occur owing to the small numbers involved, such as the chance fixation or elimination of genes by Sewall Wright's 'drift' in populations below a certain size, or the merely approximate regularities of such 'laws' as that of adaptive radiation.

The same sort of thing doubtless applies to the history of science. There are unpredictable single events, such as those which finally put Darwin aboard the *Beagle*; there are general 'statistical' trends, such as that towards the formulation of an evolutionary theory of life, which would in any event undoubtedly have come to pass some time during the nineteenth century; and there are unpredictable particular deviations from such trends, such as those due to the small number and diverse gifts of the men available to put forward an adequate and convincing theory of evolution. These notebooks confirm me in the feeling, which I expect most biologists share, that it was a very fortunate chance that made of Charles Darwin the protagonist of this great and fundamental revolution in biological thought.

UNITS AND STANDARDS OF MEASUREMENT

IN the Discussion on Units and Standards, held in the apartments of the Royal Society on March 21, members of the staff of the National Physical Laboratory contributed papers dealing with the measurement of length, mass, the electrical units and temperature. Sir Charles Darwin, director of the Laboratory, in opening the discussion, explained that it would require much more than a single day even to sketch the general field of metrology, and that it had been possible to admit only some of the more important subjects. Time would not be discussed, because this subject is primarily the responsibility of the Astronomer Royal. At the conclusion of the discussion he did, however, touch briefly on some of the derived units not covered by the papers.

Length

Mr. J. E. Sears, in his account of the standards of length, dealt with the fundamental standards in both the British and Metric systems. The present standards are the Imperial Standard Yard and the International Prototype Metre, both line-standards, and there is an interesting parallel in their evolution both as regards change of form—in each system the earlier standards were end-bars—and in the failure of attempts to establish them by reference to natural constants. To-day, however, there is every indication that a natural standard, a selected wave-length of monochromatic light, will be universally adopted in the near future as the fundamental standard for length measurement, and that the primary material standards will be end-standards, which are more suitable for wave-length measurements and can now be made with a perfection of finish that permits advantage to be taken of the enhanced accuracy offered by the natural standard.

The intercomparison of two line-standards is carried out in specially designed comparators, in which the bars are laid side by side and the difference between them determined by means of micrometer microscopes. Particular attention to temperature conditions must, of course, be paid. The accuracy with which the Imperial Standard Yard and its copies can be compared is about 0·5 part in 10^6; for the metric standards, which have more perfect graduation lines, a precision of about 0·2 part in 10^6 is achieved. The intercomparisons of the yard with three of its Parliamentary copies made in 1912, 1922 and 1932 showed that these four bronze bars had remained in the same relationship to the mean of the group, as first determined in 1852, to within 0·00005 in. Observations on a later copy, completed in 1886, suggest, however, that the Imperial Standard and its contemporary copies may all have shortened by just over 0·0002 in. since the 1852 comparison. It is of interest to note that two earlier British Standard Yards, those of Henry VII and Elizabeth, which are now at the Science Museum, South Kensington, agree with the present standard to within 1/32 in. and 1/100 in. respectively. The platinum-iridium metre standards show a very high order of constancy: intercomparisons of twenty national copies with the working standards of the Bureau International in 1919 (and later) established that each bar was within $\pm$0·001 mm. of its original value in 1889, while the mean of the group had remained unchanged to within 0·0001 mm., and a sequence of determinations of the metre in wave-lengths of light shows no indication of any progressive change.

Mr. Sears referred to the difference between the American and British inches. The former is legally defined, by relation to the metre, by the equation 1 metre = 39·370000 in. The latest determination (1933) of the ratio of the metre to the Imperial Standard Yard gave the result 1 metre = 39·370138 in. The difference between the American and British inch is therefore very small, and both are so close to the convenient round number 1 in. = 25·4 mm. that it would be distinctly advantageous if the two countries could agree on this common ratio for the future. The present difference is not negligible: it is just significant in relation to the accuracy guaranteed by makers of the most accurate end-gauges used in industry.

The researches made into the measurement of length in wave-lengths of light were discussed by Mr. H. Barrell. The first determination of the metre in terms of the wave-length of the red radiation of cadmium was the well-known investigation carried out by Michelson and Benoît at the Bureau International in 1892–93. Benoît, Fabry and Perot repeated the work in 1905–6, and their result was adopted in 1907 as the reference basis for spectroscopic measurements; later, in 1927, its use as a reference for length measurements, as an alternative to the material standards, was provisionally sanctioned by the International Conference of Weights and Measures.

These two early determinations, as also a determination in Japan in 1928, were made by reference to line-standards. In the later measurements by Sears and Barrell at the National Physical Laboratory and by Kösters and Lampe at the Physikalische-Technische Reichsanstalt, the improved types of end-standards were used, their direct measurement by interferometry being practicable by virtue of the optical perfection of their end-faces. Another important feature of the British and German work is that the methods used provided results expressed *in vacuo* as well as in 'normal' air. In all, nine experimentally determined values of the wave-length of the cadmium red radiation have been published. It so happens that the mean of the nine values is practically identical with the value obtained by Benoît, Fabry and Perot. The British and German researches, it is considered, have demonstrated that the metre can be independently established in the two countries on a wave-length basis with a precision of $\pm 0 \cdot 03\ \mu$, which is about ten times the precision attainable through the current material standards. The construction of a source of purer radiation, employing a single even-number isotope of a heavy atom, for example, mercury, excited at the temperature of liquid air, is now within the bounds of possibility; such a source, Mr. Barrell believes, would allow of the metre or yard being reproduced in terms of a wave-length measured *in vacuo*, and through the agency of end-standards, with a precision very closely approaching 1 part in 10^8.

Mass

The standards of mass in the British and Metric systems were discussed by Mr. F. A. Gould. The fundamental standard in the British system, the Imperial Standard Pound, is of platinum and takes the form of a cylinder of height approximately equal to its diameter. The metric standard, the International Prototype Kilogramme, is of platinum-iridium and also of simple cylindrical form with the height equal to the diameter. The earlier metric standard, the Kilogramme des Archives, was originally defined by reference to the mass of the cubic decimetre of water, but an appreciation of the practical difficulties associated with this definition led to its abandonment and to the adoption instead of the material standard itself. The difference between the litre and the cubic decimetre (1 litre = 1·000027 c.dm.) is, of course, a consequence of this decision.

It has always been recognized that a high degree of precision can be realized in the comparison of masses on a knife-edge balance of good quality. In recent years a further gain in accuracy has been achieved at the National Physical Laboratory by the use of a balance designed and constructed there. This balance, which has a number of special features, is installed in a closed vault, and the complete sequence of operations necessary in comparing two masses can be carried out by means of external controls. One particular feature of the balance is the provision made so that a complete double-weighing can be conducted without separating the knives and bearing planes; and the very high degree of precision, approaching closely to 1 part in 10^9, which is attainable in the comparison of two kilograms, owes much to this technique. In the comparisons, due allowance must, of course, be made for the buoyancy effects; these are computed from a knowledge of the densities of the standards, as determined experimentally, and the density of the air at the time of weighing.

Evidence as to the stability of the British standards is somewhat limited, but there is a clear suggestion that between 1846 and 1883 the Imperial Standard diminished by about 1 part in 3½ million in relation to its copies, but that it has since remained constant to within 1 part in 10^7. The earlier loss was attributed to wear resulting from too frequent usage. Changes in the metric standards have been minute; for example, the values obtained for the British copy in 1889, 1924 and 1933 do not differ among themselves by more than 2 parts in 10^8.

Mr. Gould dealt with the question of materials suitable for the construction of secondary standards and analytical weights, and indicated that choice is largely restricted to nickel-chromium, stainless steel (25 per cent chromium, 20 per cent nickel) and plated brass. The standardization of weights made of these materials by reference to a copy of the fundamental standard involves the application of large buoyancy corrections, and the accuracy of the work is reduced to 1 part in 10 or 20 million. Weights used in science and in industry are normally adjusted to balance in air a standard mass of density 8·4 gm./ml., and calibrations on this basis are made at the National Physical Laboratory to an accuracy of 1 part in 10^6. The adoption of this principle has the advantage that all the weights in a set can be regarded as having the density 8·4 gm./ml. and buoyancy corrections can be applied in bulk.

Electricity

In his paper on electrical standards, Dr. L. Hartshorn described the general character of the experimental work by means of which the ideal units derived from electromagnetic theory are related to the real units determined by the working standards. In the purely electrical comparisons of resistances and cells an accuracy of 1 part in 10^6 can be attained fairly readily, and measurements of resistance, voltage, current and quantity can, therefore, be made to this order of precision. The realization of the theoretical units through linkage with the appropriate mechanical quantities is a much more difficult task; but in recent years it has been proved that the theoretical ohm and ampere can be so established with an accuracy of about 1 part in 10^5. At the present time, the units for electrical measurements are, by international agreement, defined by reference to a column of mercury and the silver voltameter, but these will most probably be superseded in the near future by the theoretical units.

The problem to be solved in linking the electrical and mechanical quantities is essentially one of constructing an apparatus which will satisfy the theoretical conditions and provide for precise electrical and mechanical measurements. The mechanical requirements are stability, rigidity and low temperature coefficient of expansion; on the electrical side one demands the closest possible approach to linear circuits of zero resistance in a perfectly non-conducting and non-magnetic medium.

At the National Physical Laboratory, work has been done with the Campbell standard of mutual inductance, the Ayrton–Jones current balance and the Lorenz apparatus. In each case mutual inductance is involved, and the precision achieved in the work depends largely on the accuracy with which inductors of suitable size and form can be constructed and measured. Dr. Hartshorn described the technique of making and measuring such inductors, and indicated the factors which need attention if the finished coil is to have the necessary high degree of geometrical uniformity.

Temperature

In the discussion on the temperature scale, Mr. J. A. Hall surveyed the present position in regard to the realization of the thermodynamic scale and described the work which has been done in establishing the international temperature scale and in relating it to the thermodynamic scale.

The practical reproduction of temperatures on the thermodynamic scale involves the use of one of the 'permanent' gases in, preferably, a constant-volume thermometer; the gas thermometer technique is, however, inconvenient and difficult, especially at high temperatures. The task of providing a more practical temperature scale, related to the gas scale, was commenced by Chappuis, whose work, in 1888, enabled the "mercury in verre dur" scale to be reproduced over the range 0°–100° with an accuracy of ±0·005°. Subsequent progress lay in the development of new methods of measurement using the platinum resistance thermometer, the thermo-couple and the optical pyrometer, and led to the establishment of the International Temperature Scale (1927).

This scale is related to the thermodynamic scale through selected fixed points ranging from −182·97°C. (b.p. of liquid oxygen) to 1063° C. (m.p. of gold), the resistance thermometer and thermocouple being used as interpolation instruments. Extrapolation of the scale beyond the gold point is based on a radiation scale employing monochromatic light and applying Planck's equation. The international temperature scale can be reproduced much more accurately than the gas scale by virtue of the higher accuracy of the instruments used with it. These instruments have, however, no theoretical connexion with the thermodynamic scale, and the lower accuracy of the gas thermometer limits proportionately the accuracy of establishment of the relationship between the two scales. This distinction between absolute accuracy and reproducibility is always found to take a prominent place in temperature measurement.

At the oxygen point the accuracy of realization of the thermodynamic centigrade scale is ±0·02° and at the gold point it is ±1°; the corresponding accuracies of reproducibility are ±0·02° and ±0·05°. At 2000° C., the accuracy of realization depreciates to ±6° on account of the uncertainty of ±1° at the gold point and an uncertainty in the value of C_2 in Planck's equation; the accuracy of reproducibility is ±2°, the limitation being due to difficulty in establishing perfect black-body conditions and to errors in the brightness comparisons at 2000° and 1063° C. The highest accuracy of reproducibility is achieved in the range 0°–50° C., the resistance thermometer providing here the particularly good figure ±0·0003° C. As regards the absolute zero, the Comité Consultatif de Thermométrie in 1939 accepted as the most probable value −273·15 ±0·02° C. Since that date, however, Beattie has given a figure of −273·165 ±0·015° C.

When dealing with the most recent work, Mr. Hall referred to the four-fold improvement achieved in America in reproducing the boiling-point of water, thus reducing the uncertainty at this point to rather better than ±0·001° C., and to researches with the resistance thermometer at the gold point which may enable the use of this instrument up to that point and so eliminate the thermocouple.

General

In reviewing the discussion, Sir Charles Darwin referred briefly to units and standards not covered by the previous speakers, such as volume, gravity, pressure, the calorie, the candle-power and the acoustic standards, and illustrated his remarks by means of a table indicating the various precisions attainable under the most favourable conditions of measurement. The table gave, where applicable, both the accuracy of reproducibility and the accuracy of comparison, and the need for distinguishing between these two conceptions was brought out. Sir Charles also referred to certain unsatisfactory aspects of the legal situation of the British standards. The provisions for the use of the present standards of length and mass, as laid down in the Act of 1856, are in certain respects incomplete, and some of the methods of measurement prescribed are inadequate in the light of present-day techniques. There are similar difficulties associated with the legal definition of the gallon. A better legal procedure was followed in prescribing the electrical standards: the specifications are not embodied in an Act but it is provided that they should be determined by Order in Council. There would be real advantage if this more flexible procedure were extended to all the standards, by arranging, for example, for the appointment of a permanent authoritative body, advised by experts, which would, from time to time, by Order in Council or other means, make pronouncements as to what the standards should be.

J. C. EVANS.

THE DECLINE OF OYSTER POPULATIONS

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"It's a wery remarkable circumstance, sir," said Sam, "that poverty and oysters always seems to go together." ". . . the poorer a place is, the greater call there seems to be for oysters. Look here, sir; here's a oyster stall to every half-dozen houses. The street's lined vith 'em. Blessed if I don't think that ven a man's wery poor, he rushes out of his lodgings, and eats oysters in reg'lar desperation."—*The Posthumous Papers of The Pickwick Club*.—DICKENS.

THERE are few animals which in the course of less than a century have undergone such a conspicuous rise in social status as the oyster. At the time when Dickens's Sam made his somewhat disparaging remarks about oysters, these were sold at Billingsgate at the rate of five hundred million a year, and they cost only 20*s*. a bushel. Since then they have become progressively scarce and expensive. The famous Firth of Forth oysters are now practically extinct; in the sea lochs on the Scottish west coast oyster shells are abundant, but scarcely a living oyster exists. The oyster populations of the English and other European coasts have suffered similar declines. In the second half of the nineteenth century free fishing on the natural oyster beds was stopped, but the decline continued. The oyster has, on the whole, been maintained only by culture—a practice which goes back to Roman times, but owes its development and success in recent times to the French.

Along with that of the American bison, the decline of the oyster population is one of the most striking cases of the depopulation of a once-flourishing species following in the wake of man's activities. Its causes have been variously investigated and discussed. The justification for re-opening the discussion in the following account may be found in the tentative suggestion of factors contributory to this decline which have hitherto not been considered; and if the suggestion be correct it may lead to means for furthering success in the cultivation and rehabilitation of the oyster.

A brief summary of some relevant facts concerning the oyster and its relation to some environmental factors, based largely on the excellent accounts of Orton[1] and Korringa[2], may precede discussion of the causes of depletion of oyster beds.

We are here mainly concerned with the European flat oyster, *Ostrea edulis*, which occurs, or used to occur, on the Atlantic coast of Europe from Norway to Spain and in the Mediterranean as far east as the Adriatic. It is a protandric alternating hermaphrodite, that is, it starts as a male, and during its