MUSICAL ACOUSTICS

A MEETING of the Acoustics Group of the Physical Society, under the chairmanship of Mr. T. Somerville, was held at the Royal Academy of Music on February 26 to discuss: "Of what Use is Acoustics to the Musician?". Prof. E. G. Richardson opened the proceedings by introducing a list of possible uses of acoustic knowledge and apparatus, as follows.

To obtain an accurate tuning note. This is an obvious use for an electronic oscillator, amplifier and loud-speaker. The conventional instruments for giving the key-note (in singing) or *A* (in playing) are the tuning-fork or the pitch-pipe or the note given by a wind instrument, usually the oboe in the orchestra. The last two suffer from temperature uncertainties, though there is some advantage in having the oboe giving the *A* since the pitch reached by the player after warming up, even if not precisely 440 vibrations per second, will be one to which all the wind players can conform.

To check the pitch of a recorded performance and of the correct intonation of the different parts in concerted music. This is an interesting pastime which tells one quite a lot, perhaps too much. By its means it is possible to check the intonation and pitch discrimination of a solo instrumentalist or singer during a performance. It also brings out quite prodigious feats of tuning and re-orientation of pitch on the part of a good orchestra. Thus, as was shown by an analysis made of a Dutch tape-recording, at a certain performance of Beethoven's first pianoforte concerto the piano was at 440, to which the orchestra tuned within 1 c./s. When accompanying the soloist the orchestra accommodated itself to his pitch, but rose 2 c./s. higher in the *tutti*. On the other hand, a rather regrettable state of affairs was disclosed in a broadcast of Bach's oboe concerto. Oboe and orchestra tuned to 440, but when the piano came in it was at 435. It says much for the string players that they overcame this handicap by playing at 439 (to which the oboe had dropped) when accompanying the solo, and at 435 in the ensembles with piano.

The pitch generally tends to rise above the tuning note during *forte* passages, probably because the notes of the wind instruments tend to rise in pitch with the blowing pressure. The tests also showed—what has been long known—that the human voice at its best is by no means so precise in maintaining constancy of pitch as the mechanical instruments.

The fact is that a musician may be most meticulous about notes being in tune at one instant and will tolerate a considerable degree of mistuning at others. It is natural that he should wish the notes of prominent diatonic chords in a composition to be in tune, but care less about passing notes, which may be elided rapidly, or the little unaccented grace notes which the composer writes as a semi-tone above or below a prominent chord note, probably with no intention that they should be rendered as semi-tones. It is also natural that singers asked to descend a semi-tone and return to the original note, in a type of cadence prominent in the sixteenth century, should make the drop less than a semi-tone in anticipation of rising again. It is a question of accent and speed.

To establish a succession of notes to form musical scales. The construction of a musical scale stretching from one note to the other and the historical evolution of scales seems to me a rather arid and arithmetical subject of study.

Whether our musical sense is an occidental or an oriental one, we all seem to agree that the scale shall cover an octave (though it is true that, in modal counterpoint, the 'stretch' was regarded on occasion as exceeding the octave). Also, rather surprisingly, we all seem to divide the octave of the scale into seven steps whether these are based as in Western music on tones and half tones, or whether, as in Eastern music, some of the intervals are third or quarter tones. In physics, we are mostly Pythagoreans, that is to say, we think of the octave as a length of stretched string which is sub-divided into shorter pieces of string bearing fixed ratios to the whole, but throughout the ages there has existed a type of musicologist who conceives—to me—more complicated sub-divisions, which he advocates as *the* perfect scale.

For most of us two scales suffice, the major and minor of just temperament. Formerly, as is well known, there were six scales in Western music, all having two semi-tone intervals placed at different points in the scale and rejoicing in the lovely names of Dorian, Phrygian, Lydian, Mixolydian, Aeolian, Ionian (thinking in terms of the pianoforte we can say that these had as key-note in turn *D, E, F, G, A* and *C*, but were entirely made up of the white notes). Of these, that based on the note *C* became the major and that on *A* the minor scale. Later, when composers learnt to harmonize, they wanted to make a composition modulate into other keys, and although this was possible for singers and for players on the viols and sackbuts of the epoch, it was not so on a wind instrument with side holes, or on instruments with keyboards, because the frequencies of some notes on the new tonic (key-note) were not equal to any of those of the old key. So a compromise had to be reached, and after various trials the equi-tempered scale, in which the semi-tone is equal to the twelfth root of two, received the support of Bach (who wrote for it his "48 Preludes and Fugues") and became established.

An orchestra or a choir then, accompanied on a keyboard instrument, had to follow equal temperament. Singers, who in common with string players and trombonists have the pitch of the tones they produce variable at will, often claim that when singing unaccompanied (*a capella*) they use the untempered scales. But they are not justified by pitch analyses which have been made using tape records in the way already mentioned. Hard facts show that both they and unaccompanied string quartets use a temperament which is mid-way between the just and the equi-tempered. It is, of course, possible to hear music played on keyboard instruments in just temperament, in a limited number of keys. Such instruments have red and green as well as black and white keys, but require an expert to play on them.

To provide a scientific basis for theories of harmony. It is impossible in a short space of time to give a complete history of the ideas of consonance and dissonance of intervals. It is well known that Helmholtz gave the physicist's and physiologist's view of the basis of dissonance. To him it was a question of the relative number of beats between two tones sounded together as a chord. The more frequent these, the greater dissonance. He made a graph showing the number of beats for each interval of the major scale. But to a musician these matters are not so simple. In fact, some of the ideas of Helmholtz on this question of discords have since been discredited.

In classical music the striking of a discord is rather like the tasting of wine or of sauce. The ear, like the palate, has to be prepared for it ; it is then savoured and it should be followed by some contrasting sweeter sensation.

This was how it was with discords in the classical period of harmony. At first only the octave and the fifth were regarded as concords. It is supposed that the other intervals evolved in the theory of harmony on the basis of a series of upward jumps of a fifth and downward jumps of a fourth. In this way the major and minor thirds appeared and also the seventh. At first the fourth was regarded as an imperfect interval, but by the fifteenth century the root tone, third and fifth formed the accepted concord. Only when the third above the fifth was added to form the seventh above the root of the chord was a discord felt, and this discord had to be prepared by first appearing in a concord and resolved on the following chord in a special way. Later, other thirds were added above the seventh to give the ninth and the eleventh.

It was Bach who found that the discord could be made more piquant by not preparing it, and since his time a composer has followed his whim in this matter. In turn, the necessity for resolution has ceased to be felt by composers. Wagner did not resolve ninths, and Ravel treated elevenths as consonances.

To me the necessity for resolution and not the counting of beats is the essence of a discord. If I do not feel, for example, the seventh on the fifth note of the scale to lead on naturally to the chord on the key-note or any other concord, that chord is free in its progression and so becomes for me a concord.

To measure the acoustic spectra of musical instruments in order to study and improve functioning. Perhaps this is the most rewarding service which the scientist can perform. There exist firms in the musical instrument trade, perhaps more numerous in the United States and Germany than in Britain, which are well aware of the possibilities of acoustic spectrometers and employ people competent to operate them. Adjustments are then made, for example, in the thickness of the belly of a stringed instrument, in the metal of an organ pipe, so that the 'voicer', or his counterpart outside the organ-building trade, can observe the effect on the formant of the instrument which in turn governs the spectrum and the efficiency of the instrument. Not only are such studies carried out by employees of firms, but physicists who are also music amateurs have spent a lifetime of leisure in such work. One need only refer to what Dr. F. A. Saunders has done for the violin and viola in Massachusetts and Dr. W. Lottermoser for the organ (and certain other instruments) in Eastern Germany.

To make experiments with new spectra (*on electronic musical instruments*). The advent of the electronic organ has given harmonic innovators a very useful tool to try experiments on, though they do not always realize that the loud-speaker of the instrument can superpose its own formant on the register in which the player elects to play his new-fangled music. This new electronic composing is not very popular in Britain, but there exist flourishing groups of its exponents in Germany, Italy and Switzerland.

To obtain design data on concert halls and music rooms. Perhaps in this matter, the musician especially realizes his debt to the scientist who works in acoustics. Auditorium acoustics must remain largely subjective, and musicians reserve their right to say when a hall is good for the performance of music—the difficulty is that all do not speak with one voice on such topics. Nevertheless, when composers and performers are able to say what they want—in reverberation, relative weight to different parts of the gamut and so forth—the acoustic consultant is usually able to advise the architect so that a concert hall or music room satisfactory to its users results.

Dr. B. W. Robinson, continuing the discussion, said that most musicians got on quite happily without studying acoustics. Also, he thought that not many instrument makers used the precision electronic apparatus now on the market for calibrating their products. Prof. Richardson had, however, omitted to emphasize the importance to a musician of the latest high-fidelity reproducing equipment, which was a great boon to an artiste wishing to judge, after listening to himself, to what extent his performance had improved. Self-recording was also of use in teaching elocution, and for singers to show them how bad their pitch discrimination often is.

Mr. D. M. A. Mercer said that acoustic testing with modern equipment could teach the craftsmen tricks not in the text-books and enabled the organ builder to determine how many stops would be required on an organ design for a new church. By its means, Dr. R. W. Young in America had been able to formulate the best tuning system for a pianoforte. This was never done exactly in accordance with the equi-tempered scale.

Dr. A. E. Brown said that he found a knowledge of acoustics helpful in learning to play a musical instrument, for example, in forming the best embouchure for the French horn.

Mr. A. Rakowski referred to the importance for music of having people trained to take full responsibility, from the artistic point of view, for making musical recordings. In the present state of perfection of sound technique in disk recording, radio and film, it is possible for recorded music to achieve a very high degree of artistic value, but people who work in the technique should have a knowledge of both acoustics and music. In the Music Academies of Warsaw and Detmold, special courses have been established for training such personnel.

Dr. H. D. Parbrook thought that there was too much of the music student's time devoted to theoretical study of scales and tuning. Not enough attention was paid to the tonal qualities of electronic musical instruments.

Mr. Nightingale also emphasized the importance of the tape recorder to the virtuoso to improve his playing.

Dr. H. Lowery recalled Sir Hubert Parry's dictum that the acoustical knowledge of a student varied inversely as his knowledge of music. He thought there still was too big a gap between the teaching of acoustics and the requirements of the musician. He said that an understanding of auditorium acoustics was most important to the composer. It was because Bach had an instinctive knowledge of this that his works were so well adapted to the baroque style of building which was prevalent in his day.

E. G. Richardson