The smoothness of the frequency response was expressed by using ρ, the ratio of the actual spacing to the average spacing of the frequencies. The second moment of ρ gives a measure of smoothness. Diagrams were shown giving the relation between smoothness and room shape[3].

Up to the 'critical range' from the source, the energy density is predominantly due to direct radiation, and beyond this range the sound field is incoherent. The statistical properties of the incoherent field of a steady source have been studied by varying the frequency[4] or by varying the position of the microphone[2], and the results give respectively the 'transmission irregularity' and the 'space irregularity'. Satisfactory agreement has been obtained between theoretical and experimental values for the first of these parameters, and one or both of them may, in the future, prove to be convenient means of estimating the diffuseness of the sound field.

The course included a short account of the relation between the damping constants of the normal modes and the specific normal impedance of the walls, and also a discussion of the dependance of normal impedance on the porosity and flexibility of the wall. The theoretical energy losses at the wall expressed in terms of viscous and heat losses do not account for the total loss observed experimentally. In certain cases there is evidence in the decay curves of the existence of non-linear contributions to the energy loss, and this has been substantiated by photographic examination of the fluid motion at round apertures. A series of smoke photographs was shown which established the presence of vorticity near an aperture. The effect was shown with sound-levels as low as 60 db. above 0·0002 dynes/cm.[2]. It was seen to build up at greater sound-levels until at 120 db. regular shedding of vortices took place. In porous wall materials, the energy of rotation and translation of such vortices must contribute to the total energy loss. In the one case which has been fully examined, the total energy loss was exactly accounted for by including vorticity losses.

Such non-linear losses are an appreciable part of the total loss, and are, of course, a function of time as well as of amplitude. The situation envisaged in relation to pulsed sound is therefore that there must be a limit to the validity even of measured impedance values.

The theory of the perturbation of the normal modes by changes of boundary shape or of boundary impedance has been very successfully applied to determine the boundary conditions which produce a diffuse sound field. In effect, such perturbations, in the second order of approximation, result in the exchange of energy between different normal modes. For example, in the case of rectangular rooms, energy may be transferred from oblique to axial modes and *vice versa*, and when this takes place sufficiently freely, Sabine conditions are obtained. The probability of such transfer depends on the value of the surface integral $\iint \psi_M f \psi_N dS$, in which f is the function giving the boundary perturbation, and ψ_M and ψ_N are the wave functions concerned. To obtain free exchange between all pairs of normal modes, f must represent a random arrangement of patches or bumps having linear dimensions of the order of the wavelength. The results of this theory given by the index of randomness[2] are in a suitable form for use by practising architects. They include a formula for the critical frequency below which the sound is not well diffused. The critical frequency was shown to be related to the frequency giving maximum 'transmission irregularity'. The acoustical engineering aspect of this subject is, however, still in an early stage, and much more experience is needed in this field.

The course of lectures approached its conclusion with an account of the application of transient solutions of the wave equation to pulse recordings. Such a solution may be developed in the form of an asymptotic expansion, each term of which (after the first) corresponds to the appearance of a reflexion of the pulse, the time of arrival of each reflexion being determined. A new field of statistical investigation is thus opened up in which pulse records can be immediately interpreted, and in which new criteria of coherence and diffuseness become accessible. Although this approach to the problems of room acoustics is mathematically the most recondite, it is physically the simplest, and is the one normally used by architects. It remains to be seen whether its theoretical development will lead to simplifications of the technical side.

Inevitably, reference was made at various points in the lectures to the psycho-physical aspect of the subject. For example, work on the 'articulation index' for speech was described[6]. Tastes differ with regard to some of the subtler qualities of sound in buildings: qualities such as 'liveness' and 'tone' of music, and 'naturalness' of speech[5]. Much analytical work must still be done before objective standards can be laid down for good playing, speaking and hearing conditions.

Dr. Bolt's mastery of his subject was evident from the clarity and ease of his exposition. His audience and many other indirect beneficiaries owe their thanks also to the B.B.C., the Department of Scientific and Industrial Research, Mr. Joseph Emberton (Electrical Musical Instruments, Ltd.) and the L.C.C., whose gifts of money made it possible to invite Dr. Bolt to Great Britain. M. A. S. Ross

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VITAMIN C CONTENT OF AN OLD ANTISCORBUTIC: THE KERGUELEN CABBAGE

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KERGUELEN Island, in the Antarctic Ocean, equidistant from South Africa and Western Australia, has a very limited flora, of which the Kerguelen cabbage (*Pringlea antiscorbutica*) is the most striking species. Captain Cook, who visited the Island on his third and last voyage, found "not a single tree or shrub anywhere" and would have given it the name Island of Desolation "but that I would not rob Monsieur de Kerguelen of the honour of it bearing his name". With Cook's interest in combating scurvy, it was certain that he would seek to use this plant as a vegetable. Anderson, Cook's surgeon, describes the plant and its use. "It was not much unlike a small cabbage" having "not only the appearance, but the watery acid taste of the antiscorbutics". It was eaten frequently raw, "but it seemed to acquire a rank taste by being boiled; which however our people did not perceive and esteemed good". Anderson recommended that it should be introduced into kitchen gardens and improved by cultivation[1].

Since then, descriptions of the plant and of its use as a vegetable have been prominent features in the records of explorers. Sir Joseph Hooker[2], of the Ross Expedition, found the cabbage one of eighteen flowering plants on the Island and "perhaps the most interesting plant procured during the whole voyage in the Antarctic". He was "unable to point to any close affinity which the curious genus may have with others of the same natural family (Cruciferæ)". He gave the first full description of the plant and was responsible for its unusual, and surely almost unique, specific name. Anderson had given the name *Pringlea* in honour of Sir John Pringle, who wrote a book on scurvy. Hooker says, "This latter circumstance has induced me at Mr. Brown's suggestion to assign the trivial name of antiscorbutica". Evidently the name was not given entirely to mark a special property of