seem to make it clear why intermediates between unicellular animals and Metazoa are rare, while intermediates between unicellular plants and metaphytes are common. (The colonial phytomonads are, of course, only regarded as animals by zoologists on account of their motility: their nutrition, it need scarcely be said, is holophytic or saprophytic.)

I acknowledge the help given by many friends in the course of conversation. In particular, I must thank Prof. A. C. Hardy, Dr. S. M. Manton and Dr. C. F. A. Pantin for valuable advice (though they must not be regarded as responsible for any opinion here expressed).

Summary

(1) A cell is defined as a mass of protoplasm, largely or completely bounded by a membrane, and containing within it a single nucleus formed by the telophase transformation of a haploid or diploid set of anaphase chromosomes.

(2) It is argued that many algae and Protozoa are properly regarded as unicellular organisms.

(3) Certain Protozoa, notably the Radiolaria and Ciliophora, are not cells in the sense of the definition given above.

(4) It is argued that there is no fundamental difference between the cleavage of an egg and the multiplication of a unicellular protozoan by division.

(5) It is not unlikely that Metazoa may have arisen by the failure of unicellular Protozoa to separate after division.

¹⁴ Awerinzew, S., *Biol. Centralbl.*, **30**, 465 (1910).

¹⁵ Roskin, C., *C.R. Acad. Sci., U.R.S.S.*, **49**, 288 (1945).

¹⁶ Beneden, E. van, *Arch. Biol.*, **2**, 183 (1881).

¹⁷ Hallez, P., *Arch. Zool. exp. gén.*, **9**, 429 (1929).

¹⁸ Bresslau, E., *Z. wiss. Zool.*, **76**, 213 (1904).

¹⁹ Fulinsky, B., *Zool. Anz.*, **47**, 381 (1916).

²⁰ Dobell, C. C., *Arch. Protistenk.*, **23**, 269 (1911).

THE BORDERLINE OF PSYCHOLOGY, PHYSICS AND MUSIC

AT a meeting of the Acoustics Group of the Physical Society, held in the Science Museum, South Kensington, on February 12, three speakers contributed to a symposium on "The Borderline of Psychology, Physics and Music". The chairman was Mr. H. L. Kirke, head of the Research Department of the B.B.C. and chairman of the Acoustics Group.

Prof. Balth. van der Pol was the first speaker and he dealt with three problems: (a) the mathematical theory of consonance; (b) intonation from a purely musical point of view; and (c) absolute pitch.

In his discussion of the mathematical theory of consonance, Prof. van der Pol directed attention to the work of Leonhard Euler, who, in 1739, gave in his "Tentamen novae theoriæ musicæ" a rigorous numerical measure for the "gradus suavitatis" or euphonic value of consonances and dissonances. This measure was the ratio of the least common multiple to the greatest common divisor of the frequencies of the component notes. Prof. van der Pol showed a table of the euphonic values of twenty-four 2-note, six 3-note and two 4-note combinations. It was clear that these euphonic values corresponded with the purely musical impressions of the relative consonances of the intervals and chords in question. The euphonic values of several familiar intervals are:

unison, 1; octave, 2; twelfth and fifteenth, 3; fifth, 4; fourth, 5; tenth and eleventh, 6; greater sixth, 7; lesser and greater major second and lesser sixth, 8; lesser and greater seventh, 9; lesser major second and augmented seventh, 10.

Both Euler and Huygens suggested the introduction into music of the prime number 7, as all musical intervals used before could be represented by $2^i 3^m 5^n$, which led Leibnitz to state that musicians could count up to five only. Both suggested the dominant seventh chord: $g b d' f' = 4, 5, 6, 7$. The seventh of this chord, however, is too flat for musical purposes, as Prof. van der Pol demonstrated with an oscillator, with which he sounded the notes both separately and together. He showed that the chord 36, 45, 54, 64, the diatonic dominant seventh, is musically satisfying. The euphonic values of these two chords are 15 and 17, and it is clear that musicians would prefer the more dissonant of the two for æsthetic reasons.

On the matter of intonation from a purely musical point of view, Prof. van der Pol put forward the idea that the pitch of a note played is legitimately variable to a certain extent at the performer's discretion, just as the executant has some freedom in the matter of rhythmic interpretation. The intonation of *E* in the chord of *C* major may depend on its function as the third of the chord. In brilliant music, a sharp (Pythagorean) third will accentuate the typical and unmistakable quality of a major chord. Probably Beethoven was aware of this, though without knowledge of the underlying mathematical theory, when he indicated in the last movement of his Fifth Symphony, that the second note of the first bar should be an open *E* string. Similarly, in the main theme of Wagner's *Meistersinger* overture, also in *C* major, a sharp third should be played. The pitch of a note and its effect will, in fact, depend on the musical context.

A low third (the diatonic 5:4) will be appropriate in soft and floating music such as a lullaby. The leading note of the dominant seventh, thrusting towards the tonic, is not seldom sung too high, and often, indeed, the composer anticipates the tonic in his closing harmony. A Neapolitan sixth (*D*♭ in the chord *F*, *A*♭, *D*♭, in *C* major or minor) can, with advantage, be sounded low, because it leads down to the tonic.

Prof. van der Pol concluded with an account of experiments on the measurement of changes in absolute pitch, carried out on himself in 1939, with an oscillator by means of which a note of any desired pitch could be produced. During a fortnight, eighteen independent measurements of an *A* were made, as most closely conforming to his absolute pitch for that note. The estimates had a mean value of 435.2 c./s., with a mean deviation of 3.3 c./s. The greatest 'error' was 6.2 c./s., or a quarter tone. He explained that absolute pitch sometimes tends to vary in the course of years. The absolute pitch of a physicist friend of his had fallen 1.5 tones when he was about eighty years of age. Prof. Klein of Utrecht had communicated to him that the absolute pitch of the Dutch composer Wagenaar had remained unchanged up to his death at the age of seventy-nine.

The second contribution to the symposium was made by Dr. R. W. Pickford, who described three experiments on the relation of the impression of dissonance to the context of a chord. All the experiments were done by rating the critical chords on a 7-point scale running from -3 (very dissonant) to +3 (very consonant). Liking and disliking were

kept apart, and in the third experiment these qualities were also rated in the same way. In the first experiment, forty women and eight men took part, and twelve chords were rated, each in six different settings and by itself. In the second, forty-three women and seven men rated fourteen chords in all of which the actual notes were identical. They were in settings mostly taken from familiar pieces of music. In the third, forty women and ten men rated fourteen chords in all of which the notes were identical, and which were in settings specially constructed for the experiment. The piano was the instrument used throughout. In the first experiment 'clang' effects were exploited, and in the other two interest was concentrated upon the musical preparation and resolution of dissonances.

It was found that familiar dissonances were given all kinds of ratings from very consonant to very dissonant, but most often they were classed as moderately dissonant, a seventh being classed on the average as less dissonant than a ninth, so that the average results were appropriate to musical expectation. There was a strong tendency for the consonance-dissonance level of chords to vary (a) with the context and (b) with the individual subjects' peculiarities of musical attitude and experience. Nevertheless, the chords had a strong tendency to retain their relative dissonance-levels in spite of these variations. There was a moderate tendency for liking to go with the impression of consonance, and disliking with that of dissonance. Smooth musical handling of dissonances tended to lead to the impression of consonance and also to liking, but departure from smooth handling led to various other combinations of liking, disliking, consonance and dissonance. The subjects were always astonished when told that they had rated the same note-combinations in different settings.

Helmholtz's theory of fusion appeared to provide the most satisfactory explanation of consonance and dissonance, apart from the effects of musical setting and individual attitudes of listeners. A Gestalt or 'form' theory of the effect upon the dissonance-consonance level of individual chords owing to their integral membership of whole passages or contexts should be added, together with a theory of personal schemata due to differences in musical ability and experience of individual listeners. Further experiments should be carried out on the relative effects of various musical techniques in handling dissonances and of 'clang' effects upon dissonance-consonance levels, and to compare these effects for pure tones and notes of complex timbre.

The third contribution to the symposium was made by Mr. J. Steuart Wilson. He pointed out that there are unfortunate tendencies at present to exploit the performer's capacity to vary the intonation of the intervals he sang or played. This is particularly noticeable in 'jazz' and 'swing', in which it has become an objectionable form of virtuosity. Even among serious musicians, some teachers trained their pupils to vary the intonation in playing classical music to produce special effects. Sometimes this had unfortunate results, because of the variety of thirds, for example, which might be included in a major common chord played by an orchestra. In addition, the liberties taken in 'jazz' and 'swing' had taught the public to like some effects which classical musicians eschewed, with the result that they thought that serious music was intolerably dull when it was really well played.

In the discussion the main speakers agreed that slight adaptations of pitch to suit the musical needs of a passage might be justified, provided that this did not lead to intolerably slovenly performance or to a form of senseless virtuosity. They also agreed that the impression of harshness of a dissonance might be expected to vary according to the way in which it was used. Mr. Steuart Wilson thought it most unfortunate that so many peoples' ideas of musical intervals came from listening to the pianoforte, which was often badly tuned either because nobody looked after it or because there was none to criticize the work of the tuner.

Dr. Dennis Fry pointed out that many people with absolute pitch are able to assign pitch to a sound which, for the majority, seems to be a noise without definite pitch. He asked whether people with absolute pitch might have two abilities, possibly separate in some cases: first, the permanent memory for pitch enabling them to compare pitches without reference to an external standard; and second, the ability to assign pitch to a frequency complex containing strong inharmonic components. In reply, Prof. van der Pol said that it is easier for most persons who have absolute pitch to assign pitches to notes which have many overtones than to pure single tones.

Dr. Fry asked whether the pitch of a given tone of fairly low frequency, say Middle C, 261 c./s., is recognized by a person with absolute pitch regardless of its intensity. If not, then at what intensity-level would it become Middle C? Also he thought it would be interesting to know what loudness-level of a pure tone of 261 c./s. gives rise to a pitch sensation exactly equal to that of a frequency complex containing a number of terms with a constant difference of 261 c./s. between them. Prof. van der Pol demonstrated the effect of varying the intensity of a given tone with his oscillator, but did not think data were available for answering the questions asked by Dr. Fry. It was suggested by Dr. Pickford that a valuable piece of research could be carried out in which adequate psychological experiments were performed with a large group of persons having various degrees of absolute pitch, in order to find out more about its variations among individuals, which might be very great. He also suggested that the euphonic value of an interval or chord, as defined by Euler, did not in itself determine the dissonance level of that chord. The only way to determine the euphonic value which would correspond to dissonance rather than to consonance would be to study the average of individual judgments and their variability. Most people would think that a euphonic value of 8 was dissonant; but the only way to determine this would be that of experimenting with large numbers of subjects.

R. W. PICKFORD

OBITUARIES

Prof. M. C. Potter

At the age of eighty-nine, Emeritus Professor the Rev. Michael Cressé Potter died on March 9 at New Milton, Hampshire, where he had lived since his retirement in 1925 from the chair of botany at Armstrong College (now King's College), Newcastle upon Tyne.

In 1877, Potter left the Perse School, Cambridge, and entered Peterhouse, where his father, who was